MY2025 Jeep Gladiator Technology Plan and Vehicle Validation Plan Development

Abstract

In the life cycle of a product, technology and validation plan are vital to determine the customer satisfaction and to forecast the sales estimation based on several user attributes such as performance, interior and exterior technology interfaces and styling, handling, safety features and NVH levels. This report summarizes the technology plan and validation plan that is to be conducted on the available prototypes of the MY2025 Jeep Gladiator. Initially, major technologies and safety features were listed by comparing competitors, viewing guidelines for different requirements to be met for the model year 2025 and gathering customer wants. The challenges in their implementation and risks or comments for their implementation was recorded in the plan. For the validation plan, available prototypes were used to gather expert and user evaluation data. Several subjects including civilian users and industry experts were invited to perform the evaluation. Their demographic data was collected which included their age, gender, education, profession, income, and vehicle ownership details. They were asked to observe, drive the prototype and answer a checklist which recorded their experience with the vehicle in terms of ratings on a 10 point scale.

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Technology Plan

The technology plan consists of the major technologies that are proposed to be included in the MY2025 Jeep Gladiator along with the challenges and comments/issues/risk that might arise during its implementation.

Table 1. Technology plan of MY 2025 Jeep Gladiator.

Serial No.	System Name	Major changes in the system	Technological challenges	Comments/Issues/Risks
1	Powertrain Technologies	100 kW electric motor powered by 20 kWh battery pack for the hybrid-powertrain system	• Increase in vehicle costs and weight due to electric motors and battery. • Powertrain packaging issues.	The packaging of the battery pack and motor needs to be considered. The motor can be mounted on the axle or inside the wheel hub and the battery should be mounted as low as possible on the floor to keep the centre of gravity low. Battery cooling is also a major issue in terms of the life of battery and safety. It will also increase the weight and cost of the vehicle. As faster charging technologies and denser battery packs are developed in the future, the appeal of the hybrid powertrains may increase.
		Engine downsizing using 2.4L turbocharged I-4 engine	Reducing turbo-lag and risk of knocking due to an increase in intake air temperature. The engine should meet CAFÉ and EPA requirements.	Exhaust and intake system needs to be modified to incorporate the changes. An intercooler also needs to be installed before intake to cool down the intake gas temperature, adding cost and complexity.
2	Fuel-saving technologies	Cylinder Deactivation	Reliability of system	With cylinder deactivation under constant speed and in low load conditions, some of the cylinders (usually 2 cylinder in a six-cylinder engines) can be deactivated to improve up to 7.5% improvement in fuel economy. But, as the system is electronically controlled it will need timely maintenance checks, making it more expensive.
		Regenerative braking	Increased complexity and reliability concerns.	During braking the electric motor can be used as a generator, converting the kinetic energy of the vehicle to electricity to recharge the batteries. It

				also extends the life of the brakes. Sophisticated electronic control is needed to switch between regeneration and traditional brakes when regeneration is not sufficient for stopping the vehicle.
3	Light-weight and Recyclable materials	Increased use of High-Strength steel(HSS) for BIW for a reduction in weight and increased safety	Trade-off between an increase in cost and weight reduction for better fuel economy	HSS has higher strength compared to aluminum and despite weighing than aluminum lighter structures are possible through design optimization. But, in-house manufacturing capabilities of HSS components need to be considered and suppliers specializing in HSS components need to be selected.
		MSC Smart steel body panels	Increase in cost	It provides up to a 35% reduction in weight compared to steel panels and is an alternative to aluminum. It can be manufactured using the same processes as standard low-carbon steel. But, Material Sciences Corporation (MSC) is the only supplier, which may make it hard to get more competitive pricing.
		Corning Gorilla-glass windshield	Trade-off between an increase in cost and weight reduction	Ubiquitous in smartphones, with Gorilla glass the thickness of the windshields can be significantly reduced while providing improved hardness and dent resistance. But, they are currently 50% more expensive than traditional windshields.
		Blind Spot monitoring	• Improving the Reliability of the system. • Developing algorithms to increase the precision of the system • Selecting quality sensors and suppliers • Increasing the range of the sensor to better detect	The system is made safer by implementing telematics, it also warns the driver in the blind spot who can take evasive measures
		Adaptive cruise control with lane change and automatic braking		Technology needs fine-tuning to avoid unprecedented system errors. The system depends on the lane markings and sensors for a lane change. In case of improper or smudge lane marking or faulty sensors chances of risks exist.
		Forward collision warning		The system is made safer by

4	Safety System	with automatic braking and V2V connectivity	obstacles • Controlling the cost • Developing a trailer detect, guide and anti-sway system	implementing telematics, it also warns the driver in front who can take evasive measures
		Hands-free rear parking		This advanced hands-free parking assist measures the available parking space by actively scanning and suggesting the drive a spot and automatically parks the vehicle into the parking spot without driving intervention
		Dynamic assisted rear backup camera		This option was only available in the higher variant but now it will be provided as standard across all variants
		Pro Trailer assist- Dynamic Hitch Assist		Similar to parking assist this feature assists in reversing and driving with a trailer to prevent swaying of the trailer
5	Telematic system	Vehicle to Person	•Developing software to implement connected technology • Maintenance of the cloud-based servers • Developing an anti-theft system to prevent misuse of connected network technology • Network optimization for 5G connectivity	Connected technology has access to other vehicles, infrastructure and any cellular or wearable device which can lead to cyber theft issues. Cloud connectivity gives uninterrupted access to discrete databases
		Vehicle to infrastructure		
		Vehicle to Vehicle		
		Cloud connectivity		
		5G compatibility for seamless streaming and entertainment		Network Connectivity is a problem and requires optimization
		Keyless Entry/exit		Key fob malfunction is a common issue and requires a spare manual key
		Voice recognition		Need an algorithm that can identify different accents and clearly convert text to speech
		Additional sensors, actuators, and ECUs for driver assistance systems	• Integration of all the sensors and the ECUs	Integrating all the ECUs with the CAN system is required. There is an increase in processing power requirements of the microprocessor

