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Geely SEA: New Electric Vehicle Platforms

Kent Bovellan, the Chief Engineer and Head of the Vehicle Architecture Center for Geely Holding, the Hangzhou, China headquartered global automotive group, was in a planning meeting debating the platform choice for an upcoming "D" segment midsized electric vehicle in the new Zeekr brand (see **Exhibit 1** for a classification of vehicle segments). As a mid-sized car targeting both the Chinese and European Union (EU) markets, it was important to strike a balance between premium product features and product costs to meet the company's profitability target. The product team wanted to focus on affordable luxury, but at the same time, the finance team wanted to make sure the company could earn sufficient profit on what they anticipated would be a high-volume mainstream segment.

Automakers used product platforms and modular architectures to spread the development costs of new vehicles. A *product platform* defined the underbody and suspension system of a vehicle, including things like the structural frame, the front and rear floors, the placement of the engine or electric traction motor(s), and the steering system. The platform was then married with a *top hat*, which included the upper body structures including the *greenhouse* (the passenger compartment), doors, trunk, interior appointments, dashboard instrumentation, and many distinguishing features. This saved both development and manufacturing costs because a range of different models could share a common set of engineered components while having different appearances, appointments and finish levels, and even be sold under different brands. This yielded significant scale economies when multiple vehicle marques shared common modular subsystems.

Bovellan led the development of Geely's Sustainable Experience Architecture (SEA), which was a new battery electric vehicle (BEV) platform that it planned to deploy across its portfolio of eight global automotive brands. The first Geely vehicle to use SEA was the Zeekr 001, a premium EV launched in April, 2021. The company had further segmented SEA into the SEA1 platform covering D to F segment vehicles, SEA2 covering B to D segment vehicles, SEA-Entry for A to B+ segment[1] mini-compacts and city cars, as well as a SEA–Sport for premium vehicles and SEA–Commercial for vehicles like vans and light trucks (see **Exhibits 2 - 5**).

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Zeekr 001
Promo Video

[1] The B+ segment in China corresponds to the EU C-segment.

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The proposed D segment vehicle could be built with either the more expensive SEA1 or the less expensive SEA2. SEA2 was tailored for the high-volume middle market, and incorporated a less sophisticated chassis system with lower cost materials than those used in SEA1. In general, the cost of making a car scaled more slowly than the selling price, with the high end of a range more profitable than the low-end. Thus a D segment car built on SEA2 was likely to be much more profitable than a D segment car built on SEA1, if the selling prices were the same. Of course the company would seek a higher selling price, but then would consumers pay the premium?

Bovellan explained the dilemma behind the choice:

> Every time you have a break point in a platform architecture, you have a dilemma. Volume manufacturers have to choose lower cost platforms, and premium makers can choose higher cost platforms. If you downsize a car, you have to downsize the costs unless you are a really high-end premium maker. In the B – D segment, the D segment car will always earn money for you, because the costs are lower. The C segment will have good margins, but now for the B segment, that's where carmakers typically get into trouble!

"In China," a member of the marketing team interjected, "Consumers study the specs. They notice some of the premium features of a vehicle, like the number of links in the rear suspension, the power steering configuration, or in the case of an internal combustion engine (ICE) car, the number of cylinders. If they see we are using too many C car components in this D car, they might go buy an Audi instead."

"What you are saying is that customers want the premium designs and materials, but they want the lower price." Bovellan responded, "In the West, I have heard that called 'champagne tastes on a beer budget.'"

SCAN ME

Multi-link Suspension

Geely Auto Group

Founded in 1986 and headquartered in Hangzhou, Zhejiang Geely Holding Group Co., Ltd., commonly known as Geely, started out as a refrigerator parts manufacturer. It pivoted towards the production of building materials in 1991 and the production of motorcycles in 1994. Its founder LI Shufu, however, long aspired to be a car manufacturer. At the time of the company's founding, the Chinese government did not allow privately held companies to enter the automotive industry. This was so that the country could concentrate its resources on established state-owned automakers and build up their capabilities more effectively. Li nonetheless believed that the restriction would be lifted someday. To get started, Li ordered his personal Mercedes-Benz E-Class as well as a luxury Hongqi made by state-owned First Automobile Works (FAW) to be disassembled and studied. This led to Geely's first car, the "Geely One," which suffered from many flaws, leading Li to realize that a manufacturer of high-end cars was not built overnight. He also gained a better sense of the technologies involved and importance of product positioning.

Aiming to produce affordable cars for ordinary people, Li acquired an automaker and founded Geely Auto Group as a Geely subsidiary in 1997.[1] A year later in August 1998, the first production vehicle, the Geely Haoqing, rolled off the assembly line. Geely Auto became the first privately held company to receive an automobile production license from the Chinese government in 2001 and went public on the Hong Kong Stock Exchange in 2005.

On the back of unprecedented economic development, China experienced dramatic growth in car sales, and overtook the United States in 2009 as the largest single country car market in the world (see

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Exhibit 6 for comparative passenger car sales).[2] During the early 2000s, Geely grew with a very market-focused strategy, designing cars based on what was selling well in the market. As Chinese consumers raised their expectations of the quality and safety features of a car, Geely Auto entered what it called its 2.0 era (2007 - 2014), offering vehicles to cover more segments. It launched the popular Panda compact in 2008, and the then best-selling EC7 in 2009.

Geely was an early mover among Chinese companies in cross-border acquisitions. In 2006 the company purchased a 19.97% stake in Manganese Bronze Holdings, the manufacturer of London's municipal cabs, and formed a joint venture with the company to produce and sell the classic London taxi in China.[3] In 2013, Geely bought full control of Manganese Bronze and renamed it the London Taxi Company. Its most notable acquisition was the 2010 purchase of Volvo Cars from the Ford Motor Company for $1.8 billion. At Li's direction, the two companies maintained independent corporate structures and enjoyed a "brothers" relationship, though they jointly founded the China Euro Vehicle Technology Center (CEVT) in Gothenburg, Sweden in 2013.

Taking advantage of Volvo's technological and management expertise, Geely Auto experienced another stage of strong growth. In April 2014, Geely Auto announced the start of what it called its 3.0 era with a new mission of "making refined cars for everyone." In December 2014, the company launched its first third-generation vehicle, the flagship Bo Rui sedan designed by the renowned car designer Peter Horbury[4] Other affordable higher-end cars produced by Geely during this period included the Bo Rui GE and Bo Yue (sold in export markets as the Emgrand X7 Sport).

Internationally, Geely established the technology-focused Lynk & Co. brand as a joint venture with Volvo in 2016; the Lynk & Co 01 was the first vehicle to use the compact modular architecture (CMA) developed at China Euro Vehicle Technology (CEVT) a joint venture with Volvo. In 2017 Geely acquired a 51% stake in Lotus Cars, as well as 49.9% of Malaysian carmaker Proton from Malaysian conglomerate DRB-Hicom. It also acquired the American flying-car startup Terrafugia, an 8.2% stake in AB Volvo, and a 9.69% stake in Daimler AG, the German owner of Mercedes-Benz.

With its domestic and global positions in traditional ICE vehicles, Geely saw the urgent need to develop electric vehicles (EVs). Following the launch of its first EV, the Emgrand EV in 2015, Geely Auto introduced several more models. The company also debuted its first pure electric brand, Geometry, in April 2019. The company reported 68,142 units of new energy and electrified vehicles (NEEVs) sold in 2020, down 40% from 2019 owing primarily to a reduction in state subsidies for such purchase as well as intensified competition, accounting only for 5.2% of its total sales volume.[5] (**Exhibit 7** shows EV sales by manufacturer in China.)

By 2021 Geely Auto had more than 70,000 employees, five global R&D centers in Hangzhou, Ningbo, Gothenburg, Coventry, and Frankfurt, as well as five global design studios in Shanghai, Gothenburg, Barcelona, California, and Coventry.[6] Its global market share grew from 0.3% in 2014 to 1.2% in 2019.[7] As one of the largest private car makers in China, Geely Auto sold 1.32 million cars and reported RMB 92.1 billion ($14.2 billion) in revenue despite the impact of the Covid-19 pandemic in 2020. **Exhibit 8** shows Geely's revenue from 2009 to 2020, and **Exhibit 9** tallies worldwide market share of passenger cars by badge (brand) in 2019. Small SUVs generated the majority of Geely's revenue (See **Exhibit 10**).

Product Platforms

Automakers have long used *product platforms* as a way to develop families of vehicles that served a range of needs and tastes while keeping development costs in check. The goal was to identify

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components that could be shared across a product family, using them as a foundation to build related products. Sharing the underbody between models, for example, could lead to larger production scale and substantial savings in manufacturing tooling investments.[8] Multiple products tailored to specific niches could be derived from each platform, and these variants should enjoy lower overall development costs thanks to the cost sharing. Platforms also enabled reductions in product development lead times because of reuse. The platforms themselves could be adapted for new markets or evolved for new generations of products (see **Exhibit 11**). This allowed development costs to be spread across higher volumes. It also facilitated unit costs reductions as manufacturers improved their processes and reaped gains from production learning and moving down the experience curve (see **Exhibits 12** and **13**).

