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Tesla Software on Wheels: Digital Transformation of the Automotive Business Model

As the world-leading automaker for electric vehicles (EVs), Tesla Inc. had built a reputation as an innovator in the auto industry, often exceeding industry and market expectations alike, culminating with the Model Y as the best-selling vehicle globally in 2023, with 1.23 million units sold, dethroning the Toyota Corolla, which held the position for many years.[1]

Tesla's approach of introducing a new business model, powered by software and digital technology, challenged the traditional assumptions behind competition, customer engagement, and valuation in the auto industry. However, the disruptive nature of Tesla's business model received mixed responses from the stock market. In January 2022, the market expected updates on Tesla's yet-to-come Cybertruck, semi-trucks, and a $25,000 mini-car. But CEO Elon Musk announced that the company would not launch any new products in 2022 due to the industry's uncertainty related to the semiconductor chip shortage. Instead, he said, its focus in 2022 would be on developing software to improve autonomous driving capability because that would accelerate the company's overall profitability.[2] However, the stock market was not buying the argument.

The fundamental, "first-principles" rethinking of a vehicle led Tesla to design and manufacture the industry's first "software-defined" automobile.[3] Even so, rapid permeation of software into every aspect of the auto industry, from design and manufacturing to customer engagement and driving experience, was transforming the business, creating a new competitive arena, and raising questions around the valuation of a software company competing in the automobile business. Facing Tesla leadership were the questions of potential new business models, given the company's focus on software as a core capability, and how Tesla would further engage current and new vehicle owners.

Automobile History and the Shift to EVs

It's hard to imagine a society without vehicles. When Henry Ford and the Ford Motor Company first released the Model T in 1908, he envisioned it to be an answer to a fundamental question faced by society—

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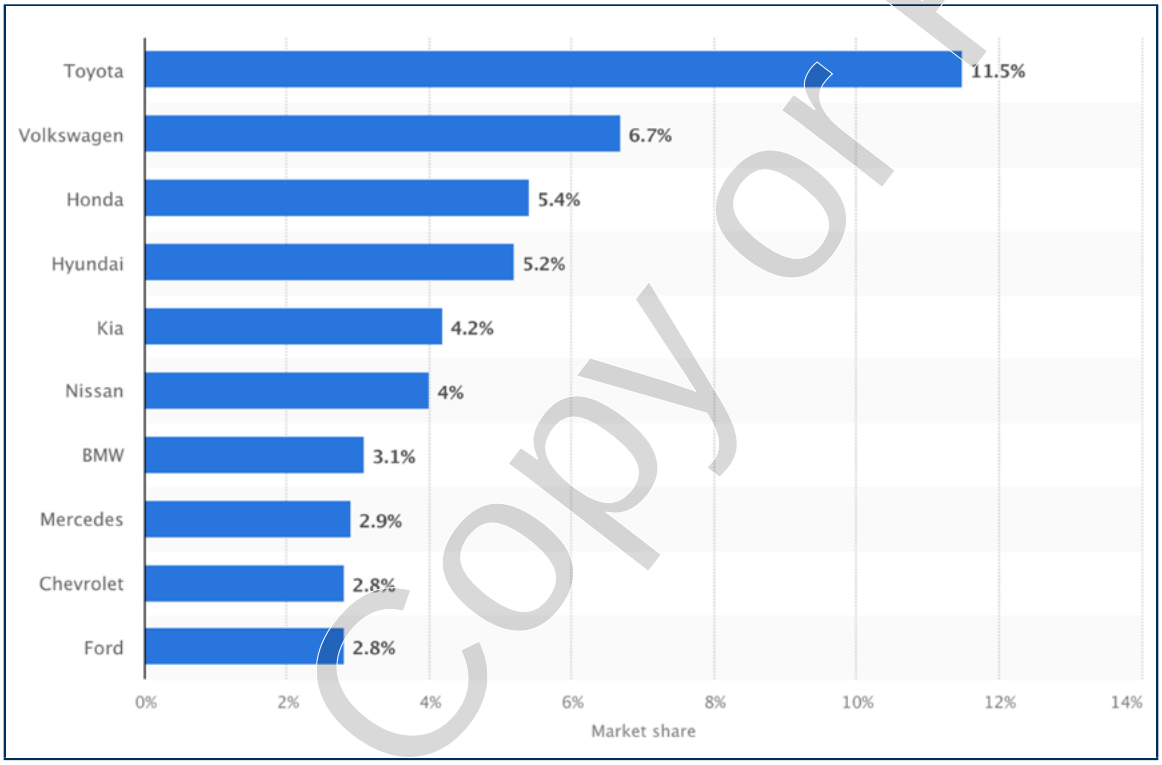
how can transportation be revolutionized for the typical person? With the Model T, Ford mass-produced safe, reliable automobiles (by the era's standards) for the average consumer. In the wake of Ford's success, hundreds of auto manufacturers emerged, hoping to fuel the American Dream. After a hundred years of competition, only a handful of those companies survived as global corporations. **Figure 1** depicts the top auto brands by sales in 2022.

Figure 1

Global Automotive Market Share in 2022, by Brand



Source: Carlier, Mathilde. "Global automotive market share in 2022, by Brand." *Statista*, 29 Aug. 2023. https://www.statista.com/statistics/316786/global-market-share-of-the-leading-automakers/. Accessed 17 Oct. 2023.

Since the 1980s, climate change had increased significantly in public discourse and the demand for more sustainable modes of transportation, such as EVs, was steadily rising. Although manufacturers began trying to launch EVs into the mainstream in the mid-1960s, technology limitations, high manufacturing costs, and substantial public skepticism stood in the way. More importantly, the industry's dominant mindset was to continue allocating organizational resources to the existing internal combustion engine product and service lines. While leading companies such as General Motors (GM), Toyota, and Nissan invested in the research and development for mass produced hybrid and fully electric vehicles, commercial success was mixed. Hybrid models, using both gasoline and battery power, were successful (such as the Toyota Prius), but manufacturers faced many challenges in the design, development, sourcing, assembly, and commercialization of fully electric vehicles. For consumers, the largest obstacles to more wide-scale and faster adoption of EVs were related to driving range and charging.

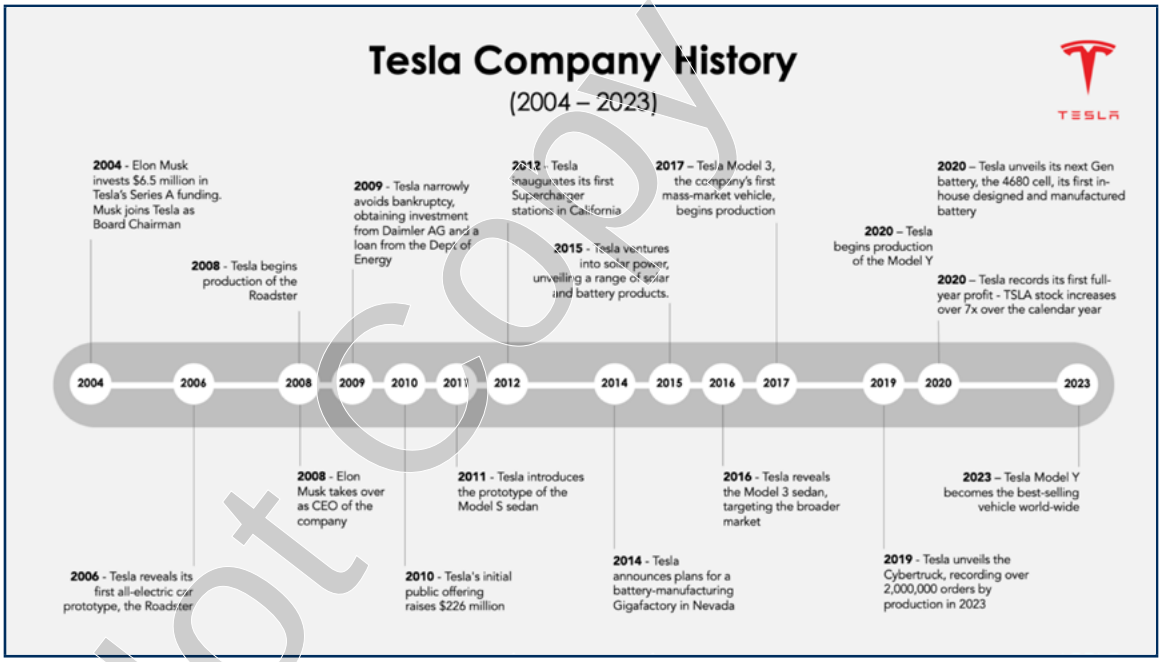
In 2008, however, a new startup named Tesla released an electric sports car called the Roadster. Fifteen years later, with an innovative business model based on software and new technological capabilities, Tesla

had accomplished what car manufacturers had been attempting to achieve for decades—the first best-selling global vehicle powered by an electric battery powertrain.

