BMIJ
ISSN: 2148-2586

bmij (2021) 9 (1):385-404

doi: https://doi.org/10.15295/bmij.v9i1.1790

Research Article

How Tesla created advantages in the ev automotive paradigm, through an integrated business model of value capture and value creation

Tesla, değer yakalama ve değer yaratmaya entegre bir iş modeli ile elektrikli araçlar paradigmasında nasıl avantajlar yarattı

John W. Lang[1]

Beat Reber[2]

Huda Aldori[3]

[1] Dr, Sheffield University Management School, Sheffield, UK, john.lang@sheffield.ac.uk

ORCID: 0000-0002-9540-5021

[2] Dr, Sheffield University Management School, Sheffield, UK, beat.reber@sheffield.ac.uk

ORCID: 0000-0002-8797-1875

[3] Ms, Business Innovation Consultant, Sheffield, UK, H.Aldori@protonmail.com

ORCID: 0000-0001-9656-5724

Corresponding Author:

John W. Lang,

Sheffield University Management School, Sheffield, UK, john.lang@sheffield.ac.uk

Submitted: 16/02/2021

Revised: 16/03/2021

Accepted: 23/03/2021

Online Published: 25/03/2021

Citation: Lang, J. W., Reber, B., & How Tesla created advantages in the ev automotive paradigm, through an integrated business model of value capture and value creation, bmij (2021) 9 (1): 385-404, doi: https://doi.org/10.15295/bmij.v9i1.1790

Abstract

There has been no research conducted that uses a holistic conceptual framework that simultaneously relates the ecosystem, platform technologies, innovations, and modularity to the firms business model. These elements are central to Tesla's shifting of the automotive paradigm from internal combustion engine transportation to electric vehicle (EV) energy powertrains. The purpose of this paper is to explore how the ecosystem, business model, modularity and innovations of Tesla, as an illustrative case, have contributed to a new vehicular platform and business model EV paradigm. The paper draws on the strategic and operations management literature and examines the relationship between the ecosystem platform's attributes, modular innovations, and a new business model created by Tesla. Battery technology has been a focal point of the Tesla platform, and this is predicted to be an essential part of the battleground for the future of the electric vehicle automotive industry. Our analysis shows the attributes of the Tesla business model's configuration, which have been the drivers of its disruptive approach to the existing legacy automotive markets, have been instrumental in creating and capturing value for its continual platform development.

Keywords: Value Creation, Value Capture, Integrated Business Model, Electric Vehicles Paradigm, Ecosystems, Platform Technologies, Modularisation

Jel Codes: M52, M31, E24

Öz

Elektrikli araçların yayılmasına ve benimsenmesine doğru hareket eden giderek daha büyük bir malzeme araştırma veritabanı olmasına rağmen, bugüne kadar, içten yanmalı motor taşımacılığından elektrikli araçların enerji aktarma mekanizmalarına doğru paragdigmayı değiştirmeye yardımcı olmak için kullanılan, Tesla gibi firmaların, kavramsal bir çerçeve kullanılarak; ekosistemini, iş modelini, yeniliklerini ve modülerliğini aynı anda ilişkilendiren hiçbir araştırma yapılmamıştır. Bu makalenin amacı, önemli bir durum olarak, Tesla'nın ekosisteminin, iş modelinin, modülerliğinin ve yeniliklerinin, yeni bir araç platformuna ve iş modeli olan Elektrikli Araçlar paradigmasına nasıl katkıda bulunduğunu araştırmaktır. Makale, stratejik yönetim ve operasyon yönetimi literatüründen yararlanmakta ve ekosistem platformunun özellikleri, modüler yenilikler ve Tesla tarafından oluşturulan yeni bir iş modeli arasındaki ilişkiyi incelemektedir. Pil teknolojisi, Tesla platformunun ve farklılaşmasının odak noktası olmuştur ve elektrikli araç otomotiv endüstrisinin geleceği için savaş alanının önemli bir parçası olacağı tahmin edilmektedir, analizimiz genel otomotiv pazarlarına ve özellikle elektrikli araç pazarına yönelik, sürdürülebilir platform gelişimi için değer yaratan ve yakalayan, yıkıcı yaklaşımın ana dayanak noktası ve itici gücü olan Tesla İş Modeli'nin şekillenmesinin özelliklerini göstermektedir.

Anahtar Kelimeler: Değer Yaratma, Değer Yakalama, Entegre İş Modeli, Elektrikli Araçlar Paradigması, Ekosistemler, Platform Teknolojileri, Birimlere Ayrıştırma

JEL Kodları: M52, M31, E24

Introduction

Tesla Motors Inc. was founded in 2003 by three partners, Elon Musk, Marc Tarpenning and Martin Eberhard, to shift the automotive paradigm away from the internal combustion engine by differentiating its offering within the burgeoning electric vehicle (EV) industry. Musk overtly stated from the outset that their goal, in creating Tesla, was to be a company that was instrumental in transitioning to electric mobility with a digitised business model, integrated with engineering principles that would help circumvent "classical" barriers to entry of the nascent disruptor (Stringham et al. 2015). The most significant particular entry barriers were economies of scale, the longevity of charging per trip (battery charge), building a platform ecosystem of research and development partners in this innovator/early adopter digitally-driven emerging market space. Musk's location of Silicon Valley, as the headquarters of Tesla, was not coincidental. At the heart of his vision was Tesla as a disruptor, using information systems at the core of the driving experience, along with modular systems that would allow economies of scope to be gained from the reusability of components, across all final products, the Model S, Model X, Model 3, using a carefully engineered base platform. The use of leading paradigmatic engineering and information systems appealed to innovator and early adopter categories of consumers, providing a base or diffusion through the disruptive niche whilst simultaneously side-stepping the entry barriers (Chen & Perez, 2018; Chong et al., 2016; Bartman, 2015).

Instrumental to the success of Tesla has been the data-driven decision-making approach to the creation and management of its products, putting data, information and knowledge exchange at the centre of an ecosystem and platform architecture that recursively creates and recreates modular components, making the complexity and therefore risk, manageable (Foster, 1986). This application of new principles to a mature industry meant new ways of creating and capturing value in the business model (see figure 1). The ecosystem and platform architecture of Tesla is the interface through which they manage their collaborations in the partner network, ensuring that the core business processes are not compromised due to fundamental design rules (Baldwin & Clark, 2000; Cacciatori & Jacobides, 2005; Gawer & Phillips, 2013). Gawer & Cusumano (2014, p420) point to ecosystem "platforms [as] manageable objects that organizations purposefully manage to bring multiple parties within the industry together – primarily users and complementors". The platform can accommodate the complementary modular innovations from ecosystem partners, from which positive feedback loops and network effects emanate (Gawer & Cusumano, 2014).

Following the above, our research aims to outline and elucidate the core characteristics of the EV industry integrated business model, using Tesla as a case study, based upon innovation, ecosystems, and the principles of modularization of technology architectures. It makes several contributions to the canon of literature on technological aspects of platform technologies, modularity, and innovation ecosystems, proposing a conceptual framework demonstrating that a firm's business model should be considered as a nexus of all of these perspectives, an integrated combination of congruent attributes (see appendix 1). Insights from each of the research strands provide a holistic view of firm business models. We demonstrate how one case firm, Tesla, has delivered a successful business model that creates and captures value from, and within, the combination of its platform architecture, innovation ecosystem, and modularity of co-specialised components from ecosystem complementors. Besides, our study contributes to the knowledge at the intersection of ecosystems, platform technologies, innovation and modularisation, which are viewed as the essential building blocks of an organisations business model in the digital electric vehicle competitive space of Tesla.

Literature review: The three literature streams

Firstly, we review the most prominently cited literature in the four research key strands related to platform technologies, innovation ecosystems, and modularity. From the literature review, we propose a conceptualisation of the business model as an integrated system of the four research strands. This conceptual framework is then applied to a case study of Tesla as a high-end electric vehicle (EV) original equipment manufacturer (OEM).

Innovation ecosystems

Ecosystems have focused on attention from strategy scholars and business sector practitioners for some time (Dhanaraj & Parkhe, 2006; Iansiti & Levien, 2004; Moore, 1993). The relevance to the technology sectors is often through the coupling of the concept and practice being linked with modularisation (KPMG, 2017a, b, c; BCG, 2016).

