Automotive Lightweighting

A savior for today and tomorrow

Supply Chain and Technology | **White paper**

Table of Contents

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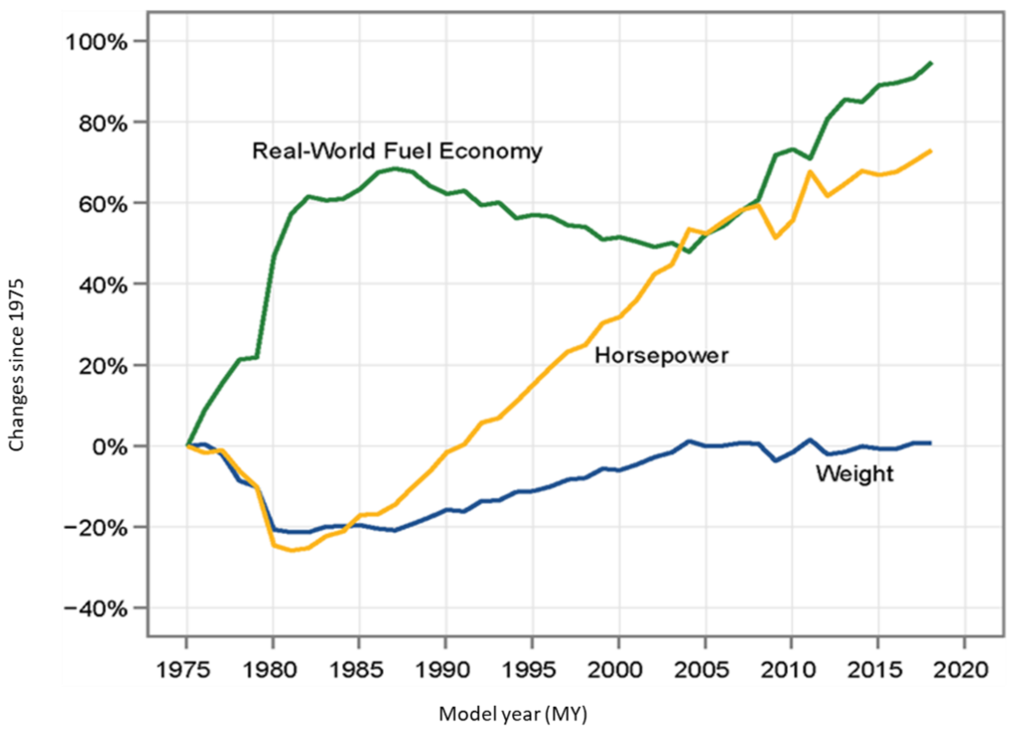
Introduction

The automotive industry has historically always been on the lookout to replace existing materials in favor of lighter and new alternatives that can help it attain cost benefits while supporting the fuel and mileage benefits for its internal combustion engines (ICEs). However, this has not always resulted in lightweighting in terms of the total vehicle weight.

Figure 1: Light-duty automotive technology, carbon dioxide emissions, and fuel economy trends: 1975 through 2018



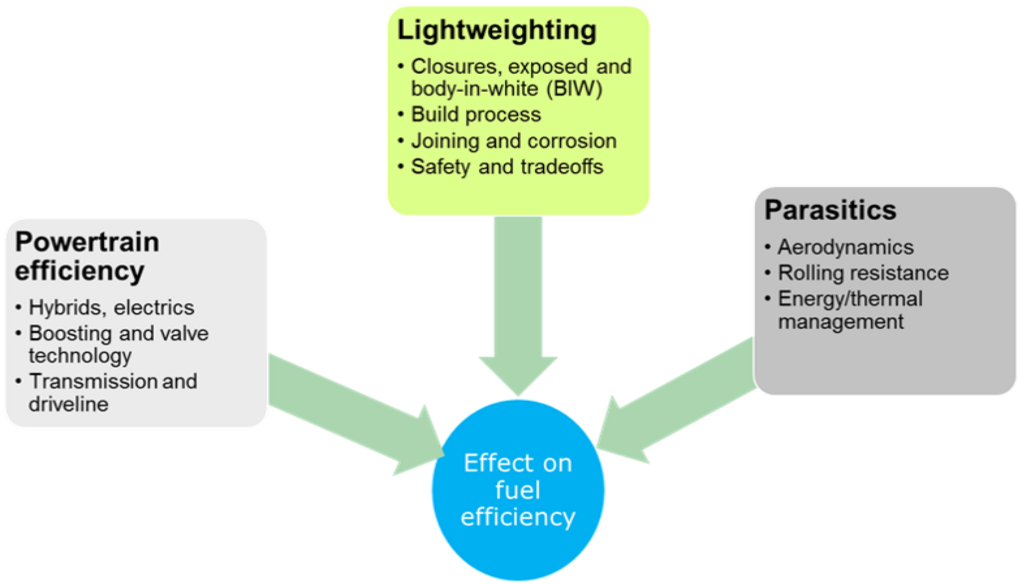
Notes: based on North America MY but valid at global level
Source: USA EPA