Tesla Launch

Tesla Inc. was founded by Martin Eberhard and Marc Tarpenning in 2003 in San Carlos, California, with the vision of building a car manufacturer that was also a technology company.[4] They aimed to integrate innovative battery technologies, computer software, and a proprietary electric motor system to produce a zero-emission vehicle capable of filling the niche for green vehicles. After onboarding Ian Wright, they raised $7.5 million in series A funding in 2004 from various investors, including $6.5 million from Elon Musk (see **Figure 2**).[5] After this investment, Musk joined the company as chairman of the board of directors, and Eberhard departed. Musk then took on a more active role in the company and oversaw production of the Roadster.

Figure 2
Tesla Company History



Source: Created by the case authors using information from: Reed, Eric. "History of Tesla: Timeline and Facts." *The Street,* 5 Oct. 2020. https://www.thestreet.com/technology/history-of-tesla-15088992. Accessed 17 Oct. 2023; "A history of Tesla year by year." Forex, 26 Jan. 2021. https://www.forex.com/en/news-and-analysis/the-history-of-tesla/. Accessed 5 Feb. 2024.

While Tesla's long-term goal was to produce affordable EVs for consumers, the company started with the premium segment, aiming at consumers with high purchasing power and likelihood of early adoption. Tesla's plan was then to use the cash flow generated from the sale of these premium electric vehicles to focus on research and development efforts with the goal of gradually expanding its product and service lines for mainstream affordable vehicles.[6] By May 2006, Musk helped raise over $53 million from investors, including Google co-founders Larry Page and Sergey Brin. Under Musk's leadership, the company announced the Roadster to the public in July 2006. One year later, Ze'ev Drori replaced Eberhard as the new CEO and president of Tesla, and in October 2008 Musk succeeded Drori as CEO. By January 2009, Tesla had raised $187 million and delivered 147 Roadsters to its customers. The Roadster's production and subsequent

demand from customers enabled the company to receive a loan of $465 million from the U.S. Department of Energy to begin developing the Model S sedan and the commercial powertrain technology.[7]

Between 2008 and 2012, Tesla produced and sold 2,450 Roadsters. While the Roadster was a key milestone toward Tesla's goal of demonstrating the viability of EV technology, several issues plagued its production. The intellectual property from AC Propulsion, manufacturer of the powertrain, could not be reproduced and commercialized, and Tesla had to make various adjustments to the chassis provided by a supplier to accommodate the battery.[8] These issues convinced the company to shift most of its production in-house. In October 2010, Tesla purchased a factory in Fremont, California.[9] In June of that year, Tesla raised $226 million by issuing 13.3 million shares at $17/share in its IPO.[10] Tesla's successful financing aimed to ensure that the issues plaguing the Roadster would not be repeated with the Model S.

Between 2012 and 2019, Tesla launched four different models of vehicles: Model S in 2012, Model X in 2015, Model 3 in 2017, and Model Y in 2019. These models garnered significant interest due to their unique aesthetics, designs, and EV and semi-autonomous vehicle technology. While the world was still getting acquainted with the various models the company would offer, Tesla was already pursuing new paths to EV dominance. During Q1 2016, Tesla revealed the prototype of its first mass-market vehicle, the Model 3,[11] after which Musk released "Part Deux" of his company's "Master Plan" in Q3 2016, emphasizing four goals: create stunning solar roofs with seamlessly integrated battery storage, expand the EV product line, develop self-driving capabilities, and enable the car to make money while not in use by the owner.[12] Tesla bought technology company Solar City for $2.6 billion[13] in November 2016 to keep on track with Master Plan Part Deux. Then in January 2017, Tesla bought Grohmann Engineering for $135 million[14] to further automate its operations. Tesla began deliveries of the heavily anticipated Model 3 in Q3 2017.

However, Tesla's challenges multiplied when the company announced its decision to produce 500,000 Model 3 units in 2018, leading to manufacturing bottlenecks and "production hell."[15] Complexities arising from the scale of this vehicle launch made it difficult for Tesla to meet its production goals and the delays of this widely anticipated product led to financial challenges and questions about the sustainability of Tesla as a viable business in the market. These challenges ultimately resulted in Tesla issuing $2 billion in new shares to finance its Model 3 production plan.[16]

Along with its challenges and successes, Tesla and its CEO generated controversy. In August 2018, Musk stated on Twitter that he was considering taking Tesla private at $420 a share, while the price per share had been $342 prior to Musk's tweet, which led to a lawsuit from the U.S. Securities and Exhange Commission (SEC) charging false and misleading statements.[17] Ultimately the two sides settled, resulting in Musk stepping down as chairman of Tesla's board, as well as Musk and Tesla each paying a $20 million fine. Meanwhile, 2018 ended with the Model 3 as the world's best-selling EV of the year.[18]

Manufacturing, Tesla-Style

Tesla was often seen as a leader in EV manufacturing. In 2010, when the company developed the Model S and was preparing for production, it purchased the New United Motor Manufacturing factory in Fremont, California, from General Motors and Toyota.[19] Tesla made significant renovations to brighten the space and improve conditions for employees by adding skylights, white epoxy floors, a new training center, dining options, a gym, 24/7 medical facilities, and outdoor areas.[20] In June 2012, the first Model S rolled off the new production line.[21] As the company continued increasing production and introducing new products, Tesla expanded to Sparks, Nevada, and celebrated the groundbreaking for its first "Gigafactory" in June 2014[22] for production of batteries in partnership with Panasonic. Tesla further expanded in 2017 to produce solar

cell products in a new Gigafactory 2 in Buffalo, New York.[23] This led to a foundation for launching its global expansion in manufacturing.

Gigafactory Shanghai

Given the company's enormous success with the Model 3 production in the United States, Tesla opened its first Gigafactory outside the U.S. in Shanghai, China, in early 2019.[24] The launch of this factory—with an annual production capacity of 500,000 vehicles, from greenfield to the production of automobiles within one year—set a record for the shortest time to start a new plant in the auto industry.[25] In comparison, the launch of a new plant in Mexico by Toyota in 2016 took more than three years.

Tesla's successful launch in China resulted in the company reporting profits for four quarters between July 2019 and June 2020. This financial success led to the inclusion of Tesla stock in the S&P 500 in December 2020[26] and culminated with Tesla increasing its market value by 740% that year. By mid October 2021, it had reached a market cap of $1 trillion.[27] This valuation was greater than the other nine largest automakers combined and made Tesla the fifth most valuable company in America.[28, 29]

Digital Manufacturing

As an innovator in the auto industry, Tesla focused on creating the world's best digital factory. During the 2016 shareholder meeting, Musk talked about "how important it is to build the machine that builds the machine" and "how much harder it is to build the manufacturing system that builds the product than it is to create the product in the first place."[30] Tesla used extensive artificial intelligence and automation in its manufacturing to maximize control over its supply chain, increase in-house production of vehicle components, and improve production quality control. For example, Tesla used cold metal transfer welding robots to produce its aluminum frames.[31] It also used robots in stamping, painting, other welding, and final assembly.[32] This high level of automation in Tesla's manufacturing processes enabled the company to better control its supply chain and production. It also enabled a high level of customization and data generation that could be used for better decision-making and process improvement.

