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EVOLUTION OF MODULAR FLEXIBLE ELECTRIC VEHICLE PLATFORMS AMONG AUTOMOTIVE INDUSTRY AND BENEFITS IN BATTERY INTEGRATION

GANESH SANKARAN[1]*, S. VENKATESAN[2] & M. PRABHAHAR[3]

[1,2]Department of Mechanical Engineering, Vinayaka Mission's Kirupananda Variyar Engineering College, Salem, Tamil Nadu, India

[3]Department of Mechanical Engineering, AarupadaiVeedu Institute of Technology, Vinayaka Mission's Research Foundation, Salem, Tamil Nadu, India

ABSTRACT

The recent increase in EV growth influencing the need for dedicated EV platform development work among vehicle manufacturers. The EV Platform is an aggregation of sheet metal components. Electric Power train components and its architecture heavily influence the integration of battery packs in the car, design & development lead time for new variants and time to market. This article discusses the evaluation of BIW to flexible modular skateboard platform and critical events in EV platforms and how it influences the battery pack integration. It talks about the benefits and challenges in EV platform workstream and why automakers are involved in moving away from conventional ICE converted Platform to native EV platform due to policy decisions and scale benefits on the overall EV Ecosystem.

KEYWORDS: OEM (Original Equipment Manufacturers), Platform Architecture, Modular & Skateboard

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Original Article

INTRODUCTION

BIW or Body in White consists of all the Sheetmetal components, which are part of the bodyshell or vehicle skeleton, essential to provide the shape and strength to the car. Over the years, there is an integrated approach to vehicle design combinations. Few systems or sub-system s are combined to form next level assembly, or a high-level system called Platform; Typical vehicle platform consists of

- Underbody - Front, Middle, Rear & Trunk Floors, Engine Compartment bay, Frames
- Wheel & Tyres
- Suspension System

The floorpan is a significant part that is like a foundation to the Platform, and every other system is built upon it. The Platform primarily consists of parts, components, and sub-systems that share a standard design across past and potential future models with no significant re-design or manufacturing effort. The platform parts have a substantial percentage of commonality and find a place in the next vehicle design with re-use, minor modification, or carryover. The advantages of the platform approach are the elimination of design time, testing, validation of the same set of parts over and over in the next models.

Modular Platform

The major components and systems of the Platform or architecture are designed and validated separately and ready to deploy to another program or model; it becomes a modular design. It is like a concept of Brick by Brick building of vehicle using the modular design packs.

The modular design is a step ahead from platform sharing, due to its independent ability to function as a proven design element. It gives the designer a choice to create various modular design packs for systems like cluster, battery, Console, Instrument panel, Brakes, Horn, etc. The objective is to create as many modules as possible for a platform using design principles and validate the modules. One can review this database for an optimum solution for commonality features. Once a robust and optimized database is ready for modular designs, it is like a plug-n -play for the engineer to choose and use it for a platform. It has become a necessary engineering tool to start the base design due to the enormous benefit of time and cost-saving.

US-based American OEM, Ford reduced the number of platforms from 30 to 9 and with a plan to reduce further to just five platforms. These 5 platforms expect to deliver the small sedans to trucks, including EV powertrain [1].

Flexible Modular Platform (FMP)

Even with platform sharing and modular Platform, there are some challenges, and so the concept of flexibility introduced. The need for flexible design is inevitable in automotive due to newer technology upgrades and customer preference. The result is the all-new Platform from the previous one. This new derivative can be used for moderate to bigger size models up to SUVs with the benefits of economies of scale, flexible design, and production.

If a platform is carry over in a few different models/brands, the constraint is the overall size or dimension remains the same and cannot change. The Flexible modular Platform helps address the issue by feature protecting the design to increase or decrease the size/dimension so that it can be used for even models with different wheelbase or trackwidth depending on the model styling and architecture. The flexible Modular Platform is the basic unit of each vehicle’s design and engineering. The ability to select and integrate the right system architectures to deliver the desired attributes is the key to success.

OEMS & Respetive Platform Work

The OEMs benefit by quickly adapting to a proven platform and reducing time to Market to introduce EVs with their nameplate.The critical point to note is modularity & flexibility. It gives the product longevity to OEMs as it protects the future design upgrades and the option to modify the structure as per market need. The MEB, developed by VW, can use various battery packs of different sizes and capacities to suit the current and future requirements. It provides a choice for customers and manufacturers to choose the right product for the right Market. The modularity plays a significant role as it helps in brick–by–brick type of expansion for batteries to offer a small o long-range capacity battery.The below table shows the Global OEMs and the EV platform architecture details [2].

