COLLEGE OF ENGINEERING & COMPUTER SCIENCE
UNIVERSITY OF MICHIGAN-DEARBORN

AENG 500 - Automotive Integrated Systems

P1 – Benchmarking & Preliminary Design specification
Mid-size Pickup truck

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Content

- Market Research
- Vehicle Selection
- Customers and their expectations
- Customers view on EV truck
- Federal Norms
- Key Benchmark Features
- Pugh analysis
- 5 Major changes
- Challenges pertaining major changes

Market Research

Market segment, Customer's vehicle & Sales report

Market Segment

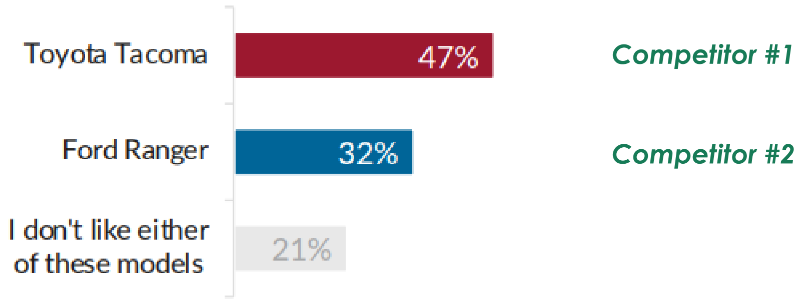
Vehicle Characteristics

- Mid-Size Pickup
- Price range = $38k to $42k
- 5-seater Cab
- IC Engine
- Automatic transmission

Customer's demography

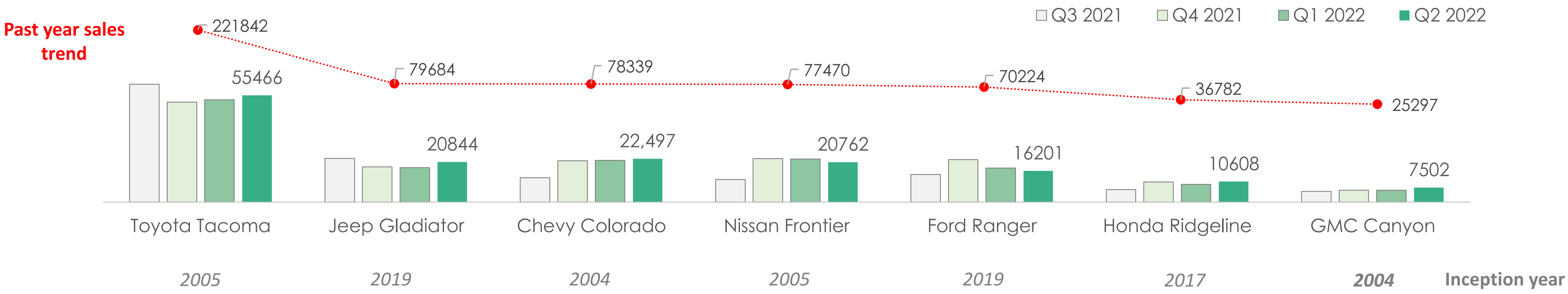
- M:F ratio = 89.7 : 10.6
- Average Household income : $80,000
- 75% of Truck owner's age : 40+
- 64% of Truck owner's ethnic : White

Customers' Favorite Midsize Pickup



Ref : 2022 CarGurus Pickup truck sentiment survey

Sales Report



Vehicle Selection

Target vehicle : GMC Canyon AT4

Key consideration

- Target & Competitors vehicle selection consideration parameters :
  - Sale volume
  - Inception year
  - Price range
  - Popularity
  - Complaints history

Target vehicle – GMC Canyon AT4

Competitor #1 – Toyota Tacoma TRD offroad

Competitor #2 – Ford Ranger Lariat

Customers and their expectations

88 feedback collected through Google form feedback

Attribute based preferences

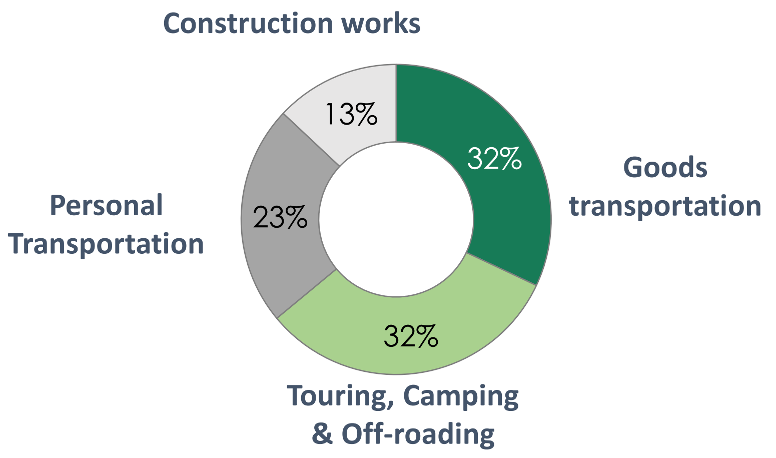
Most important for purchase decision

Vehicle Attributes	% people gave 1st priority
Safety	89%
Performance	72%
Fast charging	68%
Range/Mileage	63%
Comfort	63%
Price	43%

Least important for purchase decision

****Percentages are measured based on 88 google form responses***

Midsize Pickup - Application areas

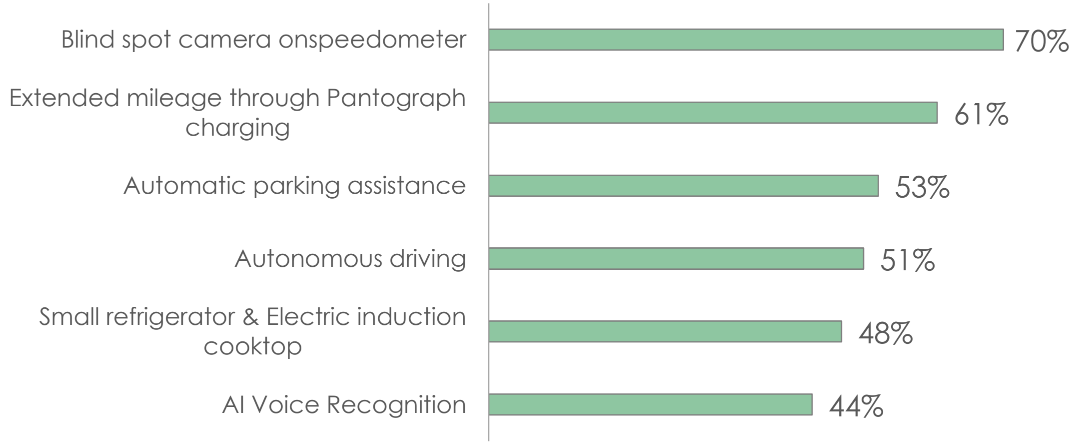


Sub attributes essential needs

Attributes	Description
Safety	Adaptive cruise control
	Collision avoidance system
	Lane Assistance
Performance	Engine power & towing capacity
	Fuel economy/Range
	Maneuverability

Attributes	Description
Comfort	8-way power driver seating
	Smooth ride and handling
	Heater & massage seat
Features	Off-Roading capabilities
	360 Surround cameras
	ADAS & self parking assist

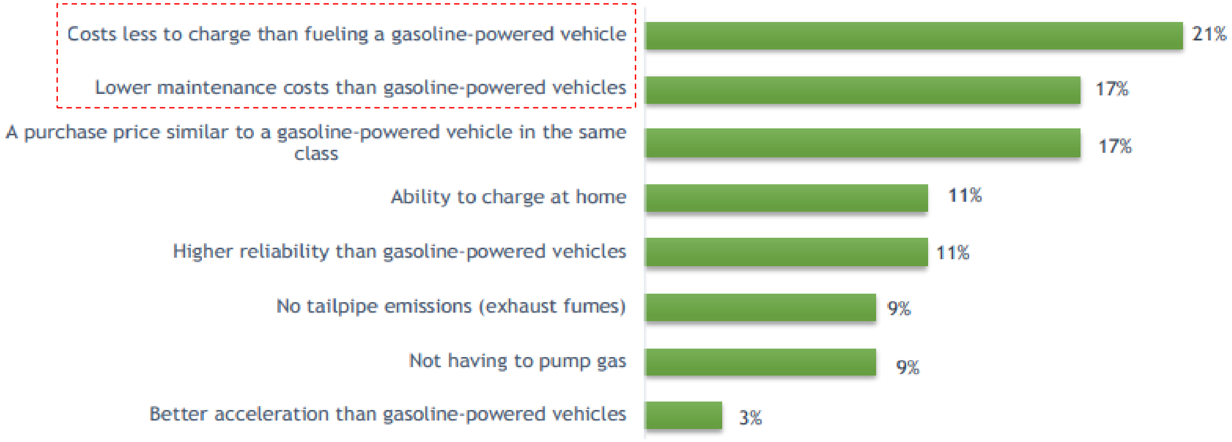
Customer's Delight features



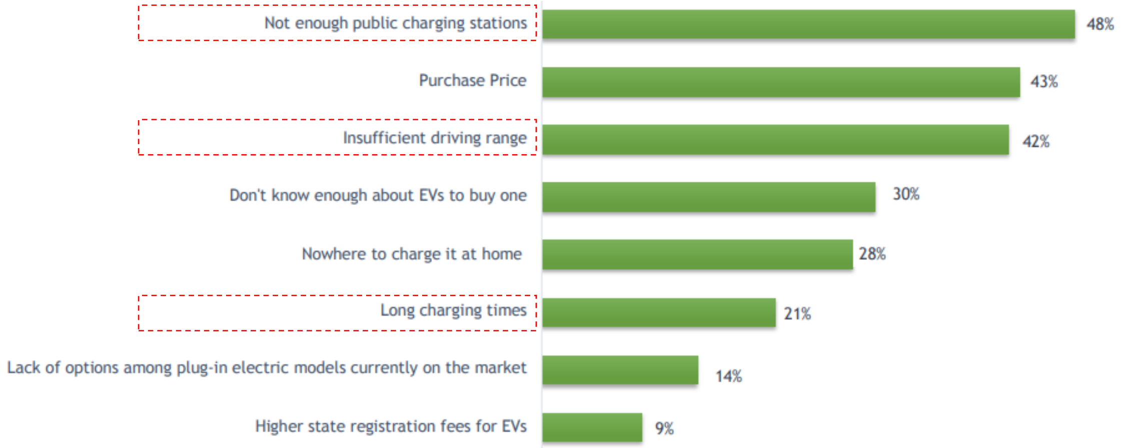
Customers view on EV truck

Reports based on Nationality Representative survey of 3879 people in USA

Attribute encouraged customers to buy EV



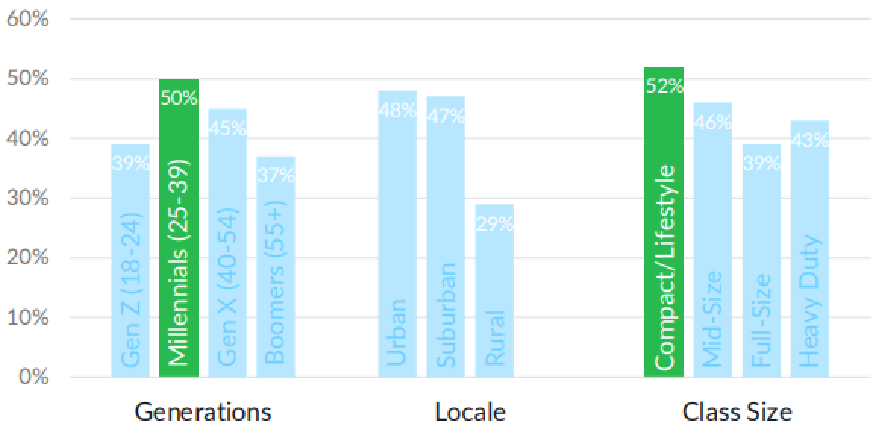
Attributes that are holding customers from buying an EV



- Respondents can choose up to 3 choices
- Respondents who do not "definitely" plan to get a plug-in EV for their next vehicle purchase.

EV – Range Expectations

Share of Truck owners expecting to buy E-Truck in next decade



Ref : CR Survey research department

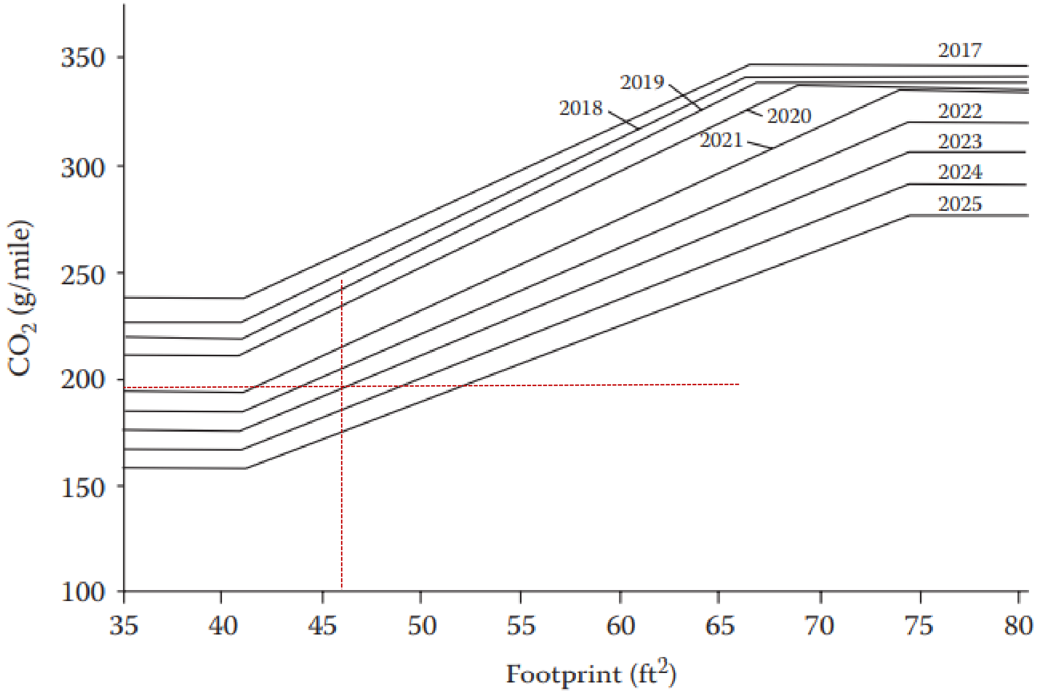
Federal Norms

CO_2 emissions | Fuel Economy

CO_2 Emission

GMC Canyon dimensions :

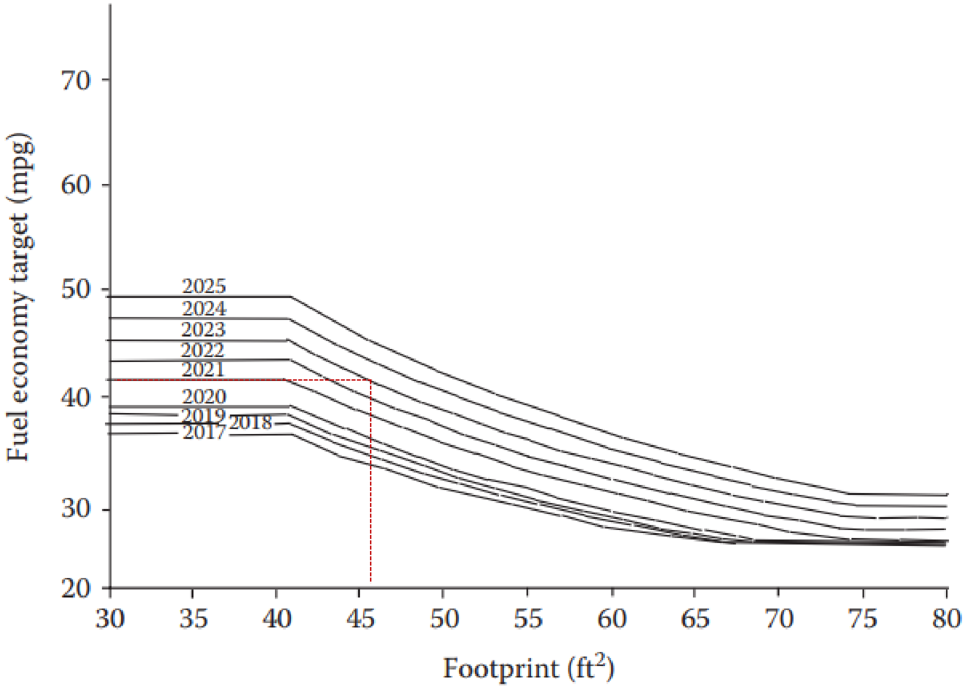
- Wheelbase : ***128.3 in***
- Trackwidth : **74.3 in**
- **Target vehicle Footprint = 66.1 ft^2**



By interpolation,

- For 2028 = CO_2 emission should be Appx. 198 g/mile

Fuel Economy



By interpolation,

- For 2028 = Fuel economy target should be Appx. 39 mpg
- Our target vehicle is expected to have ***77 Mpge.***
(43.5 KWh/100 miles)

Key Benchmark Features

Target vehicle & Competitor vehicle

Parameters	Datum vehicle *2022 GMC Canyon AT4 4x4*	Competitor #1 *2022 Toyota Tacoma TRD 4x4*	Competitor #2 *2022 Ford Ranger Lariat 4x4*	Target vehicle *2028 GMC Canyon 4x4*
Price	$41,690	$38,305	$41,870	$44,000 – $45,000
Power Unit	3.6L V6 305hp @ 6800 Rpm 275 lb-ft @ 4000 Rpm	3.5L V6 278hp @ 6000 Rpm 265 lb-ft @ 4600 Rpm	2.3L EcoBoost I4 270hp @ 5500 Rpm 310 lb-ft @ 3000 Rpm	Dual Motor 450 peak hp 775 lb-ft peak torque
Mileage/Range - EPA Combined (mpg)	19	20	22	77 MPGe
Transmission	8-speed shiftable automatic	6-speed Electronically Controlled automatic Transmission with intelligence (ECT-i)	10-speed shiftable automatic	Constant 2 stage speed reducer coupled to Dual motor
Towing capacity(lbs)	7600	6400	7500	6000
Turning circle radius (ft)	41.3	40.6	42.5	Appx. 34 ft
Suspension	Independent suspension with stabilizer bar	***Front :*** Coil spring –Double wishbone & Stabilizer bar ***Rear :*** Leaf spring gas shock absorber & stabilizer bar	***Front :*** Independent short long arm and solid stabilizer bar; Shocks Gas Pressurized ***Rear :*** Hotchkiss-type non-independent live, parabolic leaf springs and inboard shock absorbers; Shocks. Gas Pressurized	4 wheel Independent – Air suspension, Hydraulic assisted stabilizer

Pugh Analysis

Target vehicle & Competitor vehicle

Parameters	Datum vehicle *2022 GMC Canyon AT4 4x4*	Competitor #1 *2022 Toyota Tacoma TRD 4x4*	Competitor #2 *2022 Ford Ranger Lariat 4x4*	Target vehicle *2028 GMC Canyon 4x4*
Customer needs	D	3	1	18
Vehicle Attributes	D	2	0	8
Vehicle Systems	D	3	3	13

Customer Needs

- Dimension
  - Ground clearance
  - Trunk & cargo space
- Performance
  - Drive modes
  - Fuel economy
  - Noise & Vibration
  - Smooth gear shifting (RPM drop)
  - Ride & handling
  - Reliability
- Safety
  - Lane Assist, cruise control, Collision avoidance
  - Emergency automation braking

