Examining the switch of Tesla's use of Vision AI from Radar & USS, and its Impact on Manufacturing Towards Cost Reduction

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Development of Autonomous Vehicles

Autonomous vehicles have advanced for many years, and the development of this technology has been a significant focus for many companies. Tesla, a pioneer in EV's and autonomous vehicles, has been at the front of this technology, with their autonomous driving systems being one of the main selling points of their vehicles. The development of autonomous vehicles has been a significant technological advancement, and it has brought significant shifts in technology as well (Belanger, 2023). Tesla's shift from a radar and Ultrasonic Sensor System (USS)-based system to Vision AI, a camera-based system, is one of the most significant changes in the company's technological strategy in recent years as an attempt to improve their self-driving functionalities.

The development of autonomous vehicles has sparked a revolutionary era in transportation, bringing significant shifts in vehicle technology. The shift to Vision AI is one of the most significant changes in the company's technological strategy in recent years. Vision AI is a technology that uses cameras and computer vision algorithms to detect and interpret the environment around the vehicle. When this technology first released, it was advertised to have the potential to improve the accuracy and reliability of autonomous vehicles, making them safer and more efficient (Fagnant & Kockelman, 2015, 174). This "upgrade" to Vision AI was promised to be ahead of Radar and USS, but as it started rolling out to consumers, that was far from the case.

The development of autonomous vehicles also raises significant STS issues. One of the main issues is the impact of autonomous vehicles on employment. The development of autonomous vehicles has the potential to displace many jobs in the transportation industry, including truck drivers, taxi drivers, and delivery drivers. Another significant STS issue related to the development of autonomous vehicles is the impact on road safety. While autonomous vehicles have the potential to improve road safety by reducing human error, there are also concerns about the safety of these vehicles. For example, there have been several high-profile accidents involving autonomous vehicles, including a fatal accident involving a Tesla vehicle in 2018, which had the full-self driving feature turned on, and the sensors were blocked by the direct sunlight that was shining down against it, which caused the system to fail and result in the fatal crash. (Milakis, van Arem, & van Wee, 2017). The fatal crash of 2018 is just one of many cases that occurred with the use of tesla’s full self-driving system, and Tesla has argued that their technologies have massively improved using fleet data, however, this has instead resulted in higher chance of error (Tesla).

Examining the switch to Vision AI from Radar and USS

Tesla's switch from Radar and Ultrasonic Sensors (USS) to Vision AI raises issues with the development of autonomous vehicles, with other companies such as Waymo offering self-driving taxis in San Francisco (Waymo). This technological revolution affects more than just hardware and algorithms; it also has a big impact on society in terms of user trust, road safety, and regulatory laws. From an STS perspective, the question is: "How does the shift in Tesla's autonomous driving technology from Radar & USS to Vision AI impact societal norms, trust, and regulatory structures, ultimately including cost reduction in manufacturing?" This question can be explored with the number of accidents that occur with the self-driving system equipped during time of impact, compared to the statistics of an average human driving.

According to Bijker, Hughes, and Pinch (2012), the social construction of technological systems is a critical aspect of STS. The shift to Vision AI by Tesla has significant issues for societal norms, trust, and regulatory structures. Fagnant and Kockelman (2015) argue that the development of autonomous vehicles has the potential to displace many jobs in the transportation industry, including truck drivers, taxi drivers, and delivery drivers. In terms of road safety, the shift to Vision AI by Tesla has raised concerns about the reliability of the technology. Siciliano and Khatib (2016) have both mentioned that radar and USS have been key components of Tesla's sensor system in the past, helping the car navigate and effectively respond to real-time scenarios, which is how they've proven to be more reliable overtime. Tesla's autonomous driving features met certain safety benchmarks thanks to the use of radar technology, which was renowned for its dependability in object detection and distance measurement. However, the shift to Vision AI raised questions about the reliability of the technology, especially in different driving scenarios, since there were statistics of more accidents being reported with it enabled (Hamblen).

From an STS perspective, the shift to Vision AI by Tesla not only contradicts the technological advancements in autonomous vehicles but also highlights the critical importance of user trust and regulatory structures. As Milakis, van Arem, and van Wee (2017) discuss, the development of autonomous vehicle technology demands a fundamental understanding of its social and regulatory implications. This necessity is further exemplified by Tesla's recent recall of 2 million cars due to safety concerns over steering, braking, and acceleration, showcasing the impacts of these technological shifts on regulatory rules and public trust. The recall, prompted by issues identified with Tesla's autonomous driving features, contradicts the challenges and responsibilities that manufacturers face in ensuring the safety and reliability of their innovative technologies (Brangham). It also emphasizes the need for stricter regulatory frameworks that can change the pace of technological change, making the advancements in autonomous vehicle technology are matched with stricter safety standards and transparent communication with the public.