Table. 1: OEM’s and their EV Platforms

OEM	Platform Name
Volkswagen	MEB
Volvo	Compact Modular Architecture (CMA) Scalable Product Architecture (SPA 2)
Great Wall Motors	WEY Pi4 Platform
Daimler	Electric Vehicle Architecture (EVA)
Renault-Nissan-Mitsubishi	Common Module Family architecture (CMA)
Jaguar	I-Pace platform
JLR	Modular Longitudinal Architecture (MLA)
Toyota	e-TNGA platform
Hyundai	Canoo
General Motors	All-new modular platform and battery system, Ultium
PSA	EMP2 (Efficient Modular Platform)

Platform commonality in A & B segment benefits small car segment markets like India. Many derivatives can arrive with efficiencies in mass volume benefit and localized supply base for auto components. The critical point of consideration is the crash crumple zone, which is the same across the models using the same platforms. It is since significant development challenge to prove the design worthiness is crashworthiness. With the increased global safety regulations, it is much more stringent than the previous decade & there exists a substantial consideration when developing new vehicle platforms [3].

Future of Flexible Modular Platform (Fmp) in Electri Vehicles

The future Strategy is to design and develop a generic or standardized platform designed for global safety standards like GNACP for meeting safety criteria and suitably modify the rest of the sections like Tophat or upper body structures according to the local market requirement. It is easier to design from the sophisticated design rules and relax according to the demand, not the opposite. Further scoping helps in achieving fuel efficiency, homologation requirements, and customer needs.

CASE STUDY -1

As per the study by Sergio and Bruce [4], two major platform strategies are evolving for EVs.

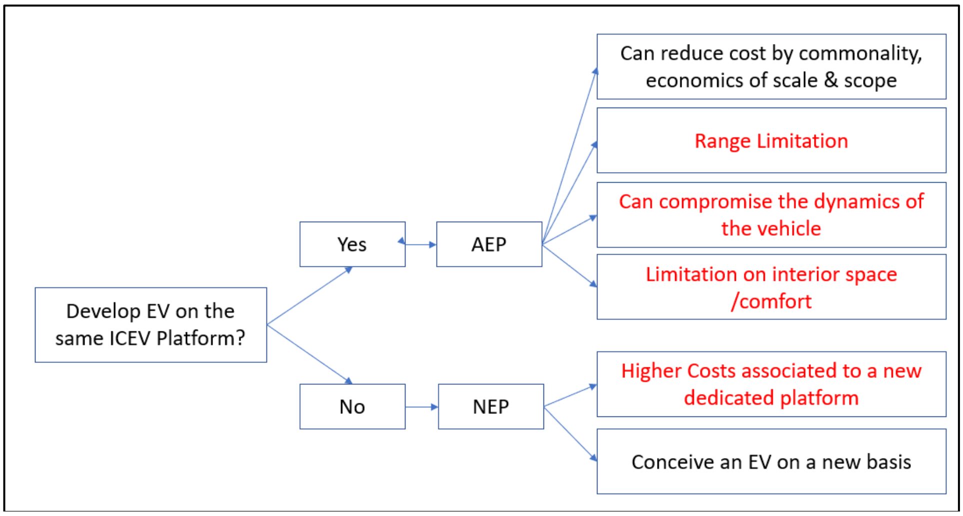

Figure 1: Development Options for EV from Start to Launch.

Electric Vehicle’s Platforms:

- Adapted Electric Platform (AEP)• New Electric Platform (NEP)
- Electric Vehicle’s Design:
- New Electric (Vehicle) Design (NED)• Adapted Electric (Vehicle) Design (AED)

The below figure shows how global OEMs are migrating from AEP+AEVD to NEP + NEVD methodology to gain maximum performance advantages in the EV market. Similarly noticed the migration of AEP+NEVD to NEP + NEVD quadrant. The conclusion from this chart is all-new EV platform development is non-avoidable to create more models. Accordingly, the new EV design is required to develop product differentiation for each EV models within OEMs.

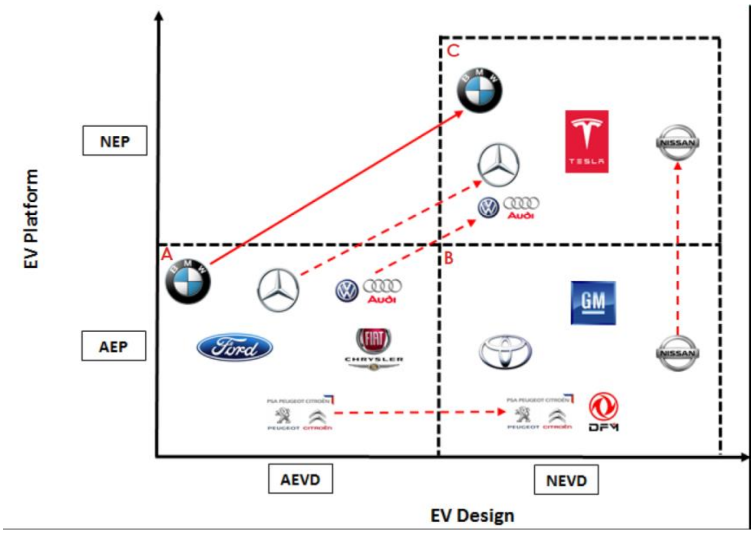

Figure 2: Mapping of OEMs Future Trend in EV Platform Strategy.