According to this graph, total vehicle weight has been increasing in the last 40 years or so, despite the efforts of the automotive industry to bring lighter alternative materials into the mix. Most of this increase in weight can be attributed to additional features being introduced in the vehicles for customer delight and improved safety norms. In the past 10 years or so, though, the average vehicle weight has been constant amid increased pressure to improve the fuel efficiency of ICEs.

However, the global push for stringent emission norms has now forced the automotive OEMs to look for options beyond the customary emissions aftertreatment. All major automotive markets have developed policies that dictate the reduction of CO_2 emissions while improving the fuel efficiency as well as the safety norms.

Automotive OEMs are currently focusing on these efforts to tackle this huge business problem:

Figure 2: Focus areas for automotive OEMs



Source: IHS Markit © 2019 IHS Markit

Of these options, lightweighting has emerged as one of the most-favored OEM strategies to meet the stricter deadlines and demands of the future business and is being seen as a savior for the automotive industry. It supports the increasing drive for stringent CO_2 norms, improving fuel efficiency and matching safety features all at once.

While the primary weight-saving strategies help in reducing weight through material substitution and manufacturing processes change, they also lead to secondary weight reduction. Primary lightweighting can be seen as isolated efforts to knock off weight, especially in the chassis and BIW, either by component integration or use of alternative materials. Secondary lightweighting efforts are generally waterfall effects due to these primary weight reductions in terms of engine downsizing, lighter components in the powertrain, and subsequent integrations that would help support a lighter body. A prominent example is the 2007 AUDI A2, which applied aluminum in its BIW and chassis to knock off some 134kgs. However, this led to further reductions to the tune of 75kgs in drivetrain, chassis, and motor sizing—contributing to a total weight savings of around 209kgs.

Hence, both types are critical in the overall weight reduction, and all OEMs keep a keen eye on attaining the maximum primary as well as secondary weight reductions.

Drivers of lightweighting

Many factors in the automotive industry ecosystem are driving automotive OEMs to lightweighting. The increased focus and strict compliance issues related to these factors have led to dedicated lightweighting initiatives by automotive OEMs.

Stricter regulations for reduction of emissions, be it CO_2 or nitrogen oxides, are being implemented across the globe. Apart from other efficiency improvements such as those in the ICE and aerodynamics, lightweighting has emerged as one with a better return on efforts.

Improving **fuel efficiency** and subsequently mileage economy is another driver of lightweighting. The pressure is on to guarantee minimum fuel efficiency targets for vehicle segments in the interest of final customers. Lightweighting has thus emerged as an option that creates a virtuous cycle with lower curb weight, leading to lower load on the powertrain and a mileage upswing.

To support the weight of heavy batteries in **battery-powered vehicles** while maintaining performance parameters, it is imperative to reduce weight of the remaining vehicle systems. Considering the expanding markets for various types of battery electric vehicles (BEVs), OEMs are forced to rethink and redesign their platforms, while introducing lightweighting as a strategic option.

It is estimated that the y/y CO_2 reduction needed for OEMs in the United States is close to 5.5%; for those in Europe, it is around 4%. This is a tough target, considering the diverse product variation in every OEM's portfolio as well as the difference in regulation standards and measurement processes across the globe. As a result, OEMs have to either strive for attaining the toughest specifications or face the risk of failing the regulations in many major markets of the world. In addition, there are huge fines associated with such failures.