Vehicle attributes

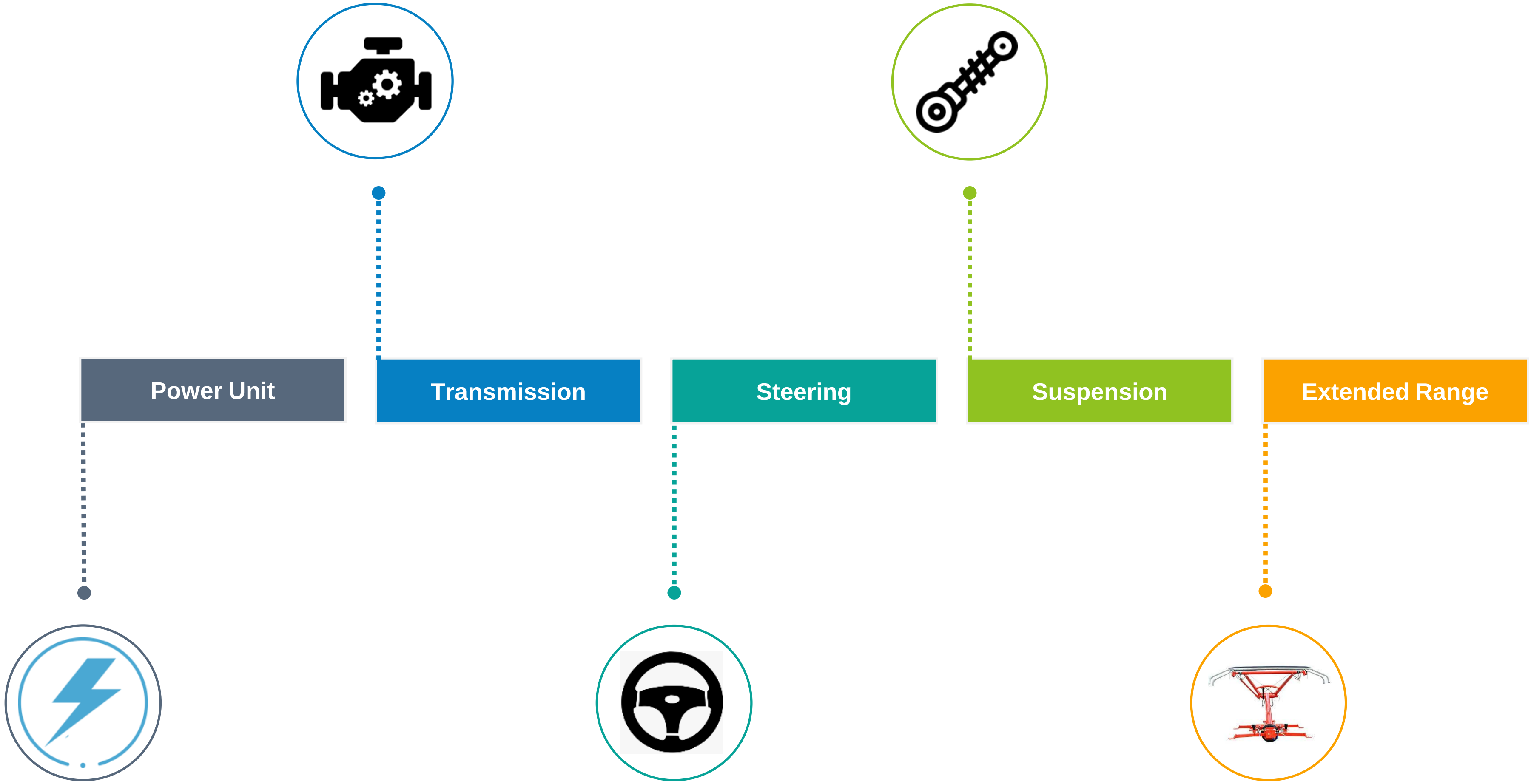
- Infotainment system
- Emission
- Product process complexity
- Braking system
- Suspension system
- Product life cycle

Vehicle systems

- Chassis system
  - Underbody Framework
  - Instrument panel
  - Seat drivers
- Powertrain system
  - Motor, Battery & controller
- Driver interface
  - Driver assistance system
  - Blind spot camera
  - Audio system
  - Navigation system

5 Major Changes

2022 Target vehicle features



5 Major Changes
Features briefing

Power Unit

- Motor
  - Dual Motor
  - 450 hp – Peak power
  - 775 lb-ft – Peak torque
- Battery
  - 100KWh Li-ion (Standard)
  - 130 KWh Li-ion (Extended range)
  - Range(Standard/Extended) = 250/330miles

Steering

- All wheel steering
  - For reducing Turning radius
  - High speed turn stability
  - Maximum rear wheel steer angle = 10 degree
  - Current turning radius = 41.3 ft
  - Turning radius expected to reduce by 34 ft.

Transmission

- Speed reducer
  - 2 stage speed reducer coupled with motor
  - Helical gear for noise reductions
  - Axle torque : 10,500 lb-ft (Through 13.5 reduction ratio)

Suspension

- Air suspension with Hydraulic assisted stabilizer
  - All wheel independent suspension
  - Double wishbone arms
  - Ground clearance = 8.2 in to 14 in
  - Roll stiffness control through Hydraulic stabilizer

Pantograph charging

- Scania Trucks implemented this technology through ***Siemens*** technology in ***Germany***.
- ***Siemens mobility*** also installed and tested 2 mile long overhead contact line system for Hybrid truck near ***U.S.A*** port of Los Angeles and Long Beach.

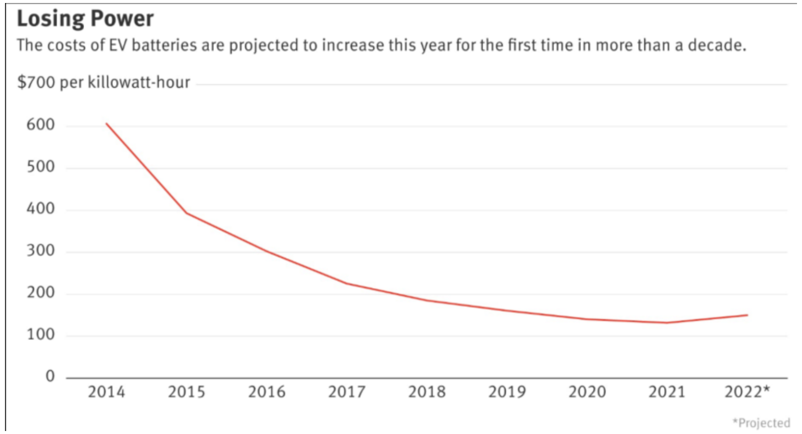
- Dearborn to Network distance = 611 miles
- Out of 611 miles, 560 miles are of highway roads.
- Total journey time : 10hrs 30mins
- ***Scenario :*** Starting the journey around 60% battery, while reaching New York, battery will be recharged to more than 95%.

Challenges pertaining major changes

Features briefing

Power Unit

- Microprocessor
  - Silicon chip shortage - Due to Covid pandemic, supply chain affected.
  - Potential improvement in supply chain expected to be in 2 years.
- Battery
  - Supply chain disruptions of Raw material (minerals) & due to Russia – Ukraine war as Russia



- In future, the cost of battery is expected to reduce after resolving the Supply chain issue

Steering & Suspension

- Complexity of rear steering geometry
  - Rear arms constraint to double wishbone geometry.
- Packaging constraint
  - Additional electromechanical assembly at rear end for controlling the rear wheel angle of steering

Pantograph charging

- Road Infrastructure
  - Government support and initial investment
  - Since already familiar with railroad technology, no complexity in implementation.
- Heavy trucks and Pickups
  - Same wire should be used by both trucks
  - Height of overhead lines – Pantograph length
  - Incase of charge voltage difference between truck & pickup, step down transformer to be used.
  - Energy consumption meter – Through apps.

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P2 – QFD, Requirements Cascade and Interface Analysis
Mid-size Pickup truck

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Content

- Executive summary
- Decomposition tree
- Attributes listing and Cascading
- Quality Function Deployment
- Interface requirements
- Vehicle Trade – Offs

Executive summary

Reference Vehicle and system selection

Reference vehicle and Vehicle system

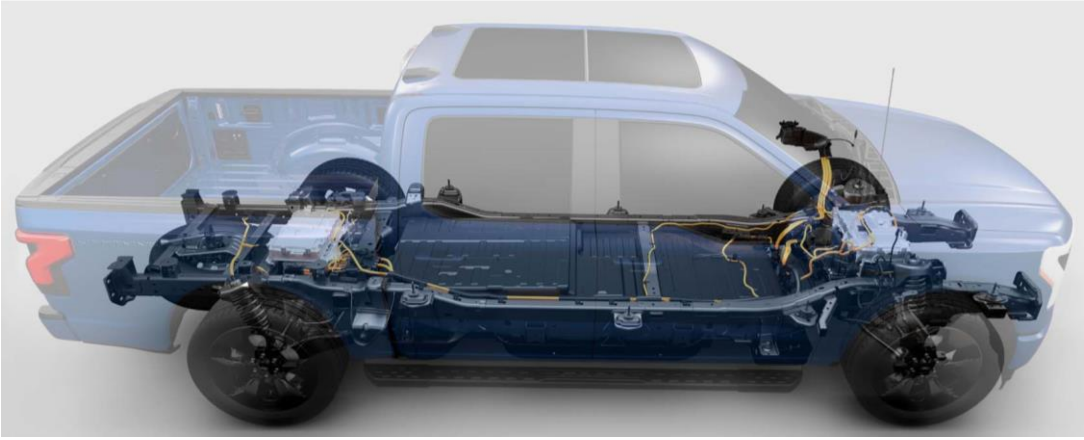
Reference Vehicle

- Market segment : Mid-Size Pickup
- GMC Canyon EV

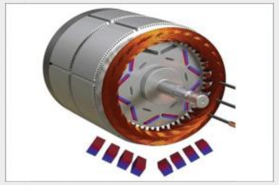
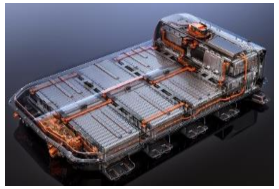
Vehicle systems

- Electrical system
  - Power Unit subsystem
  - Climate control subsystem
  - Lightening subsystem
  - Driver interface and Infotainment subsystem

Electrical Power unit Layout



Power unit's major Sub-subsystem

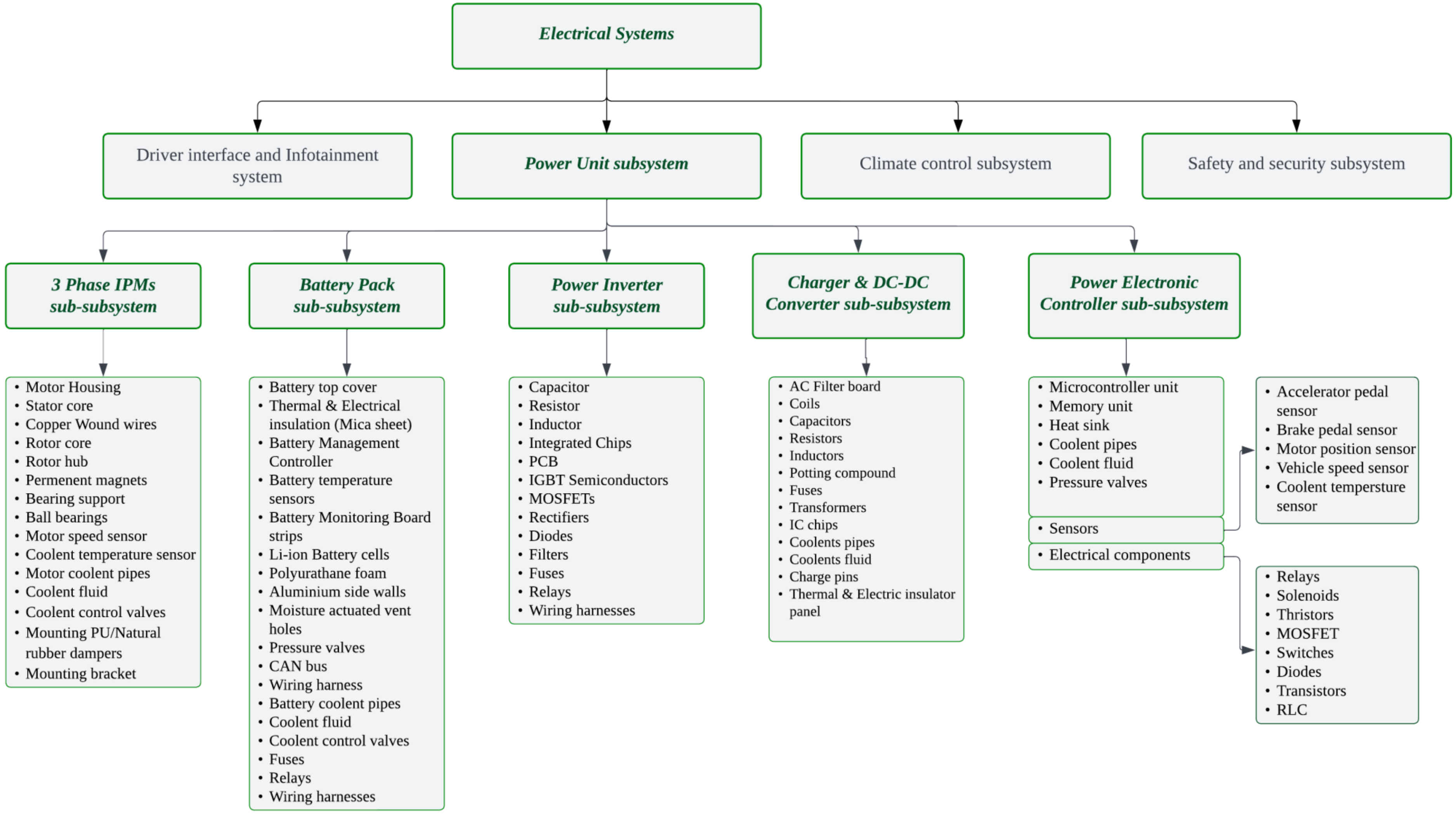
S No.	Sub-subsystem	Photographs	Specification
1	*Motor*		▪ 3 phase Internal Permanent Magnet Synchronous Reluctance motor ▪ Dual motor with 450 peak HP & 775 lbft torque
2	*Battery*		▪ Li-ion Battery pack ▪ 100 KWh (Standard) ▪ 130 KWh (Extended Range)

S No.	Sub-subsystem	Photographs	Specification
3	*Power Electronic Controller*		▪ Power Electronic Controller with CAN bus wiring harness
4	*Power Inverter*		▪ Power inverter with AC to DC conversion to Motor compatibility also AC to DC during Regenerative Braking

Decomposition Tree

Electrical systems – Power unit subsystem

Decomposition tree



Other Interfacing systems

#	Systems Interfacing with Electrical systems
1	Body systems (Motor and Battery mounting with Underbody chassis)
2	Brake system (Regenerative braking)
3	Transmission System (Speed reducer coupled to motor)
4	Suspension system (Adaptive air suspension – Change of ground clearance by ECU)
5	Climate control system
6	Driver interface and infotainment system
7	Safety and security systems

Attributes listing and Cascading

Electrical systems Attributes cascading

Vehicle Attributes and Requirements				Subsystems of Electrical systems			
Vehicle Attribute	**Sub-Attribute**	**Vehicle Level Requirements**	**Electrical systems requirements**	**Motor subsystem**	**Battery subsystem**	**Battery Charger subsystem**	**Power Electronic controller subsystem**
Package	Occupant accommodation	95% of the user population shall be accommodated with 7 or above rating on 10-point scale.	Major Electrical systems shall be operable by small 1st percentile female to 99th percentile male	Accelerator pedal should be compact and occupy less space without compromising the ergonomics	Battery should be placed underneath occupants' accommodation cabin without compromising the cabin interior dimension		
	Mechanical packaging	All vehicle systems shall be accommodated within vehicle hood/body spaces.	All Electrical system components shall be accommodated within vehicle hood/body spaces	Front and rear motors should be compact enough to accommodate beneath the front and rear trunk compartment with no components protruding below the underbody chassis	Battery cells should be enclosed with strong metal wall that prevents the anything from outside penetrating into the battery, also maintaining enough ground clearance	No high voltage wiring harness should be visible at the occupant's space	No high voltage wiring harness should be visible at the occupant's space
	Cargo Space	At least 45 cubic feet space for mid-size pickup truck	Electrical powertrain components shall be designed compact enough to provide required cargo space	Front and rear motors should be compact enough to accommodate beneath the front and rear trunk compartment providing enough cargo space	The height of the Battery Management Controller should be reduced so that it does not interfere with the base of the rear trunk.	None of charger components wiring harness interfere with the cargo space except power outlets	Power Electronic controllers of front and rear motors should not be mounted over the motors which constraints trunk and cargo space

Attributes listing and Cascading

Electrical systems Attributes cascading

Vehicle Attributes and Requirements				Subsystems of Electrical systems			
Vehicle Attribute	**Sub-Attribute**	**Vehicle Level Requirements**	**Electrical systems requirements**	**Motor subsystem**	**Battery subsystem**	**Battery Charger subsystem**	**Power Electronic controller subsystem**
Ergonomics	Controls and displays	Controls and displays shall be located in easy to find locations with rating of 7 or above on 10-point scale.	Controls and display should be at ergonomically operable distance of 1st percentile female to 99th percentile male drivers	Motor's critical MIL (Malfunction Indication Lamps) should be at clear vision range of driver on the instrument cluster	Battery charge, expected range Low battery warning indicator and other Battery health parameters should be at noticeable location on the instrument cluster	Plug connectors charger outlet should be located at the easily accessible location of car and should indicate the battery percentage through different color lights around the charger	On-Board diagnostics of sensor components should be accessible to driver in case of glow of malfunction lamp on instrument cluster
Safety	Crash Avoidance	The vehicle shall meet FMVSS 135 requirements. Must be able to stop vehicle within 95% of the FMVSS specified distances without losing vehicle control.	Electrical systems shall meet FMVSS 135 requirements and must be able to stop the vehicle within 95% of FMVSS specified distances without losing vehicle control	Motor should react to LIMP mode signal in case of any fault/failures noted by Controller and based on the criticality of failures, Motor output torque should be limited or even to fully stop	Battery Management Board should be designed such that it is capable of continuously monitoring battery voltage and temperature over the life of the vehicle		Controller should detect any critical fault/failures on electrical systems and based on the criticality of failures, vehicle should be limited to speed or even to fully stop

Attributes listing and Cascading

Electrical systems Attributes cascading

Vehicle Attributes and Requirements				Subsystems of Electrical systems			
Vehicle Attribute	**Sub-Attribute**	**Vehicle Level Requirements**	**Electrical systems requirements**	**Motor subsystem**	**Battery subsystem**	**Battery Charger subsystem**	**Power Electronic controller subsystem**
Safety	Crash protection	All vehicle systems shall meet all FMVSS 200 and 300 series applicable requirements. Must obtain 5-star NHTSA crash protection ratings.	The electrical systems must be designed to meet the FMVSS 200 & 300 Series requirements and must have minimal intrusion in case of crash	Motors should be positioned towards the driver laterally by allowing enough cushion attenuation space at the front truck spaces	Battery walls should be tough enough to protect the battery packs from crushing and intrusion during front and side impacts		
	Visibility	The driver shall be able to see objects from 200 feet at night and meet federal safety standards for warning lamp visibility specified in FMVSS 108.	The electrical system should meet the visibility range at night and meet the federal safety standards for warning lamp visibility as specified in FMVSS 108	MIL lamps warning of critical components of motor should be clearly visible on the instrument control and should glow with colors (yellow and red) based on the criticality	Battery low indication warning and estimated range indicator should be located at driver vision range	Plug connectors charger outlet should be located at the easily accessible location of car and should indicate the battery percentage through different color lights around the charger	MIL lamps warning of critical components of Electronic Controller should be clearly visible on the instrument control and should glow with colors (yellow and red) based on the criticality
Styling and Appearance	Appearance	Wheels must provide appearance to meet the vehicle image.	Visual appearance of Accelerator pedal, power outlets, infotainment control knobs and charger port door	Visual appearance of pedal should be good and motor components and wiring harnesses should not be visible while	Visual appearance of Battery wall must be consistent with the underbody frame design	Charger handle should be designed with lightening systems to indicate the charge levels and the charger door	