6	Automotive Electronics		• Reliability of systems • Need for sophisticated software • Need of over the air (OTA) software updates to quickly fix software bugs and add new features	due to additional computational load. This adds to the complexity of the system and increases the cost.
		Vehicle cybersecurity	Increase in cost and need to complex software that needs to be regularly updated	As more connected vehicle technologies are offered the vehicle is can hacked easily by exploiting a vulnerability in the software. To protect the systems from such threats OEMs will need to purchase expensive software from cybersecurity firms.
		5G communication module	Need for reliable network coverage and an increase in cost.	A large amount of data needs to be transmitted for connected technologies like V2X communication which will require a 5G connection for reliable operation.
7	Electrical Systems Architecture	800V electrical system	Internal circuit changes needed to make it compatible with most existing charging stations.	An 800V system as used in the Porsche Taycan allows for thinner and lighter wiring, faster charging and better thermal efficiency as the motors run cooler.
		Regenerative braking circuit	Need for re-configuration of the wiring	Difficulty in the packaging of the system
		Implementing CAN-FD bus protocol	Higher cost and compatibility with various sensors and ECUs.	Allows faster and more secure data transmission which will be needed for as various active safety features are added.
		Heads up Display(HUD)	There is limited space in dashboard space due to necessary structural beams, climate control ducts and steering columns. These factors limit the size and shape of space available to a	Increase in cost in-turn leading to an increase in the market price of the vehicle. The added advantage would be that virtual image distance allows the driver to view the road and display without having to refocus their eyes between the displayed information and

8	Infotainment System		HUD system.	the scene of the road
		Smart Rearview mirror	The LCD screen has constraints from the beginning because of mirror housing dimensions, the standard wide-angle camera cannot be used as it gives low resolution on the LCD screen, however, the narrow-angle camera has to be used for better resolution.	There might be issues with the reliability of the technology by the customer and in some cases, customers may not use the function of transition from normal mirror to LCD screen even when it is required. Another challenge that manufacturers face would be manufacturing high precision and stable GNSS receiver.
		Gesture recognition	Developing a software that will allow gesture interaction with the car	The placement of sensors has to be appropriate so that all gestures are recorded.
		Wide display screen with an adaptive user interface	Connectivity issues due to poor network coverage in certain regions, especially during offroading.	With the implementation of this technology, the manufacturing cost of the vehicle would rise and with respect to making vs buy decision, the selection of suppliers potential suppliers with thorough knowledge about this technology is a primary and prolonged process.
9	Lighting system	Implementing the latest intelligent LED matrix headlight technology	. The camera unit of the intelligent headlight control system should maintain functional even in low visibility environments (e.g. heavy rain, snow) . Headlight components cost should be limited for affordable maintenance and repair	It is a premium feature and may lead to high production costs making it available only for top trims of Jeep Gladiator
10	Unique Features	Trailer stability assist	• Increased cost of vehicle. • Reliability and durability of the systems. • Increase in maintenance cost	Added complexity and the need for sophisticated software
		Smart Summon		Need to extensively tested for greater reliability. Risk of being misused by customers.
		Dual-action tailgate		More mechanical linkages and added complexity

		Removable doors and roof		Doors and roofs need to be more durable. Additional storage space needs to be provided for storing the removable parts.
		Customizable digital instrument cluster		Development of new interface and software.

Validation Plan

The validation plan is used to test the vehicle for expected market response through expert and customer evaluations and survey in controlled and actual drive condition. It involves testing the vehicle for performance, handling, interior and exterior interfaces, vehicle packaging, NVH and different drivetrains and then rating the overall usability experience on a structured checklist or a survey form.

Table 2. Validation plan of MY 2025 Jeep Gladiator.

Vehicle Attributes	Sub-attributes/Technologies	Sub-attribute requirements/ Sources	Evaluation Methods	Evaluation procedure
Performance	Performance feel	Acceleration times, fun to drive.	Field tests by test drivers and customer ratings. People from management.	● All the prototypes are driven by test drive around the test track which has varying road surfaces, gradients, and curves. The driver shares his feedback based on experience and compared the different prototypes. The vehicle is driven in different modes - hybrid and electric-only to validate performance under different situations. The performance of the vehicle when cylinder deactivation systems kicks in is evaluated by the test drivers to ensure there isn't noticeable performance change ● At least 50 customers of varying ages and life-style need to be selected based on market demographics. ● Customers are asked to drive the vehicle with and without the trailer attached in various traffic conditions along a predetermined test route and asked to rate the performance feel, fun-to-drive, handling characteristics, steering feel,
	Vehicle dynamics and handling	Handling feel, cornering stability, steering feel, braking distance	Test drivers and customer ratings	
	Performance feel in electric-only mode	Acceleration times, fun to drive	Test drivers and customer ratings	
	Cylinder deactivation	Performance with cylinder deactivation activated	Field Test	