The authors conducted a study on 36 BEV's, which represents about 70% of all BEVs sold worldwide (2019) and shared the results.

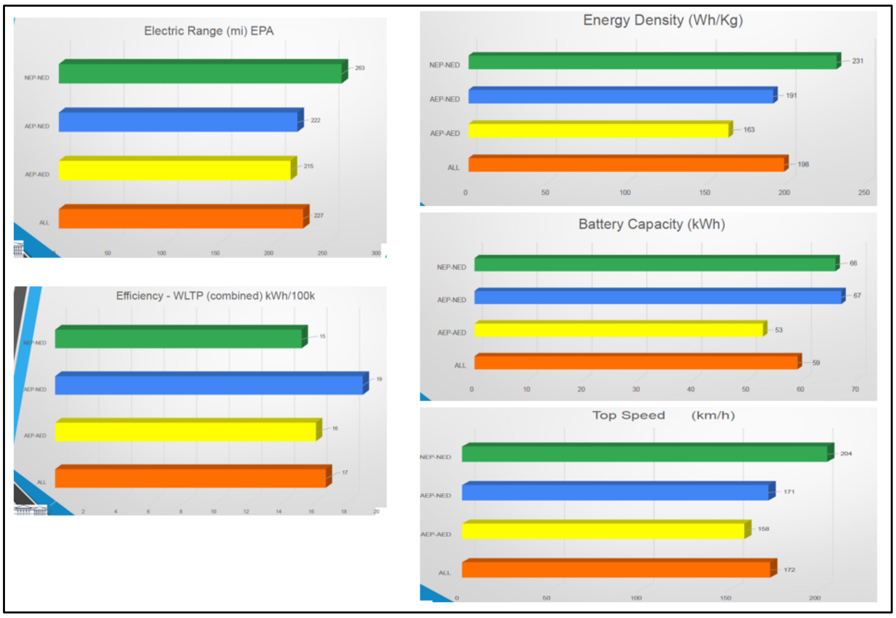

Figure 3: Segment & Performance Comparison of Vehicles using Native & Adapted Platform.

The strong link between the Platform adaption and Design methodology plays an important There is a clear linkage between a role in the battery selection, integration. The battery pack can be higher in size, which gives better efficiencies in Range, Power, Torque, and energy density.

It is due to the logical arrangement of the battery pack in the vehicle floor in Platform & its interaction with other EPT components and vehicle components to offer the right performance. It is decided by proper selection of Platform and design, whether NEP or AEP. Therefore, the type EV platform plus EV design (NEP + NEVD) is ultimately affecting the vehicle's performance positively. The move from AEP/AED to NEP/NED strategy gives much better vehicle performance metrics like top speed, torque, mileage due to more extensive Electric Powerpack options due to more space & flexibility.

CASE STUDY - 2

To meet the Time to Market, Chinese OEMs re-used the existing ICE based platforms & converted them into EV. It gave them reduced spending on the new floor, use of common parts from ICE cars to minimize the impact on capital. But with the changing business dynamics & competition on EV range/performance, the solution is not enough [5].

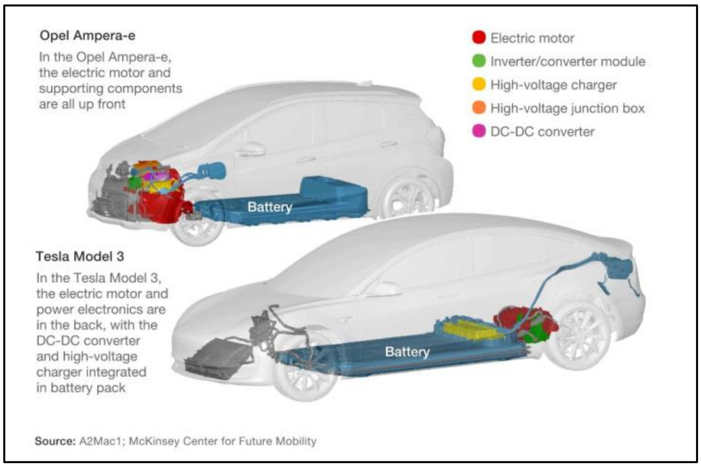

Figure 4: Battery Pack Integration on Native and Non-Native EV [6].