Attributes listing and Cascading

Electrical systems Attributes cascading

Vehicle Attributes and Requirements				Subsystems of Electrical systems			
Vehicle Attribute	**Sub-Attribute**	**Vehicle Level Requirements**	**Electrical systems requirements**	**Motor subsystem**	**Battery subsystem**	**Battery Charger subsystem**	**Power Electronic controller subsystem**
Thermal and Aerodynamics	Aerodynamics and thermal management	All vehicle system operates under -30 to 160 deg. F.	Electrical systems should be capable of operating at the range of -30 to 160 deg. F without any failure in the components	Motor should always run on the optimum temperature by controlling the coolant flow in order to avoid the lowering life of motor winding insulation	Battery thermal management should have effective control over the temperature by regulating the Battery coolant temperature	Chargers should remain idle when battery becomes full to avoid any thermal build up in battery	Controller's temperature should be controlled in order to improve life of electrical boards and CPUs
Performance and Drivability	Fuel Economy	The vehicle shall meet 39 mpg combined city and highway driving requirement.	Electrical systems should be designed to have a range of 77 MPGe	Use of IPMsyncRM Motor should reduce back EMF during high speeds, which directly consumes more battery charge at high speed.	Battery's capacity of 100KWh (standard) should be designed to provide required range with improved efficiency through effective cooling	Chargers should be designed in such a way it goes 0 - 80 % in minimal time. Also, development of pantograph mitigates range fear to the drivers	Controlled Area Network (CAN) bus should be developed to effectively communicate to the systems with lower power consumption
	Acceleration	The vehicle shall accelerate from 0 to 60 mph	Electrical Power Unit should be designed to provide acceleration of 0 - 60 mph in 4 sec	IPMsyncRM motor should be utilized to produce the maximum torque availability by shifting the Rotating Magnetic Field to desired angle and also shifting back during high speed	Battery should provide enough current to be available at the motor end by effective regularization of voltage to meet the requirements		Controlled Area Network (CAN) bus should be developed to effectively communicate to the systems with lower power consumption

Attributes listing and Cascading

Electrical systems Attributes cascading

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Vehicle Attribute	**Sub-Attribute**	**Vehicle Level Requirements**	**Electrical systems requirements**	**Motor subsystem**	**Battery subsystem**	**Battery Charger subsystem**	**Power Electronic controller subsystem**
Performance and Drivability	Braking	The vehicle shall meet FMVSS 135 requirements. Must be able to stop vehicle within 95% of the FMVSS specified distances without losing vehicle control.	Electrical system should aid braking through regenerative braking system also to meet the stopping distance criteria given by FMVSS without vehicle loss of control	Motor RMF to be aligned in such a way it produces more current to recover the wastage of Kinetic energy through braking	Battery should be designed to have longer life by improving the capacity of handling many charging & discharging cycles		Power Electronic Controller to swiftly control the power Inverter to provide required current signals (AC & DC) to the motor & battery
	Range	The vehicle shall have at least 500-mile highway range on a full tank of gas.	Electrical systems to provide a maximum range of 250 miles under standard battery pack and 330 miles under extended battery pack	Back EMF reduction during high speeds by shifting Rotating Magnetic Field to its effective position that draws less power consumption at different speeds	Battery's capacity of 100KWh (standard) should be designed to provide required range with improved efficiency through effective cooling	Chargers should be designed in such a way it goes 0 - 80 % in minimal time. Also, development of pantograph mitigates range fear to the drivers	Controlled Area Network (CAN) bus should be developed to effectively communicate to the systems with lower power consumption
Vehicle Dynamics	Lateral G's	The vehicle shall be able to handle within least 0.8g in all directions.	Electrical systems should be able to handle at least 0.8g in all direction		Since major proportion of battery weight, it should be placed such that overall CG point of the vehicle should be closer to the roll axis of vehicle to maintain roll stiffness and so the handling of vehicle		

Attributes listing and Cascading

Electrical systems Attributes cascading

Vehicle Attributes and Requirements				Subsystems of Electrical systems			
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Vehicle Dynamics	Driver Comfort	The vehicle shall have comfort ratings equivalent to other benchmarked vehicles.	Electrical components should be compact without interfacing into occupant space	Accelerator pedal should be placed at ergonomic ankle posture and with enough spring stiffness to avoid over push	Battery Thermal insulation should be well done by using mica sheet insulator so that not feeling any heat waves inside occupant space		
Noise, Vibrations and Harshness (NVH)	Road noise	No worse than benchmarked vehicles on proving grounds NVH course	Electrical system should not produce any road noise	Motor should have not produced any noise other than its own spinning sound.			
	Powertrain noise	No worse than benchmarked vehicles in blind study	Electrical power unit should not produce any road noise	Making use of Natural or polyurethane rubber to the motor mounting bracket will eliminate the even minimal vibration of motor			
Interior Climate Comfort	Heater	The vehicle shall be able to provide heat to increase passenger compartment temperature from 20 to 70 deg. F in 5 minutes	The Electrical system shall be able to provide heat with the auxiliary battery to increase passenger compartment temperature from		Battery system should have enough capacity to accommodate the use of Climate control system and driver infotainment system		

Attributes listing and Cascading

Electrical systems Attributes cascading

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Vehicle Attribute	**Sub-Attribute**	**Vehicle Level Requirements**	**Electrical systems requirements**	**Motor subsystem**	**Battery subsystem**	**Battery Charger subsystem**	**Power Electronic controller subsystem**
Weight	Weight	The curb weight of the vehicle shall be less than 4500 lbs. for midsize pickup	Compact electrical power unit and battery packaging necessary to meet overall weight goal	Compact motor and inboard speed reducer necessary to reduce the overall weight	Compact Structural battery pack pattern should be necessary for building smaller size of battery side wall		Use of CAN bus wiring harness for all power controller communication will effectively reduce overall weight
Security	Vehicle theft/ personal security	Lock out vehicle usage under unauthorized usage conditions.	Electronic controllers should be designed with high security interface				Controllers' firmware should be with high security system in order to prevent from hacking and tuning
Emissions	Tailpipe Emissions.	Must meet federal & California base emissions	Electrical system must be Zero carbon emission during its entire operation of life.	Zero emission through use of electricity			
	On-Board Diagnostics	Fully compliant with CARB regulations	Electrical systems should be designed to do diagnostics tests of all sensors and should making warning in case of any failures/fault arises	On board Diagnostic tests access should be available to the driver by legally following Right to Repair movement	On board Diagnostic tests access should be available to the driver by legally following Right to Repair movement	On board Diagnostic tests access should be available to the driver by legally following Right to Repair movement	On board Diagnostic tests access should be available to the driver by legally following Right to Repair movement

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Communications and Entertainment	Vehicle state information.	Provide warning during malfunction.	The electrical system should meet the federal safety standards for warning lamp visibility as specified in FMVSS 108	Motor should react to LIMP mode signal in case of any fault/failures noted by Controller and based on the criticality of failures, Motor output torque should be limited or even to fully stop	Battery charge, expected range Low battery warning indicator and other Battery health parameters should be at noticeable location on the instrument cluster	Plug connectors charger outlet should indicate the battery percentage through different color lights around the charger	Controller should detect any critical fault/failures on electrical systems and based on the criticality of failures, vehicle should be limited to speed or even to fully stop
Cost	Vehicle price	Priced within 5% of benchmarked vehicles	Electrical system must meet the target cost	Motor system must meet the target cost proportion to IC engine	Battery system should be designed must meet the target cost	Charger system should be designed must meet the target cost	Electronic controllers should be designed must meet the target cost
	Profit	5% profit margin per vehicle.	Electrical system must meet the target cost and also profit margin	Motor should be developed in a way to have less production cost and meet profit margin set by company	Battery system should be developed in a way to have less production cost and meet profit margin set by company	Charger should be developed in a way to have less production cost and meet profit margin set by company	Controller should be developed in a way to have less production cost and meet profit margin set by company

Attributes listing and Cascading

Electrical systems Attributes cascading

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Vehicle Attribute	**Sub-Attribute**	**Vehicle Level Requirements**	**Electrical systems requirements**	**Motor subsystem**	**Battery subsystem**	**Battery Charger subsystem**	**Power Electronic controller subsystem**
Customer Life Cycle	System Reliability	10 C's/1000 overall warranty claims.	Complaints per 1000s related to Electrical system should be less than 2	Motor should be reliable enough without from any failures for 5 years/60,000 miles and only minor servicing required post warranty period	Battery should be reliable enough without from any failures for 8 years/100,000 miles and only minor servicing required post warranty period	Charger unit should not fail at any charging cycles and only fuse replacements can be done	Controllers should and only fuse replacements can be done
	Full warranty	3 year 36,000 miles.	Major electrical systems should cover under warranty	Motor should be covered under warranty for 5 years/60,000 miles in case of any failures during the tenure	Battery should be covered under warranty for 8 years/100,000 miles in case of any failure during the tenure	Standard warranty period of chargers should be covered in case of any electrical failure happened to the system	Controllers should be covered under warranty by ECU flashing in case of faulty error on the code
Product and Process Compatibilit y	Carryover components	Check for feasibility and performance improvements through use of carryover components.	Electrical systems to be designed in such a way it can be communized with the components of future vehicles	Motor should be tunable electrically and to be utilized among different vehicle under same product segment	Battery should have considered feasibility for future improvements like providing additional electrical components provision on PCB		Controller should have considered feasibility for future improvements like providing additional electrical components provision on PCB

Attributes listing and Cascading

Electrical systems Attributes cascading

Vehicle Attributes and Requirements				Subsystems of Electrical systems			
Vehicle Attribute	**Sub-Attribute**	**Vehicle Level Requirements**	**Electrical systems requirements**	**Motor subsystem**	**Battery subsystem**	**Battery Charger subsystem**	**Power Electronic controller subsystem**
Product Process Compatibility	Platform and plant sharing	Share platform and plant with other product lines.	Electrical systems to be designed in such a way it can be easily tuned for future vehicles	Motor should be tunable electrically and to be utilized among different vehicle under same product segment	Battery should have considered feasibility for future improvements like providing additional electrical components provision on PCB	Charger ports should be standardized for each segment of vehicles for cost reduction and easy platform sharing	Controllers should be designed with enough flexibility to alter the code and the behavior without making any physical change

Quality Function Deployment

Based on 88 response on Google survey & 10 responses on direct interview

Customer Requirement (WHAT)

- Performance
- Electric Powertrain
- Battery
- Charging
- Comfort
- Infotainment System
- Safety
- Other

Functional Specification (HOW)

- Vehicle specification
- IOT Component
- Autonomous System
- Safety Feature

Importance ratings of customer needs

Desired direction of functional specification

Absolute and relative importance ratings of functional specifications

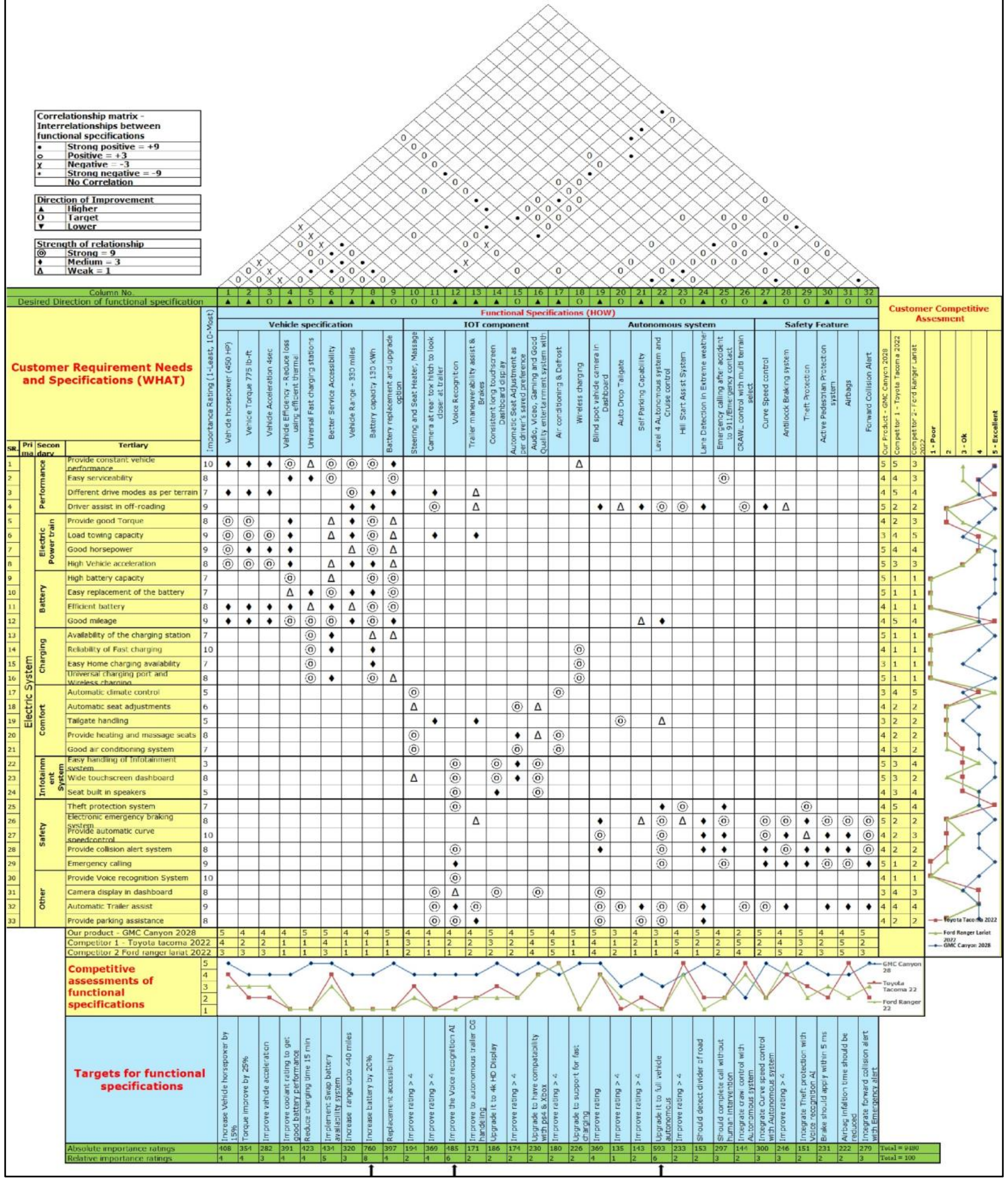
Plots of competitive assessments

Relationship matrix– shows strength of relationships between customer needs and functional specifications

Correlationship Matrix: strength and direction of relationships

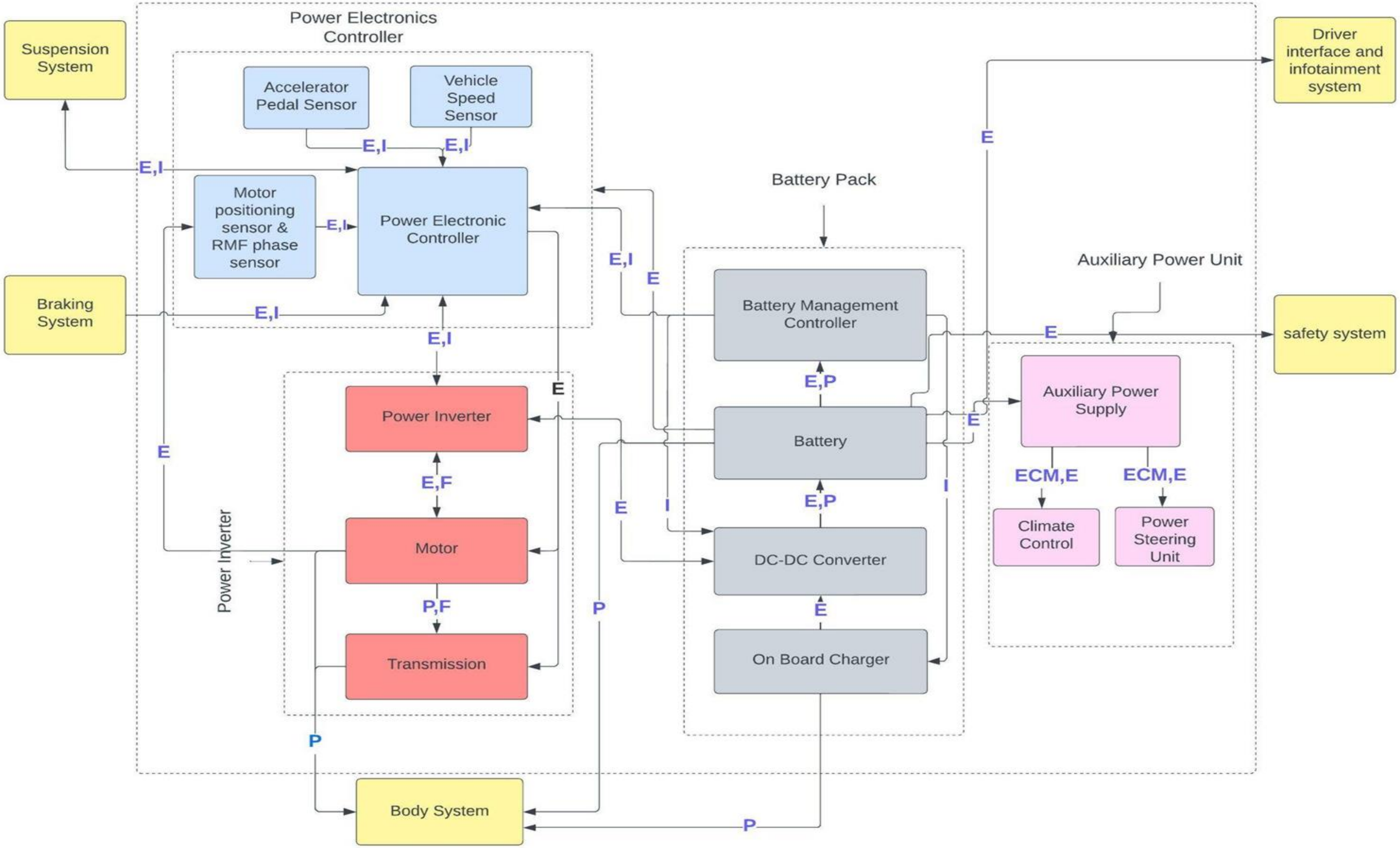
Targets for functional specifications

Quality Function Deployment



Interface Diagram

Electrical systems and its interfacing systems



Interface Matrix

Electrical systems and its interfacing systems

		SS	SSS1	C11	C12	C13	SSS2	C21	C22	C23	C24	SSS3	C31	C32	C33	C34	SSS4	C41	C42	C43	OS1	OS2	SS2	OS4	SS3
	P=Physical Attachment S=Spatial Sharing F=functional Interface E=Electrical Interface M=Material Transfer	Power Subsystem	Power Sub-Subsystem	Power Inverter	Motor	Transmission	Battery Pack Subsystem	Battery Management Controller	Battery	DC-DC Converter	On Board Charger	Power Electronic Controller Sub sub-system	Power ElectronicControlle	Motor Positioning Sensor	Vehicle Speed Sensor	Accelerator Pedal Sensor	Auxiliary power unit	Auxiliary Power Supply	climate control	Power Steering Unit	Suspension System	Braking System	Safety Sub System	Body system	Driver imterface & infotai
SS	Power Subsystem	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SSS1	Power Sub-Subsystem	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C11	Power Invertor	0	0	0	E,F	0	0	0	0	E	0	0	E,I	0	0	0	0	0	0	0	0	0	0	0	0
C12	Motor	0	0	E,F	0	P,F	0	0	0	0	0	0	0	E	0	0	0	0	0	0	0	0	0	P	0
C13	Transmission	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	P	0
SSS2	Battery Pack Subsystem	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C21	Battery Management Cor	0	0	0	0	0	0	0	0	I	I	0	E,I	0	0	0	0	0	0	0	0	0	0	0	0
C22	Battery	0	0	0	0	0	0	E,P	0	0	0	0	E	E	E	E	0	E	0	0	0	0	E	P,S	E
C23	DC-DC Converter	0	0	0	0	0	0	0	E,P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C24	On Board Charger	0	0	0	0	0	0	0	0	E	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SSS3	Power Electronic Control	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C31	Power ElectronicControll	0	0	E,I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C32	Motor Positioning Sensor	0	0	0	0	0	0	0	0	0	0	0	E,I	0	0	0	0	0	0	0	0	0	0	0	0
C33	Vehicle Speed Sensor	0	0	0	0	0	0	0	0	0	0	0	E,I	0	0	0	0	0	0	0	0	0	0	0	0
C34	Accelerator Pedal Sensor	0	0	0	0	0	0	0	0	0	0	0	E,I	0	0	0	0	0	0	0	0	0	0	0	0
SSS4	Auxiliary power unit	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C41	Auxiliary Power Supply	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ECM,E	ECM,E	0	0	0	0	0
C42	climate control	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C43	Power Steering Unit	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OS1	Suspension System	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0
OS2	Braking System	0	0	0	0	0	0	0	0	0	0	0	E,I	0	0	0	0	0	0	0	0		0	0	0
SS2	Safety Subsystem	0	0	0	0	0	0	0	0	0	0	0	E,I	0	0	0	0	0	0	0	0	0		0	0
OS4	Body system	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
SS3	Driver imterface & infota	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Interface Requirements