				braking feel and other subjective parameters on a 10 point rating scale. ● The route is selected in such a way that there is some driving across off-road portions and customers are asked to rate the off-road performance of the pickup. ● Along the route, the customer is asked to drive the vehicle in electric mode and answer questions related to the performance feel of the electric drivetrain. ● The customers may also be asked to drive vehicle from competitors after removing the badges,logos and other identification marks and rate the prototypes against the competitors. ● Some people from management may also drive the vehicle and share their opinions.
	Range in electric-only mode	Engineering requirements	Lab test, field test by drivers and Certification from EPA	● The vehicle is tested on the dynamometer under various loads to simulate the actual driving conditions and range, fuel economy and emissions are measured. ● Field tests are carried out by test drivers or engineers under city and highway driving conditions to measure range and fuel economy under real work situations. The feedback on the feel of the brake pedal is reported by the drivers with and without regeneration. ● The figures need to be certified by the separate tests conducted by the EPA using the standard testing
	Fuel economy	Engineering requirements	Lab test, field test by drivers and Certification from EPA	
	Regenerative Braking	Engineering requirements	Lab test and field test	
	Emissions	Engineering requirements	Lab test and Certification from EPA	

				procedure.
	Towing capability	Engineering requirements	Field test	● Trailer is attached to the prototypes and the benchmarked vehicles to compare the towing capacity of the vehicles.
Cybersecurity	Vehicle system security	Engineering requirement	Lab test by cyber security engineer; Expert review	● The vehicle is tested in the lab under various hacker conditions to test the cyber security level. ● Expert will review and validate the vehicle cyber security system.
Charging	Charging Speed	Battery required charging time at a different level	Lab tests by test engineers and field tests by customer ratings.	● By following the department of energy testing procedure, test the required average charging time from different level 10%-100% ● Assessing the performance and customer acceptance of vehicle charging speed ● Analyzing load profile data to determine grid impacts ● Assessing installation and maintenance costs for the utility and customers to achieve a better understanding of future infrastructure needs from projected increases in demand for electric vehicles over the long term.
Thermal and Aerodynamics	Battery performance under extreme climate conditions	FMVSS & SAE requirements	Field test and lab tests.	● Field tests are conducted using prototypes in extreme cold and hot weather conditions and the performance of the battery is monitored and the effect of the weather on the range of the vehicle is evaluated. ● The extreme weather conditions can be simulated in the labs as well and the

				vehicle is run on a test bed.
	Water and air leakage	Engineering requirements	Lab test	● The vehicle is tested in the wind tunnel for leakage test.
Safety	Front Impact	FMVSS 204,208,212 and 219 requirements.	Crash tests conducted by government agencies like NHTSA	● Front-impact or overlap crash test conducted in which the vehicle is impacted against a solid concrete barrier at a speed of 30 mph(48 kph). ● Dummies are used in the crash test which various data acquisition sensors fitted to them measure the impact forces. ● At least 50% of the windshield perimeter must remain intact in the crash. ● The fuel system integrity and spillage requirements should be met as well. ● Based on the crash test performance, the NHTSA awards a rating on a 5-star scale.
	Side Impact	FMVSS 214 requirements	Crash tests conducted by government agencies like NHTSA	● Side crash on the vehicle is performed, in which a moving mass of 1000 kg moving at 53 kph is impacted perpendicular to the vehicle. ● Side crashes are major contributors to fatalities in road accidents as the vehicles don't have crumple zones on the sides. ● The side pillars should be able to absorb the impact energy to protect the occupants.
	Rear Impact	FMVSS 301 and 303 requirement	Crash tests conducted by government agencies like NHTSA	● The tests performed in frontal impact are repeated for the rear impact test.

	Roof crush	FMVSS 216 requirement	Crash tests conducted by government agencies like NHTSA	● In the roof crush test, the roof of the vehicles is crushed using the hydraulic roof crush machine. ● The pillars should be able to hold up the roof, ensuring that there is little deformation in the passenger compartment and pillars should be able to support themselves in dynamic impact. ● Roof crush test validates vehicle safety in case of a rollover.
	Battery safety	FMVSS 305, SAE J2464, J2929, and J2380 standards	Crash tests conducted by government agencies like NHTSA	● The battery needs to be validated to ensure that they don't leak electrolytes, rupture and catch fire in case of a crash. ● When the vehicle is subjected to front/rear/side-impact the battery temperatures, electrical isolation of the battery from the chassis and disconnection of battery from the drive circuit is monitored.
	Lighting standards	FMVSS 108	Tests conducted by government agencies like NHTSA	● The NHTSA conducts photometric tests to validate the vehicle meets the standard illumination criteria that can help in preventing crashes.
	Advanced driver assistance systems	Intervention by systems like Forward Collision Warning, Blind spot monitoring, lane keep assist	Field tests and Crash tests conducted by government agencies like NHTSA.	● The vehicles are deliberately put into situations while testing in the closed road and proving grounds in situations that trigger the safety systems to intervene.
Packaging	Seating package	Accommodating	Interior coordinate	● 95% male subject is asked to

	(driver and passenger)	95 percentile of the population. SAE J1516, J1517, J4004 standards.	measurements and customer rating.	sit in rearmost position of the seat track and SgRP is estimated considering it as a hip point and interior coordinate measurements would be taken. Subjects of different heights are asked to sit in their comfortable seating position and a driver package questionnaire is developed to obtain responses in a three point scale regarding knee space, thigh space and gas pedal fore/aft location. ● Subjects are also asked to rate their ease of entry and egress in the vehicle in the questionnaire.
	Entry/exit	Head, knee, thigh, foot space requirements. Distances from SgRP.	Interior coordinate measurements and customer rating.	
	Bed cargo capacity	Engineering requirements	Coordinate measurements and customer rating.	● The cargo space of the bed is measured for both the extended bed version (6 ft) and the short bed (5 ft) in litres/ cubic meters using a coordinate measuring machine. ● For customer evaluation, subjects are asked to load bags/boxes on the bed and then requested to rate the easy of the loading/unloading the items. ● They are also asked to use straps and restraints after loading items such as bicycles, ATVs & motorcycles and asked to rate the ease of strapping and adequacy of number of straps. ● Subjects are then asked to rate the ease of loading and loading.