The New European Driving Cycle (NEDC) and the Worldwide Harmonized Light Vehicle Test Procedure (WLTP) are currently the two most prevalent methods of testing for global emissions.

Figure 3: Broad comparison between NEDC and WLTP

	NEDC	WLTP
Start temperature	Cold	Cold
Cycle time	1,200 seconds	1,800 seconds
Driving power	Average: 4 kW	Average: 7 kW
	Top: 34 kW	Top: 47 kW
Stand-still time	25%	13%
Speed	Average: 34 km/h	Average: 46.6 km/h
	Top: 120 km/h	Top: 131 km/h
Distance	11 km	23.25 km

Source: IHS Markit © 2019 IHS Markit

The WLTP is considered to be closer to what happens in real-world traffic and offers a more precise test method than that of the current NEDC. It defines clear boundary conditions for testing and thus delivers results that are more accurate, consistent, and reproducible. As a result, more countries are shifting to the

WLTP standards with time. In fact since September 2018, WLTP is the de-facto standard for new vehicles for emission testing norms in Europe Union. The next stage of this continual journey toward stringent and more practical emission testing and values will be the introduction of RDE standards from the last quarter of 2019. RDE will test the actual running vehicle model on ground through varied driving conditions and is expected to pinpoint the actual vehicular emissions by cars on ground rather than the ideal testing dynamometer conditions. The test is being carried out by using a Portable Emissions Management System (PEMS) mounted on top of the vehicle, and the testing cycle is defined to cover most of the driving scenarios in the real world. Thus, the results are expected to be reasonably higher, and the future emission standards will perhaps get an overhaul based on the comparison between the results and testing standards. Based on the test results and variance with actual driving emissions, a not-to-exceed limit is set for cars, with a conformity factor (i.e., NTE/Euro 6 limit) of 2.1 for NOx. This is set to apply to all new cars being sold in Europe post September 2019.

The Indian Ministry of Road Transport and Highways (MoRTH) undertook the bold move in January 2016 to skip Bharat Stage (BS) V emission norms and leapfrog directly from BS IV to BS VI norms by 1st April 2020, applicable across all vehicle type, category and class manufactured. This announcement was complemented with action taken by the Ministry of Petroleum and Natural Gas (MoPNG) to ensure a nationwide supply of BSVI fuel. India's proposal to adopt BS VI emission standards will bring the IMVR (Indian Motor Vehicle Regulations) in alignment with the European Union regulations for light passenger cars and commercial vehicles, heavy duty trucks and buses.