> "Tesla is as much a software company as it is a hardware company, both in car and in factory. This is not widely understood." –Elon Musk[33]

Operational Efficiency and Digital Self-Management (DSM)

Tesla's internal AI and software solutions promoted rapid innovation and operational efficiency. By leveraging data and automating workflows, Tesla minimized bureaucratic lags, allowing for faster decision-making and increased agility. Tesla's DSM software was at the forefront of its operational and innovative prowess, transforming traditional operations and employee management.[34]

Joe Justice, a former Tesla employee, described the features of the company's DSM software and its impact on work practices in several videos in the public domain. The video "Your Boss is Data: How Digital Self-Management Works" described how the daily workflow within the company was fluid and dictated by real data and machine learning. Through the use of in-house apps and always-on TV monitors, employees were dynamically directed to tasks, teams, or problems that best matched their skill sets and experience. This variability ensured that the right expertise was channeled to the right problem at the right time, optimizing productivity and fostering a culture of continuous learning.[35]

This video further explains that as employees explored new solutions, whether in AI-assisted design or on the production line, the DSM software served as a digital sounding board. Every proposed solution went

through an immediate digital evaluation. The software quickly provided a digital assurance if the solution was optimal or raised a concern if there were potential issues. This instantaneous feedback ensured that employees were not left in the dark.[36]

The video shows that the software promoted a collaborative atmosphere. Employees were exposed to new teams, problems, and skill sets. This cross-pollination of ideas and people, combined with the DSM software, created a highly innovative environment. This capability also enabled increased scalability and flexibility across multiple platforms as well as other global manufacturing locations.[37]

Vertical Integration

In its early days, Tesla faced challenges in finding an economic model for manufacturing. Its relatively small parts demand made it tough to secure contracts with suppliers, many of whom feared the risk of investing in tooling only to face a potential Tesla bankruptcy. As a startup, Tesla often couldn't secure contracts, nor rely on established supply chains, especially given the uniqueness of its EV parts that were distinct from typical internal combustion engine components. This environment left Tesla with little choice but to bring necessary manufacturing in-house, from critical vehicle software and controller components to the car seats – a component that most major automakers outsourced to suppliers.[38]

What began as a response to early challenges slowly became one of Tesla's greatest strengths. Forced to master complex and specialized processes, Tesla acquired expertise in areas that many traditional automakers had long outsourced. This vertical integration not only set Tesla apart but positioned it to maintain tighter control over its products and innovation.

Power of Controlling Hardware and Software

When discussing Apple's strategic decision to design its own hardware, Steve Jobs famously quoted Alan Kay: "People who are really serious about software should make their own hardware."[39] Just as this pursuit allowed for Apple to control each detail of the product and user experience, Tesla in turn brought this wisdom to the automotive industry.

From its inception, Tesla exhibited a forward-thinking approach to vehicle architecture. While still in the initial stages of vehicle development, the company developed a centralized electronic control unit (ECU) system, a holistic hub that oversaw all vehicle functions and features. This electronic architecture choice was a marked departure from the prevailing practices in the auto industry.

Most traditional automakers had gradually incorporated software systems into their vehicles over the years, but they did so without a cohesive strategy in place. This piecemeal approach resulted in vehicles housing hundreds of disparate ECUs at the module level. These decentralized ECUs lacked a seamless communication system, making real-time coordination impossible. Moreover, these systems were predominantly managed by dozens of suppliers who further complicated the integration and updating process. This challenge was described very well by Ford Motor Company CEO Jim Farley.[40]

> "What we've learned about electrification is it's actually not about propulsion systems, although that's interesting; it's really about what you can do outside of the propulsion system, and also the software," said Farley.

> "We farmed out all the modules that control the vehicles to our suppliers because we could bid them against each other," said Farley. "So, Bosch should do the body control module, someone else to do the seat control module, someone else to do the engine control module. We have about 150 of these modules with semiconductors all through the car."
>
> "The problem is that the software is all written by 150 different companies and they don't talk to each other. So even though it says Ford on the front, I actually have to go to Bosch to get permission to change their seat control software. Even if I had a high-speed modem in the vehicle and I had the ability to write their software, it's actually their IP. …We call it the 'loose confederation of software providers.' One-hundred-fifty completely different software programming languages. All the structure of the software is different. It's millions [of lines] of code.
>
> "That's why at Ford we've decided in the second-generation [EV] product to completely in-source electric architecture," Farley continued. "To do that you need to write all the software yourself—but just remember car companies haven't written software like this, ever. They've never written software. So, we're literally writing the software to operate the vehicle for the first time ever."

By integrating vehicle control modules developed in-house, Tesla could provide harmonized operations, easier over-the-air software and firmware updates, and better real-time coordination of vehicle functions.

Traditional Automotive Business Model vs. Tesla

The automotive industry developed from over a hundred years of evolution and innovation. In 1908, the Ford Motor Company released the Model T to revolutionize the transportation industry in America. The Model T was a resounding success because of its affordability and durability as a vehicle and because Henry Ford successfully married the technological innovations of that era with his company's business practices. By switching to a moving assembly line production in large volumes and leveraging economies of scale while increasing wages, Ford successfully reduced production lead times and costs to make the Model T more affordable and profitable.

Tesla's role as the leader in the EV industry mirrored Ford's approach to becoming a leader in the traditional automobile industry. While most established automakers faced tremendous challenges in making mainstream EVs, Tesla overcame these challenges through technological innovation in electric motors, automotive battery technology, and innovations in product and processes with software.

Tesla led its competitors with 20% of the global EV market share. Second and third were BYD of China (15%) and the Volkswagen Group (7%).[41]

Role of Dealerships and Value Addition

When automobiles were first commercially produced by Ford and other manufacturers in the early 1900s, low factory output was proportional to demand and allowed customers to purchase vehicles from the manufacturer directly. However, Ford shifted this value chain as the company began expanding its operations geographically and demand grew. With these changes, it became impractical for most customers to travel to the factory to purchase a new vehicle, and manufacturers needed a more convenient system for purchases. In addition, introduction of dealers also allowed the auto manufacturers to buffer inventory and

smooth production to meet customer demand. Thus, the concept of a dealership with a vehicle showroom was born. While manufacturers initially owned some of the dealerships, the rising demand for new vehicles along with the shift in complexity and overall scale of market operations led to adoption of the franchise dealership model. In this model, each dealership earned a margin for every vehicle sold and benefits from exclusive business relationships and operational privileges with the auto manufacturers. The effects for customers included dealer incentives, more transparent pricing, authorized maintenance and service options, and a standardized vehicle shopping experience across different cities and regions.

While the dynamic between auto manufacturers and franchise dealerships was initially intended to be symbiotic, the relationship became mutually dependent over time. Manufacturers relied on dealerships to draw customers and leverage their relationships with local businesses and the community. Dealerships relied on manufacturers to establish exclusive operational and selling rights with specific franchises to mitigate competition and ensure they offered the best products and services possible for customers. These dynamics changed so much that both parties sought to find alternative ways to acquire and maintain bargaining power, including exploring new sales channels and lobbying for favorable legislation. Dealerships become so entrenched that, during the initial e-commerce trends in the late 1990s, attempts by manufacturers to move to direct-to-customer (D2C) sales via the internet were met with strong legislative resistance and lobbying by pro-dealership political groups.[42] The auto dealers associations argued that dealers delivered significant value in managing customer experience in sales and service by acting as a constructive bridge between the customers and the automakers.

Tesla challenged this business model by asserting that ubiquitous connectivity and transparency of information on the internet allow manufacturers to show the public extensive information about vehicles and bring greater transparency in pricing. Tesla's team also questioned the service value delivered by franchise dealers. Tesla's vehicle design, powered by software, could allow for 80% of the vehicle services to be completed either remotely or by dispatching service to a vehicle's location, i.e., without putting the vehicle on a lift.[43]

So, unlike its competitors, Tesla chose to sell its products directly to customers through the internet and facilitated demos of the vehicles through Tesla showrooms. In other words, buying a car could be as simple as shopping on Amazon.[44] Tesla supplemented this sales approach by offering its consumers the opportunity to virtually customize their vehicle (performance, esthetics, self-driving features, etc.).[45] The direct connection with end customers in this sales model allowed Tesla to better understand consumer habits and requirements. Also, Tesla could make the purchasing experience more customer-centric and maintain direct control over sales data that was traditionally held by dealers, enabling better analyses of customer needs and inputs. The company could significantly improve customer satisfaction relative to its competitors in the EV market.