Platform strategies have been used for many different products where modular architectures and component reuse drastically reduced development costs. Sony Corp. of Japan famously dominated the portable audio market of the 1980s with its Walkman cassette music player using a handful of basic mechanism platforms while introducing almost 250 differentiated new models over the course of a decade.[9] 85% of the models incorporated only minor rearrangements of existing features and redesigns of the external case.[10] Similarly, Black & Decker used platforms to offer a wide range of cordless drills and other battery-operated power tools under five different brands with differentiated features and price points.[11]

When automakers first started using shared platforms, markets weren't as fragmented as they became in the 2000s. Many car models enjoyed sales volumes of a half million or more units per year, so platforms offered a way to reduce costs by sharing common parts across even larger volumes. It also helped them to quickly develop derivative products at lower cost. Over time, the number of models sharing a platform increased.[12] The key was the distinction between common elements that were shared, and elements that were unique to individual derivatives. Some firms shared so many components that their products became hard to distinguish from each other, causing confusion in the marketplace. At one point Chrysler Corporation (now part of Stellantis) had an entire product line of cars and minivans based on its single "K" platform, but the company ultimately discovered that it could not excel in any single segment because of the design compromises that were made to span such a large range or requirements.[13] It eventually replaced K with three new platforms: LH for midsized, PL for subcompacts, and JA for compact/mid-sized vehicles.[14] Thus the major challenge in platform design was to balance the desire for commonality with the need for product differentiation and capability to support widely varying needs.

A platform development team created the basic design, standard components, and the specifications for how subsystems were integrated. Automakers varied in their choices of what to include in their platforms, some preferring to include more components, while others tried to include fewer. For internal combustion engine (ICE) vehicles, the narrowest platform definitions included the front floor, underfloor, engine compartment, and vehicle suspension system.[15] Volkswagen Group's "Modularer Querbaukasten" (MQB) platform included front and rear axles, front ends, rear ends, exhaust systems, brake systems, and other elements that were shared across 40 models within its VW, Audi, Skoda, and SEAT brands,[16] and was designed for transverse-mounted engines covering the A – C segments.[17] The Ford Motor Company defined some of its platforms around common locator points among three major units of the underbody frame.[18]

The challenge in vehicle platform strategies was to achieve high volume and hence lower cost for as much of the vehicle as possible. At the same time, engineers had to ensure that the platform could respond properly to all of the different top hat configurations in terms of vehicle weight and balance, handling characteristics, and overall noise, vibration, and harshness (NVH). The question inevitably

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revolved around the boundaries of the platform, and what was the architectural bandwidth within each of those boundaries?

Kent Bovellan's Work on Vehicle Platforms

Over the course of his 40-year career in the auto industry, Kent Bovellan worked on numerous vehicle platforms. He started as a computer-aided engineering (CAE) specialist at Saab Automobile AB in Sweden. Saab Automobile was the car division of Saab-Scania, spun out in 1989 with General Motors owning a 50% sake, increasing to full ownership in 2000. Bovellan was able to "learn the whole company" while he was there, becoming the head of "body in white," the initial stage of assembling a vehicle's frame from all the structural members prior to painting and assembly. From there he moved to vehicle integration lead and became Saab's chief engineer. Then he moved to the U.S. for a year to work on GM's mid-sized front-wheel drive Epsilon 1 global vehicle platform. This platform debuted in the Opel Vectra and the Saab 9-3, and was also used in the Chevrolet Malibu and Maxx, and Pontiac G6.[19]

Epsilon 1 was a global platform with a high level of common components. The Chevrolet, Pontiac, and Opel brands used common seats, chassis systems, and climate control systems. The only major differences were that GM Europe wanted to have one type of engine mounting system, and Saab wanted a premium version for better NVH characteristics. Fuel tanks varied from market to market because of emissions requirements. In the U.S. Epsilon 1 vehicles were considered small cars; in Europe they were considered C Class.

As the outlook for Saab dimmed in the mid 2000's, Bovellan moved over to Volvo, where he became the head of concept engineering, developing top hats and architectures. At the time Volvo was owned by Ford, so he had the opportunity to work at Mazda in Japan for nine months on its SkyActiv platform. Ford had a long-standing partnership with Mazda, owning a stake from 1979 until 2014. "I should have made them use our European architectural platform," Bovellan explained, "But instead I got involved in developing SkyActiv. I learned how Mazda developed platforms, how to think about bandwidth from the beginning."

When Ford sold Volvo to Geely in 2010, Bovellan stayed at Volvo and took responsibility for compact cars from the S60 to the larger XC90. "Now that I had done Epsilon 1," he recounted, "I was thinking no more platforms for me!" Since it was no longer part of Ford, Volvo had to transition away from using Ford vehicle platforms.

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CMA Architecture

In February 2011, Geely announced an $11 billion five-year investment program in Volvo that sought to double worldwide sales by 2020. The plan included investments in new cars and manufacturing facilities, as well as a new China factory for Volvo. Using some of those funds, Volvo's engineering team set out to design a new platform for larger C/D, E, and J segment vehicles, which it called its Scalable Premium Architecture (SPA). This was to meant to support larger cars like the Volvo XC90 and S/V90 models, as well as two low-end vehicles - the XC60 and S/V60. SPA was designed for both gasoline and diesel engine versions.

Volvo lacked a platform for smaller vehicles, and it needed to discontinue using Ford platforms. In that timeframe, Geely Auto's vehicles were all more or less point designs, so Li Shufu challenged both Volvo Cars' and Geely Auto's engineering teams to develop a modern architecture that they could share for C segment vehicles. This marked the beginning of discussions on a new Compact Modular Architecture (CMA). Mats Fägerhag, who formerly led vehicle systems development for General

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Motors Europe and then moved first to Saab and then Volvo, was charged with establishing CEVT to develop CMA and other platforms to be shared between Geely and Volvo. Fägerhag tapped Bovellan to lead the development work.

Because CMA was planned to span a wide range of needs, it was designed to be highly modular, with fixed interfaces for attaching components. Designers could attach nine different suspension systems with 80% common parts, or plug in different heating, ventilating, and air conditioning (HVAC) systems using a common housing and modular components that would support everything from a one-zone manual system to a premium three-zone fully automatic system. It could incorporate a four cylinder gasoline engine as well as an electric powertrain for plug-in hybrid models.

The first application of CMA was for a new vehicle badge: the Lynk&Co 01, for which CEVT engineers also developed the top hat. After the completion of CMA, Bovellan went back to work at Volvo. CMA was subsequently used in the Lynk & Co. 02, 03, and 05, the Geely Xingyue family of crossover vehicles including the Xingrui, the Volvo XC40, and the Volvo C40 electric. CMA underpinned the all-electric Polestar 2 introduced in 2019[20] under the Volvo sub-brand, which many car magazine reviewers compared to the Tesla Model 3. Polestar vehicles were produced in a new Volvo factory in Chengdu, China.

In February 2017, Bovellan was invited to move to China to start Geely's battery electric vehicle (BEV) programs. That marked the beginning of the development of Geely's Sustainable Electric Architecture (SEA).

Geely Architecture Development Process

When Bovellan arrived at Geely in Hangzhou Bay, Cixi, China, he set about establishing a disciplined architecture management process. Historically Geely Auto's vehicles were point designs, supporting a single vehicle and variants, though the infusion of CMA into the Xingyue family as well as the increasing diversity of market segments and competition had built a consensus around the need for a true platform-centric approach.

Bovellan laid out principles for an architecture management strategy, which called for building a system from:

- A modular arrangements of components, both physical and logical.
- Interface standards between these components.
- A "Modular Toolbox" composed of interchangeable components, both hardware and software, that could provide scalable performance and cost for usage in multiple vehicles across segments.

This would lead to lower development costs and manufacturing investments, reduced R&D fixed costs, keep complexity under control, and enable decoupled development of the modules.

The first step was defining the bandwidth for an architecture – what would be the range of allowable dimensions, specific attributes, performance, and cost targets. This included consideration of how the system would scale, for example increasing the driving range for a BEV by adding denser batteries. Then desired attributes for specific platforms were mapped to market requirements (see **Exhibit 14**). This sought to identify where components could be shared across platforms, and where they needed to be unique. The steering system was an example where there was a large variation across

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classes of vehicles. In a light class B vehicle, the electric power steering (EPS) motor could be placed directly on the steering column, but increasing weight of the vehicle necessitated a shift to more elaborate systems with the steering drive motor placed directly on the steering rack. Suspension components were also highly variable. Variation in physical dimensions like height, width, or length of the vehicle gave rise to the notion of architectural bandwidth, how much a part could be stretched or shrunk dimensionally within an overall platform's design (see **Exhibit 15**).

A key step was defining the boundary between the platform and the top hat. For this, Bovellan distinguished between "architecture parts" and "architecture interface parts" (see **Exhibit 16**). The architecture interface part provided the standard connection points that all the different top hats would use when attaching to the platform. Platform development costs were roughly three times the development cost of a top hat, so maximizing reuse across a wide range of vehicles was a financial priority.

Feasibility of architectural layouts was evaluated using a range of CAE tools, with an effort to identify key parameters and the ability to meet overall vehicle requirements. All of this was documented in an "architecture red book" which served as the internal engineering reference. Bovellan also articulated a set of core development principles listed in **Exhibit 17**.

The SEA Platform

Most companies started with their ICE platform. The first step is to transfer it to an electric vehicle. Keep many of the dimensions, just put in batteries. VW has done it, all the European makers have done it. So the Mercedes EQ, the Audi e-Tron, the new BMW, every one of them is a converted ICE platform. Geely has already been down this road – you know the EV car that has the same proportions as the ICE car, only take away the grille. But the rest is like a normal ICE car. The first company in Europe to come up with a pure electric platform was Volkswagen with its MEB.