	Powertrain packaging	Engine, battery, motor, transmission envelope	Coordinate measurements and drive tests on clearances.	● Lab tests and checks are performed to ensure that there is sufficient clearance between the neighboring systems and components. ● Drive tests are also performed in order to ensure that there are no rattling sounds noticed in powertrain while driving in prototype equipped with PHEV where packaging challenges could occur.
	Removable doors/roof	Durability requirements	Customer rating	● The subjects are asked to remove the doors and roof, then asked to rate the ease of removal. ● The subjects are then asked to store the detached part in the storage space provided in the bed and asked about acceptance rating for the ergonomic appropriateness of the storage location and space.
Styling	Exterior styling	Appealing and modern. Design requirements	Customer rating	● Subjects are invited to market research clinics and where they are asked to stand in a box and different vehicles are placed on rotating platforms. ● Usually, the target vehicle is presented along with benchmarked competitors with logos/badges and other identification marks removed. The vehicles are identified using random letters to avoid bias. ● The vehicles are presented in

				different views such as front, rear, side or random orientation. ● All the vehicles are compared in the same view and vehicles are painted in the same color, usually neutral colors like silver. ● The subjects are then asked to rate the vehicles on a rating scale.
	Interior Styling	Appealing interior design and layout, Texture of materials and display graphics	Customer Ratings	● Subjects are invited to market research clinics and where they are asked to sit inside the target and may be asked to sit inside some benchmarked vehicles. ● The subject is then asked to rate various characteristics like overall interior design, feel of spaciousness, the texture of materials on the dashboard, door panels, the legibility of graphics on controls, graphics on the infotainment screen, etc.
Noise, Vibrations, and Harshness	Road NVH	NVH in hybrid mode and electric mode.	Field tests and customer ratings	● Conduct field tests using experts to evaluate the road noise protrude into the cabin, judge whether the drone of the tires could drowsiness among drivers on a long road trip. ● Subjects are asked to rate the acceptability of the wind noise while driving at different speeds.
	Powertrain NVH	Engineering requirements	Field tests and customer ratings	● Conduct field tests tunnel tests to determine the noise level due to powertrain at different speeds.

				● Subjects are asked to rate the acceptability of the powertrain noise while driving at different speeds.
	Wind noise	Engineering requirements	Field tests and customer ratings	● Conduct field tests and wind tunnel tests to determine the wind noise level. ● Subjects are asked to rate the acceptance of the road noise while driving at different speeds.
	Brake NVH	Engineering requirements	Field tests and customer ratings	● Conduct field tests using experts to evaluate the brake NVH vibration level. ● Subjects are asked to rate the acceptability of the brake noise.
	Squeaks and rattles	Engineering requirements	Field tests and customer ratings	● Conduct a field test to evaluate the squeaks and rattles noise pass into the cabin ● Subjects are asked to hear for any squeaks/rattles and rate the acceptability of the noise.
Comfort and Convenience	Ride comfort	Stability and softness of the ride in different conditions	Lab test and Customer ratings	● In the lab, the vehicle is mounted on a suspension test rig and subjected to different vibrations to simulate the road conditions. ● The spring and damper response obtained over the varying conditions are evaluated to ensure that the engineering requirements are met. ● The subjects are invited to

				drive vehicles at different speeds and across different road surfaces and then asked to answer a set of questionnaire related to driving comfort.
	Climate control comfort	Effectiveness of system in different weathers and rate of cooling/heating	Lab test and customer ratings	• Lab tests are carried out at different vehicle operating conditions by measuring the effects of heating/cooling under different weather conditions simulated in the lab, and mapping the airflow inside the cabin through CFD. • Subjects are invited to drive vehicles and asked to rate the ease of using climate controls, the rate of cooling and acceptability regarding the location of vents.
	Hands-free Parking	Ability to self-park	Field tests and Customer ratings	• In the field tests the vehicles are parked using the hands-free parking and test engineers collect data from the sensors using data acquisition software to validate that the sensors are performing accurately. • The subjects are invited to driver vehicles and asked to use the hands-free parking feature while parking into tight spaces and parallel parking. • The subjects then respond to how confident they felt while using the feature.
	Voice Control and gesture control	Accuracy to identify voice and	Customer ratings	• The subjects are asked to use the voice control

		gesture command		features and the gesture controls after the evaluator briefly introduces few gestures & voice commands to the subjects. ● The subjects are asked to rate the ease and accuracy of the voice inputs and gesture inputs and rate overall acceptability of the feature.
Ergonomics	Locations-layout of controls, displays, handles, service points.	SAE J1138. Ergonomic requirements.	Interior coordinate measurements, reach & grasp evaluations during operations.	● Asking subject to sit in their comfortable seating position. ● Validating findability, interpretability, reach and grasp of control and legibility, visibility and interpretability of display through checklists. ● Subjects are asked to use nearside part of the wide display screen for navigation and passenger is asked to use the rest of the screen for entertainment. Subjects are then asked to rate the display screen, its response to touch and the legibility of the graphics used. ● Subjects are also asked to rate the appropriateness of the location and content of heads up display.
	Hand and foot reach.	SAE J287. SAE J1516 & J4004	Interior coordinate measurements. Customer ratings in drive clinics	● Subject is asked to sit in the comfortable seating position. ● Major dimensions such as L53, H30 and maximum & minimum reach envelope distances are validated.