However, this approach had its challenges. Tesla, the only major automaker in the U.S. to not use a licensed dealership to distribute its vehicles, became the target of various lawsuits with a notable one being Tesla v. State of Michigan (2014). After a six-year legal battle, the state finally settled with Tesla, allowing the company to sell and provide service directly to consumers.[46] The possibility of such lengthy and costly legal challenges was a significant factor preventing other automakers from following in Tesla's footsteps and adopting the D2C business model.

Personalized Digital Customer Experience

With the advent of the internet and the pervasive digitization of products and processes across all industries, it became almost impossible to purchase a new automobile without digital technology integrated

into its systems. By 2021, vehicles had auto-emergency capabilities, biometric scanning for security, personalization of seat positions through technology, software-enabled digital dashboards, integrated GPS, and a host of other software-enabled features.[47] All major manufacturers came to embrace current technology capabilities, even though, as previously noted, the technology within the vehicle was not fully integrated.

Regarding market entry strategy, Tesla once again chose to diverge from the traditional auto industry approach. First, unlike traditional manufacturers such as Nissan, GM, and Toyota that introduced their electric or hybrid vehicles in the mid- or lower-price market segment, Tesla chose to enter the market in the luxury sports vehicle segment initially, and then moved to the mid-market for broader consumer appeal. All Tesla vehicles were designed with premium interiors and an integrated touchscreen dashboard that acted as the control hub for the vehicle's features, including air conditioning and infotainment. This integrated software platform enabled Tesla to provide more seamless personalized experiences than found in traditional rivals' vehicles. Musk asserted, "… I think that's why Tesla has been able to recruit some of the world's best software engineers is because we value software engineering so highly and do not regard it as an afterthought."[48]

Redefining the IT Operations Strategy

By 2023, the auto business was a complex set of operations with several business processes. Longstanding companies used hundreds or thousands of software applications that included legacy systems and packaged software such as standard enterprise resource planning (ERP) products to manage their global manufacturing and operations. Customer experience processes were often operated through CRM systems managed and sometimes even owned by the dealers. The information exchange across automakers, suppliers, and dealers was facilitated through complex data sharing protocols and contracts. Manufacturers used a demand forecasting model where inventory and customer demand information flowed in from the dealers and was aggregated to forecast daily, weekly, and monthly requirements. The production operation was managed through traditional materials requirements planning (MRP) systems for producing to the forecasted demand. In summary, the traditional companies used "make and sell" models where the vehicles were pushed into the dealers in anticipation of the forecasted demand.

In contrast, Tesla used a pull model, starting with customer orders placed directly online. The company could see the actual demand instead of forecast numbers. Tesla initially adopted one of the popular ERP software used by other automakers but soon realized it was a mistake. This packaged ERP software was not flexible enough to adapt to Tesla's model of customer orders, nor the management of the overall customer experience. Tesla developed its own ERP software called WARP Drive.[49] This system allowed for a real-time collaborative workflow across Tesla's production operations and staff functions. Tesla's vision for this software was to create a central platform that connected the entire process from customers to suppliers, allowing Tesla to respond to customer desires and delivery of new features. The traditional packaged ERP software could not do that, so Tesla created its own in-house software, which could, for example, connect vehicle infotainment to business operations and manage the charging of the vehicle's batteries.

Tesla's Autonomous Driving Aspiration and the Power of Data

Another notable innovation was automatic assisted driving in the form of Tesla's 'Autopilot' and 'Full Self-Driving' feature options, where Tesla vehicles incorporated advanced sensor coverage using eight high-definition cameras with 360 degrees of visibility at up to 250 meters, complemented by 12 ultrasonic sensors to detect objects at close proximity. An onboard computer, known as Hardware 3, processed the volumes of incoming data. Tesla used an in-house neural network trained with this data to continuously improve its autonomous self-driving capabilities.[50] The aim was to use real-time data processing to enable

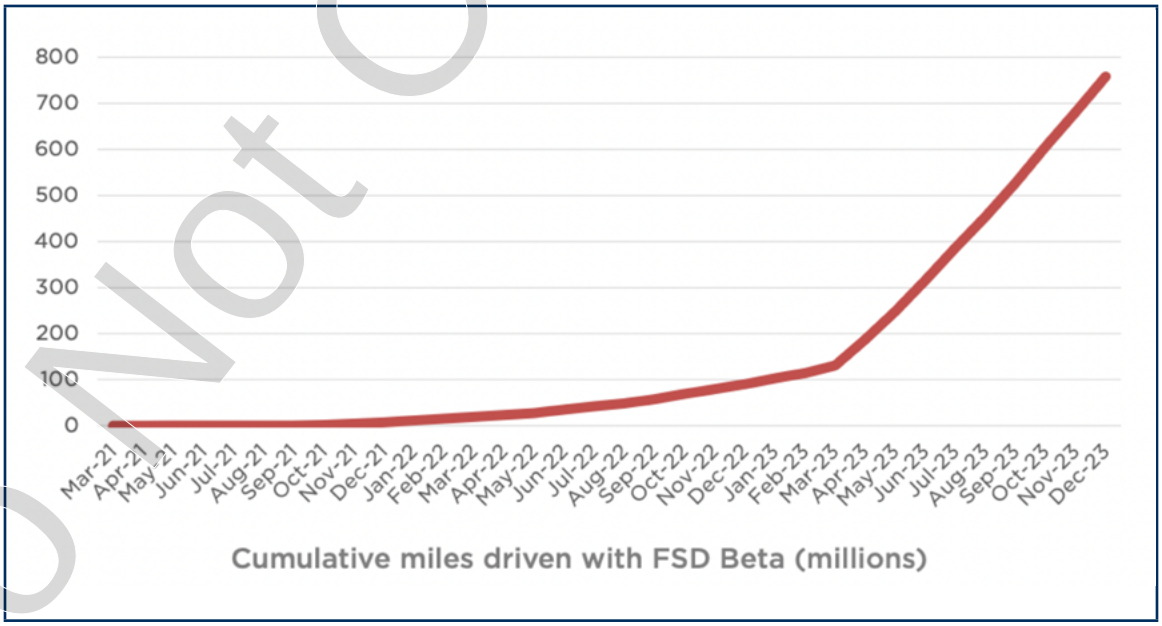
the vehicle to effectively navigate obstacles while providing riders with a refined and safer experience. The Full Self-Driving (FSD) moniker became controversial because it was not literally true; hands-on driving was still required, and the program was put on the market while still in beta form, and far from perfect. Even so, as of January 2023, 400,000 Tesla customers paid for this feature and used it on the roads.[51] The platform allowed Tesla to learn about driving behaviors and preferences of each of its customers through real-time data feeds to improve the program through updates.

A growing influx of data was foundational for Tesla's training of expansive neural networks (NNs), similar to projects like DeepMind's AlphaGo,[52] which mastered the complex strategy game of Go to outperform the game's world champions. These neural networks operated like the human brain, recognizing patterns from vast data sets, similar to how we learn from experiences. Tesla's NNs digested a wide spectrum of driving scenarios; from chaotic city streets to isolated rural roads, from clear day drives to challenging nighttime conditions, and across various climates and terrains.

Neural networks thrive and improve on large, clean, and diverse datasets. The purer and more varied the information, the more fine-tuned and sophisticated the NNs become. With machine learning at its core, and a feedback loop from millions of Tesla vehicles on the road, the FSD capability evolved continually, aiming for safer and more efficient autonomous driving as more and more Tesla cars were on the road (see **Figure 3**). Notable was that Tesla used real-time data based on the actual driving experience of its customers, as opposed to the data collected by dedicated camera-mounted vehicles used only for this purpose by some competitors. Improvements made to the FSD software were updated to all Tesla customers who opted for the feature, thus continuously improving their vehicle experience. In September 2023, with over 5 million Tesla vehicles on roads worldwide,[53] Tesla possessed an unparalleled competitive edge in data-gathering and autonomous driving capability.

Figure 3

Miles Driven with Tesla Full Safe-Driving



Source: "Q4 and FY 2023 Update." *Tesla*. https://digitalassets.tesla.com/tesla-contents/image/upload/IR/TSLA-Q4-2023-Update.pdf.