We didn't want all the compromises, we didn't want to have the old designs. We wanted to do a platform that was completely electric. We were inspired by all the start-ups that went directly to EVs. That meant we had to do the full range. If we wanted to be in all the segments, we had to do everything, it's a huge investment! We can't use the same top hats. We want to have a distinctive design language for all our electric vehicles.

— Kent Bovellan

Geely's SEA platform was a chance to start with a clean sheet of paper, unencumbered by any legacy requirements for ICE vehicles. When Bovellan first outlined the new BEV architecture, he envisioned three platforms to cover the entire range of vehicles. "In principle my process is totally separate from the top hat development," Bovellan explained. "In principle, I can do architecture development without any top hats; I use what I call a fake top hat." As part of the interface specification, the top hat had to meet certain requirements. This was not always straightforward because the platform had to anticipate and account for the overall vehicle dynamics – the loads and different vibrational modes – that different top hats might impose on the chassis system. He elaborated:

> I learned from all the work I've done, there is a difference between a hatchback, sedan, SUV, whatever car you do. There are challenges with an SUV compared to a sedan. You have to take these into consideration when doing the architecture.
>
> It turns out that it is much more difficult to do the top hat for a hatchback. When you drive a sedan on uneven roads, you don't get any big vibrations or disturbances from the back lid. With a hatchback, you're twisting the whole lid. So the lid, when it vibrates, it

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> pumps noise into the passenger compartment. You've got this low pressure noise. The lid is attached to a "D" ring, and the D ring is leaning in a hatchback, so you get the whole D ring pumping noise into the car. A hatchback is really tricky. A sedan is much simpler because you disconnect the luggage compartment from the passenger compartment.
>
> Once you know all this, then you can develop the architecture independently from the top hat … in principle.

In many respects, the platform design for an electric vehicle was simplified. For ICE vehicles, careful attention had to be paid to the weight distribution because of the placement limitations of heavy components like the engine and powertrain. For EVs this was simplified because distributing the battery weight to achieve a 50-50 front/rear balance was much more straightforward – power was moved by copper cables rather than mechanical linkages. Bovellan elaborated:

> With a BEV we were not locked into a big ICE engine and we were not locked into the fuel tank to get vehicle height. The only problem you have is the height of the battery.
>
> Many companies think that customers don't care, customers just want a nice car. They plug in an ICE engine, a PHEV[2] engine, or an EV engine, and they don't think customers believe you make a lot of compromises. But an EV platform based on an ICE platform will never be as efficient as a pure BEV platform. I can make a smaller engine space, I can move the structural members in front because EVs have a smaller engine. I don't make any compromises for fuel tanks or anything. In CMA the body is by itself, it's self-carrying. In SEA, the body is integrated with the battery box, so the battery box is a structural component in SEA.
>
> If you go from crossover vehicles upwards, no problem. An SUV should be high, it's no problem to place the battery. But if you do low sedans, then you get into more complications. You have to do more compromises because you have to account for the battery height. A really low sports cars is a little bit more complicated to do in a BEV than with ICE, but it's the only advantage with ICE engines – the height of the vehicles. But an EV platform based on an ICE platform will never be as efficient as a pure BEV platform.

"SEA is not one architecture, in principle it's five at the same time," Bovellan explained. "We started with SEA1 and SEA2, and then the types grew over time." Much as the Volkswagen Group designed MEB for its mass market vehicles and its Premium Platform Electric (PPE) for up-market car lines like Audi and Porsche,[21] the Geely team targeted SEA1 at premium D to F segments competing with vehicles like the Audi A5-A8, and SEA2 at mass markets like the Volkswagen Group MEB (see **Exhibit 5**), for segment B to D cars.

Geely then added SEA-Sport for larger performance oriented vehicles, with features like support for rear-wheel steering (*i.e.,* four-wheel steering), active roll bars, and continuously-controlled damping – an adaptive suspension technology. SEA-Sport also envisioned the future incorporation of 800 volt systems, much like the Porsche Taycan, which would enable much faster charging than the predominant 400 volt systems used by Tesla and most other EV makers. Here Bovellan was contemplating an 800 volt system with a 275 kilowatt electric motor in the front and a 450 kilowatt electric motor in the rear that could accelerate the vehicle from 0 to 100 kph in 2.8 seconds. It added

[2] PHEV stands for plug-in hybrid electric vehicle.

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SEA Commercial for light trucks, busses, and commercial vehicles ranging from 3.5 to 5.5 tons carrying 9 – 12 passengers. Finally, it added SEA-Entry as a design study for entry city and minicars.

The rapid pace of development in the BEV market meant continuing platform investments, with a likely new round of platform developments in the next three to five years. This might be driven by higher capacity batteries and smaller battery packs, which meant more packaging efficiency inside the vehicle. "The key is not to overinvest or make wrong choices," Bovellan commented. "Some of these technologies that are coming will start to standardize, and that means you have to have a shared picture (with other vehicle makers) and have the same strategies and tactics, otherwise you can't build up the (charging) infrastructure."

Geely's ambitious EV platform roadmap meant Bovellan had over 1,000 engineers working on the vehicle architecture team. It was an enormous investment, but Bovellan observed that "I can do it a lot cheaper than I could in Europe." He acted as the chief engineer on SEA1 and SEA2; he supervised the other three teams with daily morning meetings. "We will not let our EV cars come out second, you know," he added. "That was not the purpose we did them, so we want to very quickly come up in a leading position when it comes to EV cars." SEA had grown to become one of the largest vehicle platform projects in the industry.

SEA as Open Source

When Geely publicly launched the SEA architecture, it also announced that it would make the platform open-source.[22] The motivation was to build as large a volume as possible using its platforms and architecture. This would facilitate moving down the learning curve. Geely was already sharing across its own brands, but this opened up the possibility of even larger volumes. Donghui Li, CEO of Zheijiang Geely Holding Group explained:

> The SEA platform was designed to be open-source. Leveraging the platform, Geely aims to establish partnerships and build an ecosystem for smart EVs. The economies of scale created by an open ecosystem, as well as the standards developed for the SEA platform would be a moat for Geely over the long run.
>
> Currently eight brands are using the platform, with more than 16 models under development. Jidu Auto, the joint venture between Geely and Baidu, also uses the SEA platform. In these partnerships, Geely not only plays the role of a manufacturer, it also engages deeply in the engineering, research, and development. Empowered by the SEA technology, Geely hopes to elevate the overall quality of smart EVs.

Competitors were sharing their BEV platforms as well. Volkswagen announced plans to share its MEB architecture with Ford Motor Company,[23] while Honda announced plans to use GM's Ultium BEV platform.[24] Other Chinese firms, notably electronics contract manufacturer Foxconn, had indicated an intent to move into BEV manufacturing as well.[25] For Bovellan, car manufacturing was shifting to a new business model:

> If you pay this entry ticket, you can get all the design data, the tools for yourself, or you can buy parts from us, or we can source them together. We can get a better price, we have very good purchasing. Or we can manufacture the car, do the whole car for you. Or you design the top hat and we do the underbody, and we can produce the car. We can do a complete car, you just do the design that you want to have and we do the rest. We have all kinds of business models. We can do joint ventures, so we're very open to all types of cooperation, because it costs a lot of effort, especially investing in factories in the

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beginning. Developing electric vehicles initially will cost nearly as much as developing normal cars.

The New Zeekr D-Segment Car

Many competitors try to sell cars as premium, but in reality they are in the volume segment. If we want to do a really luxury vehicle for Zeekr, a big car, we will invariably end up choosing SEA1. But in the D segment, there will always be a discussion. Should we go with SEA2 or SEA1?

— Kent Bovellan

The proposed D segment car would be a new vehicle in the Zeekr lineup, a new premium BEV brand. Smaller cars on a given platform inevitably suffered from costs problems, while larger vehicles suffered from less than premium attributes. If a manufacturer achieved its cost targets on the low end, it would have a negative impact on the high end. The typical tradeoff was to center the platform on the C car, and stretch it to a D car. That meant careful cost control on the B car.

The way Bovellan thought about the problem was how would they differentiate a D car from a B or C car built on the SEA2 platform? They could scale the length of the body and chassis, within the allowed bandwidth (see **Exhibit 16**), or they could do performance upgrades like introducing an 800 volt system and all-wheel drive, or putting in a larger battery. Using SEA2 would also give them more money to spend on the top hat, perhaps with a flexible seating system, or more hospitality features like lighting and infotainment features like a heads-up display. Spending less money on the platform underpinnings meant more money available for features that drivers would touch and feel. On the other hand, building a D car on SEA1 would mean scaling down the body and chassis. That wouldn't save much money, but a shorter wheelbase would also mean a smaller battery, and that would certainly reduce costs. Bovellan explained:

> The biggest challenge when it comes to actual development is the D segment. You can do a D segment car using SEA2, the B to D platform. When you use it for a D car, you will have no cost problems at all. You can also make a D car using SEA1 – the D to F platform. That means that you put in premium systems into the D car. We have to choose now. Do we want to have a premium system? This is like a comparison with Audi/VW. If we have the money, and want to do a really, really top premium car, fighting Mercedes, BMW or whatever, we'll choose SEA1.

