TESLA VEHICLES

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Internet of Things

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ABSTRACT

The internet of things is a new dimension in technology made up of a network of physical components and devices that are fitted with sensory mechanisms that enable them to send and receive data over a network from one device to another, between the devices and other systems, and between the devices and human beings. To qualify as IOT, a system or device must meet the following conditions: First, there has to be 'things.' These are the physical components. Next, their things must have connectivity. Next, data has to be involved because IoT is built around the internet. Apart from that, there has to exist a communication system. The devices should also possess artificial intelligence capabilities. These things should also be able to perform tasks through automated or manual action. Finally, there has to exist an ecosystem in which things operate and communicate with other systems.

TESLA VEHICLES

DETAILED PRESENTATION OF THE FULL SOLUTION CHAIN

Introduction

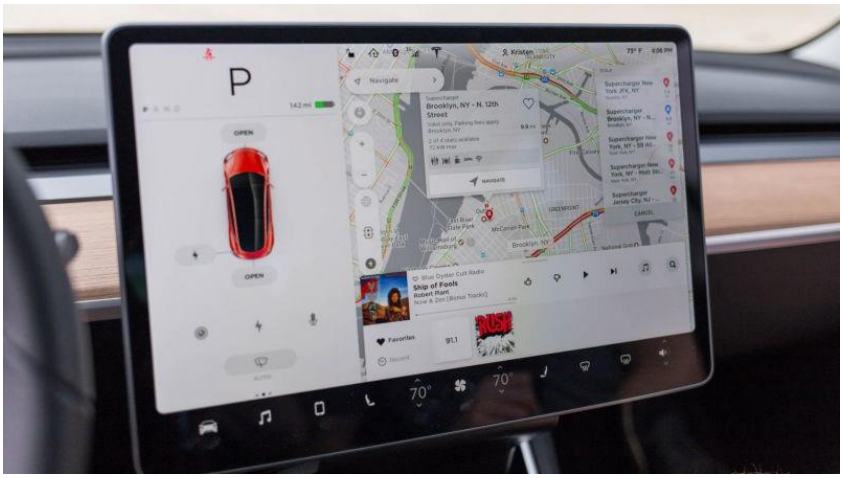
More cars are getting on to our roads every year. This has brought problems like increased environmental pollution and road accidents. This situation has created the need for smart vehicles to provide improved safety standards and save human lives. Tesla Motors has established itself as the dominant manufacture of autonomous electric vehicles in the automotive industry. As of the year 2020, Tesla Motors has produced four vehicle models; the Tesla Model S, Tesla Model X, Tesla Model Y, and the Tesla Model 3. All Tesla vehicles are electric and have self-driving features. Through machine learning, the vehicles have been able to master human behavior, make autonomous decisions, and communicate with secondary devices, the car owners, other Tesla vehicles, and Tesla service centers over a network. This article will show how Tesla vehicles meet the threshold of becoming part of the Internet of Things.

First of all, Tesla vehicles are all-electric. Rechargeable lithium-ion batteries power the cars, making them emission-free. The vehicle owners can communicate with the vehicle over the internet via various buttons, dials, and a touch interface that doubles as an infotainment system. The car also comes with an accompanying mobile application for both Android and IoS. The Tesla cars communicate with service centers and charging stations, informing the owner of their proximity to the nearest Tesla infrastructure like charging stations.

Figure 1. Tesla Model S

Tesla vehicles drive autonomously using an advanced artificial intelligence system exposed to various driving scenarios over the years through machine learning. In selected countries, Tesla cars make use of autonomous driving. The cars will steer themselves and navigate traffic and road networks to transport the users to their final destination (Dikmen, M. and Burns, C.M., 2016). They can accelerate, decelerate and brake when necessary, enter and exit junctions and interchanges, and use the cruise control to stabilize speeds.