EVs required less maintenance than vehicles with internal combustion engines because there were far fewer moving parts. Additionally, with all the modules in Tesla vehicles controlled by software, a significant portion of vehicle maintenance was completed via updates rather than mechanical fixes.

Tesla's business model and product design processes followed the N=1 approach to managing customer experience (see **Appendix A**). The connected vehicle feature of Tesla allowed the company to learn from the data collected on the usage of all vehicles and customers' behavior. This feature, for example, told Tesla who the safe drivers were, and Tesla selectively released new software to these safe drivers. Releasing new software to safer drivers first helped mitigate the risk to Tesla, its customers, and society. As another example of connected-car capability, if a customer needed an immediate firmware update to extend their driving range or have a better automobile experience, they could do an over-the-air software update to the vehicle's onboard computer. This feature was especially useful during Hurricane Irma in Florida when Tesla provided owners in the area with an update that unlocked the full battery capacity of its 60 and 70 kWh Model S and X vehicles. The update provided additional miles to the vehicle above the typical range giving the owners a better chance to escape the hurricane.[54]

By following this principle of personalized experience in product development through connected cars, Tesla showed how to change the rules of engagement with customers in the automobile business. The ability to receive new features in an automobile post-purchase was a game-changing transformation.

Tesla Supercharging

Tesla again followed a differentiated strategy in building its own charging network instead of depending on a network built by others. While it was capital-intensive initially and took several years to create a large charging network across the United States and other parts of the world, the system was an important asset for Tesla. During the quick and seamless charging experience, the vehicle's touchscreen and the Tesla app were integrated to manage the whole process, including plotting routes, showing charger availability, and even billing the user's account automatically. To make charging stops enjoyable, the car's touchscreen offered entertainment options ranging from streaming services like Netflix and YouTube, to games such as Beach Buggy Racing, where players steered their game car using the vehicle's actual steering wheel. Tesla's chargers were often built near food outlets and shops, making the charging break a convenient pit stop. These capabilities together eased "range anxiety" and trip interruption.

Tesla's charging plug and network became recognized as the North American Charging Standard (NACS) for electric vehicles,[55] and such leading automakers as Ford, GM, Nissan, Rivian, Mercedes, and Volvo announced that their vehicles would be made compatible to Tesla chargers in 2025.[56] Thus, Tesla's charging network became an additional source of revenue for the company and promised a standardized and efficient charging experience for all EV drivers.

Expanding Software Services: Safety and Tesla Insurance

Tesla cars set a new benchmark for automotive safety. Tesla's vision-based active safety features included a suite of sensors and cameras to continually monitor the vehicle's surroundings, enabling real-time decision-making and action to prevent accidents. The design of Tesla vehicles also contributed to safety. The placement of heavy batteries at the bottom of the vehicle created a lower center of mass, enhancing stability and reducing the risk of rollovers. Without a bulky engine in the front, Tesla vehicles had increased front-end crumple space to absorb impact from head-on collisions. Moreover, the dual electric

motors in many Tesla models provided precise torque control to each wheel, resulting in improved handling and responsiveness, especially in challenging driving conditions.

The vehicle's suite of active software-powered safety features enabled lower insurance rates for Tesla owners. According to the National Highway Traffic Safety Administration, Tesla Model 3 achieved a Vehicle Safety Score of 0.38, the lowest probability of injury of any vehicle it had ever tested.[57] The real-time telemetry and safety data that Tesla tracked and logged also provided an insurance advantage. As of Q3 2023, Tesla itself offered insurance coverage in 12 U.S. states: Arizona, California, Colorado, Illinois, Maryland, Minnesota, Nevada, Ohio, Oregon, Texas, Utah, and Virginia.[58]

Media Presence and Marketing

Marketing had been an important part of the automaking business for over 100 years since the launch of the Model T by Henry Ford. Auto companies spent significant amounts to promote their new models. For example, marketing expenses in 2018 for five different automakers exceeded one billion dollars each. GM led automobile manufacturers with nearly $3.14 billion in marketing expenses, the majority of which was spent on television ads. Next came Ford at $2.3 billion, Chrysler at $2.1 billion, Toyota at $1.4 billion, and Honda at $1.4 billion. In advertising spent per vehicle sold, Hyundai's Genesis luxury brand was $4,006, Ford's Lincoln luxury brand was $2,106, and GM's Cadillac brand was $1,242.[59]

In contrast, Tesla spent $3 per vehicle sold in 2018,[60] and yet it was one of the world's most renowned automobile brands. Tesla's fame was especially impressive considering that the company had no advertising department, relationships with ad agencies, or even a chief marketing officer.[61] As with its vehicles and technology, Tesla's approach to marketing was non-traditional.

Tesla relied on word-of-mouth, referrals, and media stories to improve brand recognition. This approach, coupled with Musk's frequent engagement with his 57 million followers on Twitter, allowed Tesla to connect widely. The company even leveraged negative publicity. For example, even though its first Cybertruck demo was deemed a failure, the company still reported nearly 200,000 pre-orders for the vehicle while garnering significant attention over social media and traditional news outlets.[62]

The company also partnered with SpaceX, another company owned and led by Musk, and launched Musk's personal 2008 Tesla Roadster into space in a bid to inspire people about space travel. The event received nearly 2.3 million live views on YouTube, making it the second-most live-streamed event on the platform.[63,64] Another asset of the company's marketing strategy was the attention paid to Musk's public opinions on various popular topics, including cryptocurrencies accepted as payment options for both Tesla and SpaceX (which was later reversed). Frequent press coverage regarding the company's alleged high valuation garnered the attention of both critics and supporters, further stimulating public dialogue regarding the company and its products.

Through non-traditional approaches to conventional business practices (see **Figure 4**), Tesla remained relevant in the minds of consumers and stakeholders in an era of digitization. It appeared that Tesla's approach to marketing helped the company significantly set itself apart from the competition, considering most automakers still relied almost exclusively on traditional forms of digital and physical marketing. As an example, Hertz Rental Car announced it would buy over 100,000 Tesla vehicles for its fleet and that it planned to allow Uber drivers with a 4.85-star rating or higher to rent nearly 50,000 Teslas on the Uber platform for $334/week.[65] Again, Tesla seemed to benefit significantly from adopting a non-traditional approach to brand building in the auto industry.

Figure 4

Traditional Automotive Business Model vs. Tesla Business Model

Traditional Business Model	Tesla Business Model
Product distribution managed and operated by dealerships, not the automaker.	All product sales and distribution handled by Tesla.
Product value defined primarily via hardware and ability to transport consumer.	Product value defined by a balanced focus on hardware as well as an integrated technological experience through software.
Contracts third-party enterprise management services for critical ERP solutions.	In-house ERP generates efficient, customized technological solutions to manage day-to-day operation.
Marketing focused through traditional means (digital ad space, televisions spots, etc.).	Minimal/unconventional marketing approach emphasizing exposure through word of mouth and pop culture.

Source: Created by the case authors.

Tesla Criticisms and Controversy

Tesla experienced an incredible journey since its inception in 2003 and accomplished much for a young automotive manufacturer. However, along with its numerous successes came criticism of the company, its leadership, and its products. Much as the company set itself apart from its competition in terms of technology, it was also unique due to controversy.