The Lynk & Co 01 had launched using CMA, and the new Zeekr 001 used the SEA1 platform complete with a 400 volt electrical system, air suspension, and a target driving range of 440 miles/708 km. Zeekr was trying to compete with brands like Tesla or Nio. Thus using SEA1 made sense. "If this is going to be a Geely car, there's no discussion," Bovellan argued. "It has to go B to D. Volvo would go the other way, but Zeekr is a little in between."

A chassis upgrade with SEA1 would likely be important to EU customers. SEA1 used a short long arm (SLA) suspension, also known as an unequal length double wishbone, for the front suspension, which made for superior vehicle dynamics and load handling. But in China, people spent less time driving fast on autobahns and more time sitting in traffic. SEA2 used MacPherson struts for the front suspension, which was better for NVH, something that was important to Chinese customers. Bovellan added:

> Everyone tries to split the platform too much. They want to have the optimum for everything and won't share a single component. Even now when I work with several

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> different companies, I try to get the top hats together, I try to get them to agree about requirements, functions, and interfaces between the top hat and the architecture, agree about things so we can share interfaces. Otherwise, we create too many variants again.

In the end, the volume forecast offered by the marketing team was highly dependent on price, but it was also predicated on premium feature content and positioning. Should they pick SEA1 or SEA2?

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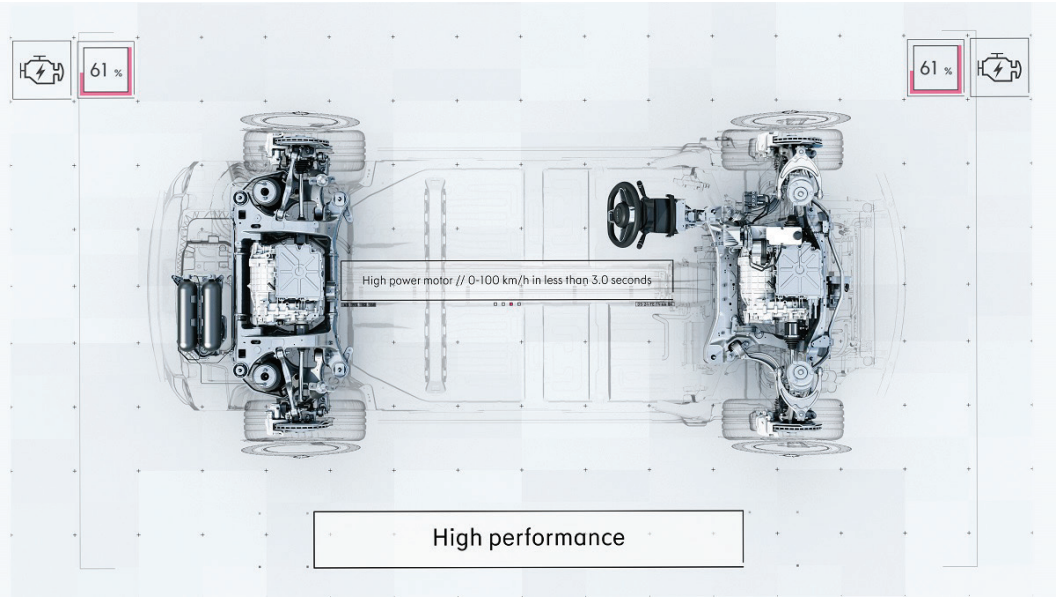
Exhibit 1 Car Segment Classifications

Segment	Description	Examples
A	City cars	Fiat 500, Chevrolet Spark, Kia Picanto, Renault Twingo
B	Small cars	Renault Clio, Opel Corsa, Volkswagen Polo Geely Coolray, Geely Icon
C	Medium cars	Audi A3, Honda Civic, Hundai Elantra, Mercedes A-Class, Toyota Corolla, Volkswagen Golf Geely Emgrand, Geely Binray, Geely Xing Yue, Geely Preface
D	Large cars	Audi A4, BMW 3-Series, Lexus IS, Mazda 6, Toyota Camry, Volkswagen Passat, Geely Bo Rui, Geely Hao Yue
E	Executive cars	Audi A6, BMW 5-Series, Mercedes E-Class, Tesla Model S
F	Luxury cars	Audi A8, Jauguar XJ, Mercedes S-Class, BMW 7-Series
S	Sport Coupes	Porsche 911
J	Sport utility vehicles (SUVs)	Honda CRV, Jeep Renegade, Toyota RAV4, Volkswagen Tiguan, Mitsubishi Outlander
M	Multi-purpose vehicles (MPVs)	Chrysler Pacifica, Renault Scénic, Volkswagen Touran

Source: Adapted by casewriters from "European classification for vehicle category based in UNECE standards, https://www.eafo.eu/knowledge-center/european-vehicle-categories accessed April 25, 2021.

Exhibit 2 Geely SEA1 Platform



Source: Company document.

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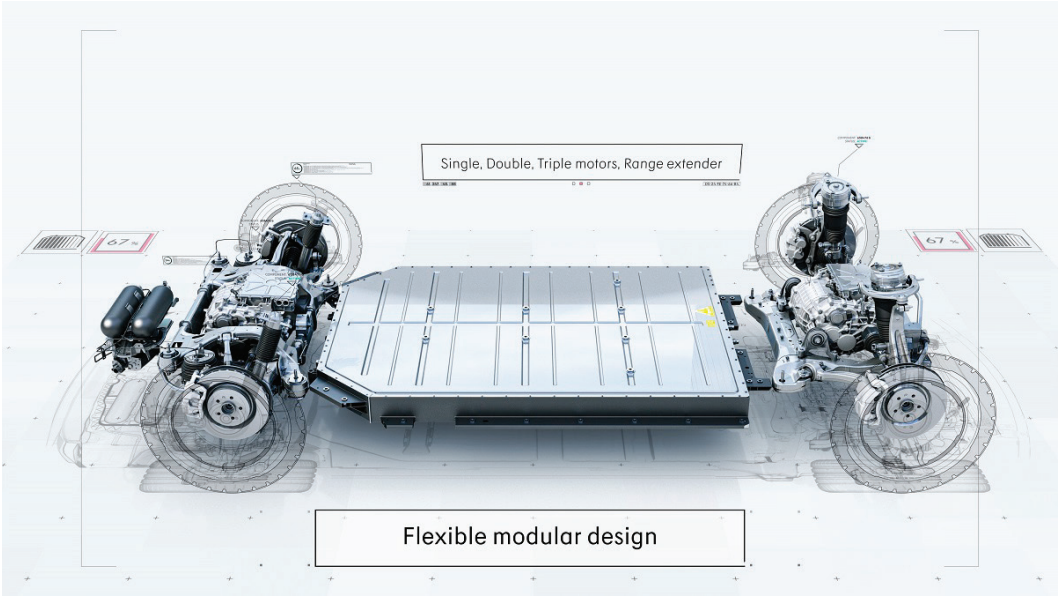
Exhibit 3 Geely SEA2 Platform



Source: Company document.

Exhibit 4 Geely SEA-Entry Platform

Source: Company document.

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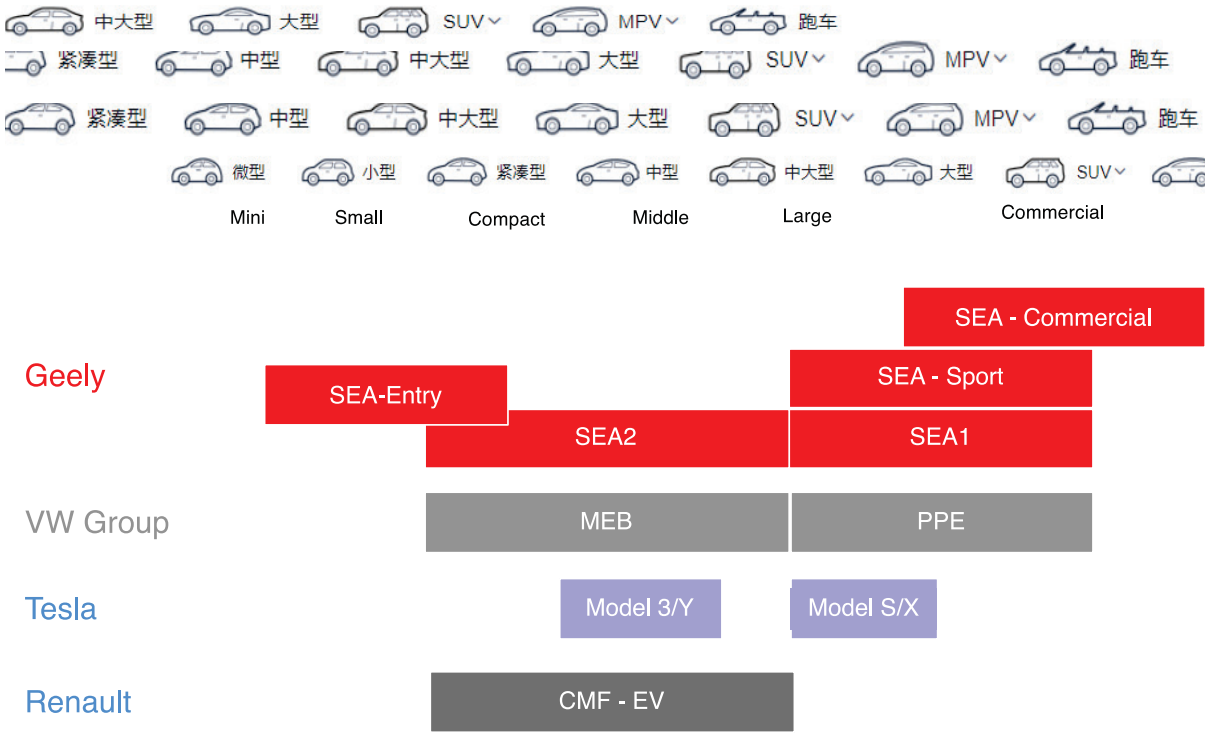
Exhibit 5 Geely SEA Platforms: Architecture – Vehicle Class Coverage, Comparison with Competitive Platform Coverage



Source: Adapted by casewriters from company document.