Ecosystems are made up of complementors that provide co-specialised skills arranged around an orchestrating firm (orchestrator), with a platform that provides a common base of standards and rules to create a product or service that have unique features. The complementarity of modular components, supplied by the ecosystem members, is essential as value is created from the component contributions' totality. The interdependence among components and organisations can give rise to highly complex interactions and products (Adner, 2017; Jacobides, Cennamo, & Gawer, 2018). Furthermore, the modular components draw on the different distinctive capabilities of the ecosystem complementors, who may have distinct economies of production and distinct innovation capacities. (Casadesus-Masanell & Yoffie, 2007; Eisenhardt & Hannah, 2018). Ecosystems add value by allowing coordination and complexity reduction through creating complementary roles and rules, with common standards governing their interactions, "thus obviating the need to enter into customized contractual agreements with each partner." (Jacobides et al., 2018, p 2255).

Ecosystems create multilateral interdependencies, which generate relational value-added, based on the combination of strong and weak ties between firms recognised as ecosystem participants (Granovetter, 1973). Jacobides et al. (2018, p2255) also posit that "ecosystems are interacting organizations, enabled by modularity, not hierarchically managed, bound together by the non-redeployability of their collective investment elsewhere". This means that the members of the ecosystem may be loosely coupled (through strong and weak ties) in terms of their interconnectedness, but they remain tightly coupled, at the product and modular level, through the component modularity rules, standard interfaces, facilitating interoperability, and retaining flexibility in design (Baldwin & Clark, 2000; Sanchez, 1999).

One aspect of ecosystems that are often overlooked at the individual firm level is the development of dynamic capabilities (Teece, 2010) in the firm's ecology and the ecosystem, maintaining the innovations and growth of future options for the resultant products and services. The collaborative arrangements of the ecosystem members foster the co-evolution of firm capabilities, and the compatibility of the mutual adaptation of modular products and processes is ensured by adherence to the platform standards (Eisenhardt et al., 2018; Gawer, 2014). Several studies have further pointed to how the knowledge sharing embedded in IP affects the ecosystem development, and therefore the platform success in attracting complementors (Brusoni et al., 2001; Leten et al., 2013).

Zulkarnain et al. (2014) has mapped the main generic EV ecosystem stakeholders, which we have adapted and presented in the table in appendix 2 of this paper. The stakeholder groupings are generic to all EV OEMs, and their needs may be addressed by the platform ecosystem orchestrating firm, as in the case of Tesla, or by contractors through various cooperative relationship modes. Thus, the orchestrating firms are the leading integrators/aggregators in the EV stakeholder groups, ensuring congruence between ecosystem stakeholder needs.

Building on the points made by Zulkarnain et al. (2014), Gomes et al. (2016, p45 – 46) proposes a conceptual framework that characterizes an "innovation ecosystem construct with the following features: an innovation ecosystem is set for the co-creation or the joint creation of value. It is composed of interconnected and interdependent networked actors, including the focal firm [orchestrator], customers, suppliers, complementary innovators and other agents as regulators. This definition implies that members face cooperation and competition in the innovation ecosystem, and an innovation ecosystem has a lifecycle, which follows a co-evolution process". Similar to the seminal work of Moore (1993), we believe that this also implies a cooperative co-evolution of complementary dynamic capabilities around the core innovation, co-creation and capture of value in the innovation ecosystem.

One could argue, as others have done, what is the point of an ecosystem of complementary firms if it is not to achieve some form of innovation in process, product, strategy for customer stakeholders (Bontempo et al., 2017; Scozzi et al., 2017; Gastaldi et al., 2015; Kukk et al., 2015; Autio & Thomas, 2015).

The most probable historical root of the term innovation ecosystems comes from Adner (2006, p2), described as "the collaborative arrangements through which firms combine their offerings into a coherent, customer-facing solution". Grandstand & Holgersson (2020, p1) offer the following definition of innovation ecosystems, clearly built on Adner (2006): "An innovation ecosystem is the evolving set of actors, activities, and artifacts, and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors." Again, we would contend that ecosystems with a tradition of technological innovations at the core of the paradigm, such as EVs, could reasonably be termed innovation ecosystems.

Due to the interdependent and, more often than not, non-hierarchical nature of the governance of the innovation ecosystem, it requires a lead firm, usually the platform sponsor (such as Tesla), to set the operating standards (operating interfaces between platforms and components) to ensure compatibility and ultimately coalitional value capture and creation. A variety of terms have been used to characterise the lead coordinating firm, such as keystone firm (Iansiti and Levien, 2004) and orchestrator(s) (Dhanarag & Parkhe, 2006; Hacki & Lighton, 2001), sponsor (Kim & Sim, 2015) are all used interchangeably, in the literature. The main functions of the orchestrator (the term we will use from this point forward) are: 1. the central OEM that coordinates the recruitment and relationships between ecosystems members ensuring network stability; 2. acts as quality controller of the modular components, emergent from the ecosystem members; 3. definer of the standardisation of the interfaces between modules and ultimately the platform on which they reside; 4. platform creator and curator, ensuring compatibility of parts to the overall platform architecture; 5. facilitator of product and process innovations, through formal and informal coordination and cooperative knowledge sharing, and the "innovation appropriability (sharing profits in the EV ecosystem)" (Rong et al., 2017, p234). Modularization is essential to help reduce complexity, direct and guide complementary innovations generated by ecosystem members, ensure flexibility may be gained by the potential to mix and match varieties of modules in a myriad of ways.

Modularity and platforms

The notion of modularity as a solution to the management of complexity, innovation, and flexibility goes back to Simon (1972), who argued that self-generating configurations emerge from decomposable [modular] complexity. "Modular design structures are favoured over integrated ones when flexibility and rapid innovation are […] important." (Ethiraj & Levinthal, 2002, pC1). Baldwin and Clarke (2000, p63) define a module "as a unit whose structural elements are powerfully connected among themselves and relatively weakly connected to other units."

Furthermore, “when the complexity of one of the elements crosses a certain threshold, that complexity can be isolated by defining a separate abstraction that has a simple interface. The abstraction hides the complexity of the element; the interface indicates how the element interacts with the larger system” (Baldwin & Clark, 2000: 64).

Modularisation has the in-built facility to accelerate component and final product innovation in two ways, “autonomous (within component) and modular (mix and match of modules) innovation.” (Ethiraj and Levinthal, 2002, pC1). These properties point to inherent flexibility and adaptability in the design and modular configuration of products and processes whilst facilitating the loose coupling of dispersed organisations in an innovation ecosystem (Christensen, 1997; Sanchez & Mahoney, 1996).

As a fundamental building block, modularity allows but forges stability and direction required for the emergence of specific platform architectures and ecosystems, facilitating the proliferation of interdependent relationships between suppliers, complementors, and customers, using common standard interfaces between independently created modular components. As can be seen in the arguments above, modularity also facilitates flexibility and potential hedging against disruptions by allowing multiple real options capabilities, from multilateral partner dependencies, to be built into the autonomous designs and rapid, plug, play replacement of modules within an overall platform architecture. “The quick-connect electronic interfaces of shared systems may allow firms to create electronically mediated product development networks [of knowledge] that further enhance the flexibility of modular product creation processes” (Sanchez, 1996, p121).

By creating multilateral dependencies, ecosystems generate a relational value-added based upon the combinatorial solid and weak ties between firms of actors (as organizations) in the ecosystem (Granovetter 1973). When the ecosystem is anchored to a shared platform, the sum of the knowledge and IP parts connected to the platform gives rise to network effects (Rietveld & Schilling, 2020). The cooperative value-added gives the platform orchestrator (also curator of the platform) the ability to capture and create value simultaneously from the ecosystem and embed this in the platform architecture. The platform itself acts as an enabler through which ecosystem partners engage in collaborative partnerships, using modularity as a necessary condition around which a core business process and model of the orchestrating (platform sponsor) firm is created (Adner, 2017; Adner and Kapoor, 2016)). The creation of a platform architecture allows parallelism in modular product adaptation, design, creation in an agile manner, increasing the rate of innovation ((Ethiraj & Levinthal, 2002; Baldwin and Clark, 2000; Ulrich and Eppinger, 1999). Platforms with embedded modular components give rise to the possibility of complementary development economies of time, co-creation and innovation, independent experimentation at the modular level, whilst dynamically accessing broader co-specialised capabilities and heterogenous knowledge (Chesbrough, 2003; Gawer, 2014).

Based on the modularity principle, the platform content is bound by rules and standards set by the orchestrating firm, ensuring conformance to quality and standards of interoperability. Modules are functional, tightly coupled elements of, say, code, sub-parts, components and IP, which are “powerfully connected within themselves”. However, they may also be “relatively weakly connected to other elements” created by other ecosystem members, such that when combined in the platform's architecture, they create added value, which is in turn captured on the platform (Baldwin & Clark 2000, p63). Engineering and management studies in the automotive sector have shown that modularity helps avoid what is referred to as the complexity catastrophe, the result of which is rigidity and inflexibility, due to non-replication of efficiency gains of the organization and product, which in turn freezes developments and innovations (Tushman & Anderson (1986); Christensen & Rosenbloom (1995); Wruck & Jensen (1998).