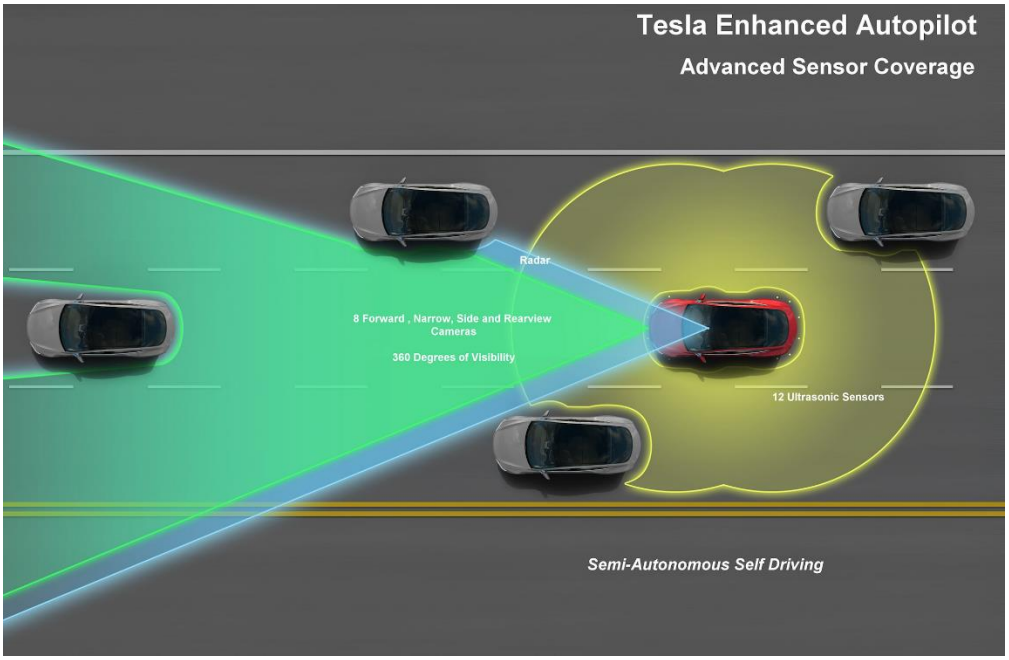
Figure 2. Tesla display screen.



The car uses GPS, vision cameras, radar, and sensors, all working together to monitor the vehicle's environment and calculate actionable manoeuvres. Tesla vehicles can identify the

physical markings on roads that denote lanes. The cars will then auto-steer to maintain driving on specific lanes and warn the driver if they attempt to switch lanes. Sensors and cameras identify other vehicles, pedestrians, and infrastructure around roads. Therefore, the cars will warn the driver or brake if necessary whenever other vehicles and pedestrians are nearby. These sensors can also scan for available parking space and autonomously drive the car into space while avoiding collisions with other parked vehicles or road infrastructure. Summon feature enables the owners of Tesla cars to 'call' the car. The car will exit its parking spot and navigate to its owner. The vehicles will identify and interpret traffic lights and stop signs along the roads without the driver's input.

Figure 3. Tesla Autopilot



Tesla regularly releases software updates to all its cars. These updates add new features and knowledge to the car's artificial intelligence system. The knowledge is gained through machine learning. As Tesla cars are exposed to newer driving scenarios, the information is sent to Tesla servers and shared with all other Tesla vehicles as updates.

IMPACTS OF TESLA VEHICLES ON THE AUTOMOTIVE INDUSTRY

Improved safety standards

Innovative features like lane-keeping assist, blind-spot monitoring, and collision avoidance systems have saved countless lives since they were introduced into the automotive industry. Tesla's artificial intelligence is fed data from past accidents potentially dangerous driving situations. The vehicles then use this knowledge base to avoid such incidences and therefore protect passengers from similar accidents. The safety features that Tesla owners enjoy are:

- Automated emergency braking. The car will automatically apply emergency brakes when it detects obstacles in its path. These obstacles could be pedestrians, other vehicles, or debris.
- Front collision warning. This feature enables the car to play warning sounds and display warning notices on the car's display to alert the driver of possible collisions with vehicles in front of the car.
- Side collision warning. Displays warning information on physical objects that could hit the car from the sides. A good example is vehicles on the same road that are switching lanes.
- Active collision avoidance. This feature enables the Autopilot to assume full control of the car and steer it clear of possible collisions.
- Automated beam adjustment. This feature adjusts the beams from low to high whenever necessary.

These revolutionary features have raised the bar on safety standards in the automotive industry. Almost all modern cars, even those without autonomous driving features, have incorporated sensors in their latest models to beef up driver and passenger safety.