Note: The SEA architecture covers from the A to F segments with five architectures. The SEA-Entry is for 2/4 seat city cars, SEA2 covers from the B to D segment, SEA1 covers from the D segment to the F premium segment, SEA-Sport is for the high-tech D to F segments, and SEA-Commercial is for commercial vehicles.

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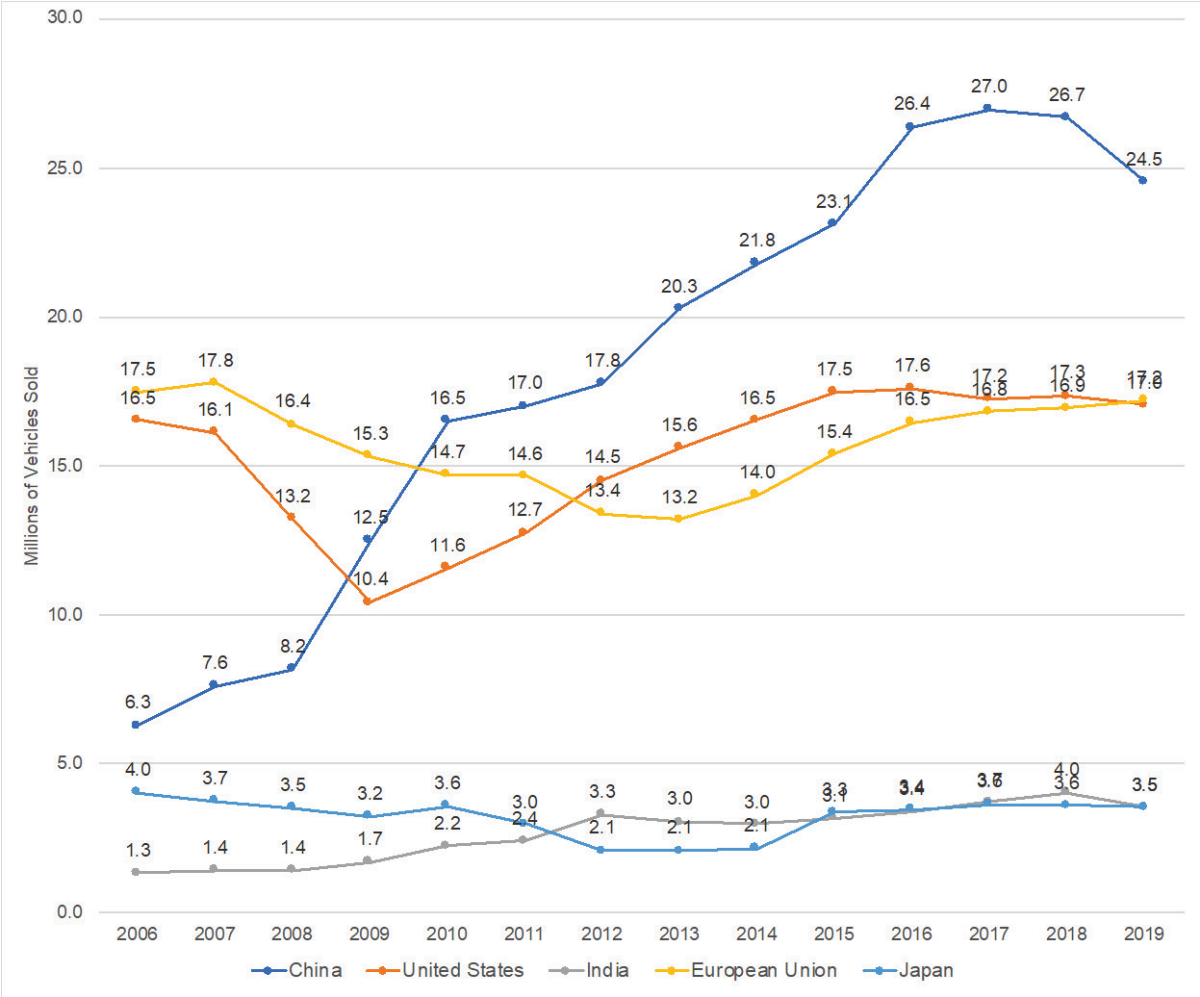
Exhibit 6 Sales of passenger cars in selected countries from 2006 to 2019 (millions of units)



Source: Adapted by casewriters from IEA, Global car sales by key markets, 2005-2020, IEA, Paris https://www.iea.org/data-and-statistics/charts/global-car-sales-by-key-markets-2005-2020 accessed May 27, 2021.

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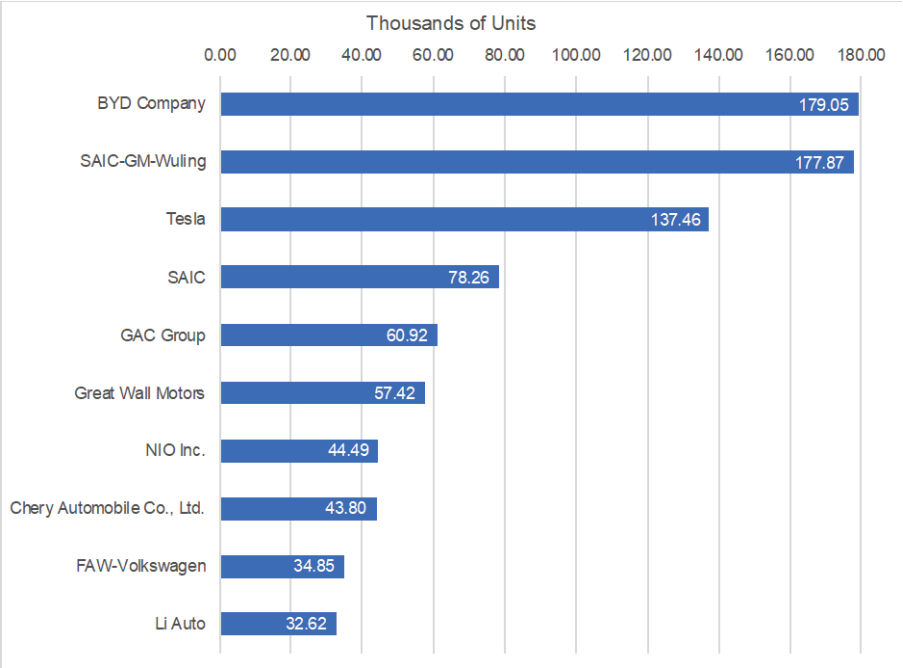
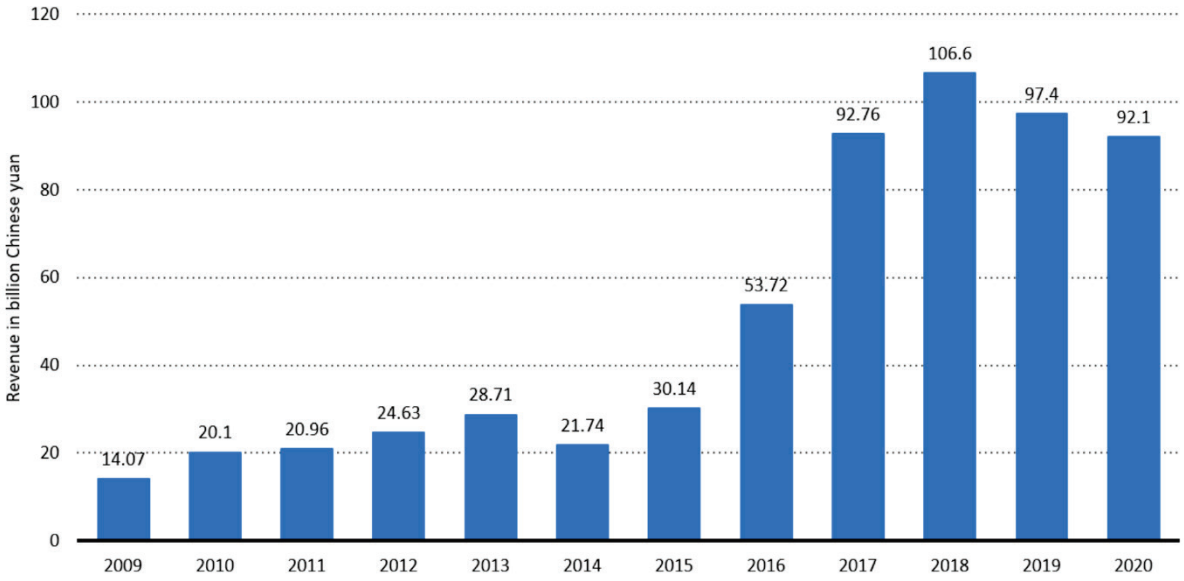
Exhibit 7 EV sales across China in 2020, by original equipment manufacturer (OEM) in 1000s



Source: Adapted by casewriters from statista.com, https://www.statista.com/statistics/976376/china-electric-vehicles-sales-by-oem/ accessed May 26, 2021.