In essence, as EVs as artifacts evolve towards more complex systems, “modularity offers a way to avoid this complexity catastrophe and to preserve flexibility within a complex system. The architects of a modular design want to admit enough uncertainty and interdependence into the design process to allow new things to happen [in other words, innovations], without [settling] into a frozen state” (Baldwin and Clark 2000, p59). The highly specified modular interfaces obviate the need for formal interconnectedness between the module designers, i.e., they may have weak ties. In summary, “complex systems can be managed by dividing [them] up into smaller pieces and looking at each one separately” (Baldwin & Clark 2000, p64). Each module's design and production complexity is hidden behind the standardised interfaces embedded in the independent specialist firms' modular architecture and is given “real functionality” when conjoined in the platform architecture through standardised interfaces specified by the platform orchestrator. The interfaces control how modules interact with the final system as a whole, i.e., the platform ecosystem architecture. Therefore, the orchestrator is sponsoring a particular business model made up of platform, ecosystem, innovations and modularity, specifying conditions over behaviours, membership, and direction of each of them (Rietverld & Schilling 2020; Ethiraj & Levinthal, 2002; Fleming & Sorenson, 2001).

The curation of the platform is performed by the orchestrator, ensuring modular product and process integration. “In other words, modules are units in a larger system that are structurally independent of one another but work together.” The orchestrators’ business models provide a “framework, an architecture, that allows for both independence of structure and integration of function” (Baldwin and Clark 2000, p63). Modularity provides a distinct strategic possibility and directionality through common rule-based, system-wide standards that allow interdependencies to function, maintaining flexibility and product agility (MacDuffie 2013). According to Nambisan and Baron (2013), the evidence that the co-specialised interdependencies of technologies inherent in platforms, ecosystems, (inter-)modularity, and driven by the "orchestrated" shared goals, focus the creation of a common strategy and unique business model value propositions. MacDuffie (2013) goes even further than product and process modularity, introducing the notion of "framing", that is, the cognitive framing of the firm's strategies based on ex-ante bounded rationality of managers and their intellectual processing limits.

From the above research, a firm's business model creates a resilient base for ecosystem firms to cooperate, recursively combining and recombining knowledge and expertise (embodied in modular forms), creating synergies between different companies together towards a joint innovation (Hearn & Pace 2006). Therefore, the evolutionary aspects of innovation are embedded in the platform ecosystem. Firms and their modular forms (products and processes) are constantly evolving to solve emergent developments and issues, keeping pace with individual ecosystem member developments in a virtual hermeneutic innovation cycle (Zulkarnain et al. 2014). The evolution is not random but is seen as "semi-regulated marketplaces" (Wareham, Fox, & Cano Giner, 2014, p. 1211) "that foster entrepreneurial action under the coordination and direction of the platform sponsor", incorporated into their business model (Jacobides et al., 2018).

The business models created in the EV sector have the advantage of having a new paradigmatic blueprint where business model innovation is necessary to address barriers to adopting and diffusion of their technologies (Kley et al., 2011). As Weiller et al. (2015, pp2 - 3) and others (Fojcik 2013; Bohnsack et al. 2013; Kley et al. 2011; Zott et al. 2011; Chesbrough 2010; Aggeri et al. 2009), contend: "the ambidexterity approach of achieving both continuous improvements of traditional business models and innovative business models is important for the development of the EV industry and [dynamic] learning capabilities are for the incumbent automotive firms concerning the discontinuous innovation from traditional vehicles to EVs".

Resulting conceptual framework

From the initial literature review, we propose a "business model" conceptual framework below (figure 1), where value is created and captured for EV OEMs. The business model may be considered a fluid interaction of attributes (see tables 2 to 5), where the fluidity gives flexibility, agility and allows the firm to hedge against future disruptions and incorporate innovations. Previous conceptualisations in this area, EVs and business models have only considered one or two of the elements in figure 1, and so are partial in their considerations. This paper uses the previously cited literature on this topic of EV and business model conceptualizations. Our framework's objective is to provide a set of attributes developed in the extant literature and apply them to a case company in the EV industry, as we do in the appendix 1 tables. We have limited the number of attributes to ten to test the completeness of our adopted conceptualisation.

The research integrates many recent developing traditions for the emerging and rapidly evolving EV industry, drawing on the strategy, engineering, and operations literature. These helped to guide the attribute listings of our framework, further elaborated in appendix 1. The attributes outlined and "scored" in appendix 1 were identified in our review and analysis of published case studies, academic literature, and specialist consultancy reports. From zero to five (highest value), the scoring system was obtained by content analysis of the number of times key terms were mentioned in the texts; then, a multiplier was applied to obtain a score.

In figure 1, and the subsequent application in appendix 1, we have separated innovation from the ecosystem purely for logically analytical purposes. Some innovations may come from outside the ecosystem or be dependent on development from external stakeholders not directly connected through the ecosystem.

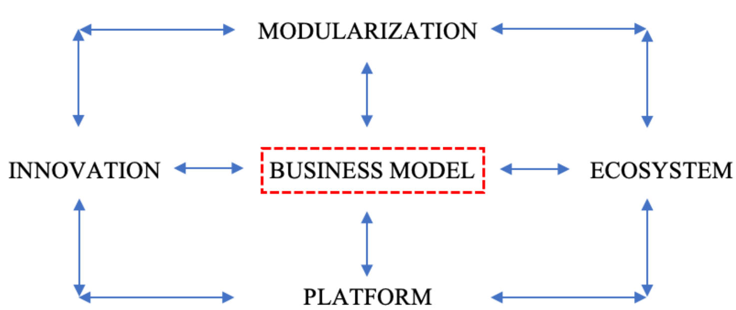

Figure 1: Nexus of combinatorial elements that permit business model value creation and value capture

In the conceptual framework above, we conclude that value is created in the modularization of product components by ecosystem members, codified and routinised, where value is captured on an orchestrating firm's technological platform's overall strategic direction modular product and process innovations. We view the variety of resultant products, guided by the orchestrator (e.g., an electric vehicle OEM) in the unique depth of combinations and attribute configurations (using the scoring system in appendix 1), as the business model, specific to the OEM, who creates a combinatorial value added from the unique orchestration of attributes outlined in appendix 1. The "ecologies of complex innovations" (Gawer, 2014, p1242; Dougherty & Dunne, 2011), such as we find in the EV industry, develop into business models whose combinatorial value-added, co-created with modular products and innovations, derived from and with ecosystem complementors, to platform specifications, satisfying particular customer franchises. To summarise, "[m]odularity in product designs allows the decoupling of the processes for developing new products, with stipulated platform architecture interface rules governing compatibility whilst "enabling those processes to become concurrent, autonomous and distributed," among the ecosystem complementor firms, making possible the adoption of modular business model designs (Sanchez, 1996, p121). Case analysis is a method used for explaining the concepts and expressing them through any suitable methods in social science research (Faizan & Haque, 2019; Ślusarczyk & Haque, 2019; Gusakov, Haque, & Jogia, 2020; Haque, Sher, & Urbański, 2020; Haque, Yamoah, & Sroka, 2020; Kot, Haque, & Baloch, 2020; Rahman et al., 2020; Ślusarczyk et al., 2020; Urbański, & Haque, 2020).

With tight modular component coupling, whose rules are governed by the platform orchestrator/sponsor, the platform ecosystem structure is a multilateral arrangement between participants that interact to create and capture value from innovations. The platform ecosystem business model is represented conceptually in figure 1. This underlines this paper's purpose, which is to show the importance of holism, concerning the platform ecosystem business model, through the interaction of the elements in figure 1.

Case justification

This research is mainly exploratory and inductive in method, making the case approach reasonable (Yin, 1994). This exploratory nature of the research objective, combined with the complexity of the topic and the early adoption, diffusion and life cycle of the EV industry, justify the case method as a research instrument (Weiller et al., 2015; Eisenhardt and Graebner, 2007). As the case application, Tesla was chosen as it is considered the leader in invention, innovation, R&D investment, and the highest performing EV OEM in total returns, sales growth, and long-term shareholder value. Furr & Dyer (2020, p1) state that the study of Tesla could be justified due to Tesla's "innovation strategy — which focuses on transforming the auto industry as a whole — offers enduring lessons for any innovator, especially in terms of how to win support for an idea and how to bring new technologies to market." Our evaluation of Tesla, using the conceptual framework in figure 1, provides an "ideal type" against which comparative cases in the EV industry may be measured, for further refinement, analysis and research.