				● Measuring reach distance to controls during operation.
	Visibility and obscurations.	FMVSS 111, SAE J1050, J902, J903.	Interior coordinate measurements and customer rating in drive clinics.	● Visibility and obscurations due to pillars of the vehicle are validated with the help of interior measurements with respect to the subject's field of view. ● Subject is asked to rate the obscuration levels in drive clinics through questionnaires.
	Operability	SAE J1139, Ergonomic guidelines	Ergonomics scorecard based on ergonomics engineers and drive clinics.	● Subjects are asked to operate certain controls while driving and in static conditions and errors made & responses timings of each subject are noted for validation purpose ● Subjects are asked to fill the scorecards with respect to the operability of the controls.

Drive Test Procedure

Descriptions of tasks to be completed by the evaluators during the tests

After the test drive, the drivers share their feedback based on experience and compare the different prototypes. The following tasks will need to be completed:

1. Evaluate the primary controls ease of use (shifting knob/button, steering force) and adjustable enough for test drivers to be comfortable
2. Evaluate if the seats are comfortable and supportive (not too soft or hard)
3. Evaluate if there are sufficient gauges, readouts, and display screens. Also, determine the easiness to view and operate
4. Evaluate the the climate-control system and how effectively the system cools/heats the cabin.

5. Evaluate the vehicle's human-machine interface, let the test drivers use their mobile device to check how good the stereo sounds, along with how easy it is to control the device once it is in sync with the entertainment system.
6. Evaluate the Bluetooth wireless, Wi-Fi connectivity, and voice activation offered, and rating how convenient are the functions to use.
7. Evaluate the storage spaces, determine if allow to conveniently place subject's personal belongings while driving.
8. Evaluate if the navigation system is intuitive to operate and gives reliable in directions feedback.
9. Evaluate if the vehicle has enough power to safely merge with highway traffic situation
10. Evaluate if the brakes have a solid, reassuring feel to their operation
11. Evaluate the vehicle's composure when abruptly changing direction over rough surfaces as well as the smoothness of the transmission operation.
12. Evaluate the easiness for exiting from parking and determine the tightness of the turning radius and the difficulty of parallel-park.
13. Evaluate the visibility of the windows and compromised outward visibility. Observe how well the test drivers can see out in all directions, particularly through the rear window. Determine whether the vehicle have dangerously large blind spots, and if so, does it have blind-spot monitors/device for assistance.
14. Evaluate the road noise protrudes into the cabin, judge whether the tires drone could lull the test drivers to sleep on a long road trip. Also determine the wind noise level, and whether the air can rush into the cabin with the windows open.

Major technologies and changes to be validated

- **Powertrain - Hybrid powertrain and new 2.4L I4 turbo engine :** For the 2025MY Jeep Gladiator apart from the existing 3.6L V6 engine, a new 2.4L turbocharged engine will be available to reduce the base price of the Jeep Gladiator. Along with that a PHEV variant with 20KW battery pack is provided to help meet the 2025 CAFE and EPA requirements.
- **Battery safety :** With the introduction of the PHEV variant, the battery safety is a critical issue that needs to be validated to ensure that the vehicle can meet the Federal Vehicle Motor Safety Standards (FMVSS).
- **Cargo space:** With the 2025 Jeep Gladiator an extended bed version (6 ft bed) will be introduced to compete better with benchmarked vehicles like Toyota Tacoma and Chevrolet Colorado which already offer long bed variants to cater to the need for small businesses which need more cargo space.

Powertrain validation plan

Field Test:

The three prototypes, equipped with 2.4l I4 turbocharged engine, 3.6l V6 and PHEV are driven by test drivers of the company in the proving grounds which has varying road surfaces, gradients, and curves and the driver shares his feedback based on experience and each of these prototypes are compared with the MY 2024 variants of the benchmarked vehicles such as Toyota Tacoma, Chevrolet Colorado and Ford Ranger. PHEV variant of the vehicle is driven in different modes - hybrid and electric-only to validate

performance under different situations. The performance of each powertrain must satisfy the engineering requirements. In order to test the cars in normal traffic conditions, Mules of MY Jeep Gladiator were driven in normal traffic conditions and acceleration performance, deceleration and braking performance of the vehicle is tested by test engineers. The fuel economy is also validated through the field tests conducted in real-world conditions with the help of mules.

Figure 1. Jeep Gladiator Mule

Customer rating:

The customers are surveyed using the 3 survey methods:

1. **Observation method:** In the observation method, the subjects are asked to perform a number of tasks and the customers may be observed by the evaluators & recorded using video cameras. The recording are carefully observed by trained experimenter to look at various customer behaviors,recording of performance measures, task durations, errors, difficulties, etc.
2. **Communication method:** In communication method, the subject is asked a set of questions before testing the vehicle, during the test or after the test, to get ratings based on the user's experiences. With personal interview with subjects it is more likely to get better feedback.
3. **Experimental method:** In experimental method, the investigator changes the independent parameters which affect the response of the system in order to validate the effect of a particular parameter.