Exhibit 8 Geely Automobile Holdings Limited's revenue from 2009 to 2020



Source: Casewriters based on company annual reports, http://www.geelyauto.com.hk/en/financial_statements.html, accessed May 27, 2021.

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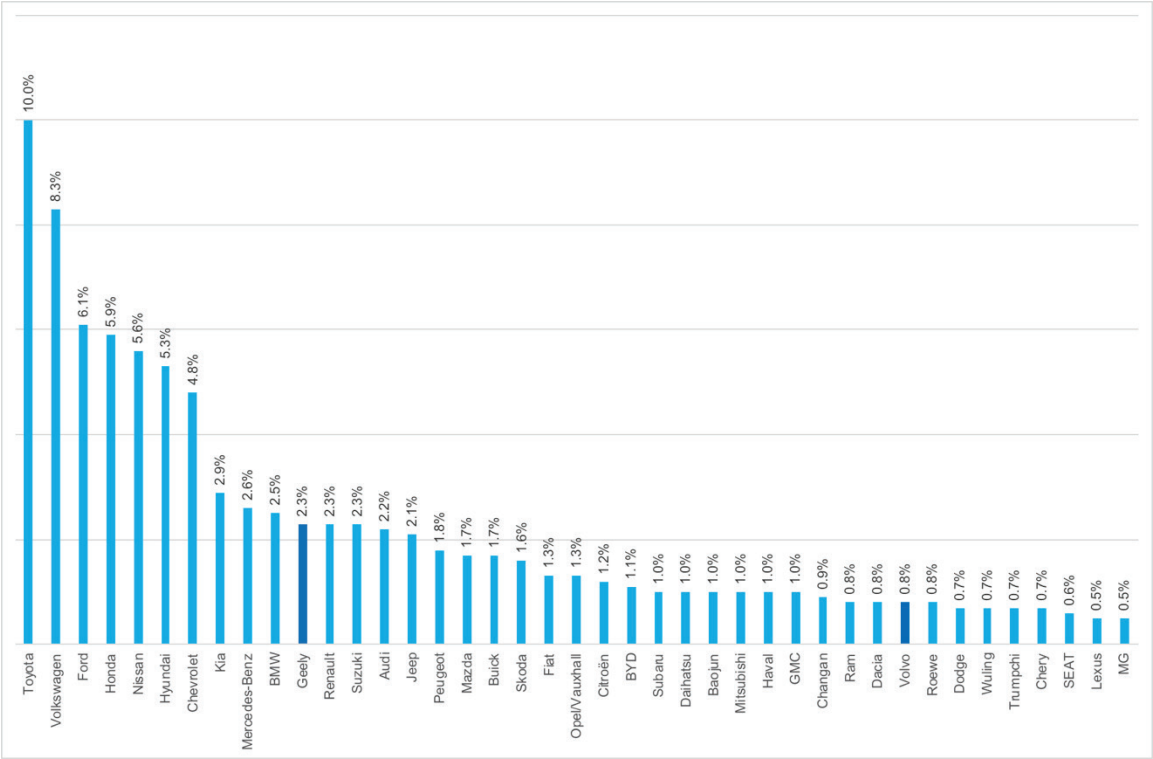
Exhibit 9 Brand Share of Passenger Cars Sold Worldwide in 2019



Source: Adapted by casewriters from Geely Report 2020, Statista Mobility Market Outlook, accessed May 2021

Note: Many brands in this ranking share platforms, e.g., Chevrolet, Buick, and Cadillac share General Motors Platforms, Volkswagen, Audi, Skoda, and Seat, Chrysler and Didge, etc.

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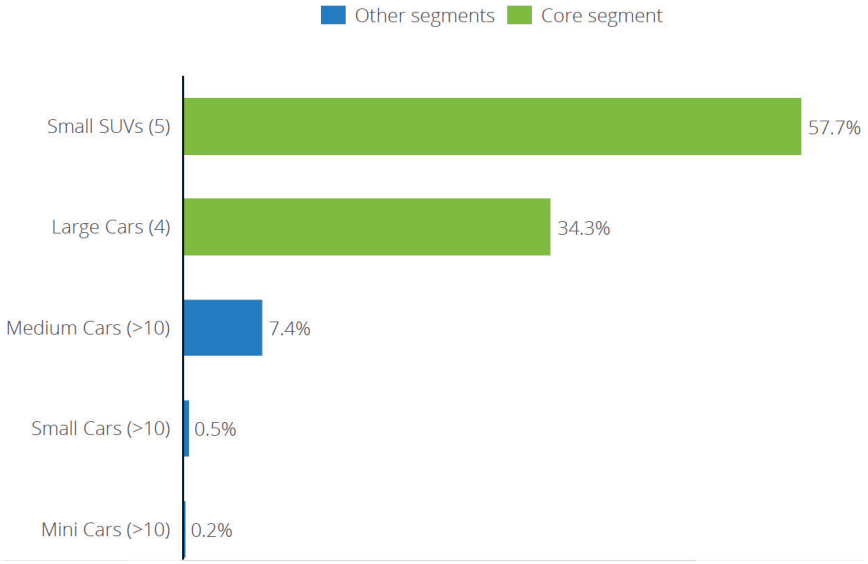
Exhibit 10 Revenue share in Geely's portfolio in 2019



Source: Statista, Geely Report 2020, https://www.statista.com/study/60874/geely-report/, accessed May 27 2021.

Note: This exhibit defines core segments as segments in which the make either generates at least 20% of their revenue, or holds a market leader position (top 10 in the segment) with at least 10% of its revenues generated in the segment. Numbers in the brackets show the position of the make in the segment.

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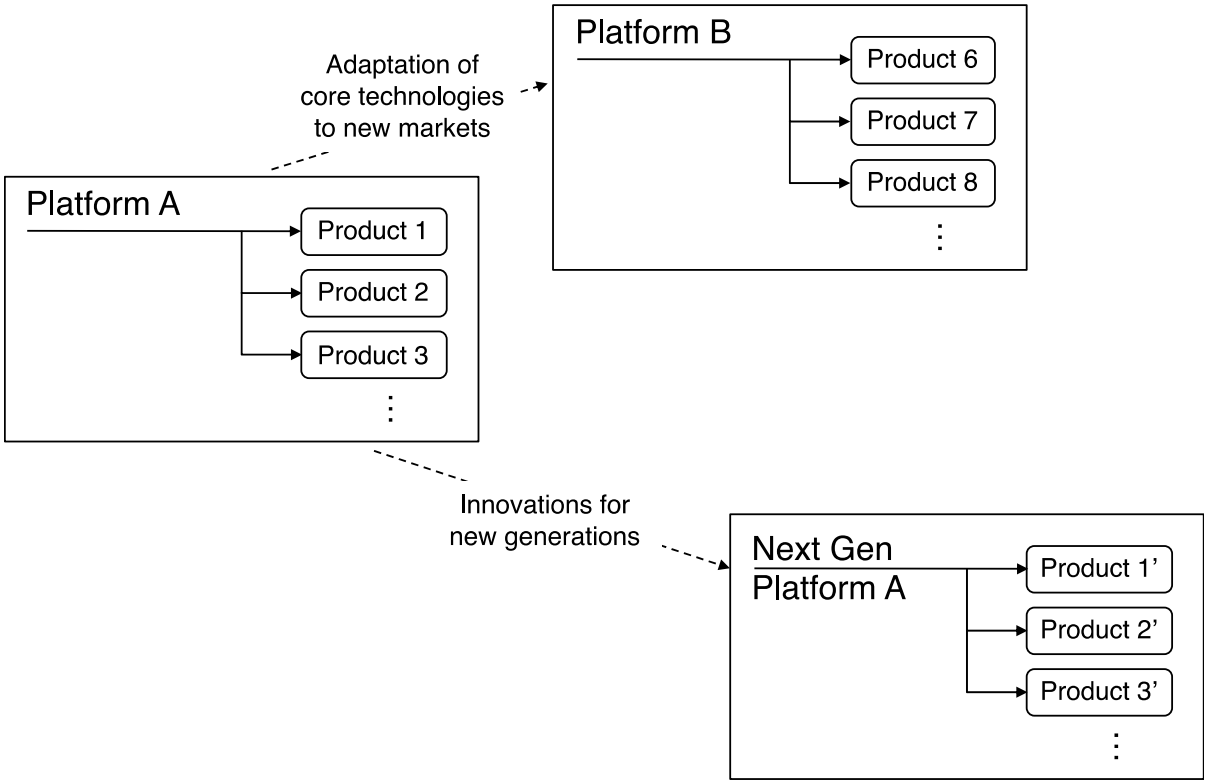
Exhibit 11 Product Platform Strategies



Source: Adapted by casewriters from Meyer, M. H., and J. Utterback. "The Product Family and the Dynamics of Core Capabilities," *Sloan Management Review* (1993): 29-48.