As of December 2020, Tesla and Musk were party to over 1,000 lawsuits. Among the most notable cases were Musk's settlement with the SEC and one involving the acquisition of SolarCity—a solar technology company owned by Musk's cousin, where Musk urged investors to approve the purchase even after publicly recusing himself from the deal. Walmart and Tesla reached a settlement in 2019 after Walmart claimed that Tesla's "negligent installation and maintenance" of solar panels caused roof fires at several Walmart locations.[66] The company also had several whistleblower complaints filed against it by former employees. Former Tesla security manager Sean Gouthro alleged that the company illegally hacked employee phones and spied on them while simultaneously failing to report illegal activities to shareholders and the authorities. In another key complaint, former high-level safety official Carlos Ramirez alleged that the company failed to treat injured workers and misclassified injuries to avoid reporting them.[67]

Tesla was also the target of criticism regarding its products, in particular the Full Self-Driving feature. Despite the name and the marketing, the software required significant driver attention to ensure the car did not introduce safety risks to other vehicles or its own passengers. Records released by the California Department of Motor Vehicles revealed that an attorney for Tesla reported to DMV officials that Tesla vehicles equipped with the Full Self-Driving feature still required a driver to steer, brake, or accelerate as needed.[68] In addition, at least three Tesla drivers died since 2016 when Autopilot was engaged but failed to detect obstacles on the road. In two instances the system did not brake for tractor-trailers crossing highways and in the third, it failed to recognize a concrete barrier.[69]

Additionally, there was considerable criticism of Tesla's leader. Musk was tagged with an eccentric approach to management, controversial statements about the COVID-19 pandemic,[70] and causing a significant drop in the Tesla share price (he said it was too high).[71] Working for Musk and the company was described as a thrilling and tumultuous experience, albeit one where "everyone in Tesla is in an abusive relationship with Musk," as one anonymous executive stated.[72] Although Tesla's operational practices enabled it to achieve significant financial success, major issues persisted that needed to be addressed by the company's leadership.

In January 2022, Musk began accumulating shares in publicly traded Twitter. Then, in April 2022, Musk initiated a full acquisition of the social media company that concluded on October 27, 2022. The purchase price of $44 billion required Musk to self-fund much of the acquisition. Between April and August of 2022, Musk sold roughly $15.5 billion worth of Tesla shares, causing a significant decline in the stock.[73] Musk's sale of shares directly conflicted with comments he had made in June 2013: "… just as my money was the first in, it will be the last out."[74] From April 1 to December 31, 2022, Tesla stock decreased 65.9%.[75]

Continuing Transformation and Business Reality

Tesla became a unique automaker, starting with how it entered the business, its various product designs, its use of technology, and its choices in operational and sales models. It went from zero to leading the market in EV technology and building capability to scale and execute, as shown in **Exhibit 1**. Industry reports stated that Tesla was multiple years ahead of its competitors, and its research and development appeared strong.[76] Tesla reached an annual revenue of $82.4 billion, selling nearly 2M vehicles annually with a gross margin of 18.2% and generating positive cashflows by the end of 2023, as depicted in **Exhibits 2-5**.

Tesla continued to introduce transformative innovations and personalization for customers and others throughout the Tesla ecosystem, as shown in the Tesla app in **Exhibit 6**. Tesla also significantly improved the scale and efficiency of production, while also contributing positively on sustainability and profits, as shown in **Exhibit 7**. For example, the introduction of 48 Volt—instead of the traditional 12 Volt standard in vehicles since 1955— promised to significantly reduce vehicle cost and weight of wiring harnesses, thus improving overall efficiency and vehicle range. Similarly, the introduction of "gigacasting", beginning with the Model Y and continuing in all future vehicles, was expected to improve sustainability, energy efficiency, and cost.

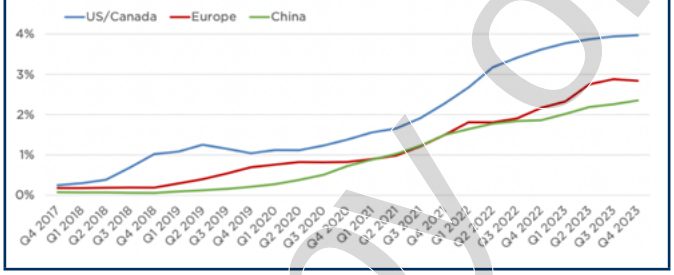
As analysts and investors reflected on the company's announcement in January 2022 that its focus for the year would be on software and not new products, questions included: Referring to **Exhibit 8**, how could Tesla build more N=1, R=G engagement with customers and employees, as discussed in **Appendix A**? What were the implications of the company's prioritizing software as a core capability? Could Tesla continue transforming the auto business model through software? If so, how? What would be the fate of traditional automakers and how could they transform to a more digitally driven management and business model to compete with Tesla and other new EV and software-centric businesses emerging in the auto industry?

Exhibit 1

Market Share of Tesla by Region, as of Q4 2023

Region	Model	Capacity	Status
California	Model S / Model X	100,000	Production
	Model 3 / Model Y	550,000	Production
Shanghai	Model 3 / Model Y	>950,000	Production
Berlin	Model Y	375,000	Production
Texas	Model Y	>250,000	Production
	Cybertruck	>125,000	Production
Nevada	Tesla Semi	-	Pilot production
Various	Next Gen Platform	-	In development
TBD	Roadster	-	In development

Installed capacity = current production rate and there may be limitations discovered as production rates approach capacity. Production rates depend on a variety of factors, including equipment uptime, component supply, downtime related to factory upgrades, regulatory considerations and other factors.



Source: "Q4 and FY 2023 Update." *Tesla-*. https://digitalassets.tesla.com/tesla-contents/image/upload/IR/TSLA-Q4-2023-Update.pdf. Accessed 6 Feb. 2024.

Exhibit 2

Tesla Inc. – Full-year 2023 Financial Summary

FINANCIAL SUMMARY
(Unaudited)

($ in millions, except percentages and per share data)	2019	2020	2021	2022	2023	YoY
Total automotive revenues	20,821	27,236	47,232	71,462	82,419	15%
Energy generation and storage revenue	1,531	1,994	2,789	3,909	6,035	54%
Services and other revenue	2,226	2,306	3,802	6,091	8,319	37%
Total revenues	24,578	31,536	53,823	81,462	96,773	19%
Total gross profit	4,069	6,630	13,606	20,853	17,660	-15%
Total GAAP gross margin	16.6%	21.0%	25.3%	25.6%	18.2%	-735 bp
Operating expenses	4,138	4,636	7,083	7,197	8,769	22%
(Loss) income from operations	(69)	1,994	6,523	13,656	8,891	-35%
Operating margin	-0.3%	6.3%	12.1%	16.8%	9.2%	-758 bp
Adjusted EBITDA	2,985	5,817	11,621	19,186	16,631	-13%
Adjusted EBITDA margin	12.1%	18.4%	21.6%	23.6%	17.2%	-637 bp
Net (loss) income attributable to common stockholders (GAAP)	(862)	721	5,519	12,556	14,997	19%
Net income attributable to common stockholders (non-GAAP)	36	2,455	7,640	14,116	10,882	-23%
EPS attributable to common stockholders, diluted (GAAP)	(0.33)	0.21	1.63	3.62	4.30	19%
EPS attributable to common stockholders, diluted (non-GAAP)	0.01	0.75	2.26	4.07	3.12	-23%
Net cash provided by operating activities	2,405	5,943	11,497	14,724	13,256	-10%
Capital expenditures	(1,327)	(3,157)	(6,482)	(7,158)	(8,898)	24%
Free cash flow	1,078	2,786	5,015	7,566	4,358	-42%
Cash, cash equivalents and investments	6,268	19,384	17,707	22,185	29,094	31%

Source: "Q4 and FY 2023 Update." *Tesla*. https://digitalassets.tesla.com/tesla-contents/image/upload/IR/TSLA-Q4-2023-Update.pdf. Accessed 6 Feb. 2024.