The layout of the native and non-native is shown in the above picture. The simpler and easier arrangement of EV systems is evident from the native EVs. The battery pack takes a well-defined space along with the wheelbase and can take additional volumetric density due to the extra space. It means battery pack energy capacity can increase for a higher range.The study showed that nine of the ten benchmarked BEVs share features such as battery shapes, battery positions, and floor shapes. It means that there is an excellent use of existing or shared ICE Platforms. It helped them achieve manufacturing efficiency and scale due to stock parts, production facilities, and supply base. It is essential for much-required EV time to Market.

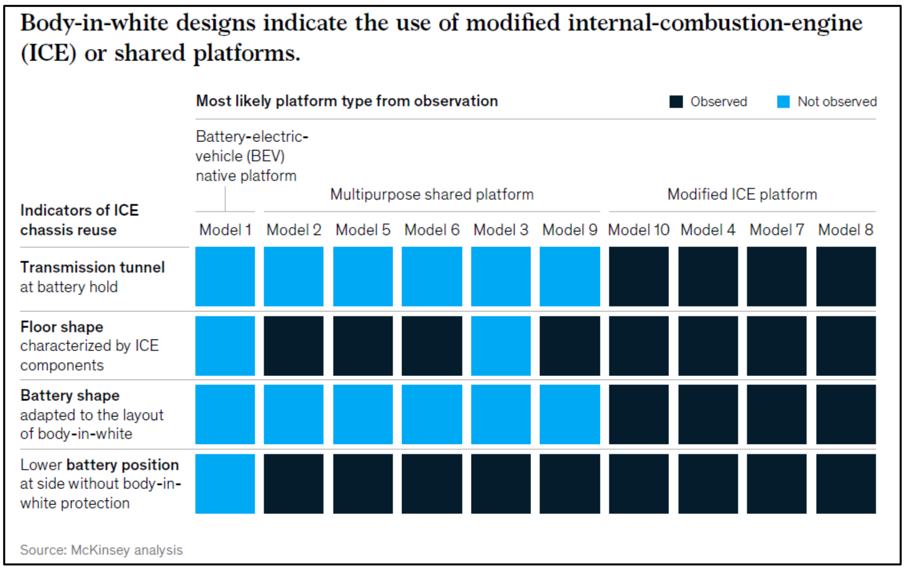

Figure 5: Use of ICE based Platform & Systems for EV Development [5].

Many OEMs still use the pre-existing steel body-in-white. It does not help achieve the weight reduction initiative, which is vital for EV performance. Since many redundant panels, reinforcements, and tunnel areas still exist in the EV model, it does not require any functionality or structural rigidity. The simply add weight and cost. The critical two systems showing more inclination towards modularity are E-Drive containing axle and few powertrain portions and battery pack, a primary system from cost, and weight perspective.

Another advantage of a dedicated Platform is Complexity Reduction: The glider and electric powerpack design minimizes the complexity and use of minimal mechanical parts in EVs, which are less than typical ICE vehicles. For example, GM plans 19 different battery and drive unit configurations initially, compared with 550 internal combustion powertrain combinations available today [7].

Ev Skateboard Platfrom

An EV platform is an integral portion of EV without the Upper body portion. It consists of chassis, Front & Rear axles, Suspension, Steering Systems and mainly Electric Battery and Motor. The flexible advantage of Platform allows much more space to accommodate a bigger battery size. The larger battery delivers more power to the motor and improves specific power and range capability of EV.

The below table shows the development work on EV platforms from major OEMs [8].

Table 2: OEM EV Platform Details and Models Planning Information

OEM	Expected Models / Volumes	Electric Powertrain Spec
#1 - Volkswagen Group MEB	Volkswagen ID3 and ID4; Seat El Born; Audi Q4 e-tron; Skoda Enyaq 15 million vehicles by 2025	Battery sizes: 52kWh to 77kWh Range: 205 to 342 miles Charging capacity: 125kW EMotor: Rear-drive first; twin motor AWD
#2 - GM Global EV Platform	Cruise Origin; Cadillac Lyriq; GMC Hummer 1 million per year in the US and China by 2025	Battery sizes: 50kWh to 200 kWh Range: Up to 400 miles Charging capacity: Up to 200kW EMotor: Front , Rear & AWD
#3 - Toyota Electric New Generation Architecture e-TNGA	Toyota C-HR; Lexus UX300e 1 million per year by 2025	Battery sizes: Three available, 54.3kWh confirmed with up to 100kWh coming Range: 186 to 372 miles Charging capacity: 50kW announced so far EMotor: Front , Rear & AWD
#4 - Renault-Nissan-Mitsubishi CMF-EV	Renault Morphoz concept (above); Nissan Ariya concept 1 million per year by 2022	Battery sizes: 40kWh to 90kWh Range: 249 miles to 435 miles Charging capacity: TBC EMotor: Front & AWD
#5 - Hyundai-Kia E-GMP Global EV Platform	Hyundai 45 and Prophecy; Kia Imagine Hyundai 560,000 per year by 2025; Kia 500,000 per year by 2026	Battery sizes: 58kWh to 73kWh Range: 218 to 311 miles Charging capacity: Up to 200kW EMotor: Front & AWD