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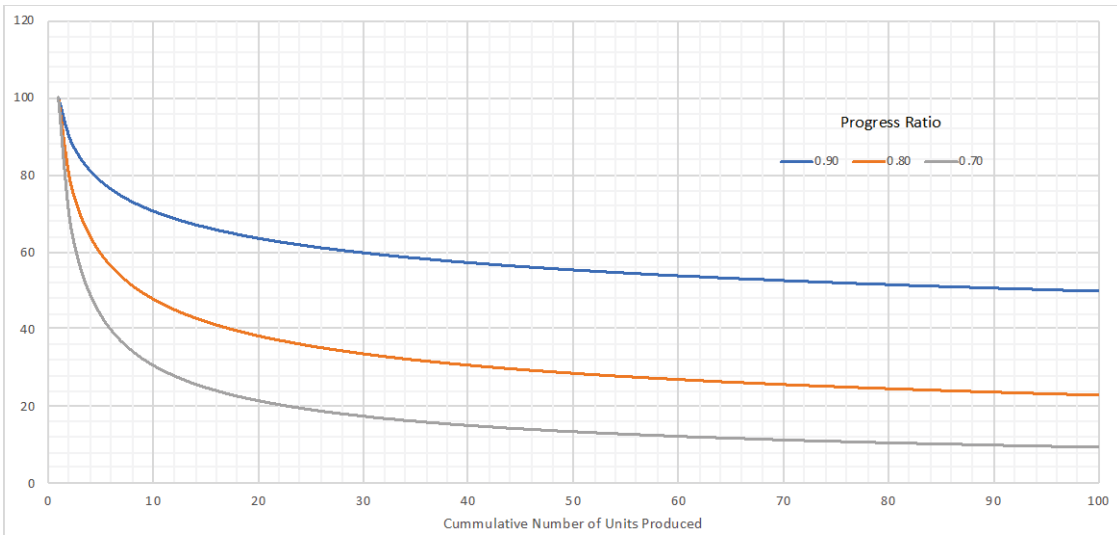
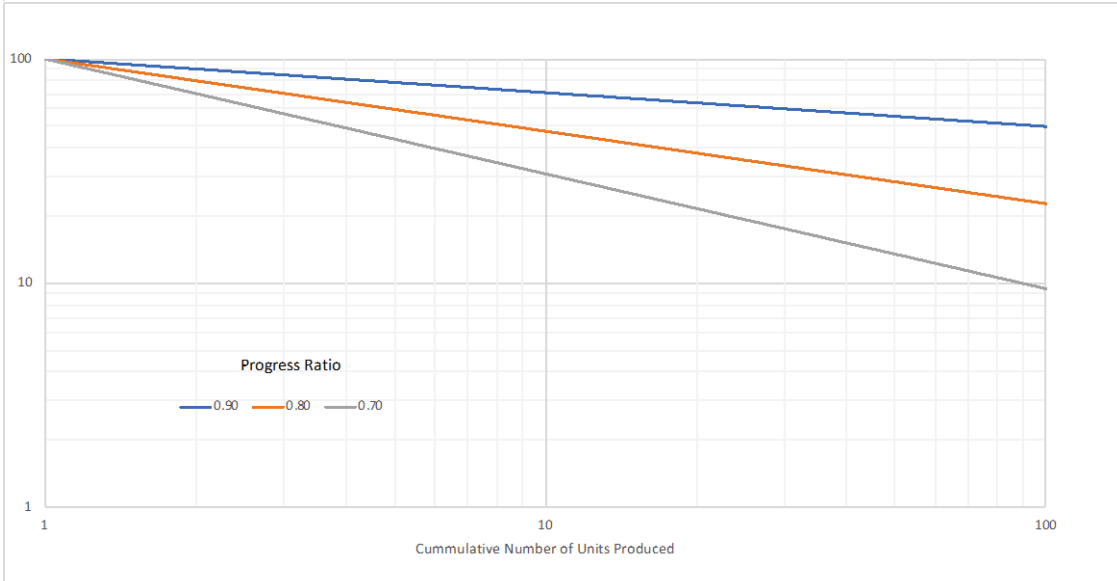
Exhibit 12 Cost improvements from experience curve effects





Source: Prepared by casewriters.

Note: The experience (learning) curve originated from the work of Theodore Wright, who studied aircraft production.[26] He observed that the more times a task was repeated, the less labor time was required in each subsequent iteration. Empirically this takes the form of

$$C_x = C_1 x^{\log_2 (b)}$$

where C_x is the unit cost of producing the xth unit, C_1 is the cost of producing the first unit, and *b* is the progress ratio. *(1 - b)* is the proportionate reduction in unit cost with each doubling of cumulative production volume. The experience curve benefits can be attributed to improvements in labor efficiency as workers' dexterity improves, standardization, specialization and work method improvements, improved use of tools and equipment, product redesigns to improve assembly efficiency and productivity, material substitutions and more efficient use of inputs, and a shared experience effect when multiple products share usage of common resources.

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Exhibit 13 Representative Learning Rates by Industry

Industrial Process	Progress Ratio
Aerospace manufacturing	15%
Automotive vehicle assembly, internal combustion engine	16 – 20%
Shipbuilding	15 - 20%
Machine tools, new models	15 – 25%
Electronics, repetitive assembly	5 – 10%
Electrical wiring, repetitive	15 – 25%
Machining operations	5 – 10%
Manual assembly + 25% machining	20%
Manual assembly + 50% machining	15%
Manual assembly + 75% machining	10%
Punch press operations, for stamping metal	5 - 10%
Welding operations, repetitive	10%
Raw materials (principally purchased)	5 – 7%
Purchased parts	12 – 15%

Source: Adapted by casewriters from Quarterman, Lee, "Learning & Experience Curves in Manufacturing," Strategos, Inc. (2014), http://www.strategosinc.com/downloads/learning-curves-dl1.pdf accessed June 5, 2021; Hirsch, W. Z. (1956). Firm progress ratios. *Econometrica, Journal of the Econometric Society*, 136-143; Sebrina, Lucia Diawati, and Andi Cakravastia, "Learning curves in automobile assembly line," In *International Conference on Industrial Engineering*. 2011; Dar-El, Ezey M., and Jacob Rubinovitz. "Using learning theory in assembly lines for new products." *International Journal of Production Economics* 25, no. 1-3 (1991): 103-109; Levitt, Steven D., John A. List, and Chad Syverson. "Toward an understanding of learning by doing: Evidence from an automobile assembly plant." *Journal of Political Economy* 121, no. 4 (2013): 643-681; Wiersma, Eelke. "Conditions that shape the learning curve: Factors that increase the ability and opportunity to learn." *Management Science* 53, no. 12 (2007): 1903-1915.

Note: Hirsch argues that machine work and assembly work varied by product, and that in most cases assembly work lent itself better to progressive savings than machine work, reflected in the lower progress ratios when machining made up a higher percentage of the process.

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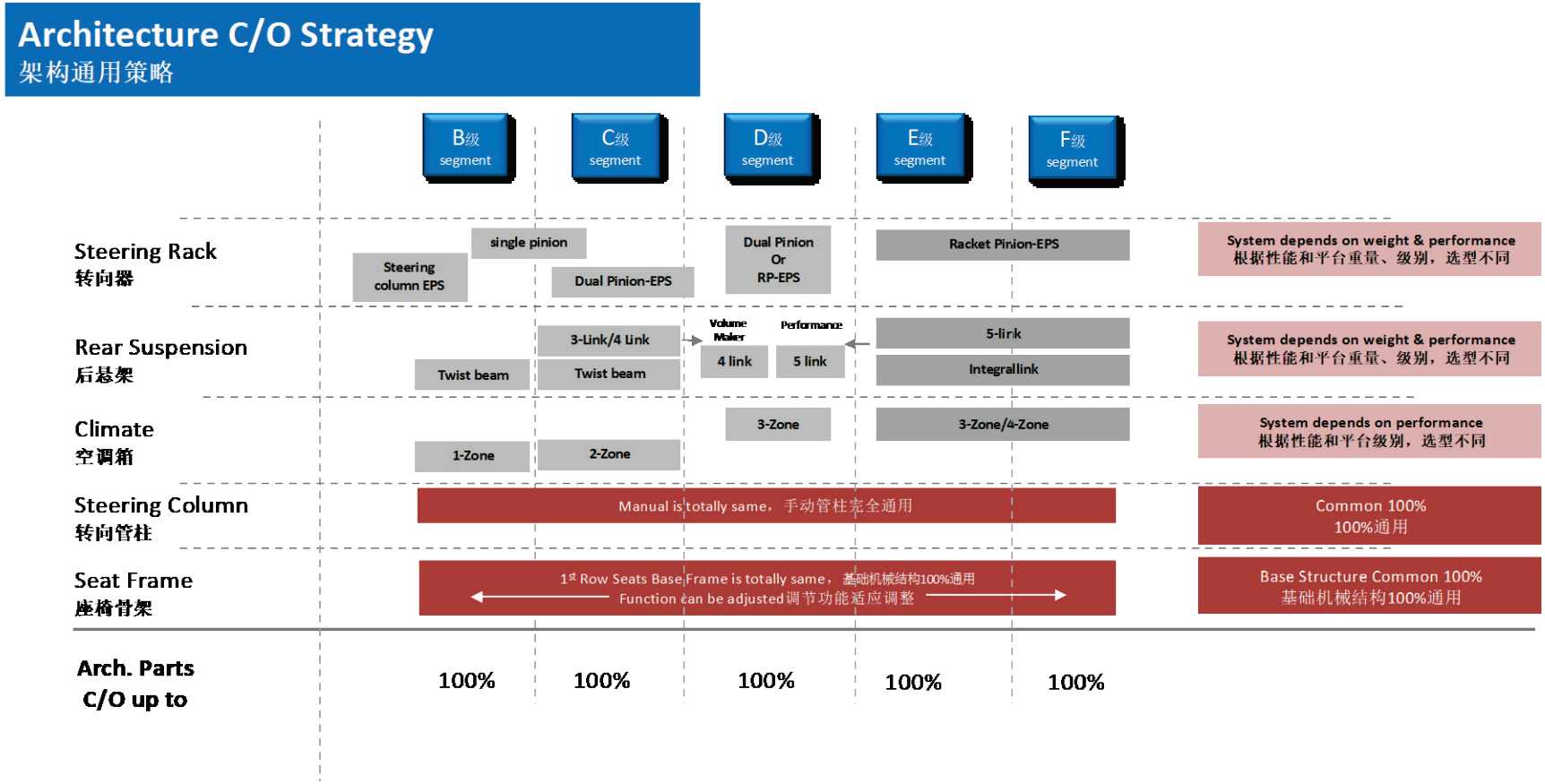
Exhibit 14 Geely Architecture Common/Overlap Strategy



Source: Company presentation.