Performance efficiencies

Through electric motors and artificial intelligence, Tesla Motors produces cars that outperform internal combustion engine vehicles. Electric vehicles are faster because electric motors produce instant torque. This instant torque, working alongside artificial intelligence, enables the vehicles to produce impressive performance figures. For example, the Tesla Model S is one of the fastest accelerating cars in the world. Car owners can enjoy these efficiencies without compromising on performance. Traditionally, vehicles could not meet this performance threshold without compromising major aesthetics. For instance, the fastest cars with internal combustion engines that compete the model S are much more expensive. They also have massive engines (V12's, W12's, etc.), which need high octane fuels and have high fuel consumption levels. As if that is not enough, these internal combustion engine cars are environmental pollutants.

The performance of electric vehicles can be measured using the range they cover on a full charge. On the other hand, the performance of internal combustion engine cars can be measured using the distance they cover on a full tank of fuel. For accurate results, this is measured under constant driving patterns and environmental and weather disparities. This is because these factors greatly influence range and fuel consumption, respectively. Tesla produces lithium-ion battery packs that deliver the most range. This has seen them dominate the autonomous vehicle industry by a considerable margin, with the closest competitors merely playing catch-up.

Environmental Impacts

Internal combustion engines emit pollutants into the atmosphere. There has been a need to reduce the global carbon footprint, hence adopting eco-friendly alternatives to build a sustainable energy future. Several manufacturers are making efforts to building electric vehicles. All manufacturers who are creating autonomous vehicles are building them on the electric platform. Those that are not electric are built on hybrid systems. Hybrid vehicles are powered by internal combustion engines that are mated to electric motors. The car switches from IC to the electric motor at different speeds, which dramatically lowers emission levels. Hybrid vehicles can power their battery packs while the car is being driven and through engine braking. Hybrid vehicles are becoming very popular, mainly because most countries still lack a well developed electric vehicle infrastructure, especially charging stations. Tesla Motors is still the undisputed leader in producing electric cars due to its breakthrough in creating lithium-ion battery packs that give the most extended range and its well-developed support system, especially in the United States, where it has superchargers in almost every corner of the country.

Technological Impacts

Artificial intelligence is increasingly being adopted by automakers more than before. Large quantities of data are gathered every day from drivers and from sensors fitted into motor vehicles that send performance and diagnostic information back to the manufacturer. The data contains crucial information on day-to-day driving experiences, patterns, and real-world dynamics vehicles and passengers are exposed to. This information is used to build better artificial intelligence systems or improve existing ones to create more intelligent cars.

The full self-driving cars by Tesla have revolutionized the automotive industry and sparked a new and heated competition towards better electric vehicles and developing autonomous driving systems.

Research and development

Tesla Motors and other automakers spend billions every year in research and development activities. These are aimed at creating more advanced artificial intelligence systems through machine learning.

Similar and Related Solutions

Several other vehicle manufacturers have risen to rival Tesla in producing autonomous vehicles and lithium-ion batteries to power electric vehicles. Although none has received the global success of Tesla, they have provided alternative solutions that are worth reviewing. Several car models have come close to outperforming Tesla cars, but Tesla has somehow always had the upper hand.

For decades, Japanese and German automakers have dominated the automotive industry for mass production of vehicles and for producing luxury vehicles, respectively. However, when the autonomous and electric vehicle era arrived, they could not establish themselves as global leaders. For years, Japanese manufacturers like Toyota and Honda have had electric cars in the market. An example is the Toyota Prius hybrid and the Honda Insight. These manufacturers are also developing autonomous and semi-autonomous vehicles capable of competing with Tesla, the industry leaders. Some of these cars are the 2020 Cadillac CT6 and the Nissan Rogue. These cars don't have full autonomy but come fitted with similar smart features to those available in the Tesla. Their manufacturers are also building networks through which the cars can communicate as IoT devices.

Possible New Business Models

Tesla motors lag behind in building cars that meet the luxury standards of premium German vehicles. Tesla vehicles lack the premium interior features that make German manufactures dominate the luxury car market. Tesla makes simplistic interiors that would not be present in

German cars of similar value. This is an area Tesla can invest in to increase the consumer base of their cars. If at all the German manufacturers can catch up with Tesla on battery technology and charging infrastructure deployment, they will have overtaken the American automaker in the eyes of the customers, and Tesla should fix this situation before it gets to such a point.