Flexible Modular Platform resembles a skateboard is called "EV skateboard" platform. The concept is designing the EV chassis with integrated power pack and battery pack, Suspension, Wheel & Tyres, and ready to integrate with varieties of upper body shell right from hatchback to truck using a modular approach. The design ownership of EV platform remains with platform developers, and OEMs take the integration responsibly of donor platform & in-house designer upper body.

Ev Platform Work – A Study on Major Platform Developmnt Teams

The two companies have developed simple skateboard concepts, namely AEV Robotics, REE, Rivian, and Canoo have first developed EV vehicles and now make their EV platforms available for other applications. Tier 1 suppliers like Bosch, Benteler are also working on developing Skateboard. The critical inference is the availability of technology, ease of manufacturing platform, flexibility, usage of advanced electrical systems, and lesser mechanical systems because many players participate in platform development.

Canoo Platform

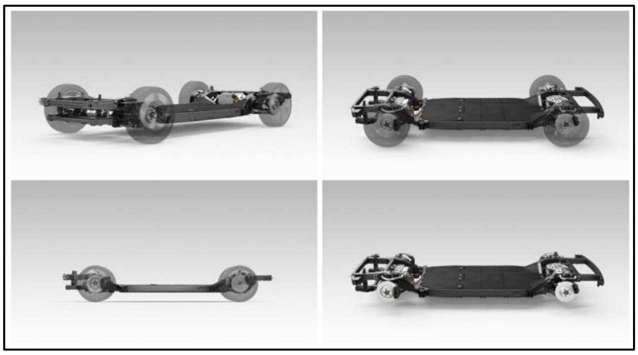

Figure 6: Canoo's Modular and Flexible Skateboard EV Platform [9].

The evolution of the EV platform created many avenues for companies to speed up the time to Market the cars, lesser capital, and entry of many new mobility companies. The laser-focused approach is towards fully electric vehicles and existing OEM to continue to strengthen the platform work and partner with platform donors as required in vital segments or selective markets.

Benteler - Bosch

BENTELER, together with its development partner Bosch, has developed a rolling chassis for battery electric vehicles (BEVs) to meet these new demands. The modular Platform includes the high-voltage battery storage and thermal system, electric Powertrain and chassis system with integrated steering and braking systems, and control electronics. Customers benefit from an adaptable e-mobility solution, which can be personalized according to the vehicle type and performance requirement.

Figure 7: Benteler Electric Drive System 2.0 is a Scalable Platform Solution [11].

With the battery located under the passenger compartment, the design of BEVs differs significantly from other drive systems. The rolling chassis developed by BENTELER and Bosch forms the underbody. It is the backbone of the Platform to which most systems are connected [10].

Mahindra Electric

Mahindra Electric Scalable Modular Architecture (MESMA) is India's first electric architecture that has been designed & developed entirely in-house. Apart from Battery cells, every other component & system of this architecture are indigenously developed and assembled in India. It helps in converting exiting ICE based cars to Electric powered cars and capable of developing an all-new electric Tophat program. There is a family of electric platforms from the base MESMA like MESMA 48, MESMA 350, and MESMA 650. These platforms help in making different segments of automotive. The MESMA 350 is likely to be used in future EV vehicles of Mahindra.

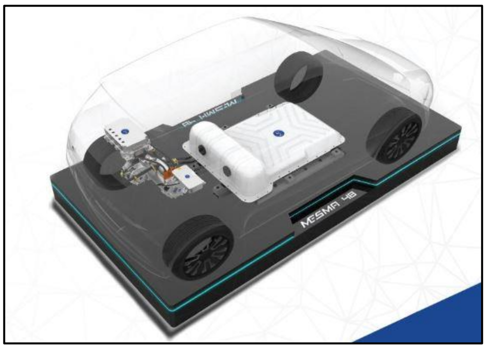

Figure 8: Mahindra Electric Scalable Modular Architecture (MESMA) [12].