Electrical systems and its interfacing requirements

S.No	Subsystem	Requirements	Interface type	Interfacing system	Interfacing Requirements
1	Power Electronics Controller	*Requirement 1*	I, E	Microcontroller	Controller should detect any critical fault/failures on electrical systems and based on the criticality of failures, vehicle should be limited to speed or even to fully stop.
		Requirement 2	I, E	Motor speed sensor	Monitors the motor speed and gives an indication to the glow malfunction indicator if it detects irregularities.
2	Motor	*Requirement 1*	E	Motor temperature sensor	Motor should always run on the optimum temperature by controlling the coolant flow in order to avoid the lowering life of motor winding insulation
		Requirement 2	P	Ball Bearings	The interface that is used between the shaft and the motor to transfer loads at high efficiency.
3	Battery	*Requirement 1*	I, E	Battery Management Controller	The BMC is interfaced with the battery pack with the help of a microcontroller should control the temperature levels across the battery pack, ensuring the pack doesn't overheat.
		Requirement 2	F	Battery Cover	Battery cells should be enclosed with strong metal wall that prevents the anything from outside penetrating into the battery, also maintaining enough ground clearance
4	Charger	Requirement 1	E	Fuses	Charger should be connected with fuses to protect the customer during a power surge.
		Requirement 2	I, E	IC Chips	Chargers should remain idle when battery becomes full to avoid any thermal build up in battery
5	Power Inverter	Requirement 1	E	Capacitor	This is a system that is integrated to the inverter to avoid voltage fluctuations in the inverter.
		Requirement 2	E	Inductors	Inductors are used to convert the electrical energy into magnetic energy for storage. It's integrated through the use of wires and soldering.

Vehicle Trade-Offs

- There is a trade-off between the ***large battery size*** and the ***charging time*** of the car. Due to the increased size of the battery the charging time of the vehicle has increased from 6 hours to 7.5 hours. This is a necessary trade-off because the large 130 KWh battery gives an extended range of 320 miles eliminating range anxiety for the customer. The large battery size also reduces the number of times a customer must charge his/her truck which increases the life of the battery and makes it more economical for the customer to own.

- The is a trade-off between the ***overall weight of the car*** and the ***features*** provided. The weight of the car has increased from 1785 kg to 1940 kg. This is a result of luxury amenities provided like ventilated and massaging seats, dual climate control and driver assistance systems. The increased weight does lead to more wear ands tear of the components but features like active lane keeping and blind spot assist does improve safety and comfort for the customer and passengers

COLLEGE OF ENGINEERING & COMPUTER SCIENCE
UNIVERSITY OF MICHIGAN-DEARBORN

AENG 500 - Automotive Integrated Systems

P3 – Conceptual Design, Program Timing Plan and Financial Plan Development

Group 7 :

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Prem Kumar R N
Rahul Menon
Varun Raj Irukulla

Content

- Executive summary
- Conceptual design
- Ergonomics and vision window
- Timing Plans
- Selling Price Estimation, Cost distribution & Sales Projection
- Pickup Truck Market Share & Sales Prediction
- Cost and Revenue

Executive summary

Reference Vehicle and system selection

Reference vehicle and Current specifications

Reference Vehicle

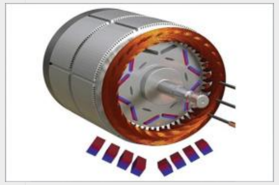
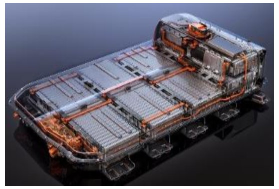
- Market segment : Mid-Size Pickup
- GMC Canyon EV

Specifications

- IC Engine – 3.6L V6 – 305hp & 275lbft torque
- 8 speed shiftable automatic transmission
- Independent suspension with stabilizer bar
- Front wheel steering with turn radius of 41.3 ft

Target vehicle – GMC Canyon AT4

Major changes on target vehicle 2028

S No.	Sub-subsystem	Photographs	Specification
1	*Motor*		▪ 3 phase Internal Permanent Magnet Synchronous Reluctance motor ▪ Dual motor with 450 peak HP & 775 lbft torque
2	*Battery*		▪ Li-ion Battery pack ▪ 100 KWh (Standard) ▪ 130 KWh (Extended Range)

S No.	Sub-subsystem	Photographs	Specification
3	*Steering*		▪ 4 wheel steering with maximum rear wheel articulation of 10 degrees ▪ Turning circle radius change - 35 ft
4	*Suspension*		▪ Air adaptive suspension for roll stability with adjustable ground clearence.

Key Benchmark Features

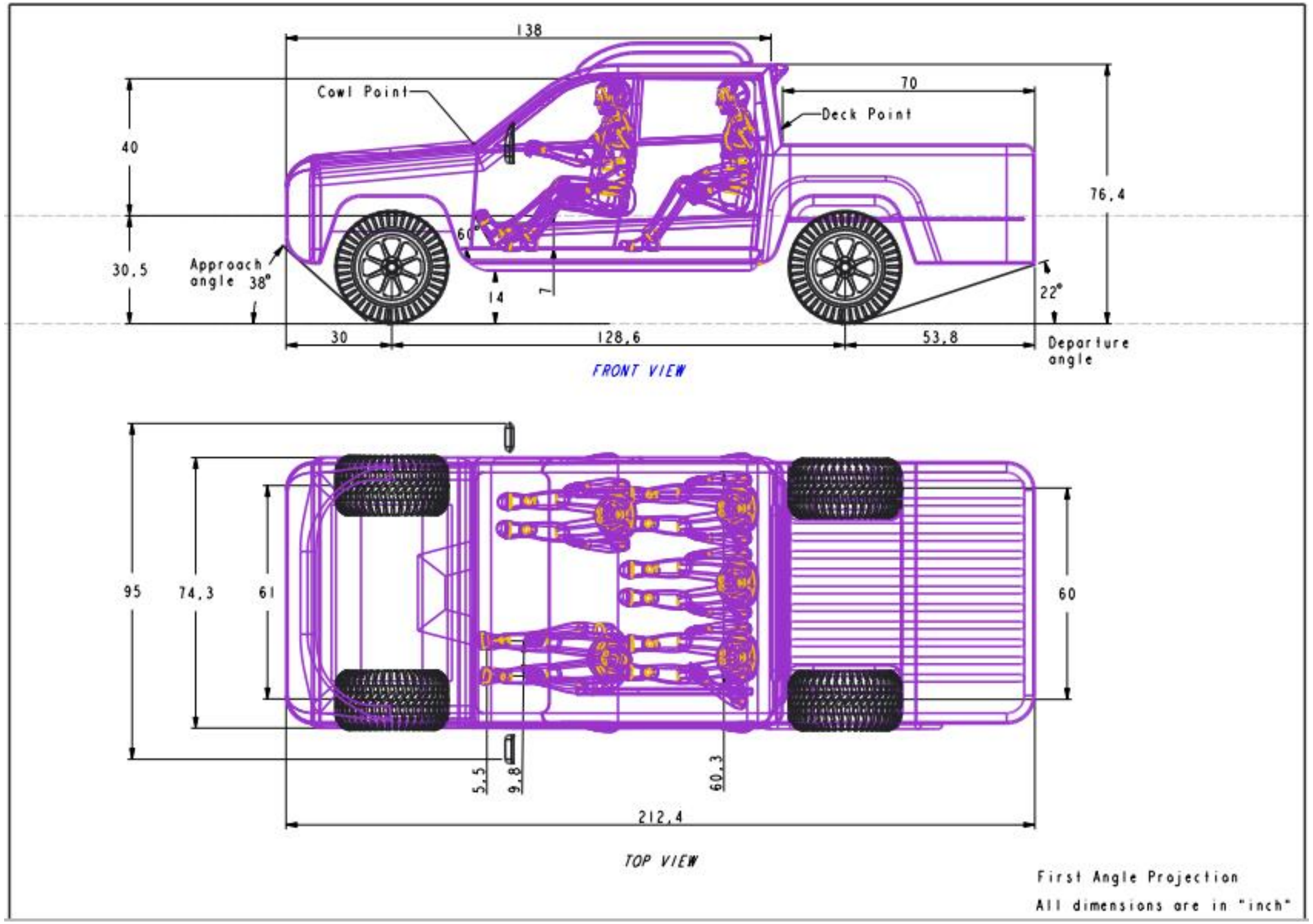
Target vehicle & Competitor vehicle

Parameters	Datum vehicle *2022 GMC Canyon AT4 4x4*	Competitor #1 *2022 Toyota Tacoma TRD 4x4*	Competitor #2 *2022 Ford Ranger Lariat 4x4*	Target vehicle *2028 GMC Canyon 4x4*
Price	$41,690	$38,305	$41,870	$44,000 – $45,000
Power Unit	3.6L V6 305hp @ 6800 Rpm 275 lb-ft @ 4000 Rpm	3.5L V6 278hp @ 6000 Rpm 265 lb-ft @ 4600 Rpm	2.3L EcoBoost I4 270hp @ 5500 Rpm 310 lb-ft @ 3000 Rpm	Dual Motor 450 peak hp 775 lb-ft peak torque
Mileage/Range - EPA Combined (mpg)	19	20	22	77 MPGe
Transmission	8-speed shiftable automatic	6-speed Electronically Controlled automatic Transmission with intelligence (ECT-i)	10-speed shiftable automatic	Constant 2 stage speed reducer coupled to Dual motor
Towing capacity(lbs)	7600	6400	7500	6000
Turning circle radius (ft)	41.3	40.6	42.5	Appx. 34 ft
Suspension	Independent suspension with stabilizer bar	***Front :*** Coil spring –Double wishbone & Stabilizer bar ***Rear :*** Leaf spring gas shock absorber & stabilizer bar	***Front :*** Independent short long arm and solid stabilizer bar; Shocks Gas Pressurized ***Rear :*** Hotchkiss-type non-independent live, parabolic leaf springs and inboard shock absorbers; Shocks. Gas Pressurized	4 wheel Independent – Air suspension, Hydraulic assisted stabilizer

Conceptual design

Side and plan view of target vehicle with Exterior, Interior & Packaging dimensions

GMC Canyon EV 2028 Exterior, Interior & Packaging dimensions



Parameters considered while designing

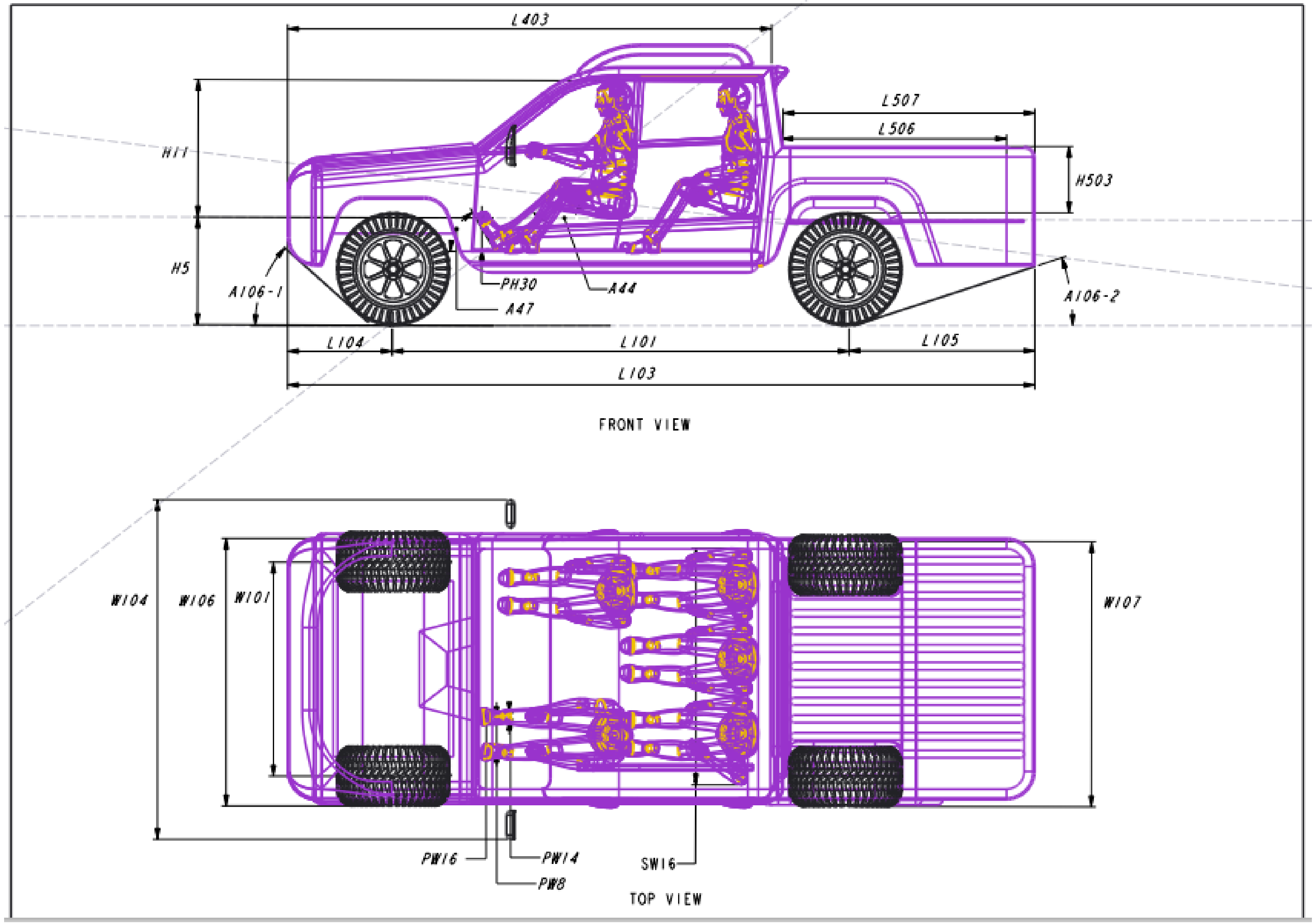
#	Important change area parameters
1	Motor and Controller space volume to be maximum of ***20%*** of overall vehicle space.
2	Fender to tire gap to maintain minimum of 2 inch at extreme rear wheel steering articulation angle with a ***trade off*** of 2 cu.ft cargo volume.
3	Battery space to cover ***80%*** of vehicle floor area for the 100Kwh standard pack and about ***95%*** vehicle floor area for Extended battery pack of 130Kwh. The maximum height including the Battery Management controller of the Battery pack should not exceed ***6 in***
4	Suspension system (Adaptive air suspension) stiffness change should maintain minimum of ***20%*** higher at 14 inch ground clearance than at 9in clearence to prevent body roll.

- Driver and passengers – 95^{th} Percentile Manikin considered

Conceptual design

Side and plan view of target vehicle with SAE standard dimension reference

GMC Canyon EV 2028 Exterior, Interior and packaging SAE Standard dimensions



SAE Reference materials

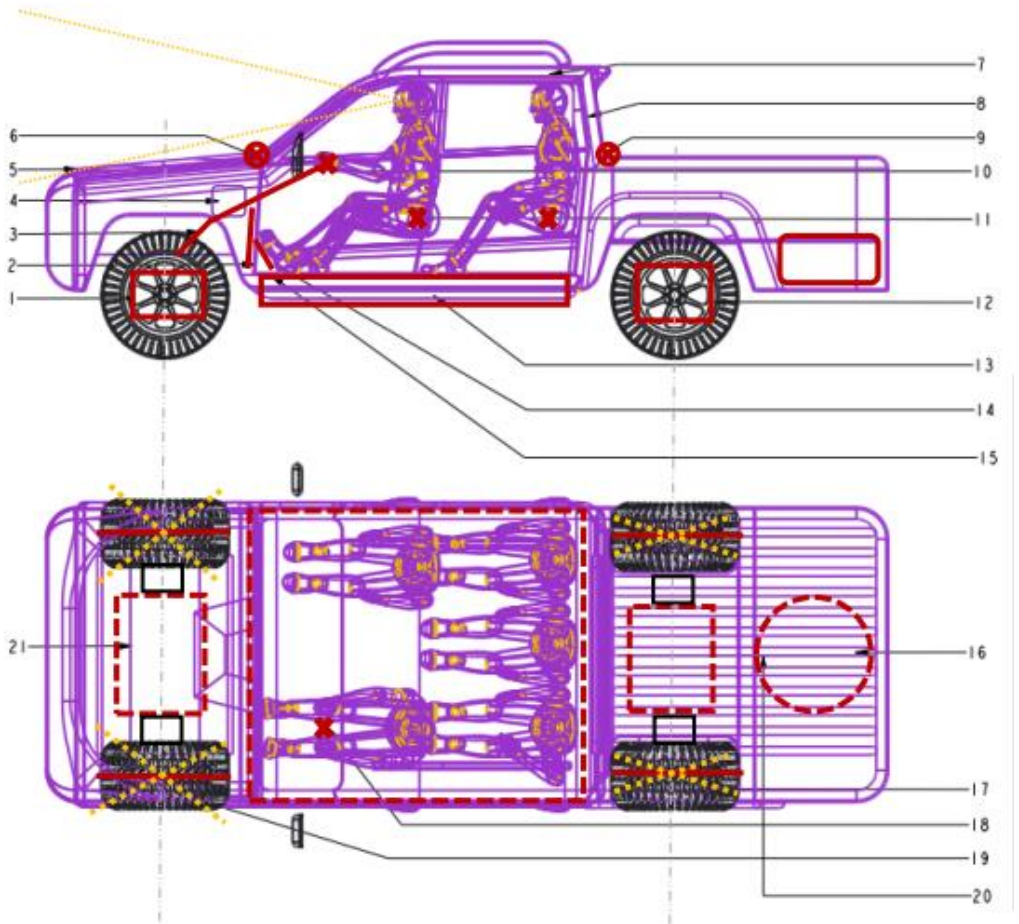
SAE	Description
SAEJ110	Exterior & interior dimensions
SAEJ1516	Pedal pane dimensions
SAEJ826	H-Point template