Tesla case study application and analysis

Digital technologies have been instrumental in reconfiguring maturing legacy industries, such as the automotive sector, which could be argued are now in a significant paradigm shift. In the EV industry, they have become integral in the functioning of new business models, the elements of which are held together by data, artificial intelligence, and advanced innovations. Digital transformation and disruption were driving motive of Tesla Inc. (Tesla) from the outset. Modular components and organisational complementors, mediated by the internet of things, allows Tesla to manage complexity and retain flexibility in its platform architecture.

By disrupting and transforming the metrics away from traditional mechanical, analogue automotive engineering, ICE mobility solutions to telematics, digital, electric powertrain solutions, Tesla shifted the paradigm, avoiding confrontation, traditional entry barriers extant in the automotive industry. Tesla was one of the first automotive enterprises to embrace and build a cloud-based infrastructure that enabled data capture from all elements of the platform ecosystem stakeholders, including the customer.

As the complexity of the EV platform ecosystems increases, with the advent of autonomous vehicles, of which Tesla is again a significant innovator, coopetition becomes more normalised, creating new value networks which include consumer electronics and software companies; emergent OEMs, such as Tesla and BYD; mobility providers such as Zipcar; established OEMs (McKinsey, 2016). As we have seen, modularity plays a vital role in managing and reducing complexity whilst simultaneously allowing innovations. One area of the business model of Tesla, where this is evident, is in the lithium-ion battery packs that drive their power train.

Due to the properties of the platform ecosystem business model of Tesla, with an emphasis on high interdependencies, within the parameters of the module, platform interface specifications, set by Tesla as orchestrator, there is the reduced requirement for coordination "across modules [allowing] focused and autonomous attention to a component design by [ecosystem] specialised suppliers [leading] to more rapid and less constrained innovation" (MacDuffie, 2013, p9). There is a reliance on the ecosystem partners specialised dynamic capabilities to innovate their contributions continually. A case in point is Tesla's relationship with Panasonic in Li-ion (Lithium-ion) batteries (see table 1). Tesla recognised from the outset that the battery power pack would be the most critical competitive space upon which the foundations of the modular automotive platform would be built. It recognised that EV battery technologies would be the performance bottleneck, as they had been in mobile technology markets, among others.

Business models define how and where value is created and captured by companies. In relatively nascent industries such as electric vehicles, there is an opportunity for firms to reconfigure business models that exploit new paradigmatic opportunities. From our depiction of the main features of the Tesla business model attributes in appendix 1, firm boundary permeability is essential if the platform orchestrator maximises value creation and capture from co-specialised partnerships (Teece & Linden, 2017). As has already been noted, this could tend to entropy (disorder from complexity) but is orderly (simplified) and orchestrated due to the standardised rule-based interfaces between component modules, Tesla and its partners.

The value creation goes to the pioneers in the adoption cycle. However, as the technology matures and modular systems dominate design architectures, the value capture accrues to innovators that exert control through driving the adoption cycle, improving modular designs, and achieving economies of scale (mass) and scope (customization). For Tesla, the mass customization is achieved by becoming the dominant, mass-produced design in battery technology (very efficient battery use, with up to three times the average distance between charges of other suppliers), whilst simultaneously sharing the modular battery technology with other cooperators, such as Toyota and Daimler (Reuters, 2020). Through early battery innovations and output from its Gigafactories, Tesla has developed a competitive specialisation over legacy automotive OEMs. The battery of Tesla is a "root module" of their physical automotive drivetrain platform and their platform ecosystem around which other modules coalesce. They currently run a battery joint venture with Panasonic Corp and source batteries from China's Contemporary Amperex Technology and South Korea's LG Chem, expanding its ecosystem reach further. Some battery and battery-related platform ecosystem members of Tesla is shown in table 1.

Table 1. Tesla's Selected Strategic Partnership: Platform Ecosystem Firms

STRATEGIC ALLIANCE PARTNER	TYPE	EQUITY / NON-EQUITY JV	PRODUCTS / SERVICES PROVIDED
TOYOTA	JV partner	Equity & Licensing	Tesla battery packs developed for several vehicles in the portfolio
Panasonic (Japan)	R&D	Equity	Battery cells R&D
Panasonic (multiple suppliers in Japan)	R&D	Equity	Builds Tesla battery packs
SolarCity	Electricity generation	Equity the acquired 2016	Powerwall for home electrify generation
Google	Sensor obstacle detection system instead of optical	Non contractual collaborations	Autonomous vehicular transport
Contemporary Amperex Technology	Production and Technology Partner	Equity	Builds Tesla battery packs
LG Chem.	Production and Technology Partner	Contractual collaborations	Builds Tesla battery packs
Daimler	JV partner	Equity & Licensing	Tesla battery packs developed for Smart Fortwo Daimler car
Dana Holdings	R&D	Non-equity	Heat exchange technology to cool batteries
US Government DOE	Funding	Loans	Loans to accelerate affordable fuel-efficient vehicles

Created and Compiled from various sources in the reference list

The battery technology developed by Tesla goes beyond EVs. The first modular "energy" product was the Tesla Powerwall, a series of high storage capacity Li-ion energy cells that may be used in EV charging units and in-home energy systems. The Tesla Gigafactory battery production facilities ensure future supplies an innovation. The Gigafactories are in Nevada, Shanghai, in agreement with the Shanghai municipal government, and 2025, Berlin. Battery technology is the critical modular product in the EV powertrain (N S Energy, 2020).

Tesla recognised the necessity of building consumer confidence in "long-distance trips" per charge for shifting consumers attitudes and behaviours from an affinity with ICEs and over to EVs (Turrentine et al., 2007), reinforcing the argument made in this paper that their battery technology and innovations, mass production facilities and strategic partnerships are a significant building block on the business model supply side, and the consumer demand side, reducing cognitive barriers in behaviour, helping shift the business model paradigm (Kley et al., 2011).

The Tesla business model (outlined in our attribute framework in appendix 1) allows multiple opportunities in creating and capturing value by sharing and innovating their battery technology with partners, as well as their platform with ecosystem complementors (see table 1, table 2 and table 3), and modularity of products and processes. Besides, integrating the customers into the Tesla digital infrastructure gives an immediacy of feedback for continuous improvement.

According to the literature reviewed for this paper, tables 2 to 5 and the accompanying figures 2 to 5 in the appendixes are an attempt to evaluate the position of Tesla relative to the most critical attributes of their business model. These figures show Tesla's strength in the following: an integrated business model that promotes entrepreneurialism with platform ecosystem partners, the results of which may then be leveraged into broader markets (e.g. the Powerwall), and deeper into the mass EV market segments, from its high-end position; using modularity as a fundamental building block of value creation and capture, and in doing so, gaining access to co-specialised assets; the creation of a cooperative value network around a core platform their expert understanding of entrepreneurship and of the importance of high - performance innovation in establishing competitive leadership. The configuration of the business model attributes, categorised in tables 2 to 5 for Tesla, contributed to Tesla's role in shifting the automotive paradigm and changing the value network imperatives around their business model, creating a competitive advantage.

Conclusion and generalisability of findings

By treating the business model as a juncture of modularity, platform technologies, and innovation ecosystems, it allows a fuller picture to emerge of the (in-)congruence of the significant building blocks of Tesla's unique business model. As a recommendation, we propose a comparative study that may compare the Tesla case "attribute" evaluations, tabulated in the appendixes with other EV OEMs. The purpose would be to apply the attributes to other EV OEMs to provide comparative analyses of other EV firm business models for current industry benchmarking purposes. Innovations in our conceptual framework elements, and more deeply the attributes, may be benchmarked internally and competitively. As modularity, platform technologies, and innovation ecosystems are ubiquitous in industries as diverse as online service provision, computer software and hardware development, social media, our framework has resonance as a comparative positioning model, strategy and technology development. Therefore, the conceptual framework of analysing and attributing the most relevant and important factors for company business models could be expanded to other industries with multiple technological bases for their positioning. The attributes would change for each new industry application, but it would generate comparative analyses based on essential attributes. It integrates stakeholder/complementor contributions relative to orchestrating the firm as enablers of value capture and value creation, allowing calibration of total attribute coalitional value.

The main findings and managerial implications gleaned from the literature, which informed this research on Tesla, include the need for firms to consider the integration of the processes, which meld together to make up the business model, including the platform architecture, ecosystem complementors and modular components, taken together as the provision and facilitation of innovations. Breaking down each of the proposed business model elements into a series of attributes (see appendix 1) will highlight the factors where value is created and captured for each firm, providing a unique snapshot of comparative similarities and differences between each firm. Also, by iterating attribute creation, new attributes may be added to the value creation and value capture of the business model framework.