The advantages of MESMA is highly scalable, modular, flexible, and capable of creating B to D segment vehicles to support broader product portfolio. The other highlights are the forefront ability to predict the commonality and carryover parts usage across segments and help in minimal launch time for even a smaller volume program. It can use various battery packs up to 80 kWh and motors ranging from 60 kW to 280 kW.

BMW EV Platform

BMW's Platform work has the flexibility to have a model with either electric Powertrain or gasoline engine.

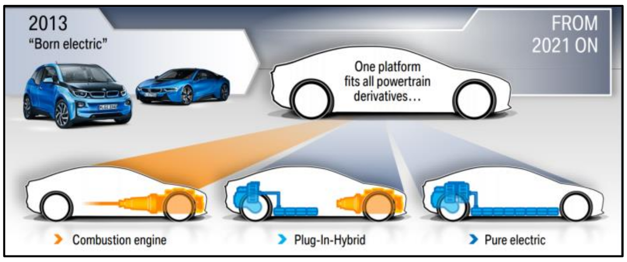

Figure 9: BMW I- One Platform Serves all Powertrain [13].

The Platform has many standard architecture components like Firewall, Climate Control, Interior, Chassis, and even common driver positions. This way, there is an opportunity to use standard parts among all the powertrain variants, which supports cost and scale advantages.

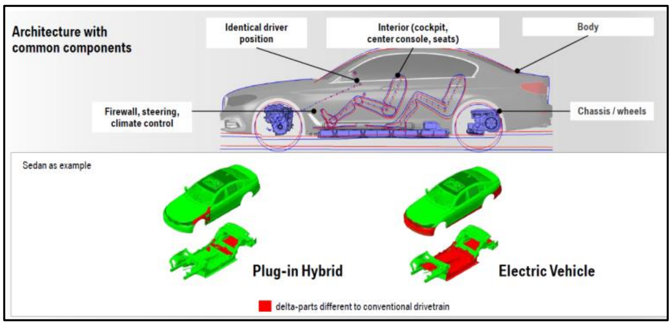

Figure 10: BMW- Common Modular Architecture with Common Parts usage [13].

Volvo EV Platform

Volvo Cars extend its range of compact cars into new segments on its highly-innovative Compact Modular Architecture (CMA), a smaller but equally advanced version of Volvo's acclaimed Scalable Product Architecture (SPA). The CMA platform is the foundation for the new Volvo XC40 Recharge, the first of Volvo's fully-electric Recharge range. The new CMA platform shares mutable features such as powertrains, infotainment, climate control, data network, and safety systems with the larger SPA platform. Volvo Car Group exceeds 600,000 vehicles sold on the CMA platform.

Figure 11: Volvo CMA Platform based EV Architecture [14].

Due to the lesser mechanical parts and more dependence on the electric drive system, Non-traditional vehicle manufacturers and large fleet owners are participating in manufacturing customized passenger EVs, Smaller commercial trucks, and even dedicated platforms for other OEMs. The volume is the key, so they are using the platform sharing concept with selective car makers.

PSA

Groupe PSA fortifies its electric mobility portfolio by introducing the new eVMP Platform (Electric Vehicle Modular Platform) in July 2020. The eVMP engineering can deliver the EVs with an energy capacity of 60 to 100 kWh. The architecture is designed to fully utilize the sub-floor for the battery integration to maximize the size and capacity for better EV range [15].Battery packs are expected to be in standard form for modules. The idea is to extend the same modules so that they can be best adapted for each vehicle type to utilize the available installation space and reducing the investment & engineering costs.

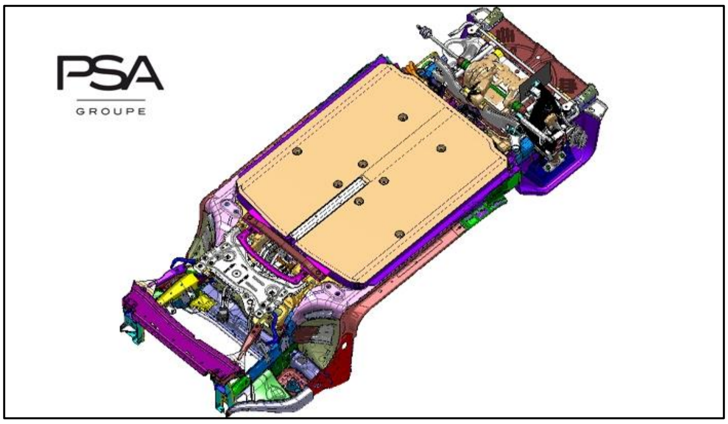

Figure 12: PSA eVMP based EV Platform.