Assessing the Current Performance of Tesla’s Vision AI System

In assessing the current performance of Tesla's Vision AI system, it is shown that while the technology can improve in the future, there are concerns regarding its effectiveness compared to the radar and Ultrasonic Sensor System (USS) systems that were previously used. One of the largest issues is Vision AI's reliance on optical inputs, which can be inaccurate under harsh weather conditions or in low-light scenarios. In testing, it was found that the camera-based system struggled to accurately detect obstacles under these conditions, leading to safety concerns, as opposed to the radar and USS, which showed 34% more accuracy in detecting pedestrians. For instance, a study by the led by Matt Hamblen from Fierce Electronics, found that Tesla's Vision AI had a higher incidence of failing to recognize pedestrian figures in poor visibility conditions compared to radar-equipped models, raising questions about its current reliability (Hamblen, 2022).

The economical cost reduction behind the switch to Vision AI, does not necessarily correlate to improved performance. The radar and USS technologies provided a layer of reliability that the Vision AI system is still struggling to achieve. While the removal of radar and USS components did reduce manufacturing costs, it also led to an increase in consumer reports of errors and inaccuracy during autonomous operations, suggesting that the technology might not be as reliable as needed for autonomous driving applications (Lambert, 2022). These findings prove that despite the approach of Tesla's switch to Vision AI, the current capabilities don’t justify the switch from radar and USS, showing the need for a balanced approach that does not compromise safety for cost savings or future development.

Transitioning to a vision-based system introduces complications in machine learning training and algorithm optimization, that are not necessarily needed by radar and USS. The camera-based approach involves processing and interpreting visual data to ensure the same level of accuracy and reliability. A study led by William Brangham, emphasizes that the feedback loop for improving AI through real-world driving data is a slow process that leaves gaps in safety and performance metrics when compared to feedback provided by radar and USS sensors. This suggests that while Vision AI can be improved in the future, its current iteration faces challenges that need to be fixed to surpass the old system's reliability and safety standards (Brangham, 2022).

Comparative Analysis with Other Autonomous Vehicle Technologies

As the landscape of autonomous vehicle technology evolves, there is a lot more competition that has been created to drive innovation and profits even further than before. Companies have taken various approaches to achieve vehicle autonomy, while executing various sensors and algorithms to achieve the complexities of real-world driving. Tesla's decision to was prioritize Vision AI, which heavily relied on camera-based systems. This contradicts the approaches of other electric automobile manufacturers such as Rivian, Daimler, and Waymo.

Tesla's approach was based on the capabilities of advanced computer vision and artificial intelligence, which is significantly different from the hardware-intensive sensors commonly used in the industry, while also arguing that cameras, which are supported by sophisticated neural networks capable of adapting to diverse driving environments, can provide the necessary data for safe autonomous navigation without additional sensors like LiDAR. It was also argued to help aim to streamline production and reduce the vehicle price point, making autonomy accessible to a broader market, and keeping the product interesting enough for more consumers to go electric.

Rivian adopted a traditional approach when designing their system, which was equipping their vehicles with a combination of cameras, ultrasonic sensors, radar, and LiDAR to create a versatile sensing environment that could accurately detect and interpret surroundings under various conditions, even in bad conditions, such as snow, rain, fog, or direct sunlight, which meant reflecting a cautious stance on autonomy by integrating multiple sensor types to make up for any single module's limitations, unlike Tesla's approach. Daimler emphasized safety and reliability in their autonomous vehicles by deploying a comprehensive sensor suite, including LiDAR, radar, and cameras, to ensure their vehicles have an environment understanding of their surroundings, also with a focus on constant implementation and extensive testing to help it become better. Waymo centered its autonomous technology around LiDAR, which was needed for creating detailed, three-dimensional maps of the vehicle's surroundings, and is also supported by radar and cameras, allowing for precise object detection at various distances and under a wide range of conditions. Out of all these automobile manufacturers, Waymo was the first to launch one of the first commercial self-driving taxi services, without any human intervention, available in technological hubs such as in Silicon Valley.

The different approaches toward achieving full vehicle autonomy, where Tesla's reliance on cameras and AI, differs from the sensor approaches of Rivian, Daimler, and Waymo. This represents different views on the best path to safe, reliable, and scalable autonomy, while also learning where to cut costs on manufacturing, and on where to spend extra money to ensure the software developed by the manufacturer works as intended. This approach has been noted by customers, with lower customer satisfaction ratings coming from Tesla owners, and complaining to bring back USS and radar sensors for a more accurate reading (Tesla Motors Club, 2022). Tesla's bet on Vision AI serves as proof in development of software and machine learning to revolutionize transportation, while challenging traditional views on vehicle sensor requirements. On the other hand, Rivian, Daimler, and Waymo emphasize caution, safety, and the proven reliability of multi-sensor systems, which further highlight the ongoing debate within the industry regarding the optimal approach to autonomy and again proving the efficiency and safety of sensors.