LITERATURE REVIEW

This section reviews literature around the technological solutions provided by Tesla Motors in their autonomous vehicles. The review considers the hardware and software components of Tesla vehicles and how they interact with each other and other systems to achieve autonomy. The terminologies that arise in the operations are also looked into.

The Tesla Cars

In the context of the Internet of Things, the Tesla vehicles are the things. They are equipped with a plethora of sensors and devices that enable them to communicate with the users of the vehicle, other Tesla vehicles, Tesla service centers, and Tesla charging stations. This communication happens over the internet. All the cars produced by Tesla operate under a single network where new concepts learned by one Tesla car are sent in the form of updates to all other vehicles. This interconnectivity ensures that the artificial intelligence systems are continually getting smarter due to a continuous stream of information from real-life situations worldwide.

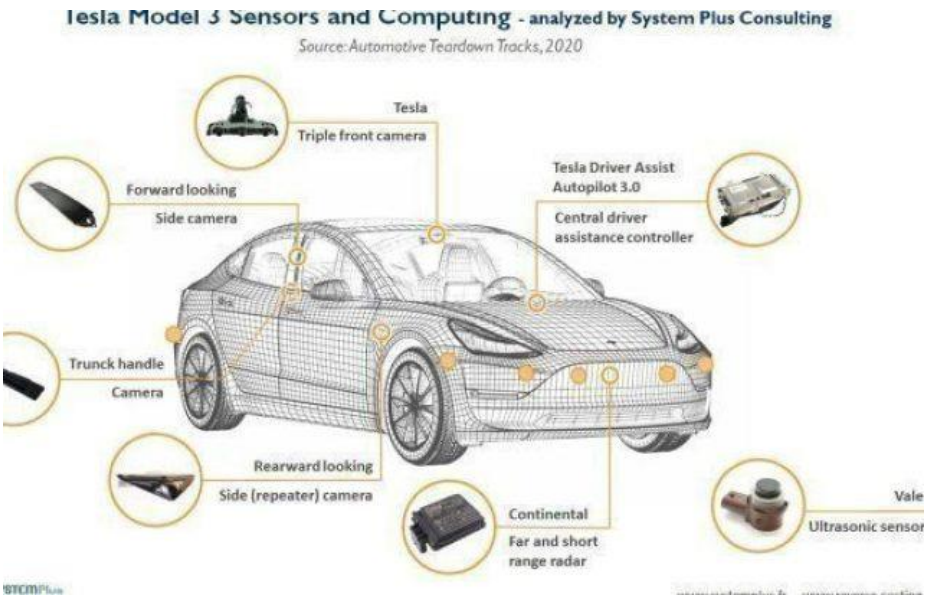
Autopilot

Tesla vehicles feature artificial intelligence systems that allow for autonomous driving. The latest vehicles being made by Tesla come equipped with hardware and software components that enable full self-driving in every possible driving situation. The vehicles are equipped with a powerful computer that can process data at lightning speeds to make autonomous real-time decisions on the road. The computer has software that can process rada, sonar, and vision in ways that no human driver could possibly manage. These developments are all in line with Tesla's dream of making all its cars fully autonomous. The company wants the vehicles to have the capacity to make entire trips without the driver having to do anything actually to drive the vehicle (Ingle, S. and Phute, M., 2016).

Tesla releases regular software updates that add newer features to the car's artificial intelligence. Tesla has a dedicated team that works tirelessly to improve the current AI systems and future systems.

Sensors

Figure 4. Tesla sensors



Tesla vehicles can perceive their environment so well, thanks to a variety of sensors fitted to the vehicles. The sensors are either placed in the interior of the car or on the exterior body. They work together and with other hardware and software components of the vehicle to provide accurate information that helps arrive at informed driving decisions. The sensors come in three categories: surround cameras, ultrasonic sensors, and radar.

- Surround Cameras

These are special cameras fitted to the vehicles to provide a comprehensive view of the vehicle's environment. A typical Tesla car contains eight of these cameras. They provide perspectives from different angles and positions of the vehicle and then feed the images to the

car's computer. The computer then intelligently combines the images and displays a seamless 360-degree view of the environment.

Apart from merely observing the environment for navigation purposes, the cameras also help secure the vehicle. When a Tesla vehicle is parked, and the owner is away from it, the cameras will monitor the car in real-time and capture video footage of intruders. These footages can be used to identify criminals in the event of someone breaking into the car.