In summary, the paper drew upon four strands of extant literature in order to create an analytical framework of attributes against which we could measure the strengths of Tesla in the areas of innovation, its ecosystem and platform, and finally, the use of modularity as elements which describe, and to some degree circumscribe, the business model. Many authors have concentrated on the individual constructs making up the business model, whilst we have integrated those same constructs into one conceptual framework, arguably making our heuristic a more useful tool, as a multidimensional framework, to aid firms in evaluating their business models, relative to competitors. It also reveals a more prosperous evaluation of the most pertinent attributes for firms themselves and potential comparative purposes. Ultimately and pragmatically, the research shows that Tesla has balanced the framework's attributes in what appears to be a deliberate and orchestrated fashion.

Peer-review:

Externally peer-reviewed

Conflict of interests:

The author(s) has (have) no conflict of interest to declare.

Grant Support:

The authors declared that this study has received no financial support

References

Adner, R., & Kapoor, R. (2016). Innovation ecosystems and the pace of substitution: Re-examining technology S-curves. *Strategic management journal*, *37*(4), 625-648.

Adner, R. (2006). Match your innovation strategy to your innovation ecosystem. *Harvard business review*, *84*(4), 98.

Adner, R. (2017). Ecosystem as structure: An actionable construct for strategy. *Journal of management*, *43*(1), 39-58.

Aggeri, F., Elmquist, M., & Pohl, H. (2009). Managing learning in the automotive industry–the innovation race for electric vehicles. *International Journal of Automotive Technology and Management*, *9*(2), 123-147.

Autio, E., & Thomas, L. (2014). *Innovation ecosystems* (pp. 204-288). The Oxford handbook of innovation management.

Baldwin, C. Y., Clark, K. B., & Clark, K. B. (2000). *Design rules: The power of modularity* (Vol. 1). MIT press.

Bartman, T., 2015. Why Tesla Won't Be Able to Scale. Harvard Business Review, 2-5.

BCG, 2016 *Batteries for Electric Cars: Challenges, Opportunities, and the Outlook to 2020,* The Boston Consulting Group

Bohnsack, R., Pinkse, J., & Kolk, A. (2014). Business models for sustainable technologies: Exploring business model evolution in the case of electric vehicles. *Research Policy*, *43*(2), 284-300.

Bontempo, José-Vitor, Chaves Alves, Flavia, de Almeida Oroski, Fabio, 2017. Developing new platform chemicals: what is required for a new bio-based molecule to become a platform chemical in the bioeconomy? Faraday Discuss 202 (0), 213–225. https:// doi.org/10.1039/C7FD00052A.

Brusoni S, Principe A, Pavitt K. (2001). Knowledge specialization, organizational coupling, and the boundaries of the firm. *Administrative Science Quarterly* **46**(4): 597– 621.

Cacciatori, E., Jacobides, M.G., 2005. The dynamic limits of specialization: vertical integration reconsidered. Organ. Stud. 26, 1851–1883.

Casadesus-Masanell, R., & Yoffie, D. B. (2007). Wintel: Cooperation and conflict. *Management Science*, *53*(4), 584-598.

Chen, Y., & Perez, Y. (2018). Business model design: lessons learned from Tesla Motors. In *Towards a Sustainable Economy* (pp. 53-69). Springer, Cham.

Chen, S., Wang, Y., & Tseng, M. M. (2009). Mass customisation as a collaborative engineering effort. *International Journal of Collaborative Engineering*, *1*(1-2), 152-167.

Chesbrough, H. W. (2003). *Open innovation: The new imperative for creating and profiting from technology*. Harvard Business Press.

Chesbrough, H. (2010). Business model innovation: opportunities and barriers. *Long range planning*, *43*(2-3), 354-363.

Cheong, T., Song, S. H., & Hu, C. (2016). Strategic alliance with competitors in the electric vehicle market: tesla motor's case. *Mathematical Problems in Engineering*, *2016*.

Christensen, C. M. (1997). Marketing strategy: learning by doing. *Harvard business review*, *75*(6), 141-151.

Christensen, C. M., & Rosenbloom, R. S. (1995). Explaining the attacker's advantage: Technological paradigms, organizational dynamics, and the value network. *Research policy*, *24*(2), 233-257.

Dhanaraj, C., & Parkhe, A. (2006). Orchestrating innovation networks. *Academy of management review*, *31*(3), 659-669.

Dougherty, D., & Dunne, D. D. (2011). Organizing ecologies of complex innovation. *Organization Science*, *22*(5), 1214-1223.

Dutta, S., Lanvin, B., & Wunsch-Vincent, S. (Eds.). (2018). Global innovation index 2018: Energizing the world with innovation.

Eisenhardt, K. M., & Graebner, M. E. (2007). Theory building from cases: Opportunities and challenges. *Academy of management journal*, *50*(1), 25-32.

Eisenhardt, K., Gawer, A., & Hannah, D. (2018, July). Shaping Sectors, Changing Architectures, Constructing Ecosystems. In *Academy of Management Proceedings* (Vol. 2018, No. 1, p. 12100). Briarcliff Manor, NY 10510: Academy of Management.

Ethiraj, S. K., & Levinthal, D. A. N. I. E. L. (2002). Search for architecture in complex worlds: an evolutionary perspective on modularity and the emergence of dominant designs. *Wharton School, University of Pennsylvania, pdf copy*.

Faizan, R., & Haque, A.U. (2019). Working Efficiency of Contrasting Genders under Eustress, Distress, Hyper-Stress, and Hypo-Stress, *Prabandhan: Indian Journal of Management,* 12(11), 32-46.

Fleming, L., & Sorenson, O. (2001). The Dangers of Modularity. *Harvard Business Review*, *79*(8), 20-21.

Fojcik, T. M. (2013). Exploitation, exploration and the ambidextrous design choice in the transition to electric vehicles–an analysis of small and medium-sized automotive suppliers in Germany. *International Journal of Automotive Technology and Management 20*, *13*(4), 354-371.

Foster, R. N. (1986). Working the S-curve: assessing technological threats. *Research Management*, *29*(4), 17-20.

Furr, N., & Dyer, J. (2020). Lessons from Tesla's approach to innovation. *Harvard Business Review, available at: https://hbr. org/2020/02/lessons-from-teslas-approach-to-innovation*.

Gastaldi, Luca, Paolo Appio, Francesco, Martini, Antonella, Corso, Mariano, 2015. Academics as orchestrators of continuous innovation ecosystems: towards a fourth generation of CI initiatives. Int. J. Technol. Manag. 68 (1–2), 1–20. https://doi.org/ 10.1504/ijtm.2015.068784.

Gawer, A. (2014). Bridging differing perspectives on technological platforms: Toward an integrative framework. *Research policy*, *43*(7), 1239-1249.

Gawer, A., Phillips, N., 2013. Institutional work as logics shift: the case of Intel's transformation to platform leader. Organ. Stud. 34, 1035–1071.

Gawer, A., Cusumano, M.A., 2014. Industry platforms and ecosystem innovation. J. Prod. Innov. Manag. 31, 417–433. http://dx.doi.org/10.1111/jpim.12105.

Gomes, Augusto de Vasconcelos, Leonardo, Lucia Figueiredo Facin, Ana, Sergio Salerno, Mario, Ikenami, Rodrigo Kazuo, 2018. Unpacking the innovation ecosystem con- struct: evolution, gaps and trends. Technol. Forecast. Soc. Chang. 136, 30–48.

Granovetter, M. S. (1973). The strength of weak ties. *American journal of sociology*, *78*(6), 1360-1380.

Granstrand, O., & Holgersson, M. (2020). Innovation ecosystems: A conceptual review and a new definition. *Technovation*, *90*, 102098.

Gusakov, A., Haque, A.U., & Jogia, A.V. (2020). Mechanisms to Support Open Innovation in Smart Tourism Destinations: Managerial Perspective and Implications, *Polish Journal of Management Studies,* 21(2), 142-161.

Hacki, R., & Lighton, J. (2001). The future of the networked company. *The McKinsey Quarterly*, (3), 26.

Hannah, D. P., & Eisenhardt, K. M. (2018). How firms navigate cooperation and competition in nascent ecosystems. *Strategic Management Journal*, *39*(12), 3163-3192.

Haque, A.U., Yamoah, F., & Sroka, W. (2020). *Willingness to Reduce Food Choice in Favour of Sustainable Alternatives: The Role of Government and Consumer Behaviour* (chapter 3), In: W. Sroka (ed), Perspectives on Consumer Behaviour, Springer.

Haque, A.U., Sher, A., & Urbański, M. (2020). Is the role of Authentic Leadership Effective in Managing Occupational Stress and Psychological Capital? *Forum Scientiae Oeconomia,* 8(2), 59-77.