For validating the powertrain performance the following procedure is followed:

At least 50 subjects of varying ages and life-style are selected based on market demographics. The market research clinics gather data from vehicle registration information in the selected county for vehicles in the same class, i.e., mid-size pickup trucks. The market clinics are held in 3-4 cities which represent the major market for the target vehicle.
The subjects are invited to the market research clinic where they are asked to check-in their names and verify their identity. The subjects are then given instructions about the test like the route to follow and the tasks to be completed.
Subjects then drive the vehicle with and without the trailer attached in various traffic conditions along the

predetermined test route and after the test are asked to rate the performance feel, fun-to-drive, handling characteristics, steering feel, braking feel and other subjective parameters on a 10 point rating scale.
The route is selected in such a way that there is some driving across off-road portions and customers are asked to rate off-road performance of the pickup truck.
Along the route, the subject is asked to drive the vehicle in electric mode as well and answer questions related to the performance feel of the electric drivetrain.
The subjects may also be asked to drive vehicle from competitors after removing the badges,logos and other identification marks and rate the prototypes against the competitors.

Figure 2. Trailer being towed by a pickup truck

Battery safety validation plan

Crash test:

To validate the safety the the battery pack the vehicle needs to be crash tested by government agencies such as NHTSA (National Highway Traffic Safety Administration). The vehicle needs to pass the test to get a safety certificate and will be rated by the NHTSA on 5-star scale rating based on the standard crash test performance. For the PHEVs and EVs apart from the front, rear, side and roll impact test the safety of the battery also needs to be accessed. The vehicle needs to meet the FMVSS 305 requirement to ensure that the battery doesn't leak electrolytes, rupture and catch fire in case of a crash.

To conduct the test the vehicle is subjected to front/rear/side-impact/rollover crash tests but along with the sensors measurements taken on the dummies, the battery temperatures, electrical isolation of the battery from the chassis and disconnection of battery from the drive circuit is also monitored. For monitoring the battery parameters a IIHS (Insurance Institute for Highway Safety) '305' box is used which is connected to the positive and negative leads of the manual service disconnect (MSD). The IIHS box contains internal circuitry with thermocouple which is used to identify potential fire hazards post-crash.

Figure 3. Front Impact crash test

Figure 4. IIHS 305 box, showing thermocouple readout

Cargo space validation plan

Laboratory test: The cargo space of the bed is measured for both the extended bed version (6 ft) and the short bed (5 ft) in litres/ cubic meters using a coordinate measuring machine. The cargo space can also be measured using standard cargo space tests derived from daily scenarios like by trying to fit boxes or bags of certain dimensions. The cargo volume can then be easily compared with the benchmarked vehicles.

Subject ratings: The subjects are invited to market research clinics are are asked to accommodate different items on the bed. The subjects are asked to load bags/boxes on the bed and then requested to rate the ease of loading/unloading the items. They are also asked to use straps and restraints after loading items such as bicycles, ATVs & motorcycles and asked to rate the ease of strapping and adequacy of number of straps. To replicate a real world scenario, subjects are asked to load items purchased from

places such as Home Depot, in order to test if the subject can load all the purchased items in the cargo bed and the number of items that can be loaded depending on their size and level of ease with which the subject can load them.

Questionnaire Form

An example of the questionnaire asked during various validation tests are shown below.

The form below collects user's information for demographics such as age, gender, education, profession, income, driving experience and vehicle ownership details along with the type of vehicle the user drives on a daily basis.

Participant Questionnaire Form

Please fill in the below requirements before proceeding to test the vehicle.

1. **What is your age?**

2. **Gender**
   Mark only one oval.
   - Male
   - Female
   - Other:

3. **What is your highest level of education?**

4. **What is your profession?**

5. **What is your income range?**
   Mark only one oval.
   - $40,000 - $60,000
   - $60,000 - $80,000
   - $80,000 - $100,000
   - $100,000 and above

6. **How many years have you been driving from?**
Mark only one oval.

- ◯ 1
- ◯ 2
- ◯ more than 3 Years

7. **What type of vehicle do you drive?**
Mark only one oval.

- ◯ Sedan
- ◯ SUV
- ◯ Minivan
- ◯ Hatchback
- ◯ Truck
- ◯ Coupe'

8. **Please provide a proof of ownership of a vehicle you drive the most (Drivers ID, Registration details, Vehicle Insurance etc.)**
Files submitted:

Data Collection Form

The data collection form lets the user rate the experience after using the vehicle on a set of prepared questions that target specific attribute requirements.

The questions are either in multiple-choice form or the 10-point rating form. For the multiple-choice questions, several options are provided for each question. And the participants will select one option which is based on their experience. For the 10-point scale rating questions, the ratings are collected on a 10-point scale where 1 is the lowest and 10 is the highest rating that one can provide indicating the level of satisfaction. The data collected are compiled, reviewed and any minor changes that are to be made based on the acquired results are implemented before producing the final job and beginning the production line and start of distribution for sales.

Scale Value / Rating	1	2	3	4	5	6	7	8	9	10
Descriptor	Not Acceptable		Poor		Border-line	Accep-table	Fair	Good	Very Good	Excell-ent
Expected Customer Satisfaction	Very Dissatisfied				Some-what Dissatis-fied	Fairly Well Satisfied		Very Satisfied	Completely Satisfied	
Problem/Product Defect Detectibility	Most Customers			Average Customer		Critical Customers		Trained Observers		Not Percep-tible

Fig 5. 10 point acceptance scale with descriptors.

The below set of questions could be asked to subjects for validation of various vehicle attributes.

Table 3. Example of questionnaire to subjects.