- Ultrasonic sensors

A Tesla car is fitted with twelve ultrasonic sensors. These sensors actively monitor the car's environment to detect and identify both hard and soft objects that fall within their sensory range. The sensors work together with the surrounding cameras to identify these objects. From this, the car can carry out functions like applying emergency brakes when driving to avoid collisions with vehicles, pedestrians, and other obstacles, keep and switch lanes, follow traffic lights and stop signs, and navigate roundabouts and junctions.

- Radar

A radar is fitted into the front part of Tesla vehicles. The radar emits waves that interact with the world in front of the car and help perceive it under extremities. The radar helps provide improved visibility to drivers of Tesla vehicles at night or during extreme weather like fog, thick dust, and storms.

Tesla Mobile Application

Figure 5. Tesla mobile app.

Tesla owners can pair their vehicles to a mobile application available for Android and Ios operating systems. The mobile application uses the internet to synchronize with the car and allow the user to perform various operations on the vehicle while inside the car, outside the car, or remotely. The users create an individual account using a unique email address and secure the account with password encryption.

According to Tesla, the mobile application allows logged in users to enjoy the following features:

- Updates.

Tesla car owners get instant notifications whenever updates are available. Tesla rolls out new features and fixes bugs using updates. The updates could be in the form of software downloads or the purchase of physical parts. The car owners can then plan for and purchase the upgrades.

- Valet Mode

Tesla vehicles come with a feature called Valet mode. This security feature controls what information and features of a Tesla vehicle, that other user of the same vehicle, other than its official owner, get access to. The owner can create a limit for a speed that the car should not drive above. The owner can also hide private information from appearing on the display screen of the car.

- Keyless Driving.

The mobile application can fully function as a car key for a Tesla motor vehicle. The owner can lock and unlock the car just like they would with a physical key. They can also start the car without having the physical car key.

- Global Positioning System.

The owners of Tesla cars can get their car's exact location using GPS right on their mobile phones. They are also able to use the summon feature, which, within a given range, will engage the car to autonomously steer itself to the owner's location from wherever it is parked.

- Climate Control.

The climate control system of a Tesla car can be manipulated from the tesla mobile application. The owner can turn it on or off and control the direction, speed, and temperature of the AC's air.

- Range Information

On a full charge, the battery packs that power a Tesla car can cover a specific range. The battery packs are fitted with sensors that monitor the level of charge left. The car's computer then using

this data to compute the expected coverage range based on weather and driving patterns. This information is then displayed to the owner on the car's display and the mobile app. The system also informs the nearest Tesla supercharging station owner they can drive to within the battery range.

- Roadside Assistance

In the event of a Tesla car breaking down out away from a service station, the mobile application allows the car owner to request roadside assistance. This feature uses GPS to feed the Tesla server with the exact location of the car that has broken down. The Tesla server will then contact the service station that is nearest to the origin of the distress. The service station then dispatches a unit to tend to the car.

- Vehicle Servicing

Whenever a Tesla car undergoes official service, the service details are updated on the car's computer. This creates a service record that the owner can access anytime on their phone. The service records show the date and time when the car was serviced, the place where it was serviced, and the nature of service is received. The owner of the car can schedule service appointments and get notifications about it all from their phones. The owner can also review their service history in this way.

- Customer support.

The Tesla mobile application enables Tesla to directly contact Tesla Motors to report complaints, make inquiries, or ask for help regarding their vehicle's condition and operation. Since the users are already logged in with a profile for their specific car model, and because the tesla server is in sync with the user's car profile, service delivery is direct and precise. Minor

diagnoses, recommendations, and improvements can be made this way without physically driving to actual service centers.

Summary

All the hardware and software components mentioned above are interconnected parts of an overall system that make up a complete IoT device, in this case, the Tesla car. There are several of these devices in diverse geographic locations. They communicate with each other through the internet via the manufacturer's server environment. They can make analyze situations and make smart, independent decisions to help them achieve the objectives they are built for. These cars are also continually getting smarter by growing their knowledge base through machine learning.

SECURITY ISSUES TO BE CONSIDERED DURING IMPLEMENTATION

Hacking.