- Driver and passengers – 95th Percentile Manikin considered

Conceptual design

Side and plan view of target vehicle with Interior and Exterior Envelopes

GMC Canyon EV 2028 Exterior and Interior Envelopes



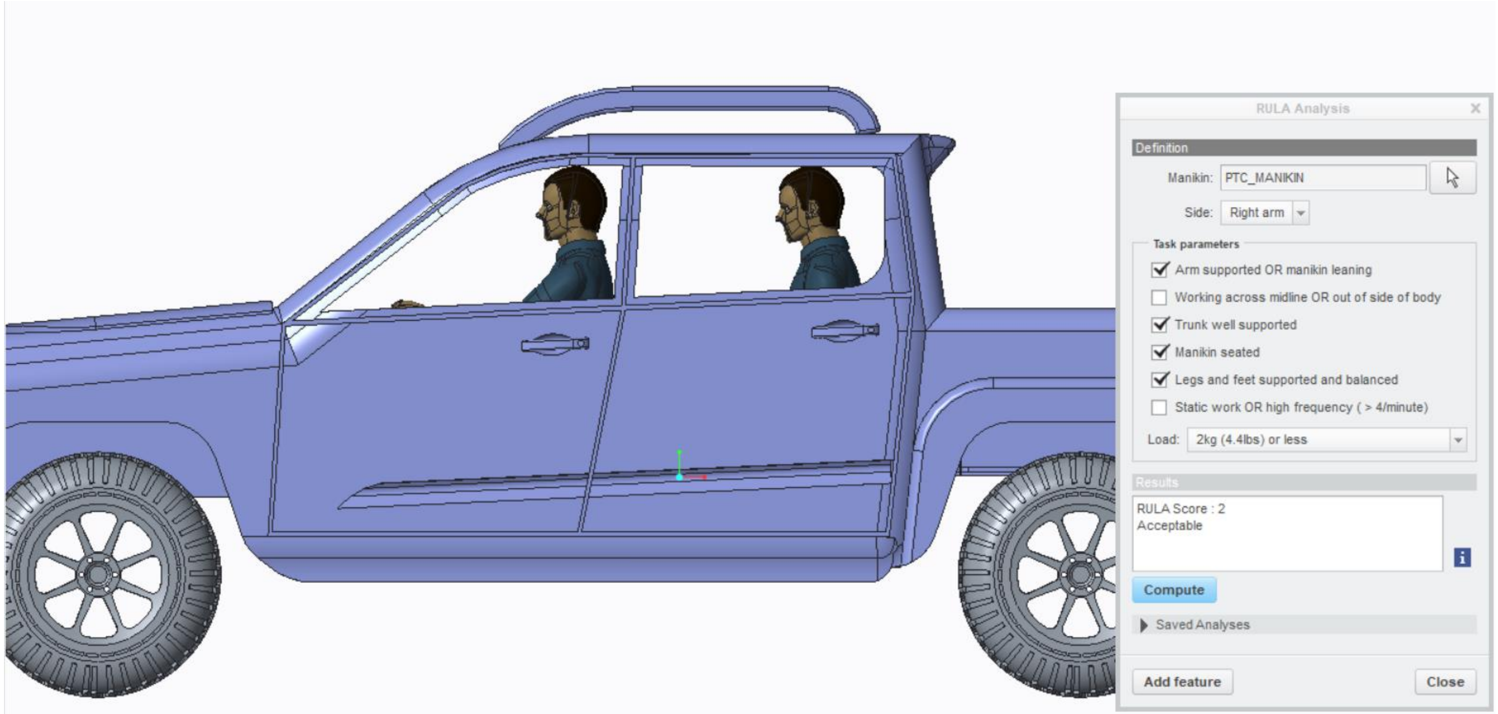
Description

#	Description
1	Front Motor and Controller envelope
2	Firewall
3	Steering column
4	Charger port
5	Driver vision window
6	Cowl point
7	Headliner
8	Back side of rear seat
9	Deck point
10	Steering point
11	Seating Reference Point (SgRP)
12	Rear Motor and Controller envelope
13	Battery Envelope
14	Gas pedal location
15	Vehicle Floor
16	Spare tire location
17	Rear steering angle projections
18	Steering point
19	Front steering angle projection
20	Rear trunk
21	Front trunk

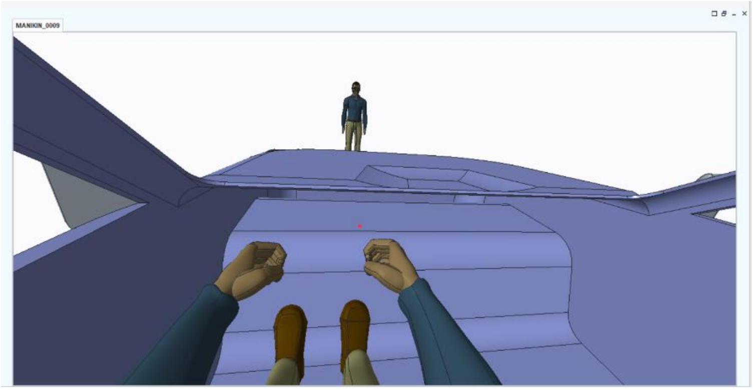
Ergonomics and Vision window

95th Percentile male – RULA Analysis & Driver vision

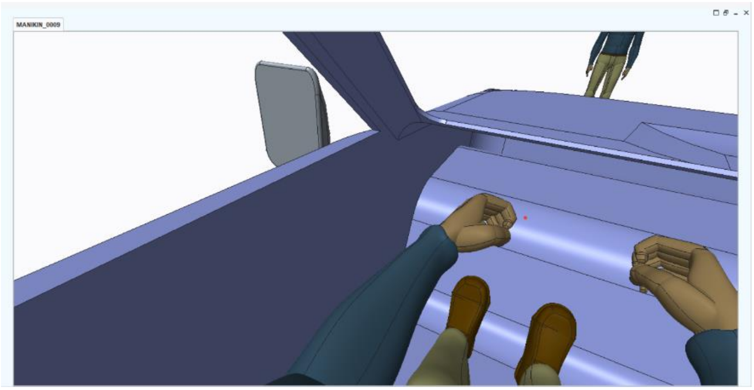
Rapid Upper Limb Assessment (RULA) Analysis



Driver Vision Window



Vision window to Pedestrian at 5 meter distance



Vision window to Left view mirror

Timing Plans

Phase, Steps, Gateway and Planned timeline chart

Description of Phase	Description of Step	Gateway Description	Label	Planned Dates
Pre-program work	Define Program for GMC Canyon	Program Definition	PD	***Sep-24***
	Acceptance of Program by senior management and the program is kicked off.	Program Kick-off	PKO	***Sep-24***
	Program leader and team leaders for Electrical, Powertrain, Suspension, packaging and other are selected	Start of Team Formation	STF	***Oct-24***
Vehicle definition, target setting, concepts development, and systems design	Body engineering, chassis engineering, powertrain engineering, electrical engineering, aerodynamics engineering, packaging teams are formed, and Benchmarking of selected competitive vehicles begins with Toyota Tacoma & Ford Ranger	Team Formation	TF	***Nov-24***
	Information is gathered from customers and key suppliers are selected.	Data collection	DC	***Dec-24***
	Functional Specification targets are set and several vehicle concepts are created using CAD drawings or models.	Target Setting	TS	***Feb-25***
Concept selection	Market research clinics are performed and a vehicle concept is selected from observation and technical reviews of alternate concepts.	Concept Review	CR	***Apr-25***
Systems approval and engineering sign-offs	System level design work begins and testing work is performed to check the feasibility.Functional and interface aspects are also constantly reviewed.	Engineering Launch	EL	***Feb-25***

Timing Plans

Phase, Steps, Gateway and Planned timeline chart

Description of Phase	Description of Step	Gateway Description	Label	Planned Dates
	All design attributes are finalized.	Hardpoint Freeze	HF	***Sep-25***
	Managers reviews all the systems w.r.t to other systems obtains approval of the system-level design	1st engineering sign-off	ES 1	***Sep-25***
Detailed engineering, Verification Testing	The Vehicle Program is approved by management and funds are released for detailed system design and integration work.	Program approval	PA	***Nov-25***
	Tests are conducted at component level, which are assembled subsystems, and systems level that are tested and changes are done to hardware and software using the results.	Verification tests 1	VT1	***Jan-26***
	Prototype vehicles are assembled, and vehicle-level verification tests are performed, and customers reviews are taken	Prototype test vehicles	PTV	***Dec-26***
	Further tests are conducted and inputs from customers are incorporated in design	Verification Test 2	VT2	***Jan-27***
	Final production prototype is made available for engineering which is made by taking inputs from the previous test results, reviews given by experts, management, and customers.	Prototypes final (final prototypes)	PF	***Jun-27***
	Final Testing is performed for durability.	Verification Test 3	VT3	***Jul-27***

Timing Plans

Phase, Steps, Gateway and Planned timeline chart

Description of Phase	Description of Step	Gateway Description	Label	Planned Dates
Manufacturing Readiness and sign-offs	Marketing and other personnel are provided with necessary technical information,	Marketing and field support plan launch	MFS	***Sep-27***
	Manufacturing plant is retooled and tested	Product Readiness	PR	***Oct-27***
	Manufacturing and plant managers sign-off on the functionality and build quality of the production vehicle.	Final manufacturing sign-off	MS	***Nov-27***
	Engineering leaders sign-off functioning, reliability, and durability of the production vehicle.	2nd engineering sign-off	ES2	***Dec-27***
Vehicle production, sales, and service	Approval for release of vehicle for sales and first produced vehicle comes out of assembly plant	Job#1	JB#1	***Jan-28***
	All the feedbacks, sales,warranty, and costs data are reviewed periodically to determine future changes to manufacturing process or products	Program status reviews 1	PSR	***Jan-29***
Operation and refinement	Changes like updating electronic features,sensors, design modification from reviews and market demand are proposed	Start of refinement 1	SR 1	***Apr-29***
	These minor changes are incorporated in the vehicle and the new model is designed and approved by senior management for sale.	New Variant rolls-out	NVR	***Jan-30***

Timing Plans

Phase, Steps, Gateway and Planned timeline chart

Description of Phase	Description of Step	Gateway Description	Label	Planned Dates
	Customers reviews,sales, warranty,costs data are reviewed periodically	Program status reviews 2	PSR 2	***Jan-32***
	Small changes in safety,infotainment system, overall design,and sensors are proposed.	Start of refinement 2	SR 2	***Apr-32***
	A new variant is approved for sale which is incorporated with all the changes	Second variant rolls-out	SVR	***Jan-33***
Retirement and disposal	Vehicle is pulled from market as it becomes old and outdated and production is stopped	Stop operation	STOP	***Dec-35***
	At this point, the assembly plant and its equipment are recycled or retooled for the next vehicle.Components that remain are either recycled for extraction of the materials or sent to the junkyards.	Disposal	END	***Apr-35***

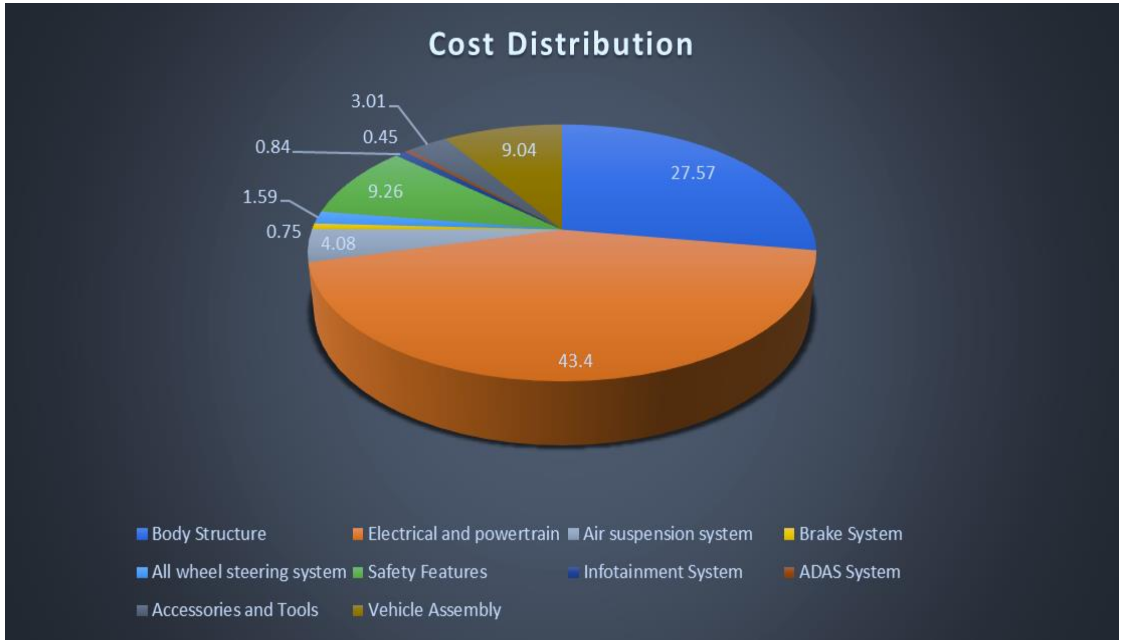
Selling Price Estimation

Benchmarking of Market Price with Competitors | "Market price minus" approach - Costs = Market Price – Profit

	Toyota Tacoma	Ford Lariat	GMC Canyon AT4	GMC Canyon 2028 Target Vehicle
Years	TRD Off road 4x4 V6 3.5L Engine 6 Speed AT 5-Ft. Bed	4x4, 4 Cyl. 2.3L Eco Boost Engine 10 Speed AT 5-Ft Bed	4x4 Crew Cab 5 ft. box 128.3 in. WB All Terrain w/Leather	100 kwH, Dual motor 450Hp 775 Lb-ft, 5 ft. bed, 4WD-2 stage speed reducer
2018	34685	38200	38500	37128
2019	35135	38565	39200	37633
2020	35335	38675	39300	37770
2021	35700	39035	40200	38312
2022	36475	39730	41340	39182
2023	38305	39945	41690	39980
2024	38698	40385	42507	40530
2025	39378	40771	43279	41143
2026	40058	41157	44050	41755
2027	40738	41544	44822	42368
2028	41418	41930	45593	43999
2029				44559
2030				45216
2031				45873
2032				46531

Cost Distribution

System-wise Cost distribution



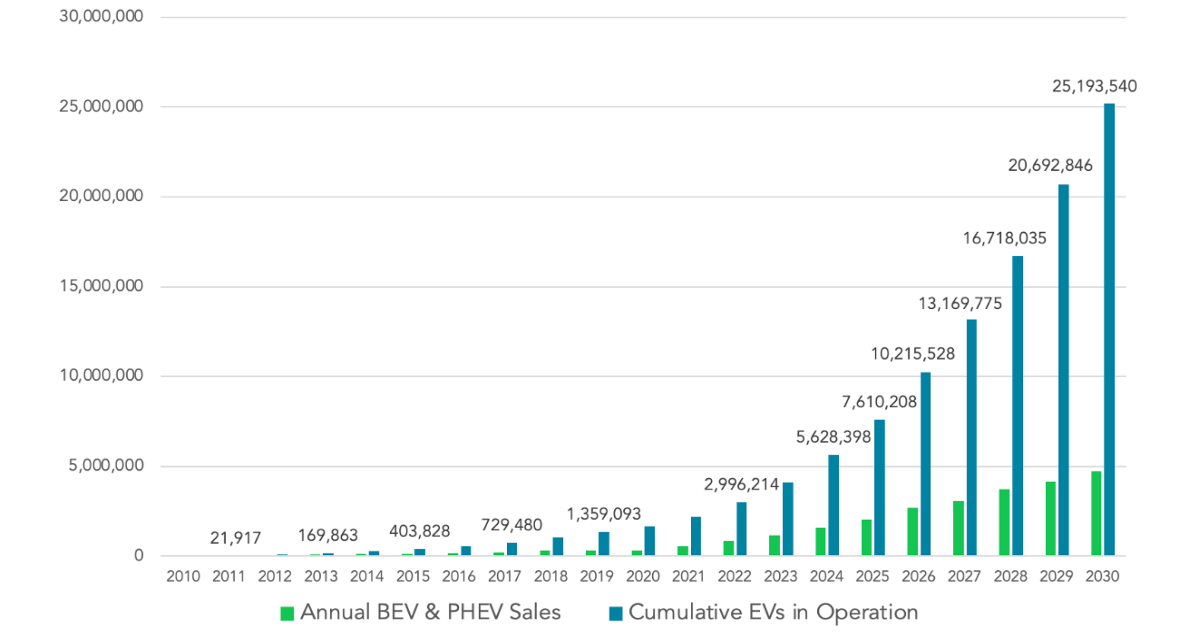
MSRP			43999
Dealer Margin (8% MSRP)			3519.92
Factory Invoice			40479.1
Company's Profit (18%)			7286.23
Vehicle Total Cost (Variable Costs plus Development Costs) (VC)			33192.9
		% VC	USD
Body and Structure	BIW	18.08	6000
	Bed - 5ft	3.77	1250
	Chassis platform for battery	0.75	250
	Doors	1.51	500
	Other body parts - Fender, bumper, Hood, Grill and Fender liner	1.66	550
	Interior - Seats, Carpet and Mirrors	1.81	600
Electrical Powertrain	Battery Pack	36.15	12000
	Dual Electric Traction Motors	4.52	1500
	DC-DC Converters	0.26	85
	On-board charger	0.35	115
	Power Electronics Controller	0.29	95
	Thermal System	0.5	165
	Transmission	1.34	445
Air suspension system	Air compressor	0.15	50
	Air tanks	0.05	15
	Manifolds	0.26	85
	Wheels and Tires	1.51	500
	Air suspension front and rear Struts	1.93	640
	Fittings	0.2	65
Brake System	Antilock Braking system	0.45	150
	Brake pad	0.08	25
	brake rotor	0.15	50
	brake caliper	0.08	25
All wheel steering system	Electromechanical front axle steering	0.66	220
	Active Superposition steering	0.27	88
	Electromechanical rear axle steering	0.66	220
Safety Features	Theft protection system	0.45	149.85
	Airbags	7.53	2500
	Electronic emergency braking system	0.29	95
	Provide automatic curve speed control	0.45	150
	Provide collision alert system	0.35	115
	Emergency calling	0.2	65
Infotainment System	touchscreen dashboard	0.53	175
	Seat built in speakers	0.32	105
ADAS System	CRAWL control system	0.23	75
	Lane Detection in extreme weather	0.23	75
	Accessories and Tools	3.01	1000
	Vehicle Assembly	9.04	3000
	Total	100	33192.9

Sales Projection

USA EV Forecasts

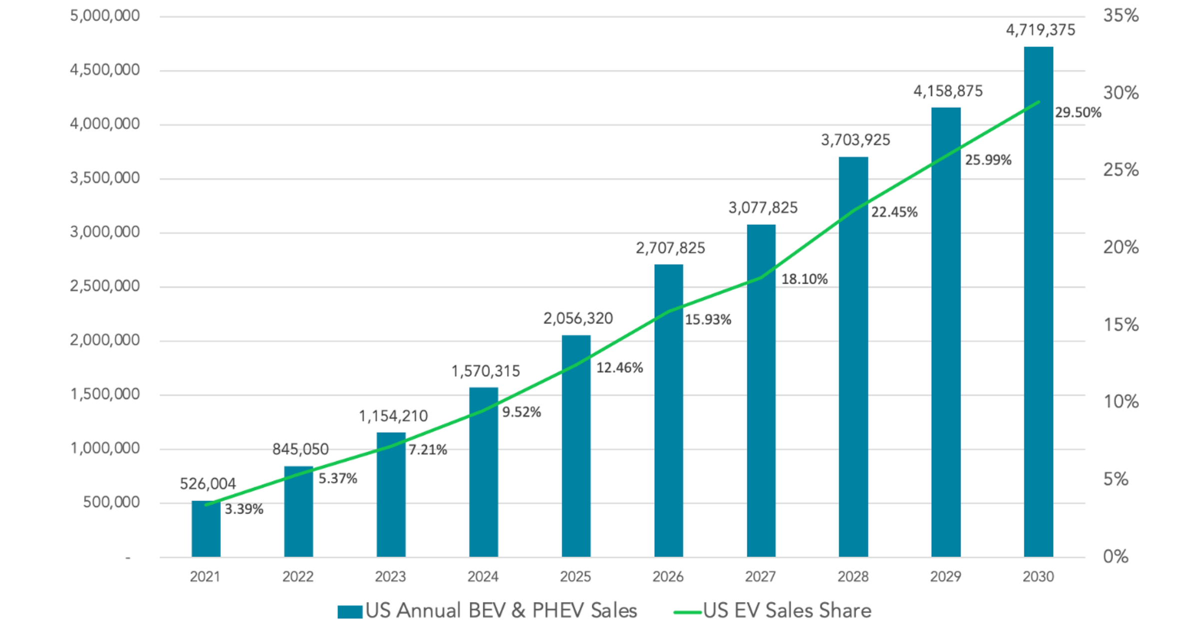
- Inflation reduction act boost the volume of electric cars produced in the US market. The number of EVs on U.S. roads is projected to reach 25.2 million in 2030
- Annual sales of EVs will be nearly 4.71 million in 2030, reaching more than 32 percent of annual light-duty vehicle sales in 2030