Sl No.	Questions	Acceptance Rating(1-lowest, 10-highest)
Performance and handling evaluation		
1.	Please rate the acceleration performance while driving the vehicle with only the engine engaged.	
2.	Please rate the acceleration performance of the vehicle in electric only mode	
3.	How likely are you to drive this vehicle in electric mode?	
4.	Please rate the off-road performance of the vehicle. (How easy was it to maneuver the vehicle in off-road conditions)	
5.	While driving the vehicle with a trailer on tarmac, how did you feel about the performance of the vehicle?	
6.	While driving the vehicle with a trailer in off road conditions, how did you feel about the performance of the vehicle?	
7.	Please rate the braking performance of the vehicle without trailer.	
8.	Please rate the braking performance of the vehicle with trailer.	
9.	Please rate the handling performance of the vehicle while cornering without trailer.	
10.	Please rate the handling performance of the vehicle while cornering with trailer.	
11.	Please rate the steering feel.	
12.	Please rate the brake pedal feel.	
13.	How fun was the vehicle to drive?	

NVH evaluation		
1.	Please rate the overall acceptance of wind noise while driving at different speeds .	
2.	Please rate the overall acceptance of road noise while driving at different speeds.	
3.	Please rate the overall noise due to engine.	
4.	Please rate the overall acceptance of road noise while driving at different speeds in electric mode.	
5.	Please rate the overall acceptance of road noise while driving at different speeds in electric mode.	
Exterior & interior styling		
1.	Please rate the frontal appearance of the vehicle.	
2.	Please rate the rear appearance of the vehicle.	
3.	Please rate the appearance of the vehicle from the side view..	
4.	Please rate the appearance of the vehicle from the three-quarter (from an angle) view.	
5.	Please rate the overall appearance of the interior.	
6.	Please rate the smoothness of the dashboard material.	
7.	Please rate the legibility of the labels on the controls.	
8.	Please rate the legibility and appeal of the graphics used in the infotainment screen.	
Accessibility		
1.	Please rate the ease of opening and closing of the tailgate of cargo compartment.	
2.	Please rate the ease with which the cargo can be loaded into the bed	

3.	Please rate the ease of entry and egress into the vehicle.	

Passenger and cargo compartment space

1. **Please rate the legroom space available in driver seat and rear passenger seat.**
   Mark only one oval.
   - ◯ Too less
   - ◯ Too much
   - ◯ About right

2. **Please rate the steering wheel, fore and aft location.**
   Mark only one oval.
   - ◯ Too less
   - ◯ Too much
   - ◯ About right

3. **Please rate the space above the driver's head.**
   Mark only one oval.
   - ◯ Too less
   - ◯ Too much
   - ◯ About right

4. **Please rate the cargo space of the vehicle**
   Mark only one oval.
   - ◯ Too less
   - ◯ Too much
   - ◯ About right

5. **Please rate the adequacy of the straps available in the cargo bed for holding the loaded components.**
   Mark only one oval.
   - ◯ Too less
   - ◯ Too much
   - ◯ About right

Data Analyzation Method

The data obtained from the entire evaluation process will be in two types: the multiple-choice question answer and the 10-point scale rating answers.

For multiple-choice question answers, numbers of responses for each provided options are counted. In each multiple-choice question, the option with the highest number of choices is considered to be the majority preference. Each multiple-choice question results will be shown in the pie chart, and the arc length of each slice in the pie chart is proportional to the number of selections of the option it represents.

For 10-point scale rating answers, numbers of each score for each item are counted. For each 10-point scale rating question, a bar graph is created to show the score distribution. The scores for the same item across all vehicles are compared and tabulated in a single analyzation chart. In this chart, the number of scores are converted to the representation of participant's preference of each vehicle. The number of highly preferred, poorly preferred, preferred, non-preferred for each vehicle is counted. Furthermore, the ratio of numbers of preferred to non-preferred, the mean, the average, and the standard deviation of the scores are calculated and also shown in the chart.

Illustrative Examples of Results

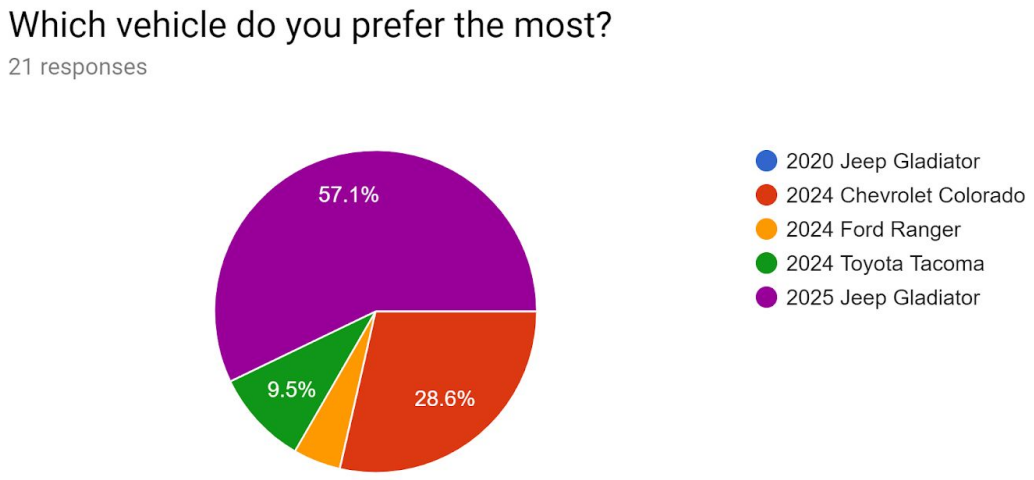

Figure 6. Example of a pie chart showing the multiple-choice question results.