Between 2020 and 2025, Groupe PSA will gradually move from two multi-energy platforms to two 100% electrified platforms to support e-mobility development. The new eVMP Platform will serve as the basis for a wide range of electric vehicles for the C- and D- segments. eVMP will offer high-performance with an autonomy of up to 650 km (WLTP cycle) and a benchmark storage capacity with 50 kWh per meter available within the wheelbase.

BATTERY INTEGRATION

The Platform concept evolved from ICE based No-Native to Native Electric to Skateboard Platform mainly for Electric Vehicles.

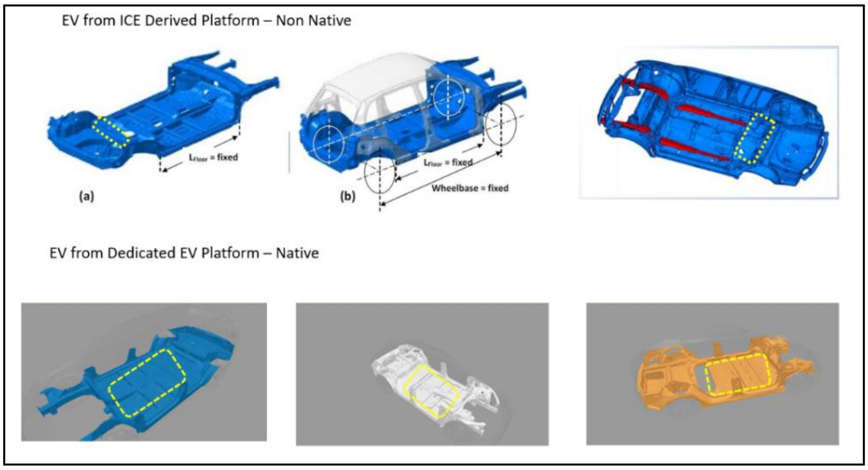

Figure 13: Comparison of Battery Pack Integration in Non -Native and Native EV Platforms.

As seen in the above picture, the amount of space available for packaging a battery pack is almost the volume/space open for the fuel tank in the non-native EVs. It is to avoid substantial changes in the floor structure and to use many common parts. The table below shows the battery pack's location as some of the Models, which shows most of the battery pack stored in Floor panel has a higher battery capacity than the one mounted below the seats due to broader space availability [16].

Table. 3: Electric Vehicles, Battery Location and System Data

Brand & Vehicle Model	Battery Pack / location	Energy [kWh]	Range [km]	System weight [kg]
BMW Mini E (EV)	Below rear seats	35	249	260
Daimler Smart ED (EV)	Below front seats	16.5	132	140
Mitsubishi i-MiEV (EV)	Floor panel	16	150	150
Tesla Model S (EV)	Floor panel	40-85	>250	454
Tesla Roadster (EV)	Below rear seats	56	392	450
Chevrolet Volt (EV with range extension)	Below rear seats and tunnel	16	40-80 (electric)	198
Nissan Leaf (EV)	Floor panel	24	141	294

The Modular Platform helps in providing more flexibility and adaptability for future designs. This concept is useful for EV models where the packaging space is challenging for battery and Electric power train systems. The flexible platforms can create space like a cradle for accommodating a range of batteries from 20kwh to 80 kWh to meet the range demand. It also helps in suitably placing the motors in the front or rear or both as per the requirement and handle varied power capacity levels.

The Skateboard is the latest of all the EV platform technology, and it is very compact and complete a fully flat floor. The battery pack is neatly laid out along the car's length and width with minimal height to meet ground clearance. The battery is located at the lower level of the vehicle gives additional stability and dynamic improvement for vehicle attribute performance. The Skateboard is some advanced stages that offer the plug and play type of upper body with well-defined hardpoints on the floor. The following table shows the benefits and challenges in Platform development, Commonality, Sharing.

Table. 4: Benefits and Challenges of EV Platform Development Workstream

Benefits of Flexible Modular Platform	Challenges in Platform Development
Reduced Material Cost due to single, flexible design & Scale benefit Reduced Engineering Cost due to elimination of new design work	Creativity plays a significant role in achieving the different body styles, or vehicle top hats depend on the designer. The challenge being many design varieties or models need to evolve from the same single Platform and sometimes very minimal changes.
Low Inventory level at Dealer, Plant due to simpler & fewer parts	The repeated standardization of critical components and systems might have a technical backlog as the matured and mass scale design may not be able to upgrade for new technology without significant modification.
Optimized Production Facilities like Stamping, Bodyshop Improved Material flow & lesser floor space requirement for common Platform Global Manufacturing feasibility using Common Bill of Process	The more and more reduced platform crates challenge to design the product for global markets due to the respective country market & regulation requirement.
Helps in accommodating various Powerpack Combinations on Single Platform (Gasoline, Diesel, Hybrid, Electric) Improved Capital Efficiency by spending less capital to scale its business due to the ability to use existing property, including land, buildings, tools, and production equipment such as body shops and paint shops.	Creating uniqueness on vehicle characteristics like ride comfort, vehicle dynamics, braking, suspension tuning for each model derived from the same Platform. OEM to make cars from basic hatchback to full-size SUV from the same Platform. Each requires signature vehicle performance criteria, so individual adjustments & tuning is inevitable.
Improved the degree of commonality , promotes resource efficiency Improved Time to Market Platform sharing helps in easier adaptation to the future models with fine-tuning. Requires lesser cost, time, and past mistakes, quality of design can be improved.	It requires flawless quality control and management system, especially common parts shared with many global models. Any quality issue in a shared component creates a lot of part tracking & potential vehicle re-call.