Hearn, G., & Pace, C. (2006). Value-creating ecologies: understanding next generation business systems. *Foresight*.

Iansiti, M., & Levien, R. (2004). Creating value in your business ecosystem. *Harvard Business Review*, *3*, 68-78.

Jacobides, M. G., Cennamo, C., & Gawer, A. (2018). Towards a theory of ecosystems. *Strategic management journal*, *39*(8), 2255-2276.

Kim, J. (2016). The platform business model and business ecosystem: Quality management and revenue structures. *European Planning Studies*, *24*(12), 2113-2132.

Kley, F., Lerch, C., & Dallinger, D. (2011). New business models for electric cars—A holistic approach. *Energy policy*, *39*(6), 3392-3403.

Kot, S., Haque, A.U., and Baloch, A. (2020). Supply Chain Management in SMEs: Global Perspective, *Montenegrin Journal of Economics,* 16(1), 87-104.

KPMG Global Automotive Executive Survey 2017a

KPMG Innovation Convergence Unlocks New Paradigms, kpmg.com/techinnovation, 2017b

KPMG The Changing Landscape of Disruptive Technologies, kpmg.com/Technovation, 2017

Kukk, P., Moors, E.H.M., Hekkert, M.P., 2015. The complexities in system building strategies — the case of personalized cancer medicines in England. Technol. Forecast. Soc. Chang. 98, 47–59.

Leten, B., Vanhaverbeke, W., Roijakkers, N., Clerix, A., & Van Helleputte, J. (2013). IP models to orchestrate innovation ecosystems: IMEC, a public research institute in nano-electronics. *California management review*, *55*(4), 51-64.

MacDuffie, J. P. (2013). Modularity-as-property, modularization-as-process, and 'modularity'-as-frame: Lessons from product architecture initiatives in the global automotive industry. *Global Strategy Journal*, *3*(1), 8-40.

McKinsey Inc. 2016. Evolution: Electric Vehicles in Europe: Gearing up for a New Phase? *McKinsey Quarterly 2016*

Moore, J. F. (1993). Predators and prey: a new ecology of competition. *Harvard business review*, *71*(3), 75-86.

N S Energy (2020). Power Mission Clean Technology, accessed January 10th, 2021

Nambisan, S., & Baron, R. A. (2013). Entrepreneurship in innovation ecosystems: Entrepreneurs' self–regulatory processes and their implications for new venture success. *Entrepreneurship theory and practice*, *37*(5), 1071-1097.

Rahman, M., Kamal, M. M., Aydin, E., & Haque, A. U. Impact of Industry 4.0 drivers on the performance of the service sector: comparative study of cargo logistic firms in developed and developing regions, *Production Planning & Control,* Special Issue, DOI: 10.1080/09537287.2020.1810758.

Rong, K., Shi, Y., Shang, T., Chen, Y., & Hao, H. (2017). Organizing business ecosystems in emerging electric vehicle industry: Structure, mechanism, and integrated configuration. *Energy Policy*, *107*, 234-247.

Sanchez, R. (1996). Strategic product creation: Managing new interactions of technology, markets, and organizations. *European management journal*, *14*(2), 121-138.

Sanchez, R. (1999). Modular architectures in the marketing process. *Journal of marketing*, *63*(4_suppl1), 92-111.

Sanchez, R., & Mahoney, J. T. (1996). Modularity, flexibility, and knowledge management in product and organization design. *Strategic management journal*, *17*(S2), 63-76.

Schilling, M. A. (2000). Toward a general modular systems theory and its application to interfirm product modularity. *Academy of management review*, *25*(2), 312-334.

Scozzi, Barbara, Bellantuono, Nicola, Pontrandolfo, Pierpaolo, 2017. Managing open innovation in Urban labs. Group Decis. Negot. 26 (5), 857–874. https://doi.org/10. 1007/s10726-017-9524-z.

Simon, H. A. (1972). Complexity and the representation of patterned sequences of symbols. *Psychological review*, *79*(5), 369.

Ślusarczyk, B., & Haque, A.U. (2019). Public services for business environment: challenges for implementing Industry 4.0 in Polish and Canadian logistic enterprises. *Administratie si Management Public,* (33), pp. 57-76.

Ślusarczyk, B., Tvaronaviciene, M., Haque, A.U., & Olah, J. (2020). Predictors of Industry 4.0 Technologies affecting logistic enterprises' performance: International perspective from economic lens, *Technological and Economic Development,* 26(2), 1-21, DOI: 10.3846/tede.2020.13376

Stringham, E. P., Miller, J. K., & Clark, J. (2015). Overcoming Barriers to Entry in an Established Industry: TESLA MOTORS. https://doi.org/10.1525/cmr.2015.57.4.85

Teece, D. J. (2010). Business models, business strategy and innovation. *Long range planning*, *43*(2-3), 172-194.

Teece, D. J., & Linden, G. (2017). Business models, value capture, and the digital enterprise. *Journal of organization design*, *6*(1), 1-14.

Turrentine, T. S., & Kurani, K. S. (2007). Car buyers and fuel economy? *Energy policy*, *35*(2), 1213-1223.

Tushman, M. L., & Anderson, P. (1986). Technological discontinuities and organizational environments. *Administrative science quarterly*, 439-465.

Ulrich, K & Eppinger, S. (1999). *Product Design and Development,* McGraw-Hill

Wareham, J., Fox, P. B., & Cano Giner, J. L. (2014). Technology ecosystem governance. *Organization science*, *25*(4), 1195-1215.

Urbański, M., and Haque, A.U. (2020). Are You Environmentally Conscious Enough to Differentiate between Greenwashed and Sustainable Items? A Global Consumers Perspective, *Sustainability,* 12(5), 1-26.

Weiller, C., Shang, T., Neely, A., & Shi, Y. (2015). Competing and co–existing business models for EV: lessons from international case studies. *International Journal of Automotive Technology and Management*, *15*(2), 126-148.

Wruck, K. H., & Jensen, M. C. (1998). Coordination, Control, and the Management of Organizations: Course Content and Materials (3rd of 4 Ccmo Documents). *Control, and the Management of Organizations: Course Content and Materials (3rd of 4 Ccmo Documents) (April 20, 1998)*.

Yin, R. K. (1994). Discovering the future of the case study. Method in evaluation research. *Evaluation practice*, *15*(3), 283-290.

Zott, C., Amit, R., & Massa, L. (2011). The business model: recent developments and future research. *Journal of management*, *37*(4), 1019-1042.

Zulkarnain., Leviäkangas, P., Kinnunen, T. and Kess, P., 2014. The electric

vehicles ecosystem model: Construct, analysis and identification of key challenges. *Managing Global Transitions*, *12*(3), p.253.

Appendix 1:

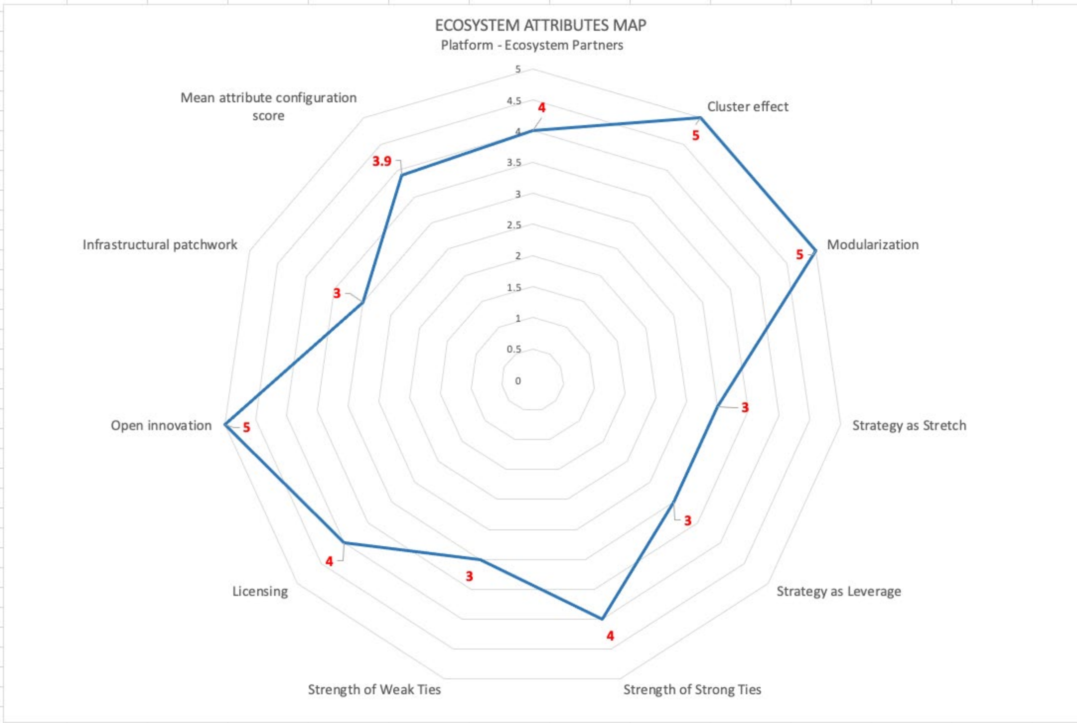

Figure 2: Ecosystem Attributes Map

Table 2: Ecosystem Attributes

Attribute	Explanation	Tesla Score
Platform - Ecosystem Partners	The extent and depth of partnerships with key complementary, cospecialised partner firms.	4
Cluster effect	Silicon Valley location in a strong digital innovation cluster, co-specialization and co-location of employees to and from complementors. A conducive environment for innovation in an entrepreneurial community.	5
Modularization	Patented highly specified platform and modular interfaces with Tesla as platform orchestrator.	5
Strategy as Stretch	System complementors in technology and overall product and platform architecture – transferability of modular components giving economies of scope.	3
Strategy as Leverage	Multiple manufacturing plants covering the three main markets: USA/North America; China/Asia and Germany / Europe giving rise to potential economies of scale (yet to be fully realised).	3
Strength of Strong Ties	Access to complementary technologies in the value chain network of suppliers directly (contractually) tied to Tesla.	4
Strength of Weak Ties	Access to complementary technologies in the value chain network of suppliers not directly (non-contractually) tied to Tesla.	3
Licensing	Markets open to using Tesla battery and other intellectual property. Licensing to companies such as Daimler and Toyota open new revenue streams.	4
Open innovation	Tesla as new entrant, unincumbered by extant processes, e.g., pioneering Li-ion battery use, alum. body design.	5

Infrastructural patchwork	Charging network installations, charging point availability and charging times are variable and not as ubiquitous as customers (actual and potential) would like.	3
Mean attribute configuration score		**3.9**

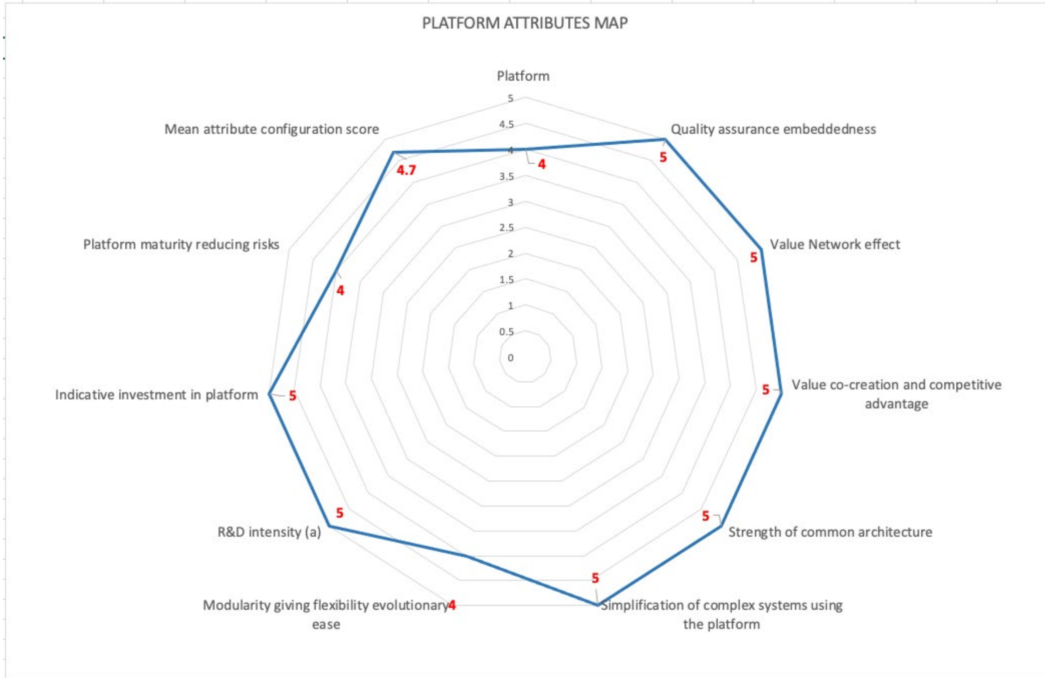

Figure 3: Platform Attributes Map

Table 3: Platform Attributes

Attribute	Explanation	Tesla Score
Platform	The extent and depth of partnerships with key complementary, cospecialised partner firms continually enriches the libraries of modules. Co-creation of products from modularity helps create a stability in the platform.	4
Quality assurance embeddedness	The platform creates a stable base for innovation in modular products and processes, with standards and quality assurance established by the platform orchestrator independently of the firms innovating.	5
Value Network effect	Interdependence of orchestrator and complementors, add value (real or perceived) to the ultimate consumers of the products, increasing the overall value of the network around the platform.	5
Value co-creation and competitive advantage	In platform mediated settings, there is a reliance on the orchestrating firm to push complementors to innovate and gain value co-creation, and to leverage this into competitive differentiation of the end products, creating a dynamic hermeneutic ecology.	5
Strength of common architecture	Strong common architecture based on a core innovative technology, acting as a pillar around which complementors' modules coalesce. In this case, Tesla has created this around its battery technology and powertrain, as differentiating foundations.	5

Simplification of complex systems using the platform	Tesla has managed to reduce the drivetrain on its vehicles to an average of 17 moving components. The average for an equivalent ICE drivetrain has an average of up to 2000. The simplicity of the Tesla drivetrain system obviates the need for as many physical interventions. The majority of repairs and maintenance to the Tesla range can be made remotely, through the onboard telematics software. (Forbes, 2019).	5
Modularity giving flexibility evolutionary ease	The ease with which the platform can e extended to incorporate new modules. Due to the modular nature of the products and processes using the platform architecture, as long as there is a compliance with standardised interfaces, the platform may evolve with relative ease, taking on new complementors that add new functionality and/or features. This s important when the rate of change is rapid and as their EV competitive space becomes more crowded.	4
R&D intensity (a)	With an R&D intensity percentage of 12% over 2017 – 2018 (PWC 2018), far outweighing competitor investments, the platform development is a major beneficiary of diffusion of innovations with ecosystem complementors.	5
Indicative investment in platform	Tesla's market capitalization dwarfs that of other automakers. The top three automakers by market cap. are: Tesla $442.7bn; Toyota $185.4bn; VW $86.3bn. This bodes well for investment of funds in the underlying platform and R&D (Statista 2020).	5
Platform maturity reducing risks	The maturing Tesla platform gives them a solid innovation process base from which incremental changes, to the modular libraries that use it, may be made. This also helps manage risks within the platform systems and reduces cognitive dissonance of consumers.	4
Mean attribute configuration score		**4.7**