Exhibit 3

Tesla Inc. – Q4 2023 Balance Sheet

BALANCE SHEET
(Unaudited)

In millions of USD	31-Dec-22	31-Mar-23	30-Jun-23	30-Sep-23	31-Dec-23
ASSETS					
Current assets					
Cash, cash equivalents and investments	22,185	22,402	23,075	26,077	29,094
Accounts receivable, net	2,952	2,993	3,447	2,320	3,508
Inventory	12,839	14,375	14,256	13,721	13,626
Prepaid expenses and other current assets	2,941	3,227	2,997	2,708	3,388
Total current assets	40,917	42,997	43,875	45,026	49,616
Operating lease vehicles, net	5,035	5,473	5,935	6,119	5,989
Solar energy systems, net	5,489	5,427	5,365	5,293	5,229
Property, plant and equipment, net	23,548	24,969	26,389	27,744	29,725
Operating lease right-of-use assets	2,563	2,800	3,352	3,637	4,180
Digital assets, net	184	184	184	184	184
Goodwill and intangible assets, net	409	399	465	441	431
Deferred tax assets	328	399	537	648	6,733
Other non-current assets	3,865	4,185	4,489	4,849	4,531
Total assets	**82,338**	**86,833**	**90,591**	**93,941**	**106,618**
LIABILITIES AND EQUITY					
Current liabilities					
Accounts payable	15,255	15,904	15,273	13,937	14,431
Accrued liabilities and other	8,205	8,378	8,684	8,530	9,080
Deferred revenue	1,747	1,750	2,176	2,206	2,864
Current portion of debt and finance leases (1)	1,502	1,404	1,459	1,967	2,373
Total current liabilities	26,709	27,436	27,592	26,640	28,748
Debt and finance leases, net of current portion (1)	1,597	1,272	872	2,426	2,857
Deferred revenue, net of current portion	2,804	2,311	3,021	3,059	3,251
Other long-term liabilities	5,330	5,979	6,924	7,321	8,153
Total liabilities	**36,440**	**37,598**	**38,409**	**39,446**	**43,009**
Redeemable noncontrolling interests in subsidiaries	409	407	288	277	242
Total stockholders' equity	44,704	48,054	51,130	53,466	62,634
Noncontrolling interests in subsidiaries	785	774	764	752	733
Total liabilities and equity	**82,338**	**86,833**	**90,591**	**93,941**	**106,618**
(1) Breakdown of our debt is as follows:					
Vehicle and energy product financing (non-recourse)	**2,001**	**1,708**	**1,475**	**3,660**	**4,613**
Recourse debt	44	44	44	44	44
Total debt excluding vehicle and energy product financing	**44**	**44**	**44**	**44**	**44**
Days sales outstanding	10	11	12	12	11
Days payable outstanding	72	75	70	70	63

Source: "Q4 and FY 2023 Update." *Tesla*. https://digitalassets.tesla.com/tesla-contents/image/upload/IR/TSLA-Q4-2023-Update.pdf. Accessed 6 Feb. 2024.

Exhibit 4

Tesla Inc. – Q4 2023 Statement of Cash Flows

STATEMENT OF CASH FLOWS
(Unaudited)

In millions of USD	Q4-2022	Q1-2023	Q2-2023	Q3-2023	Q4-2023
CASH FLOWS FROM OPERATING ACTIVITIES					
Net income	3,707	2,539	2,614	1,878	7,943
Adjustments to reconcile net income to net cash provided by operating activities:					
Depreciation, amortization and impairment	989	1,046	1,154	1,235	1,232
Stock-based compensation	419	418	445	465	484
Deferred income taxes	(81)	(55)	(148)	(113)	(6,033)
Other	354	40	(47)	145	262
Changes in operating assets and liabilities	(2,110)	(1,475)	(953)	(302)	482
Net cash provided by operating activities	**3,278**	**2,513**	**3,065**	**3,308**	**4,370**
CASH FLOWS FROM INVESTING ACTIVITIES					
Capital expenditures	(1,858)	(2,072)	(2,060)	(2,460)	(2,306)
Purchases of solar energy systems, net of sales	(0)	(1)	(0)	1	(1)
Purchases of investments	(4,368)	(2,015)	(5,075)	(6,131)	(5,891)
Proceeds from maturities of investments	19	1,604	3,539	3,816	3,394
Proceeds from sales of investments	–	–	138	–	–
Receipt of government grants	76	–	–	–	–
Business combinations, net of cash acquired	–	–	(76)	12	–
Net cash used in investing activities	**(6,131)**	**(2,484)**	**(3,534)**	**(4,762)**	**(4,804)**
CASH FLOWS FROM FINANCING ACTIVITIES					
Net cash flows from other debt activities	(162)	(127)	(124)	(140)	(141)
Net (repayments) borrowings under vehicle and energy product financing	(335)	(294)	(233)	2,194	952
Net cash flows from noncontrolling interests – Solar	(65)	(43)	(34)	(45)	(76)
Other	67	231	63	254	152
Net cash (used in) provided by financing activities	**(495)**	**(233)**	**(328)**	**2,263**	**887**
Effect of exchange rate changes on cash and cash equivalents and restricted cash	123	50	(94)	(98)	146
Net (decrease) increase in cash and cash equivalents and restricted cash	(3,225)	(154)	(891)	711	599
Cash and cash equivalents and restricted cash at beginning of period	20,149	16,924	16,770	15,879	16,590
Cash and cash equivalents and restricted cash at end of period	16,924	16,770	15,879	16,590	17,189

Source: "Q4 and FY 2023 Update." *Tesla*. https://digitalassets.tesla.com/tesla-contents/image/upload/IR/TSLA-Q4-2023-Update.pdf. Accessed 6 Feb. 2024.

Exhibit 5

Tesla Inc. – Full-year 2023 Operational Summary

OPERATIONAL SUMMARY
(Unaudited)

	2019	2020	2021	2022	2023	YoY
Model 3/Y production	302,301	454,932	906,032	1,298,434	1,775,159	37%
Other models production	62,931	54,805	24,390	71,177	70,826	0%
Total production	**365,232**	**509,737**	**930,422**	**1,369,611**	**1,845,985**	**35%**
Model 3/Y deliveries	300,885	442,562	911,242	1,247,146	1,739,707	39%
Other models deliveries	66,771	57,085	24,980	66,705	68,874	3%
Total deliveries	**367,656**	**499,647**	**936,222**	**1,313,851**	**1,808,581**	**38%**
of which subject to operating lease accounting	25,439	34,470	60,912	47,582	72,226	52%
Total end of year operating lease vehicle count	49,901	72,089	120,342	140,667	176,564	26%
Global vehicle inventory (days of supply)[1]	13	15	6	16	16	0%
Solar deployed (MW)	173	205	343	348	223	-36%
Storage deployed (MWh)	1,651	3,022	3,392	6,541	14,724	125%
Tesla locations[2]	433	523	644	963	1,208	25%
Mobile service fleet	758	894	1,281	1,584	1,909	21%
Supercharger stations	1,821	2,564	3,476	4,678	5,952	27%
Supercharger connectors	16,104	23,277	31,498	42,419	54,892	29%

Source: "Q4 and FY 2023 Update." *Tesla*. https://digitalassets.tesla.com/tesla-contents/image/upload/IR/TSLA-Q4-2023-Update.pdf. Accessed 6 Feb. 2024.