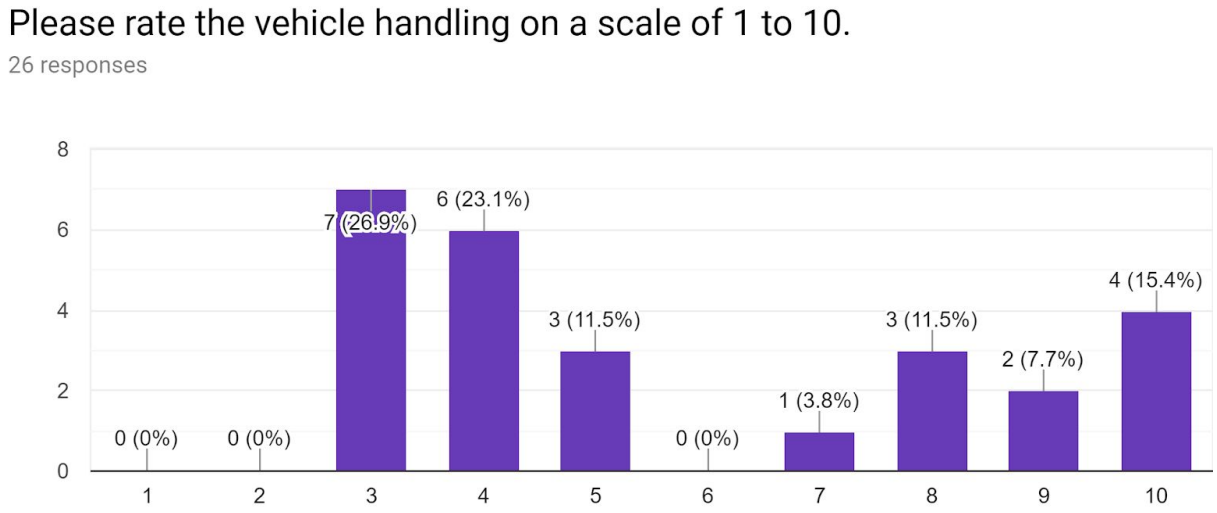

Figure 7. Example of a bar graph showing the the score distribution of a 10-point scale rating question.

Table 4. Example of a analyzation chart showing the scores for the same item across all vehicles and the calculated evaluation measures.

		2020 Jeep Gladiator	2024 Chevrolet Colorado	2024 Ford Ranger	2024 Toyota Tacoma	2025 Jeep Gladiator
	Rating	Number of Responses				
10-Point Rating Scale	10	4	2	0	1	6
	9	2	5	3	5	8
	8	3	6	4	2	5
	7	1	6	3	4	5
	6	0	3	8	7	1
	5	3	3	2	5	1
	4	6	0	4	2	0
	3	7	1	1	0	0
	2	0	0	0	0	0
	1	0	0	1	0	0
	Total	26	26	26	26	26
Evaluation Measures	# of Highly Prefered (≥8)	10	13	7	8	19
	# of Poorly Prefered (≤3)	7	1	2	0	0
	# of Prefered (≥6)	10	22	18	19	25
	# of Non-prefered (≤5)	16	4	8	7	1
	Ratio of Preferred to Non-preferred	0.625	5.5	2.25	2.71	25
	Log (Preferred to Non-preferred)	-0.18	0.74	0.29	0.31	1.12
	Median Value of Ratings	4.5	7.5	6	6	9
	Average Value of Ratings	5.73	7.35	6.08	6.69	8.38
	Standard Deviation of Ratings	2.14	1.97	1.83	1.45	1.12

Improvements for validation plan

The validation plan can be improved, provided additional resources and fundings where allocated. Some of the improvements are listed as below:

- The vehicle could be better validated if the time period allocated was longer. With more time more validation test and iterations can be performed to improve the results.
- Additional funding if allocated could facilitate Drive evaluations and customer focus sessions in target international markets.
- Additional man-power would improve the feedback quality due to variation in responses and more test engineers would help in conducting simultaneous tests in short periods of time.
- Having more prototypes will facilitate the conducting of internal crash tests and other destructive tests.
- Making an initial/intermediate/final validation report that documents the results of the technical performance validation tests, as well as the process design and cost estimate assessment.
- Drafting a protocol guideline for all the validation groups for the vehicle level validation plan design, experienced validation engineers from all areas can work together to put all the design guidelines and requirements into one corporate level standard.

The technology plan and the validation plan that are described and presented above includes some of the majors changes and the tests that are to be implemented and performed for customer satisfaction and to achieve good sales in the intended target market against competitors in the same segment. However the implementation of these technologies and conducting the validation test come with trade-offs. Some of the major uncertainties are listed below:

- Trade-off between cost and weight to meet CAFE and EPA standards and improve efficiency
- The reliability and quality of the sensors and other embedded components
- The market fluctuations as the plan progresses
- Cyber security vulnerability
- Network connectivity
- Customer expectation change with time
- Accuracy of the software algorithm to precisely perform maneuvers such as Smart Summon and auto parking.
- Achieving best in class battery range

Conclusions

In order for the vehicle program to progress without any delays and to ensure the implementation of all the proposed technology and validation test procedures, the proposed plans should be executed on schedule without delays and regular checks should be conducted to evaluate the progress and any required minor changes should be incorporated during the initial phase of the program. This will allow for a systematic and structured development of the MY2025 Jeep Gladiator.

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