There emerged a security flaw that hackers took advantage of to gain unauthorized access to Tesla cars. This vulnerability affected the keyless entry feature of the vehicles. Tesla, however, fixed the vulnerability by providing an update patch that rectified the flaw. There have also been fears of hackers gaining complete remote control of a Tesla vehicle with malicious intentions. Although not yet a real threat, the advancements in technology could make such attacks very possible. A new buyer of any unit should consider the possibility of such breaches happening again in the future.

Questionable Road accidents

There have been a series of accidents reported that involved Tesla vehicles running on autonomous mode. In most cases, the car was unable to make the right decision to avoid the accident. There was fear that the vehicles sometimes misinterpreted physical obstacles and failed to perform the right safety manoeuvre. For instance, infrastructure like overpass roads and bridges would confuse the sensors. This has created controversy around the topic of self-driving vehicles. People have questioned if the world is prepared for the era of autonomous vehicles. In their defence, Tesla Motors have stressed that their cars are designed to inform the driver to keep their eyes glued to the road at all times when the car is in autonomous mode to enable them to take over control of the vehicle should anything go wrong.

Human errors.

Accidents had occurred in the past when humans failed to acknowledge the limitations of autonomous features such as Autopilot and therefore ended up getting involved in road accidents. Tesla always reminds drivers to keep their eyes on the road even when Autopilot is

engaged. Some people ignore this or stretch the car's autonomous capabilities beyond its practical limitations. Every product comes with a user manual. The manual is supposed to direct the user on using the product to extract optimum satisfaction from the use. Vehicles are no exception. Some people have shifted from regular vehicles to autonomous ones and failed to acknowledge the vast driving dynamics that accompany the cross over. Others simply wanted to do experimental manoeuvres on busy roads. Either way, human negligence poses a security concern that is worth looking deeper into.

Incomplete databases

The possibilities of unexpected events occurring on the roads are numerous. Tesla vehicles can analyze driving conditions to make predictions that ensure the driver's safety. However, there have been cases where the cars were not able to identify obstacles or events because these obstacles did not exist in the database of the system. The system learns from events like these because these events contribute to the knowledge base that influences the decisions made by artificial intelligence.

ETHICAL AND PRIVACY ISSUES

Users purchasing Tesla vehicles enter into a deal that raises several ethical and privacy concerns. A car owner is supposed to feed their details into the car system to personalize it and enjoy the full range of services that the cars offer. In the 21st century, data security and privacy are big concerns. This is because data has gained significant value over the decades, and it is what can be attributed to the success of leading global firms. User data is vital for a company's operations, and companies have engineered complex algorithms to aid them in data mining. At the same time, users are concerned about what companies do with their data. This has called for data protection mechanisms to protect this valuable data from getting into the hands of an unintended third party or being used for the wrong reasons by the data recipient (AboBakr, A. and Azer, M.A., 2017).

Tesla Motors collect user data to help them provide top-notch service delivery. They also use some of this data to develop artificial intelligence systems. The company has an ethical duty to safeguard this data at all times and not use it for purposes other than the specific ones stated.

The decision-making ability of autonomous vehicles can lead to ethical concerns. There have been accidents that had happened when Tesla vehicles were running on autonomous mode. Artificial intelligence failed to prevent accidents like it is expected to. As much as some of the accidents happened due to the driver's negligence, an ethical concern arises. Self-driving cars are designed to protect the driver and passengers of the vehicle and save millions of lives in the long run. People have, however, died on several occasions due to machine errors. This makes one question the reliability of these systems.

Apart from the obvious visible limitations of autonomous vehicles, there is concern about the limits to what information artificial intelligence systems and their accompanying security system obtain from users and their environment. Having a system that actively monitors your location and holds your private data is one thing; having a system that can independently make decisions with this data is another problem. After seeing the limitations of artificial intelligence systems and how they have, on several occasions, led to fatal road accidents, one is left wondering what limitations the security features have. Hackers have successfully managed to bypass keyless entry in Tesla cars in the past. As much as Tesla fixed the vulnerability that these people exploited, what other vulnerabilities exist in this system? Do artificial intelligence systems possess significant privacy flaws being exploited by their providers or third party systems?

Finally, there lack of elaborate data and privacy protection laws in some markets. This is true for countries that fall outside the European Union and American markets. Tesla sells its vehicles to these countries. There is an ethical concern on what guidelines to follow to address the privacy concerns of consumers in these markets.

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