Cumulative US Electric Vehicles In Operation: 2010-2030



Historical Data: GoodCarBadCar.net, InsideEVs, IHS Markit I Auto Manufacturers Alliance, Advanced Technology Sales Dashboard I Research, Forecast & Chart: Loren McDonald / EVAdoption

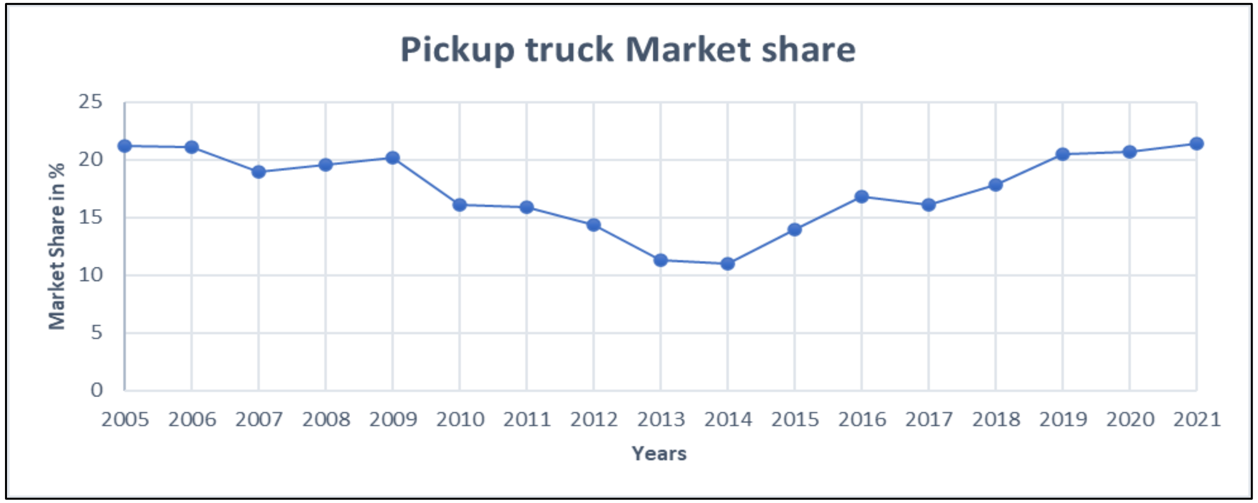
US EVs (BEV & PHEV) Sales & Sales Share Forecast: 2021-2030



Historical Sales Data: GoodCarBadCar.net, InsideEVs, IHS Markit / Auto Manufacturers Alliance, Advanced Technology Sales Dashboard I Research & Chart: Loren McDonald/EVAdoption

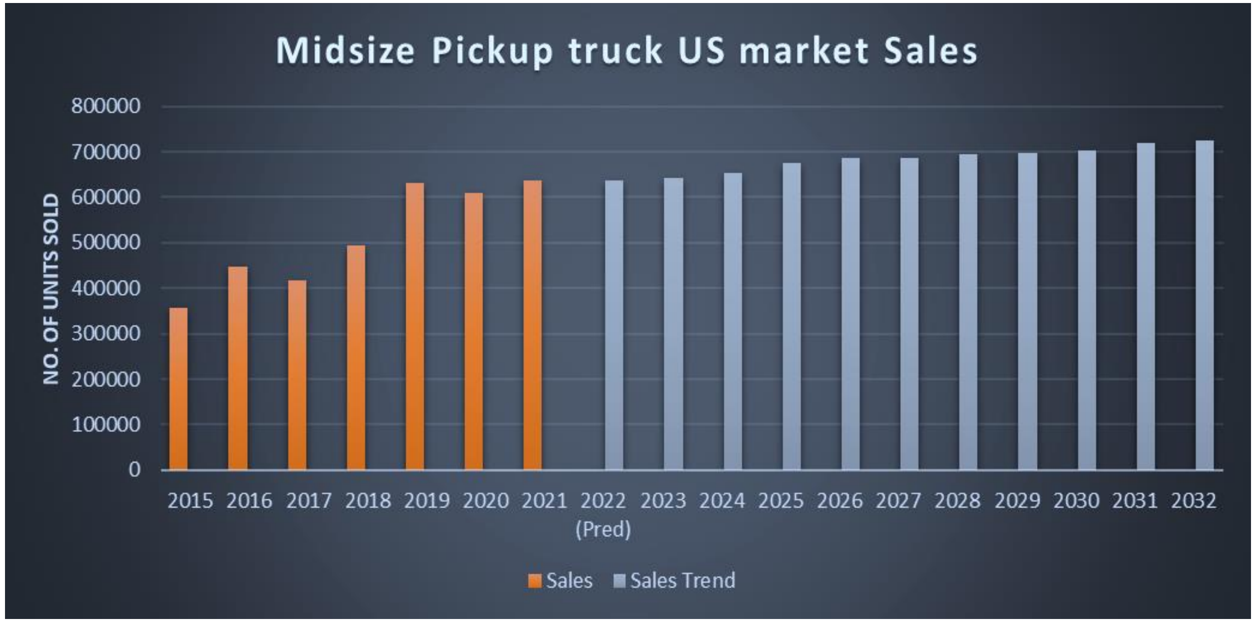
Pickup Truck Market Share

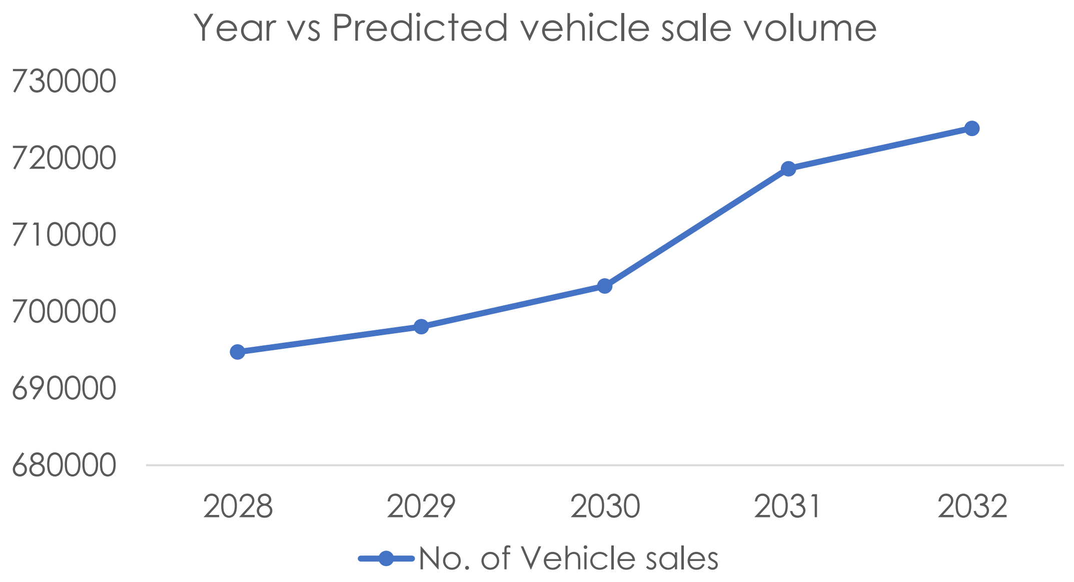
USA Market data & Forecasts



Pickup trucks (Full, small and mid)

1. Revenue is projected to reach USD 78.46 billion in 2022.
2. Annual growth rate of 2.07%, resulting in a projected market volume of USD 95.17 billion by 2028.
3. Pickup trucks market segment unit sales are expected to reach 3,242.7K vehicles in 2028





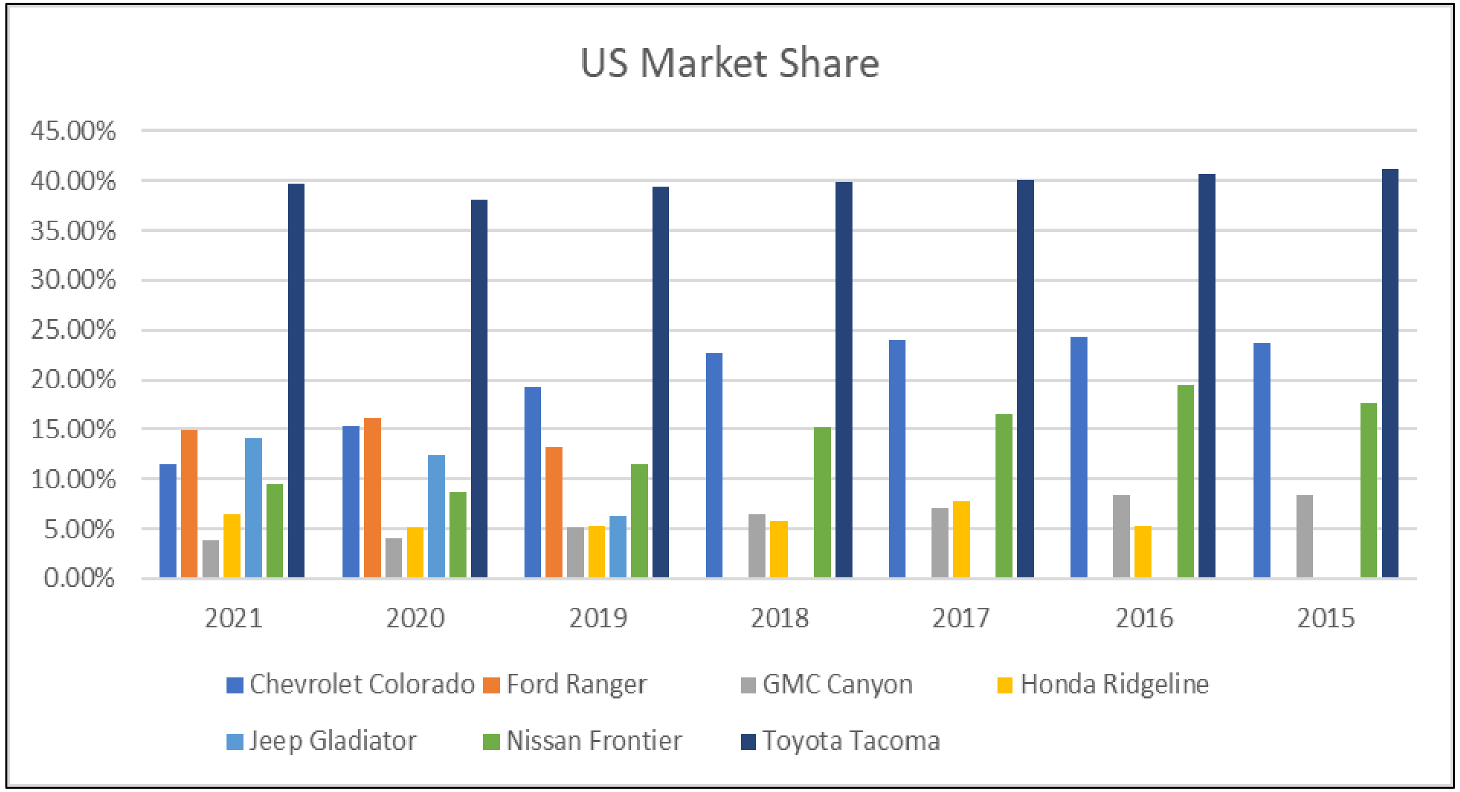
Pickup Truck Market Share

EV in midsize pickup segment & Key competitors market share

Electric Vehicles in midsize pickup truck segment

Year	Total units of midsize truck sold each year	Market share of EV in midsize truck segment	Units produced in Electric midsize truck segment
2022	635934	3.93%	25000
2023	642651	5.27%	33867
2024	654562	7.21%	47193
2025	676429	9.52%	64396
2026	687141	12.01%	82525
2027	687442	14.96%	102841
2028	694743	19.21%	133460
2029	698042	21.56%	150497
2030	703341	25.94%	182446
2031	718640	29.83%	214370
2032	723893	33.25%	240694

Key players in the midsize pickup truck with high market share



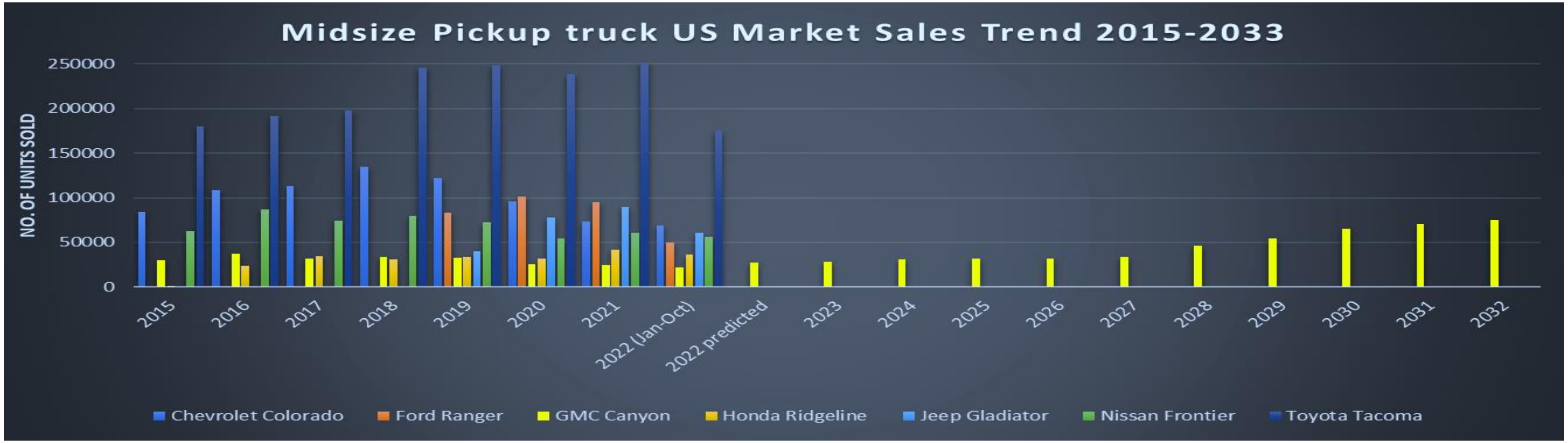
Sale prediction

GMC Canyon EV | 2028-2032

Sale prediction of GMC Canyon for the years 2028-2032

Year	Total units of midsize truck sold each year	Market share of EV in midsize truck segment	Units produced in Electric midsize truck segment	Market share of GMC Canyon w.r.to total midsize truck segment	Market share of GMC Canyon w.r.to units sold in electric midsize truck segment	GMC Canyon AT4 Sales predicted	GMC canyon cumulative sales
2028	694743	19.21%	133460	6.64%	34.56%	46,125	46125
2029	698042	21.56%	150497	7.75%	35.96%	54,126	100,251
2030	703341	25.94%	182446	9.26%	35.70%	65,128	165,379
2031	718640	29.83%	214370	9.77%	32.75%	70,214	235,593
2032	723893	33.25%	240694	10.40%	31.27%	75,256	310,849

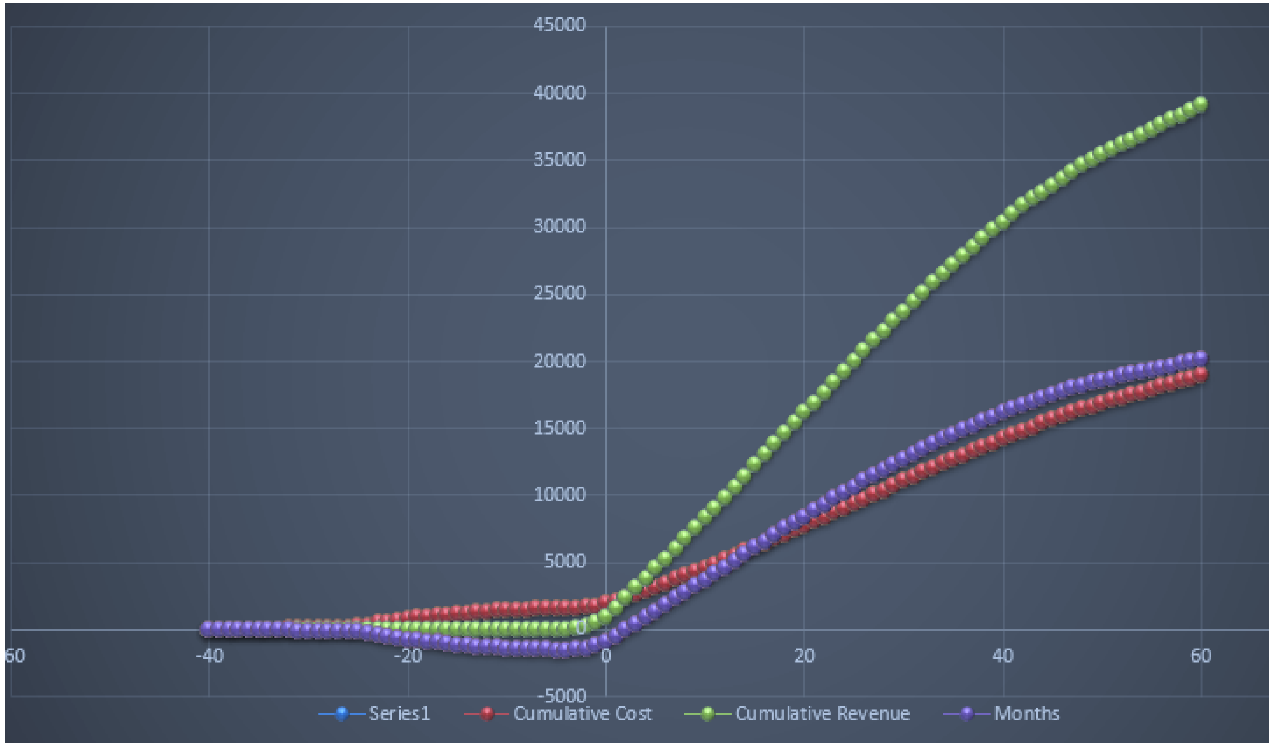
Forecasting number of vehicles sold by GMC Canyon in future



Cost And Revenue

GMC Canyon EV | -40 to 60 Months Program timeline

- The overall cost and revenues are analyzed based on the whole project timeline.
- The timeline starts 40 months before the Job 1 and extends to 60 months or 5 years after the 1st job.
- The main costs taken into consideration are the manpower costs, services and supply costs, facilities and tooling costs and product development costs.