Exhibit 6

Tesla Personalization Capabilities

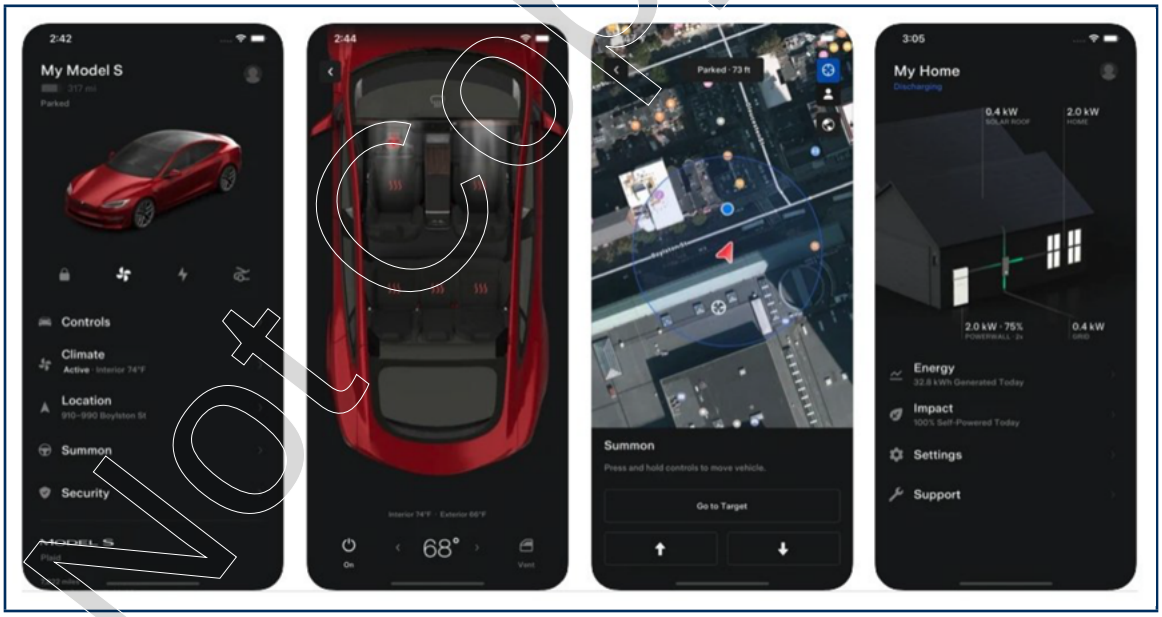


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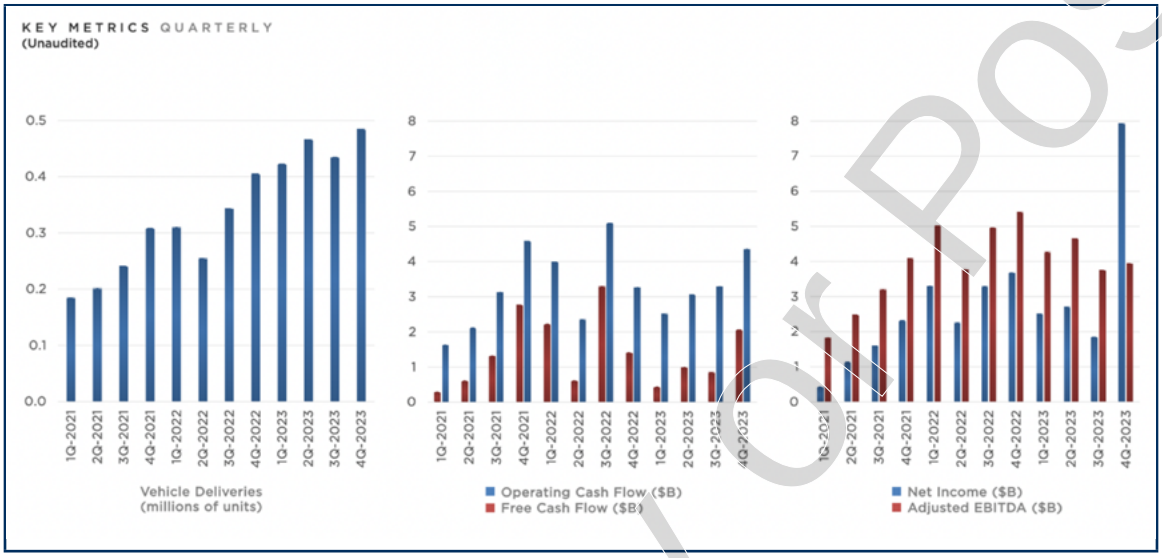
Exhibit 7

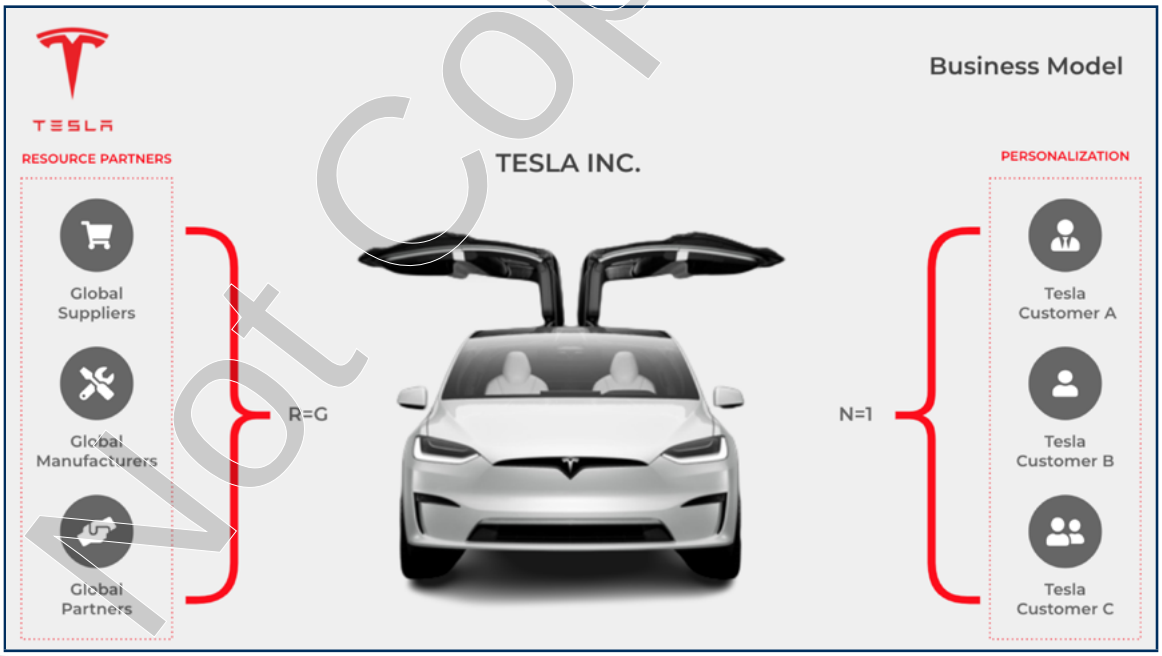
Tesla Inc. Quarterly Key Metrics, as of Q4 2023



Source: "Q4 and FY 2023 Update." *Tesla.* https://digitalassets.tesla.com/tesla-contents/image/upload/IR/TSLA-Q4-2023-Update.pdf. Accessed 6 Feb. 2024.

Exhibit 8

Tesla Business Model



Source: Created by the case authors.

Appendices

Appendix A

New Age of Innovation: N=1, R=G Business Models

In 2004, C. K. Prahalad and M. S. Krishnan, two professors at the University of Michigan, were beginning to see structural changes to traditional business models emerging because of the major technology trends, such as ubiquitous connectivity, pervasive digitization, convergence of industries, and the budding social media platforms like Myspace and Orkut. This was just before the launch of Facebook as a business and the iPhone as a product, long before Uber or Airbnb. In a book published in 2008, they set forth that the structure of business models was morphing, and that businesses across industries were moving away from mass selling of products and services and toward more personalized experiences that were co-created with customers. They said this focus on unique personal experience was increasingly permeating industries as diverse as toys, financial services, travel, hospitality, retail, software, and entertainment. They suggested that firms could provide platforms on which this could happen. They called this phenomenon N=1 (sample size of one customer) and recognized it as one of the two emerging pillars of innovation in all business models.[77]

The professors suggested that to deliver an N=1 personalized experience for each customer, firms would need to collaborate with multiple resource partners, both locally and globally, and not rely only on a limited set of suppliers in traditional linear supply chains. They designated this trend toward access to resources from multiple sources, including from outside the firm and its subsidiaries, as R=G (resources are global), which was the second pillar of innovation in business models. They argued that it was not necessary for firms to own all the resource bases needed to orchestrate N=1 personalized experiences when capacity to access networks of resources was available.[78]

N=1 & R=G Business Enablers

Appendices (cont.)

Appendix A (cont.)

New Age of Innovation: N=1, R=G Business Models

This N=1/R=G framework for capturing the emerging structure of technology-enabled business models was fully evident across industries when the book was published in 2008. It appeared then that the framework of N=1/R=G might apply only to digital businesses such as Google or Netflix. And vocal pushback on the idea arose from Rust Belt industries such as auto manufacturing that were built on the foundations of economy of scale, where the perceived cost of personalization is very high. However, rapidly evolving trends in technology challenged these assumptions and perceptions. In the summer of 2011, *The Wall Street Journal* published an essay titled "Why Software Is Eating the World" by Marc Andreessen, general partner of VC firm Andreessen-Horowitz and co-founder of Netscape. His essay correctly claimed that the number had significantly increased of industries and businesses, ranging from media and movies to agriculture and national defense, which were run on software and delivered as online services.[79] His essay went on to predict that even more industries would be disrupted by software in the next decade. His prediction was proven correct. As software and digitization permeate every aspect of business, traditional constraints are relaxed and new opportunities emerge for personalized value creation and global resource partnership, making N=1/R=G a reality.

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