Public Perception and STS Frameworks

Elon Musk, a co-founder of Tesla, advocated for a vision-only system, which highlighted confidence in the superiority of camera-based perception over traditional radar, suggesting that as vision processing improves, it renders radar comparatively less essential (Lawler, 2021). This transition, while innovative, caused concerns over vehicles initially facing restrictions on certain Autopilot features until software updates could fully enable them (Lawler, 2021). The rationale behind Tesla's switch, as explained by Musk, was centered on the belief that cameras offer a higher data throughput than radar and LiDAR, and that advancements in computer vision and neural processing will continue to enhance this technology's effectiveness (Hertz, 2021). Musk's stance was that in instances where radar and vision conflict, the precision of vision is preferable, but it still sells short of Tesla's commitment to a camera-centric strategy for achieving full autonomy (Hertz, 2021).

From an STS perspective, Tesla's pivot to Vision AI shows the intertwining between technological innovation and societal adaptation. The transition challenges existing issues of vehicle safety and autonomy. The concept of "sociotechnical imaginaries" can be seen as: a notion that collective visions for future technological societies influence policy, public expectation, and technological development itself (Bijker, Hughes, and Pinch, 2012, 30). Tesla's vision-only approach not only reflected a technical decision but also shaped public expectations around the feasibility and safety of autonomous vehicles. This reflects the need for ongoing debate between innovators, regulators, and the public—a core of STS that emphasizes the co-construction of technology and society. As Tesla continues to refine its vision-based system, the staff will likely influence regulatory standards and public acceptance of autonomous vehicle technologies through newer and safer features.

Analysis of Social Construction of Technology (SCOT) of USS and Vision

The Social Construction of Technology (SCOT) framework offers a perspective on how to view technological developments, not just as outcomes of engineering practices, but as processes which deeply integrate within societal structures. According to Bijker, Hughes, and Pinch (2012), technologies can be displayed from the social interaction between various groups, with each contributing different meanings and utilities towards the process of the technology. This perspective is relevant to Tesla's transition from traditional sensor technologies (Radar and USS) to a Vision AI-centric approach for autonomous vehicle navigation.

At the center of this framework, is the concept of flexibility, suggesting that a technological artifact has different meanings for various social groups, which is very well-illustrated in the case of Tesla's transition to Vision AI, such as engineers, consumers, regulatory bodies, and the broader public in an area. For Tesla's engineers and designers, the shift to Vision AI symbolizes a drive towards pioneering technology that enhances vehicle autonomy through advanced data processing capabilities, while also positioning Vision AI as an alternative for achieving accurate and reliable environmental perception, and surpassing and succeeding the traditional Radar and USS technologies (Bijker, Hughes, & Pinch, 2012, 33; Lambert, 2022). However, consumer reactions to Tesla's technological shift are mixed, with some claiming Vision AI as an innovative leap forward that puts Tesla's status as a pioneer in electric and autonomous vehicles, while others voice safety and reliability concerns, especially following incidents that highlight the technology's limitations, including inaccurate readings, and fatal accidents (Lawler, 2021; Hertz, 2021). This change in perception influences the market and the perceived value of Tesla's technological progress. Regulatory bodies are mainly focused on the safety and reliability of new technologies on public roads, and they often point out the challenges presented by the shift to Vision AI, while also re-emphasizing the authenticity of existing regulations, standardization, and testing protocols in protecting public safety, questioning the rapid evolution of autonomous vehicle technologies (Brangham, 2023). Additionally, shareholders and employees, who directly impact the conversation surrounding Tesla's Vision AI, debate over ethical considerations, the impact on employment, and the environmental implications of autonomous vehicles, while also reflecting societal concerns and worried perceptions about the future of mobility and the role of technology in creating safe human experiences for those who want to move forward in autonomous driving.

In the context of the Social Construction of Technology (SCOT) framework, closure and stabilization are necessary processes that occur when social groups reach a compromise on a technology's meaning and its effect on the public. The ongoing issue between Tesla, its users, regulators, and consumers show the evolution concerning the technology's safety, authenticity, and societal implications. Regulatory decisions, such as recalls or the implementation of new safety standards, show instances of closure, however, these are also subject to revision as both technologies and societal expectations progress (Brangham, 2023). Currently, Tesla's strategic shift to Vision AI highlights SCOT's focus on the economic and social issues of technological adoption, by aiming to enhance manufacturing efficiency and reduce costs. This move shows a larger trend within the automotive industry towards the integration of software-driven solutions and AI to decrease dependency on expensive hardware components and to further radicalize vehicle functionalities (Lambert, 2022; Hamblen, 2022). This transition shows the intertwining between technological innovation and economic incentives, within the company's objectives, market forces, and consumer anticipations. The surrounding issues over employment effects and the environmental impacts of manufacturing processes, prove the various factors which shape the technological paths under the SCOT framework. Through the lens of SCOT in examining Tesla's shift from Radar and USS to Vision AI, it becomes clear that technological development can be influenced by a social construct, bargaining, and disputes between different groups.