Cost And Revenue

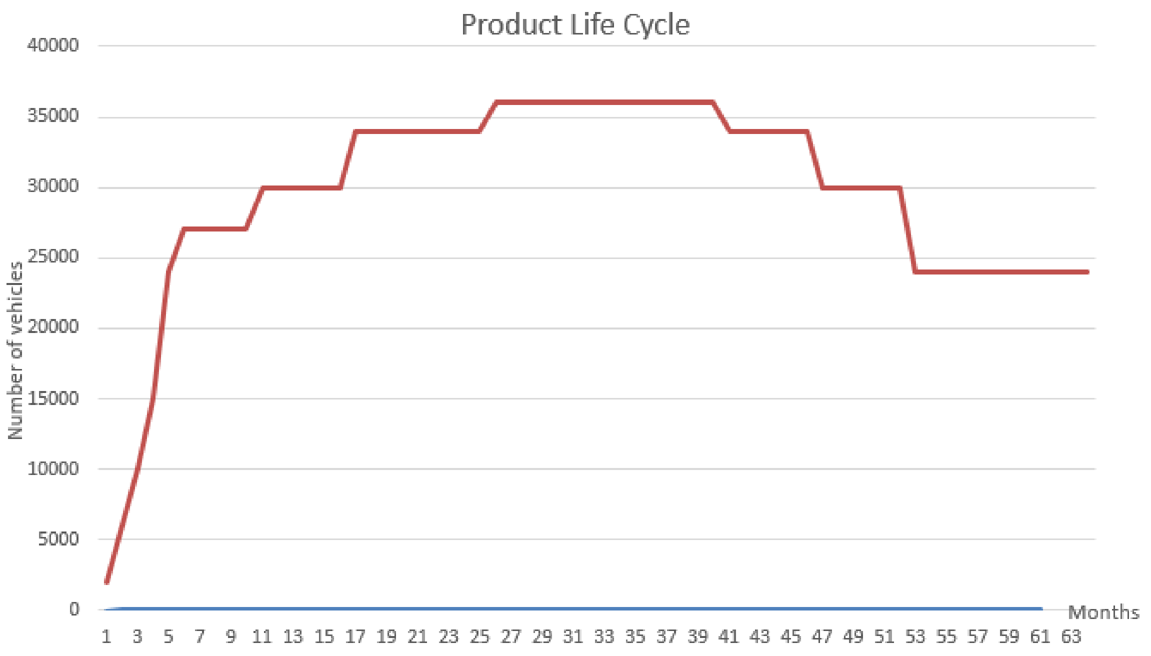
GMC Canyon EV | -40 to 60 Months Program timeline

- We have managed to reduce the manpower tooling costs by using Industry 4.0 and highly efficient machines.
- The production will only use high skilled labor and all the monotonous and jobs will be using Artificial Intelligence and Machine Learning.
- Our plant is situated in South Carolina where the taxes are between 0 and 7% and Skilled labor is readily available.
- Tooling cost are one of our biggest cost aspects because we are using highly technologically advanced and efficient machinery which will help us cut down our manpower cost and help reduce wastage of resources and supplies.
- It will also help us cut down on down time caused by human errors.

Cost And Revenue

GMC Canyon EV | -40 to 60 Months Program timeline

- The sum of all values excluding profit represents the total costs of the vehicle.
- The cost price of the vehicle was decided based on all the cumulative costs and the number of vehicles that we can produce over a 5-year span.
- We are planning to sell 1.8 million vehicles over the course of 5 years with each individual unit at a price of $43,000. This plan will help generate enough revenue to overcome the costs and help fund future projects of our company.



Note : *This chart shows life cycle of the target vehicle 2028 alone. Variants of this models with continuous improvement based on customer feedback and technology demand will be released in the subsequent years*

COLLEGE OF ENGINEERING & COMPUTER SCIENCE
UNIVERSITY OF MICHIGAN-DEARBORN

AENG 500 - Automotive Integrated Systems

P4 – Technology Plan and Vehicle Validation Plan

Group 7 :

Abhishek Borde
Prem Kumar R N
Rahul Menon
Varun Raj Irukulla

Content

- Executive summary
- Technology Plan
- Validation Plan – Noise Vibration Harshnessness
- Validation Plan – Communications and Entertainment

Executive summary

Technology and Validation plan

Reference Vehicle – GMC Canyon AT4

- Market – Mid size Pickup
- Proposal for the MY2028
- Competitors : Toyota Tacoma TRD 4x4, Ford Ranger Lariat 4x4

Session Agenda

- Technology plan - Major changes and challenges
- Validation plan – Noise Vibration Harshnessness
- Validation plan – Communication and Entertainment

Technology Plan

Major changes and challenges

#	Vehicle Systems	Major Changes planned	Major Technological Challenges	Comments/Open Issues/Risks
		Powertrain System		
1	**Power Unit**	IPMsyncRMS Dual motor with peak horsepower of 450 in place of 3.6L V6 Engine to maintain emission levels as per CAFE and NHTSA standards for 2028	Development of a motor for the mid-size pickup truck which is having towing capacity of 6500 lbs that draws more power and creates much back EMF loses. Balance between Power and Range is the challenge.	Endurance testing of 3 proto vehicles at different environments considering different weather and terrains to collect the data of motor performance and further analysis for optimization.
	Transmission	Two stage reduction gearbox in place of 8 speed shiftable transmission	Many advantages due to less rotating parts compared to 8 speed AT. Noise level is the only Key challenge that needed to be controlled.	With precision Helical gear with AGMA Quality 12 or higher, Noise level can be controlled. Gearbox housing can be made with Aluminum 7075 T6 alloys for lightweight.
		Fuel System		
2	**Battery**	Battery pack with 100 KWh as Standard and 130 KWh as extended range in place of 21 gal fuel tank	Active cooling such as water cooling adds complexity to safety and increases weight and power consumption for separate radiator. Hence better passive cooling batteries by efficient BTM controllers should be the challenge.	Feasibility of passive cooling system to be verified and the supplier need to be fixed.

Technology Plan

Major changes and challenges

#	Vehicle Systems	Major Changes planned	Major Technological Challenges	Comments/Open Issues/Risks
			Lightening System	
3	**High beam**	New feature – Auto on & off High beam headlamps	Speed detection and distant vision, identifying other cars location. To use ADAS feature cameras for adding this feature to reduce the electrical load.	If not correctly engineered, any failure in changing the beam may lead to accidents. This feature should be introduced only after fail proof validation.
			Chassis System	
4	**Suspension System**	Independent air suspension with continuous damping in place of conventional spring suspension system	The design and selection of the air suspension strut polyurethane air bag (rolling sleeve, tapered sleeve and double convoluted) according to variable loading condition. The packaging complexity increases due to increased in the number of components.	Testing and designing the air suspension strut rubber polyurethane air bag for different loading and compression test for more than 6500 lbs loading conditions. Size and position of the compressor and integrated air tank is makes it difficult in the packaging.
	Steering System	Front wheel steering system is changed to Steer by wire All wheel steering system	High precision calculations are required in steer by wire, the sensor data at 77 GHz frequency need to calculate at 16nm processor which need to be highly accurate otherwise it results in accidents. The ECU controller of all wheel steering system needs to be programmed to get the best steering geometry at different speed and driving condition to help the driver.	Steer by wire needs to be tested and validated because its prone to failure due to sensors fault, electric power loss and by controller miscalculations. Vehicle steering geometry like toe angle, camber, castor behaves differently at high speed, low speed and at emergency braking.

Technology Plan

Major changes and challenges

#	Vehicle Systems	Major Changes planned	Major Technological Challenges	Comments/Open Issues/Risks
4	**Brake System**	Mechanical braking system is replaced by brake by wire regenerative braking system.	The battery and motors need to be the right size and type to match the regen rate/C- rate. This may have a direct impact on the cost and life of the entire system.	Regenerative braking does not store electricity at low speed braking and at high speed fast braking there will not be enough capitalization because of the diodes selected in the Electric control unit have the ratings up to 25 amp to overcome the infinite resistance.
	EV Chassis integrated with battery	To be able to compensate for the space lithium-Ion batteries are located in the structure of chassis.	Chassis structure need to be strong to hold the heavy distributed weight of the battery, decision between hot stamped steel or aluminum alloy as material for the task is difficult choice. Thermal resistance chassis design and material selection to make the occupant and structure safe.	The distributed load generated due to weight of the battery causes the fatigue and cracks due to thermal fatigue.
			Electrical System	
5	**Wireless Charging system to charge the battery on the platform.**	The complexity of the packaging system increases as the power receiver needs to be in align with power transmitter which makes difficult to arrange the system. High speed charging system on the wireless charging results in high temperature of the battery.	The electrical wireless is costly and difficult to implement, it also causes to fire hazard due to electromagnetic waves. The metal foreign object in the electrical charging results in the electromagnetic interference.	Wireless Charging system to charge the battery on the platform.

Technology Plan

Major changes and challenges

#	Vehicle Systems	Major Changes planned	Major Technological Challenges	Comments/Open Issues/Risks
		Electronic Control Unit		
6	**Hill start assist controller ECU in coordination with Hydraulic modular unit.**	Programming of the hill start assist controller and the Hydraulic modular unit to treat the HSA ECU as high priority while executing the braking task by hydraulic modular unit.	The complexity of the Hydraulic modular unit in the brake by wire system is difficult to model, HSA ECU sends the high priority messages as per the road inclination condition to assist the driver on the slopy road.	Hill start assist controller ECU in coordination with Hydraulic modular unit.
		CRAWL control unit to assist the driver in off roading	Programming and designing Electronic Stability Control (ESC) system to control the vehicle speed and acceleration in different road condition.	ESC gathers data from different sensors and changes the speed accordingly.
		Safety System		
7	**Lane changing assist**	Detects indication of lane change and assist in completing it safely	Advance system is required to detect vehicles quickly and accurately to prevent collision. Snow, fog, rain or unclear lane markings may cause disruption in functioning.	Driver can switch it on or off. Will be developed in-house by GMC.

Technology Plan

Major changes and challenges

#	Vehicle Systems	Major Changes planned	Major Technological Challenges	Comments/Open Issues/Risks
		Electronic Control Unit		
7	**Lane keeping assist**	Gives steering support to assist driver in preventing vehicle moving away from lane	Determine whether driver is changing the lanes intentionally or not	Can be manually turned on or off. Depending upon driver it has two modes of operation such as passive, active whether to correct the actions or not.
	Forward collision avoidance	Detects a potential collision and alerts the driver and if needed applies brake automatically	Assumes that the road surface and suspension are good. (if roads are slippery or tyres worn out stopping efficiency is decreased.	Uses high resolution cameras and sensors system will alert drivers and apply brakes automatically if driver did not respond in time
	Curve speed assist	Reduce the vehicle speed before the sharp turns if speed is too high	Functionality may be limited if map data is not updated or lost connection with satellite system. Along with that adverse weather and road condition may also affect its functioning.	It has two different modes comfort and dynamic. Dynamic mode cornering will be sporty and more acceleration
		Climate Control System		
8	**Tri-zone climate control**	Tri-zone automatic climate control system lets driver, front passenger and rear passenger adjust air flow and temperature according to their requirement.	Systems require additional power which vehicle may not be provided so additional power consumption need to be calculated.	Both rear and front can be controlled by driver if needed and has humidity control designed to prevent windows from fogging. Potential package issues as additional venting and control module are required.

Technology Plan

Major changes and challenges

#	Vehicle Systems	Major Changes planned	Major Technological Challenges	Comments/Open Issues/Risks
		Body System		
9	**Body in white**	Redesigned under the vehicle to fit the battery pack. Aluminum and its alloys are used in body construction. (Inner panels and truck bed is made up of carbon fiber weight)	Difficulty in welding joints	Price is higher compared to steel body. Development cost, die cost and sourcing of material needs research
		Driver Interface System		
10	**Advanced ADAS System**	An Advanced ADAS system, which enables a semi - autonomous driving under certain conditions like on a highway.	A large array of sensors and cameras should be equipped into the car. Each sensor will be exposed to harsh outdoor conditions like dust, rain and snow. The outdoor conditions must not affect the functionality of the sensors and cameras.	A camera and sensor cleaning system is implemented to ensure that the camera is always free of dust and debris. Extensive functionality tests are also conducted for the ADAS system on different traffic and weather conditions.
	Automatic Brake System	An automatic brake system combines sensors and brake controls to prevent high speed collisions.	The brakes should be fully integrated with the ADAS system. The sensors and the computers should correctly calculate the braking distance at any given situation.	The function of the automatic braking engages when the sensors feel that a crash is imminent. The minimum distance for automatic braking is set at 7ft for speeds under 25 mph and 20ft for speeds under 70 mph. The function automatically adjusts based on speed and driving conditions.

Technology Plan

Major changes and challenges

#	Vehicle Systems	Major Changes planned	Major Technological Challenges	Comments/Open Issues/Risks
10	**Automatic Speed Detection**	The car will possess a speed detection function, that will automatically notify the driver of the speed limit on the road they are driving on.	The front facing cameras capture the speed signs on the road display it for the driver using image processing. The cameras scan for round and square signs that are typical of speed signs.	The speed limit is shown to the driver via a heads-up display. This will ensure that the driver's concentration will not be affected from the road.
		Security System		
11	**Sentry Mode**	This is a security system that reduces the anxiety of parking when you park on a street or unknown location.	The system is on guard when it is parked, and the car is connected to your phone. The sentry mode sends alerts to the phone of the user if it detects any activity near the car.	There are proximity sensors near the car which activate, when it recognizes movement. The car will also turn on the cameras and send you a live feed of the cameras if it detects a break-in
	Intrusion Alarm	The car will automatically sound an alarm and will call 911 if an intrusion is detected		The car might detect an intrusion and falsely make a 911 call unless the owner disables the alarm with the key fob.
		Ergonomics		
12	**17" infotainment Screen**	The car will feature a 17" infotainment system that will be fitted on the dashboard.	The screen will control major systems on the car, like climate control and functions like opening the tailgate and boot.	The air vents for the climate control have to be moved around to accommodate the screen. It is also a challenge to integrate these many functions into the center console.

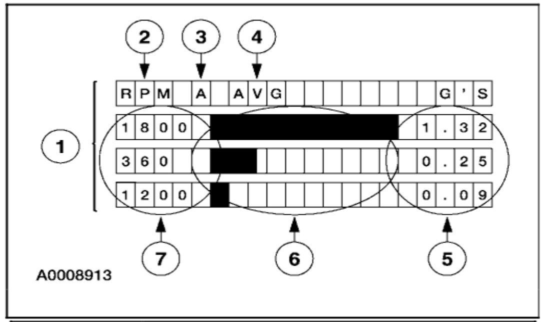
Validation Plan

Noise Vibration and Harshnessness

Tools for NVH

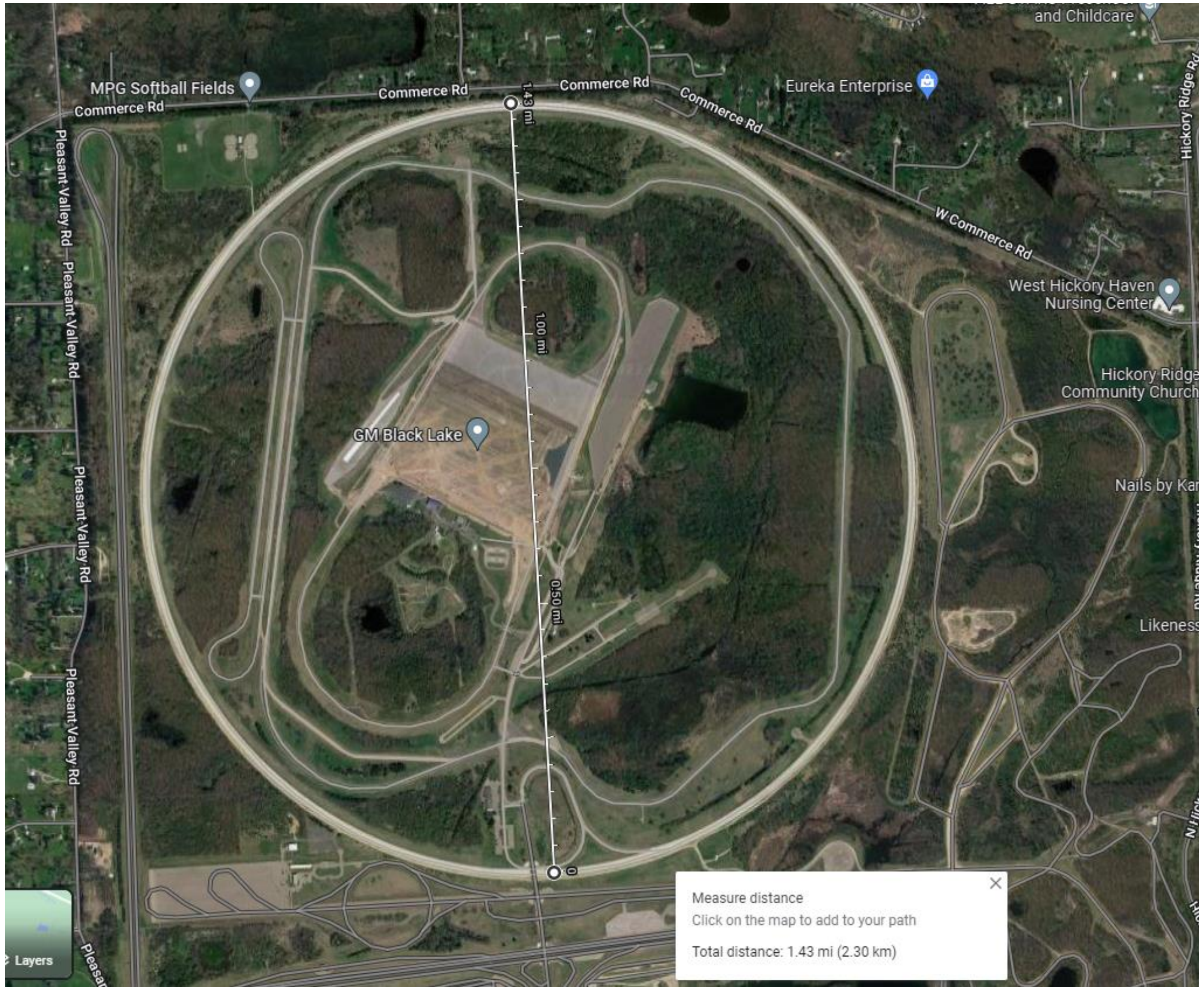
- Vibration Analyzer
  - Portable Electronic Diagnostic equipment
  - 3 prevalent vibration frequencies and its amplitudes
  - Relative G Forces
  - Strobe Balancing function

Parameters	Value
Sensitivity (±10%)	10.2 mV/m/s²
Measurement range	±490 m/s² pk
Frequency range (±5%)	0.5 to 3000 Hz
Resonant frequency	≥40 kHz
Phase response (±5 ◦) (at 21 ◦C)	2 to 3000 Hz
Broadband resolution (1 to 10,000 Hz)	0.0015 m/s² rms
Non-linearity	≤1%
Transverse sensitivity	≤5%



Item	Description
1	VA screen
2	Frequency mode displayed in rpm or Hz
3	Active sensor input (A or B)
4	Current active mode
5	G force indicators or the strongest frequencies in descending strength of each vibration
6	Strength of each vibration
7	Frequency in rpm/Hz of each vibra-tion

Test Track - General Motors Proving Ground



No. of Evaluators required : 2

Validation Plan

Noise Vibration and Harshnessess

Drive Test Procedure

- To take the fully equipped prototype vehicle on the GM Proving Ground.
- Initially the vibration sensors to be fitting inside the vehicle cabin space arbitrarily, based on past experiences like seat bottom, steering wheel, doors and so.
- Test drive the vehicle on the GM 4.5 mile circle track and maintain different range of speeds for a certain time period to record the data.
- Then based on the recorded data and feel of the evaluator, the sensor is altered in position.
- Once again the evaluator need to capture the data and to interpret at which point/speed the peak vibration attains. All the frequencies to record in average mode.
- To calculate the normal frequency of the vehicle at a specified speed and multiply the rear axle ratio by the Hz (1 Hz per every 5 mph)
- Place the vibration sensor near the suspected area outside the vehicle and further testing to be done on track.

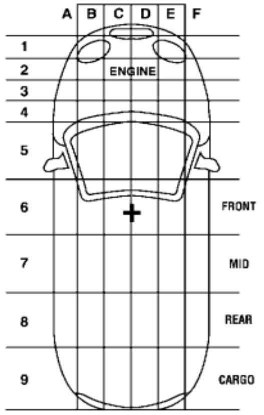
Questionnaire & Data Collection

SPECIFIC SENSE IDENTIFICATION AND LOCATION ON VEHICLE OF CUSTOMER SYMPTOM(S)

INSTRUCTIONS: Check below sense affected and location of concern on the generic vehicle illustration (darken the vehicle area). Plus circle appropriate responses to the right.