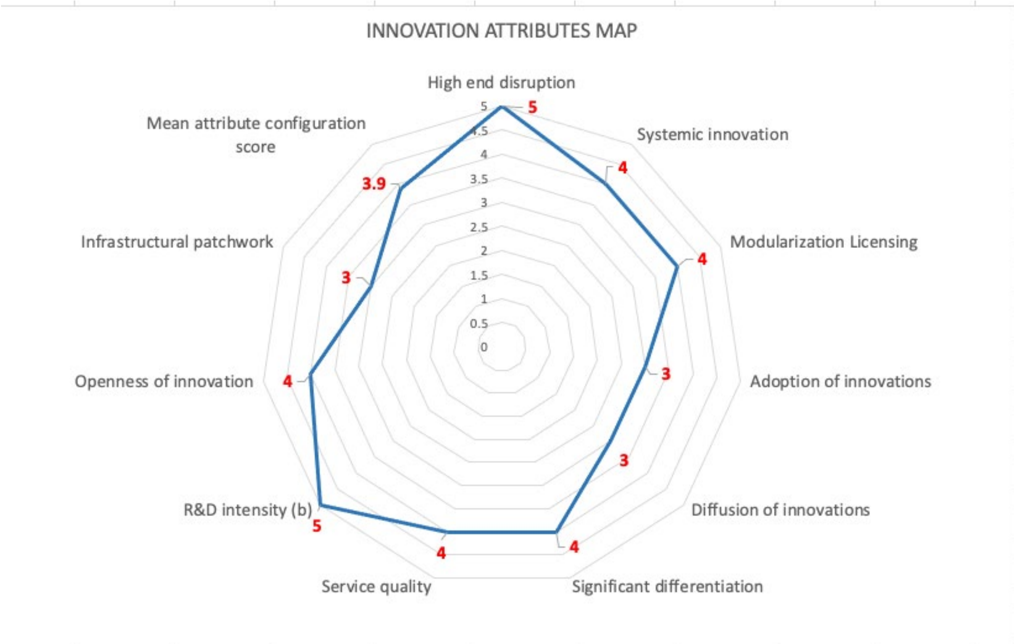

Figure 4: Innovation Attributes Map

Table 4: Innovation Attributes

Attribute	Explanation	Tesla Score
High end disruption	Competing with incumbent OEMs at the high end, e.g., BMW, Daimler is a less corded competitive space, and Tesla avoided many traditional entry barriers, a avoiding head on competition, by reconceptualising the strategic gameboard towards early digitisation.	5
Systemic innovation	Innovations are not only technological (design, engineering and production), but service innovations (through internet CRM system) are as important to Tesla in areas of remote diagnostics, software updates.	4
Modularization Licensing	Patent protection for core components whilst allowing peripheral patents to be open sourced from Tesla	4
Adoption of innovations	Systems technology and architecture are all transferrable across industry sectors and economies of scope are gained from modular reusability across Tesla's and its partners' product ranges.	3
Diffusion of innovations	Systems technology and architecture replicable from one generation/version of products to the next – economies of scale	3
Significant differentiation	Tesla was the first high end disruptor in the EV industry. With the advent of more competitive pressures from legacy ICE firms, such as Daimler, BMW and Jaguar, moving into the EV competitive space, the cycle of value capture and value creation is shortening.	4
Service quality	Proactive incorporation of customers into the quality, function, deployment framework through digitisation, real time data capture, and AI analytics makes the customers; complementors; suppliers and other stakeholders, integral parts of the innovation processes.	4
R&D intensity (b)	Between 2017 and 2018, Tesla's average R&D intensity (R&D as percentage of revenues) was 12% (rounded) compared to VAG Group (5.5%); Toyota (3.8%); Daimler (3.8%). Of the top 10 automakers by revenue, Tesla had between 200% and 400% greater R&D investment intensity. (Data from PWC 2018).	5
Openness of innovation	When Tesla opened up its patent library to other firms, it showed the standards that it was setting partly to entice others to the ecosystem, but also to show an openness, signalling less opportunistic behaviour form its position as orchestrator within the platform – ecosystem.	4
Infrastructural patchwork	The charging infrastructure does not yet have one unified standard, nor are the charging stations of any of the OEM competitors. This creates potential barriers to adoption.	3
Mean attribute configuration score		**3.9**

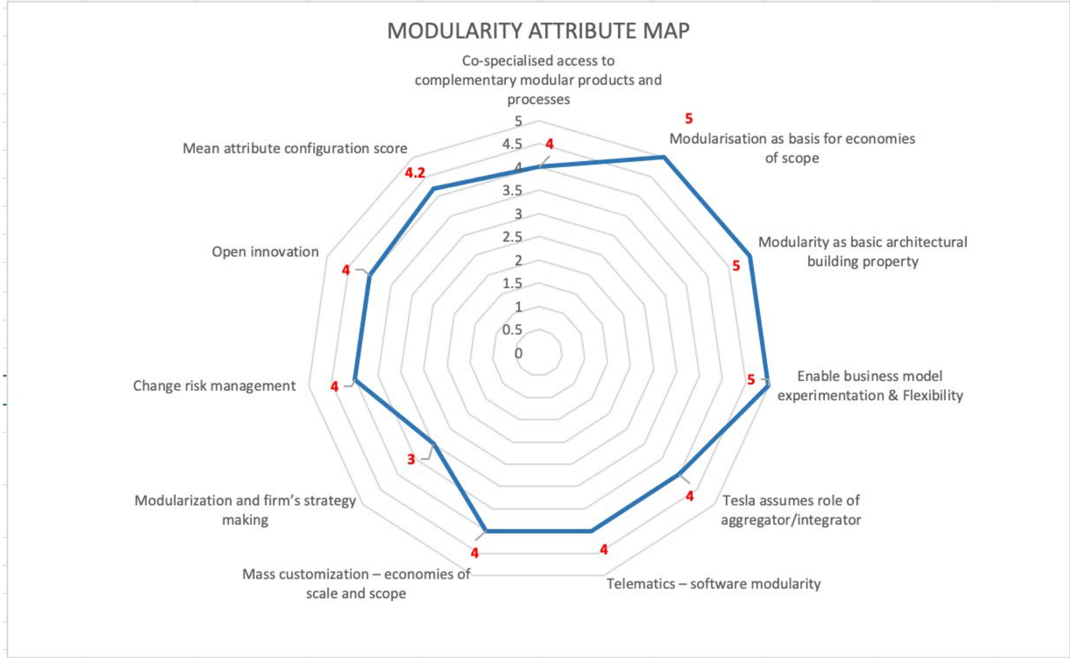

Figure 5: Modularity Attributes Map

Table 5: Modularity Attributes

Attribute	**Explanation**	**Tesla Score**
Co-specialised access to complementary modular products and processes	Tesla has access to partner specialist modular innovations through its ecosystem, and due to the standardisation of interfaces, it is clear that there will be a conformance to the platform architecture.	4
Modularisation as basis for economies of scope	Interoperability of the modular components allows reduction in the costs of coordination whilst allowing autonomous innovation from co-specialised ecosystem members.	5
Modularity as basic architectural building property	Emphasis on higher designed-in interdependencies within and between modules, reducing requirement for inter organisational coordination	5
Enable business model experimentation & Flexibility	Modularization of product gives rise to ease of introducing and phasing out as improved versions of modules may be introduced without disrupting the whole architectural basis of the final product. This decoupling and coupling property in modularisation processes enable experimentation and real options flexibility.	5
Tesla assumes role of aggregator/integrator	Aggregation and integration, by the platform orchestrator, of systems technology and architecture underpinning the platform ecosystem, is controlled by the lead OEM.	4
Telematics – software modularity	As new supplier's software functionality is developed, and innovations are introduced, digital integration may become more tightly coupled.	4

Mass customization – economies of scale and scope	An example of mass customization can be seen in Tesla's initial development of the Li-ion battery. The battery packs may be customised to varying sizes (in physical and Watt output sizes), for different vehicular types (sedans, SUVs, trucks etc.) without disruption of the basic architecture of the powertrains. Individual cells themselves are modular in their configuration of the above, allowing ***mass*** – economies of scale through volume production; ***customisation*** – economies of scope through modular reconfiguration of cellular makeup for different requirements.	3
Modularization and firm's strategy making	In terms of product, process and firm strategy making, MacDuffie (2013) has pointed out that modularity provides a cognitive conceptual framework for managers in a boundedly rational (through complexity) context, affecting information processing	4
Change risk management	Due to the incremental evolution of modules the risk of being surprised by change within the ecosystem is reduced, whilst simultaneously creating disruptive risk to competitors, through rapid modular and product innovations.	4
Open innovation	By opening up a large proportion of its patent portfolio as "free to use", Tesla is attempting to avoid the competency trap, whereby they may lose some system integration if the outsourced products become increasingly anarchic over time.	4
Mean attribute configuration score		**4.2**

Appendix 2:

Table 6: EV ecosystem key stakeholder groups (from Zulkarnain et.al. 2014, pp266 – 268)

Stakeholder	Explanation
EVs end users:	The key consumers who use EVs for their mobility. They comprise consumers, corporate customers, and public sector. Customer acceptance challenges apply for the EVs end users and determine the critical success factor for EVs deployment.
Power utilities and infrastructures (PUI):	The EVs-enabler facilities, i. e. charging points, power network providers, electricity producers, fuel suppliers (for hybrid-type of EVs), including their upstream value chain actors.
EVs manufacturers (EVM):	The key motor in EV that contains EVs manufacturers (OEM), EVs suppliers, component suppliers and their related services providers (e.g. mobility/telematics service providers and EVs rental service providers).
Battery suppliers (BS):	Including battery manufacturers, component suppliers, and related R&D. Together with power utilities/infrastructures and EVs manufacturers, they deal with identified technical aspect challenges.
Regulators and external actors (REA):	Policy makers/regulators from any levels of governments, e. g. inter-governmental bodies, regional, member states, municipalities and local authorities; EVs related industry association, academic research and development, and environmentalists as 'catalysts' for EVs policy deployment.
EVs aggregators/integrators (EVAI):	A system integrator that is proposed to be a key operator for the ecosystem. The integrator can be one of the existing players, usually the orchestrator of the platform ecosystem, an entirely new one or a combination of both (e. g. a joint venture). The EVs aggregator/integrator is driven by regulators and integrating/coordinating the roles of the main actors in eve.