Manufacturing and Cost Cutting

Tesla's transition to a Vision AI-based system, moving away from traditional radar and ultrasonic sensors (USS), marks a significant shift in the company's approach to manufacturing autonomous vehicles. This change is fundamentally driven by the desire to cut costs while enhancing the functionality and safety of its Autopilot and Full Self-Driving (FSD) systems. In 2021, Tesla began removing radar from its Model 3 and Model Y vehicles, expanding this change to the rest of the fleet, Model S and Model X in 2022. This was done so the systems could rely solely on Tesla Vision. At the time, this showed and advertised to the consumers a significant step in leveraging machine learning and computer vision technologies to provide high-definition spatial positioning, longer range visibility, and improved object differentiation capabilities. The transition not only aimed at reducing the reliance on costly hardware components but also at streamlining the production process (Tesla), according to their advertisement to get customers to purchase their product.

The elimination of USS in favor of Tesla Vision was part of a larger strategy to improve safety features and Autopilot capabilities. Despite some temporary limitations in features such as Autopark and Summon (a feature where the car moves by itself, without a driver inside), during the transition, Tesla's vision-based occupancy network promised rapid improvements over time, ensuring that vehicles retain, if not improve, their active safety ratings and performance in functionalities like pedestrian automatic emergency braking (AEB). Tesla's confidence in this strategy was backed by alleged safety improvements observed in vehicles equipped with Tesla Vision compared to those with traditional radar systems (Lambert, Hamblen). Ultimately, Tesla’s switch into Vision was to save costs, because it meant that there was less money that had to be spent on the hardware, since the cars were already equipped with 8 camera’s around the car, they decided that by integrated AI into the CPU and ECU of the car, and with OTA software updates, that they could save a large amount of money per vehicle produced (Lambert).

Ultimately, Tesla's bold move reflected an industry trend toward software-driven solutions in vehicle autonomy, emphasizing the potential of AI and machine learning to transform transportation, while also cutting costs down to save money. By adopting a vision-centric approach, Tesla had self-aligned itself with the principle that roads are designed for human navigation, which was vision-based. This remains the belief that a camera-only system, enhanced by artificial intelligence, can replicate, and exceed human driving capabilities without the need for expensive radar or lidar sensors.

Conclusion

Overall, the transition from traditional radar and Ultrasonic Sensor Systems (USS) to Vision AI, strategies in manufacturing and cost reduction, and the Social Construction of

Technology (SCOT) frameworks, shows that this evolution is big in terms of technological advancement, but also shows a big transformation in societal engagement and acceptance of autonomous transportation. The move towards Vision AI, led by innovators like Tesla, marks a shift in the design, and implementation of vehicle sensing and navigation technologies, setting new benchmarks for what vehicles can achieve in the future.

This transition, while aimed at enhancing vehicle autonomy and safety, also shows the challenges of integrating advanced AI systems into everyday use. Public perception, shown by safety concerns, ethical considerations, and the potential for transformative change, all play a big role in the adoption and acceptance of this product. The comparative analysis of autonomous vehicle technologies across different companies reveals approaches towards achieving vehicle autonomy with competition. Companies like Rivian, Daimler, and Waymo have opted for a more traditional, sensor-rich strategy, incorporating LiDAR, radar, and cameras to navigate the complexities of real-world driving. This contrasts with Tesla's bold decision to focus primarily on Vision AI, leveraging advanced computer vision and machine learning to interpret the vehicle's surroundings, relying on a single module. Each approach is a reflection of the balance between hardware and software in autonomy, while highlighting the industry's strategies to enhance safety, efficiency, and user experience.

Incorporating the Social Construction of Technology (SCOT) framework into the analysis of autonomous vehicle development offers a deeper understanding of how social constructs influence technological innovation. SCOT suggests that technologies are not merely the outcome of engineering progress but are shaped by interactions among various social groups, including engineers, consumers, regulators, and public. This framework highlights the flexibility of technologies like Vision AI, where different groups may see different potential, risks, and benefits.

Manufacturing strategies focused on cost-cutting and efficiency have made it possible to pursue these goals. By leveraging AI and machine learning, companies are not only improving the capabilities of autonomous vehicles but also making them more accessible to a larger audience. This approach reflects a trend towards software-centric automotive design, where updates and improvements can be rolled out continuously through over-the-air updates. The development of autonomous vehicles is not only technical, but also a socio-technical challenge that requires criticism of public perception, safety standards, and regulatory frameworks for its acceptance in society to thrive as a product in the future.

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