CONCLUSIONS

The significant advantages of EV in developing the skateboard platform is the minimum number of components and lesser moving parts. It helps in generating a more straightforward and liner layout of Platform in X and Y directions.

As discussed, there are many OEMs, and non-automotive companies are developing dedicated skateboard EV platforms. It is mainly to build ground-up vehicles or sharing the Platform to other OEMs to gain mutual benefits. This platform development and sharing concept is like an increasing trend due to the massive thrust on emission and operating cost reduction initiative by OEMs to promote Electric vehicles. At the same time, there is a clear need for a standard battery pack, which helps develop the Platform in a shorter time and enables platform sharing to use standard battery pack designs. Further research scope may be in the areas of robust platform design and crashworthy structural components, which can significantly reduce lead time for future carryover models.

REFERENCES

1. *How It Works: Modular Vehicle Platforms - https://driving.ca/subaru - JIL MCINTOSH - 2019*
2. *Automotive IQ Guides: Electric Vehicle platforms - https://www.automotive-iq.com/ - Peter Els – 2019*
3. *Big Rewards, Hurdles Seen with Next-Gen Flexible Vehicle Architectures - https://www.wardsauto.com/ - David E. Zoia | Oct 28, 2013*
4. *Upadhyay, Chetan, and HinaChandwani."Ultracapacitor–Future of Regenerative Storage In Electric Vehicle." International Journal of Electrical and Electronics Engineering (IJEEE), 2 (2) 41 (2013): 48.*
5. *Carmakers Electric Vehicles Strategies; Platforms, Marketing & Charging, SergioTadeuGonçalves Muniz & Bruce M. Belzowski -MIT – 2016*
6. *How to drive winning battery electric-vehicle design – Mckinsey - Mauro Erriquez, Philip Schäfer, Dennis Schwedhelm, and Ting Wu – June 2020*
7. *Zabbar, MdAjijulBin, and ChistyNafiz Ahmed. "Design & Implementation of an Unmanned Ground Vehicle (UGV) Surveillance Robot." International Journal of Electrical and Electronics Engineering (IJEEE) 5.6 (2016): 2278-9944.*
8. *What a teardown of the latest electric vehicles reveals about the future of mass-market EVs - MckinseyBy Antoine Chatelain, Mauro Erriquez, Pierre-Yves Moulière, and Philip Schäfer – March 2018*
9. *GM Reveals New Ultium Batteries and a Flexible Global Platform - GM Corporate News Room -https://media.gm.com/*
10. *Gupta, Ankit, Kuldeep Chaudhary, and B. N. Agrawal."An experimental study of generation of electricity using speed breaker." International Journal of Mechanical Engineering (IJME), 1 (1) (2012): 35-40.*
11. *Top Five: Global EV Platforms -https://www.automotive-iq.com/ - Tom Philips – June 2020*
12. *Courtesy -Copyright Image - https://www.canoo.com/engineering/*
13. *Rolling Chassis: A concept co-developed by Benteler and BoschMarco Kollmeier, Ulrich Schulmeister, https://book.yunzhan365.com*
14. *Copyright: Benteler International AG, source: benteler.com*
15. *Lin, Zhi-Ping, Her-Shing Wang, and Shao-Jyun Tsai."The Intelligent Charging Path Planning for Electric Vehicle." International Journal of Computer Networking, Wireless and Mobile Communications (IJCNWMC) ISSN (P) (2016): 2250-1568.*
16. *One electrification platform -MESMA 48 - https://www.mahindraelectric.com*
17. *E-Mobility – BMW Group Technology Workshops -Dec 2016*

18. *Volvo EV Platform - https://www.media.volvocars.com/*
19. *PSA EV Platform https://media.groupe-psa.com/*
20. *Structural analysis of a BIW for Battery Integration using FE & Macro element with focus on pole crash optimization; Peter Luttenberger, Marian Ostrowski, - ECCOMAS 2012*