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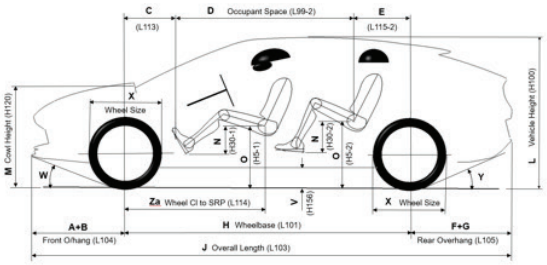
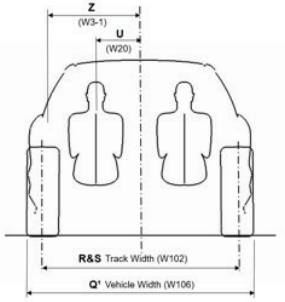
Exhibit 15 Geely Architecture Bandwidth Example – Key Dimensions

	CV Spec	Bandwidth						
	Main Dimensions Exterior	Min	Max					
J	Overall Length (L103)							
Q[1]	Vehicle Width, Front Axle (W106-1)							
L	Vehicle height, @ Curb 0 (H100)							
H	Wheelbase (L101)							
A+B	Front Overhang (L104)							
F+G	Rear Overhang (L105)							
R&S	Track Width, Front/Rear (W102-1/W102-2)							
V	Ground Clearance, Min @ Curb 0 (H156)							
W	Approach Angle, @ Curb 0 - Styling dependent							
Y	Departure Angle, @ Curb 0 - Styling Dependent							
X	Wheel Size (Max diameter)							
	Main Dimensions Interior							
C	Distance Front wheel CL to Pedals BOF (L113)							
D	Compartment Length (L99-2)							
E	Distance between Rear SRP & Rear Wheel (L115-2)							
N	SRP to Heel point, front/Rear (H30-1/H30-2)							
O	SRP to Ground, @ Curb 0 (H5-1/H5-2)							
T	Luggage Width (W202)							
U	SRP Width front/Rear (W20-1/W20-2)							
Z	Shoulder room - Front (W3-1)							
Za	Front Wheel CL to Front SRP (L114)							

- Measurement
- Exterior & Interior





Source: Company presentation.

Note: CL = Centerline, BOF = Body on Frame(?), SRP = Seat reference point

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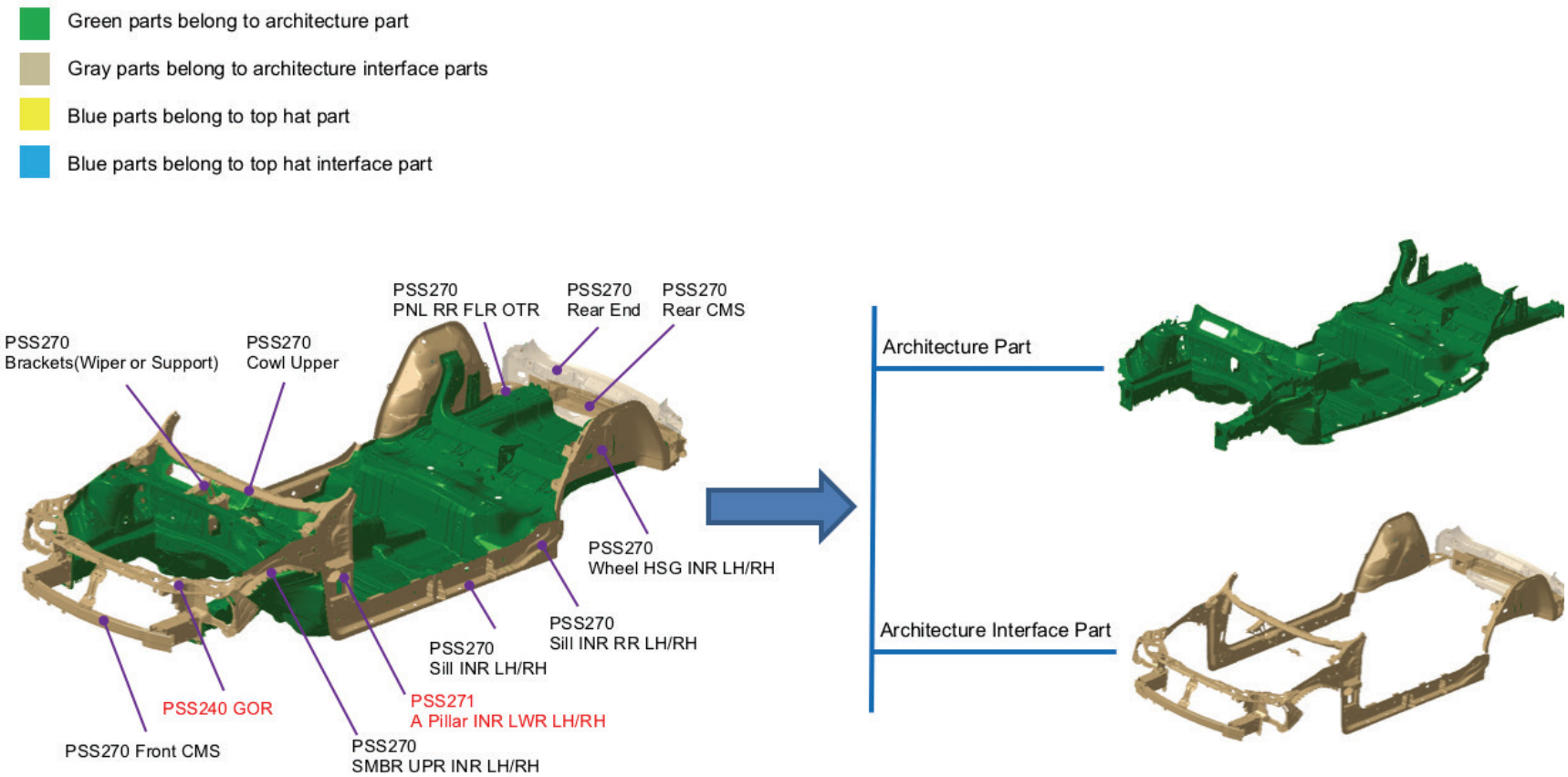
Exhibit 16 Architecture Parts and Architecture Interface Parts



Source: Company presentation.

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Exhibit 17 Kent Bovellan's Architecture Development Principles

Architecture Development Principles

1. Combability before completeness
2. Function before weight
3. Quality before time
4. CAE is a Design tool, do design changes directly in the finite-element model
5. Use multi-dimensional optimization (MDO) to reach weight target
6. Use Vehicle Integration(Packaging) and Attributes to direct PSS work
7. M1 is Job 1 for Architecture
8. At M1(UNV2) release all attributes to be green and weight on target
9. Focus on manufacturability as much as attributes
10. Regular PSS Design Reviews to secure quality
11. Operational Leadership: ex. Start-up meeting every day, no hierarchy in daily work

Source: Company presentation.

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Endnotes

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[8] Muffatto, Moreno. "Platform strategies in international new product development." *International Journal of Operations & Production Management* (1999); Suh, Eun Suk, Olivier L. De Weck, and David Chang. "Flexible product platforms: framework and case study." *Research in Engineering Design* 18, no. 2 (2007): 67-89; Muffatto, Moreno, and Marco Roveda. "Developing product platforms:: analysis of the development process." *Technovation* 20, no. 11 (2000): 617-630; Suh, Eun Suk, Olivier L. De Weck, and David Chang. "Flexible product platforms: framework and case study." *Research in Engineering Design* 18, no. 2 (2007): 67-89.

[9] Sanderson, Susan, and Mustafa Uzumeri. "Managing product families: The case of the Sony Walkman." *Research Policy* 24, no. 5 (1995): 761-782.

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[11] Sudjianto, Agus, and Kevin Otto. "Modularization to support multiple brand platforms." In *International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*, vol. 80258, pp. 125-138. American Society of Mechanical Engineers, 2001.

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[14] Connelly, Mary, *ibid.*

[15] Muffatto, Moreno, *ibid.*

[16] Sudjianto, Agus, and Kevin Otto, *ibid.*

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[18] ibid.

[19] Kranz, Ron, "GM: Epsilon must be more global," *Automotive News* (September 27, 2004)

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