NOTE: Shaded backgrounds indicate caution areas. Selection of two or more caution areas "flag" difficult repairs. In general, shaded areas are the more difficult to verify and repair, and require all applicable columns to be completed.

SEE YES ☐ FEEL YES ☐ HEAR YES ☐ SMELL YES ☐



VEHICLE SYMPTOM AREA	HOW OFTEN?	VEHICLE OPERATING MODE	VEHICLE CONDITIONS	VEHICLE SPEED(mph)	WHEN VEHICLE IS?	AMBIENT CONDITION
Front of Vehicle	Always	Start Up	Accessories On	0	Turning Left	____° Below Zero
Engine Compartment	Daily A.M. P.M.	Idle	(define below)	1-9	Turning Right	Below Freezing (0°-19°)
Dash	Conditional	Gear Selection	Windows Open	10-19	Over Bumps	Below Freezing (20°-32°)
Steering Wheel	Weekly	Accel Light	4x4	20-29	Up Hills	33°-49°
Accelerator Pedal	Monthly	Accel Moderate	Hauling	30-39	Down Hills	50°-69°
Brake Pedal	Intermittent	Accel Heavy	Towing	40-49	Shifting	70°-89°
Clutch Pedal	Unknown	Steady Speed	Snow Plowing	50-59	Parked	90°+
Seat		Deceleration	Other	60-69	In Traffic	Sunny
Rear of Vehicle		Neutral	(define below)	70+		Dry
Top of Vehicle		Reverse		ENGINE		Windy
Floor Pan		Stopping/Braking		TEMP		Wet/Humid
Under Vehicle				Cold		Rain
Other (define below)				Normal		Snow
				Hot		Ice

DEALER VERIFICATION	YES	NO
SERVICE ADVISOR	☐	☐
SHOP FOREMAN	☐	☐
SERVICE MANAGER	☐	☐
QC MANAGER	☐	☐
TECHNICIAN	☐	☐
VERIFIED WITH CUSTOMER	☐	☐

WHAT THE CUSTOMER SAID

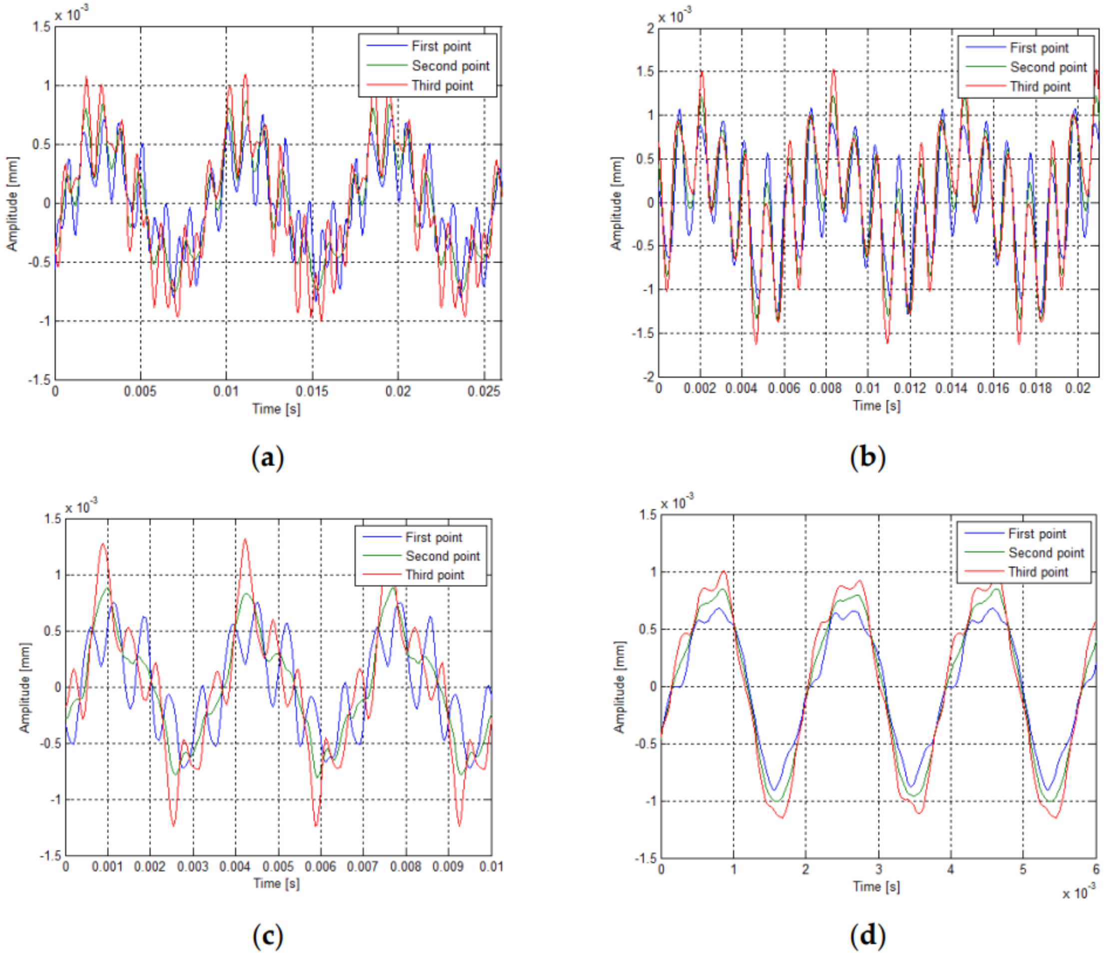
OASIS SYMPTOM CODE(S)

VIN NUMBER

Validation Plan

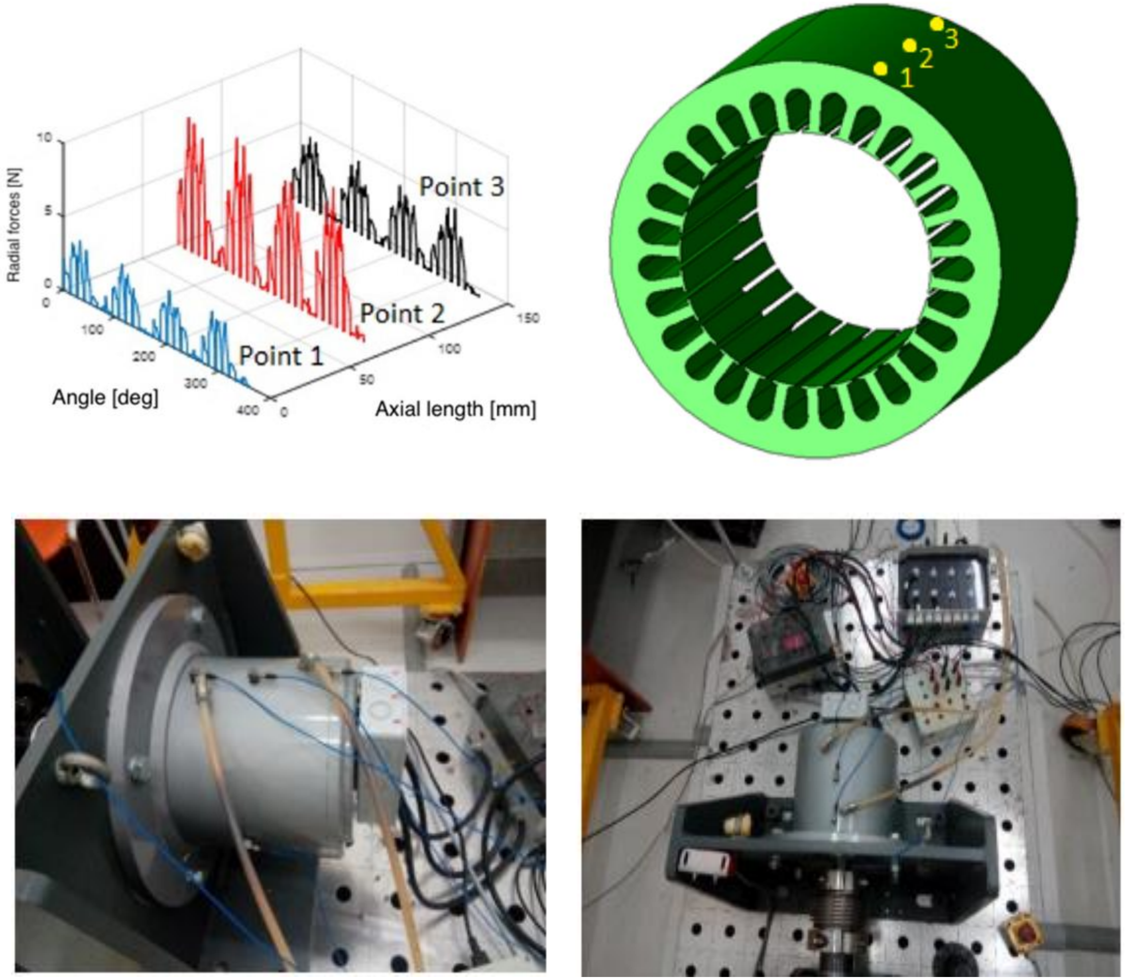
Noise Vibration and Harshnessness

Illustration of Measurements



Vibration of the stator three different points at 4 different speeds : a) 800 rpm b) 2500 rpm c)5000 rpm d)8000 rpm

Vibration test on Stator

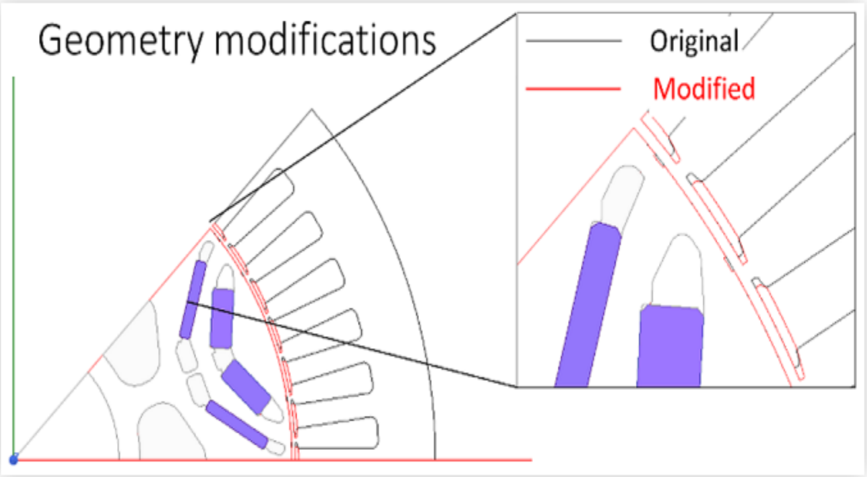


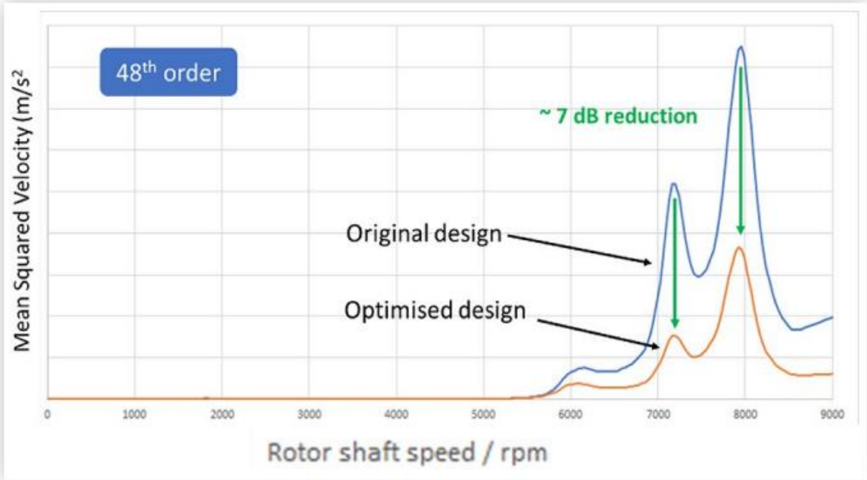
The above figure shows the vibration measurement points of the stator and the corresponding radial loads

Validation Plan

Noise Vibration and Harshnessness

Illustration of Noise level reduction





Geometry change in stator and the corresponding reduction in noise to prove that the noise level can be regulated as per the requirements and regulations

Ways to improve validation plan with additional resources

- If additional resources are available, in the noise level analysis to identify the components making the noise it's hard to identify in the vehicle level analysis, its being solved for using the JMAG software test and providing the test setup for each system analysis.
- Vibration sensors have the sensitivity error up to $\pm 10\%$ and frequency range variation of $\pm 5\%$ which needs to be reduced to gather the more correct data, so the sensor with high accuracy needs to be used to gather the data.
- In the test procedure the number of vibration sensors collects the data needs to be increase so that it will cover more space of the vehicle to identify the major source of vibration.
- Noise level reduction of the motor the actual testing on the test rig to identify the noise is necessary to select the most suitable design, prototypes generated at that time needs to increase so that more designed will be tested.
- In the validation plan, two evaluators are selected for each car, the expert evaluators cost money, if the funding to the validation plan increased the number of evaluators per car should be increase to 5.
- The data collected and questionnaires to each evaluator needs to be modified by the expert for that purpose more manpower is needed to handle the data and the test equipments.

Validation Plan

Communication and Entertainment

Instrument Panel

Evaluation Methods :

1. **Customer ratings**

- **Identification:** If the customer can recognize each and every function of the controls on the instrument panel.
- **Visibility:** The controls should be visible from the driver's seat to his/her eye level.
- **Reach:** The controls should be at a comfortable reach position according to SAE J 287.
- **Effort:** Force applied in pressing a control. (Can be measured using a force gauge)
- **Tactile feedback:** The clicking of rotary controls for stepwise adjustments for that particular knob. (Example: A/C knob)
- **Less Distraction:** The ease of remembering the locations of the switches.

2. **Laboratory test**

- A switch endurance test will be conducted to validate the durability of the instrument panel system. The variables to be measured are as the following: Switch quality: To check for cracks and marks over continuous usage. Switch endurance: Durability of the switch over continuous usage. Switch spring stiffness: To check whether the activation becomes ineffective.

Procedures for validation

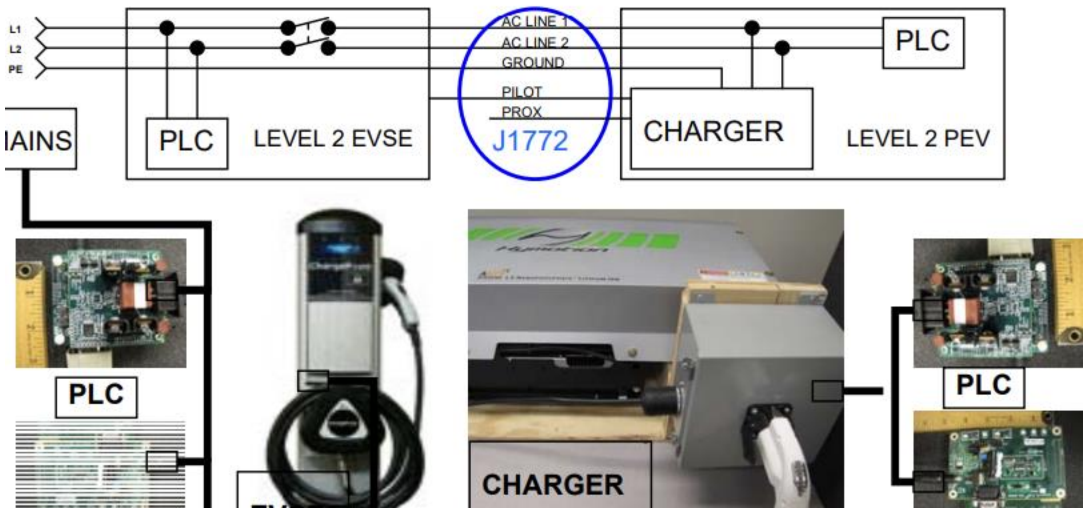
- The instrument panel to be tested is placed in a jig.
- The switches on the instrument panel are endurance tested for a cycle of 100,000 times.
- Custom actuators are present for individual switches, rollers and knobs to check their functionality over time for continuous usage.
- Switch quality is checked by observing if cracks or indent marks occur over continuous usage.
- Switch engagement variation is checked. That is if under continuous usage the switches get jammed or not.
- Switch spring stiffness is evaluated as to whether its quality deteriorates over continuous usage over time.
- Finally, the results are analyzed.

Validation Plan

Communication and Entertainment

Vehicle to Grid Communication

- Vehicle to grid communication.
- SAE Standards J2836/11 and J2847/12.
- Two power line communication (PLC)technologies.
- Data collection times varied based.
- Records messages sent, messages with errors.
- Measure latency, Bit error rate and accuracy and reliability.



Test Layout

Validation Illustrations

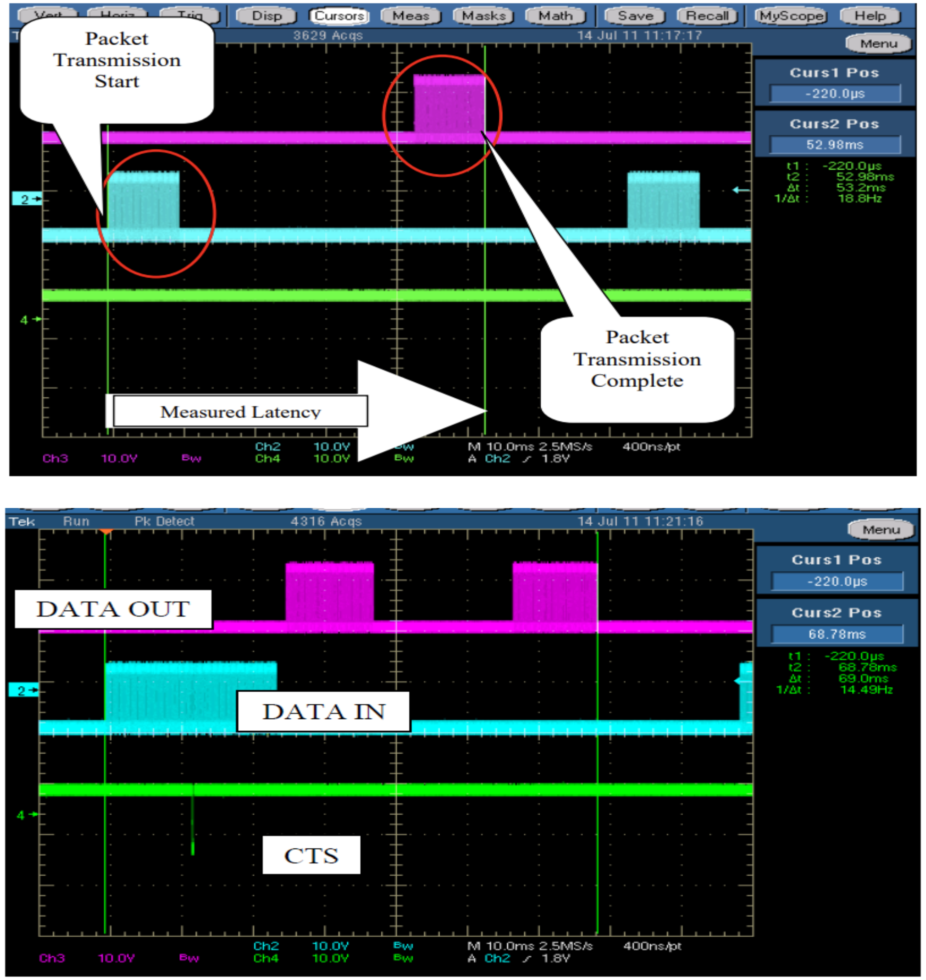


Illustration of test result

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Thank you!