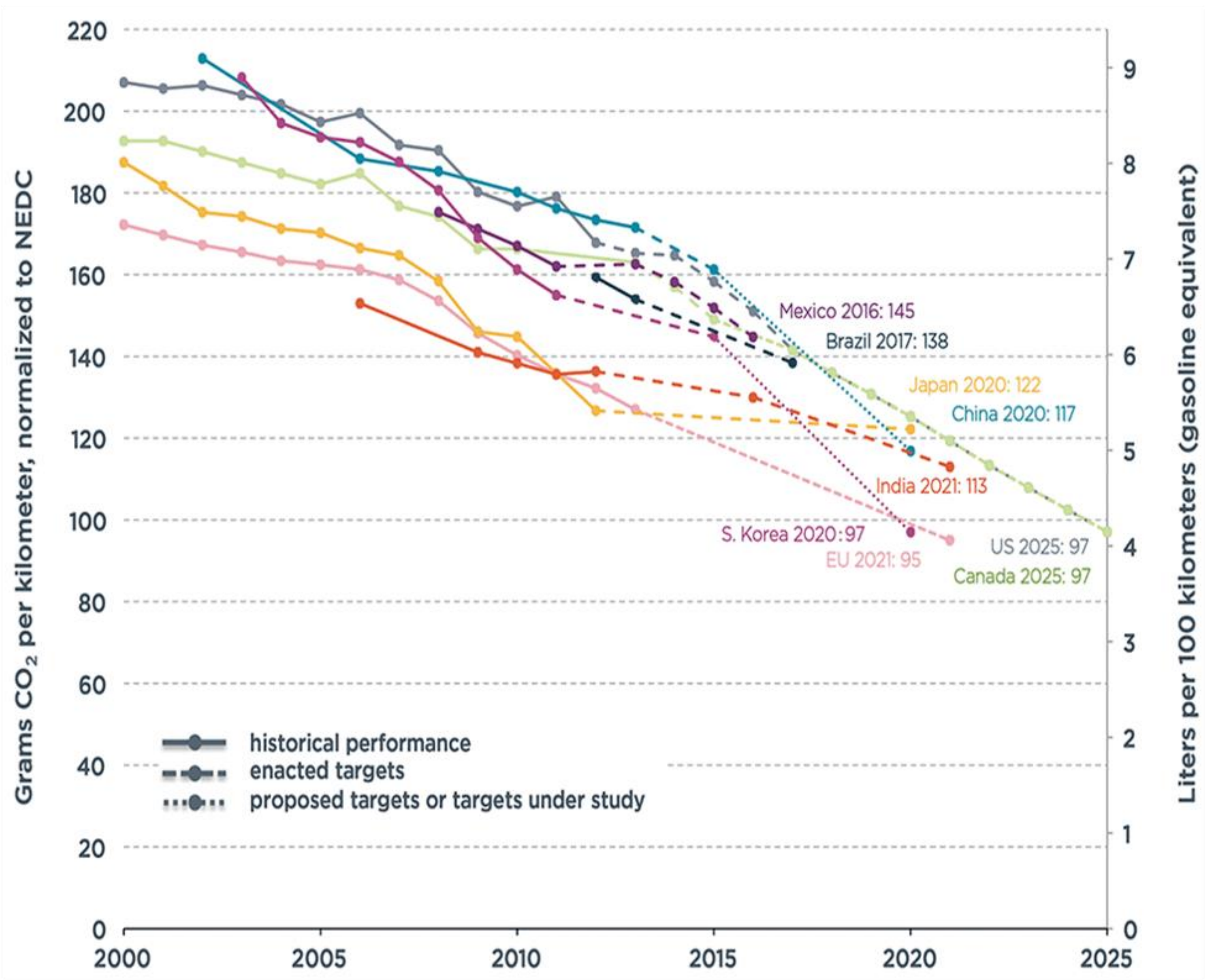
Figure 4: Worldwide comparison of emission targets and deadlines

Country/ region	Target year	Standard type	Fleet target	Method	Test cycle	Fines
EU-28	2015	CO_2	130 g/km	Weight-based average	NEDC	EUR1/g exceeding
	2021		95 g/km			
United States	2016	Fuel economy/CO_2	36.2 mpg	Footprint-based average	EPA 2-cycle test	USD1/0.1 mpg not met
	2025		54.5 mpg			
Brazil	2013	Fuel consumption (MJ/km)	2.01 MJ/km	Weight-based average	EPA 2-cycle test	N/A
	2017		1.82 MJ/km			
India	2016	CO_2	130 g/km	Weight-based average	NEDC for low-power vehicle	N/A
	2021		113 g/km			
Japan	2015	Fuel economy	16.8 km/L	Weight-based average	JC08	Economical fines + public proclamation
	2020		20.3 km/L			
China	2015	Fuel consumption	6.9 L/100 km	Weight class–based average	NEDC	Economical fines (proposed) + public proclamation
	2020 (proposed)		5 L/100 km			

Source: IHS Markit

As shown in the previous table, the CAFE standards in the United States have defined quite stringent targets for 2025: a target of 54.5 miles per gallon (mpg) in 2025 as compared with 36.2 mpg in 2016—a massive 47.6% efficiency improvement required over 10 years. The Chinese and Japanese markets have similarly set very strict norms, expecting an improvement of approximately 38% and 20%, respectively, from current mileage standards. Additionally, with the EU target set at 95 g/km of emissions by 2021, one can understand why mass OEMs are worried about the regulations in these biggest markets. Lightweighting seems to be a direct answer to this dilemma as the vehicle weight is estimated to impact or drive approximately 75% of the fuel consumption, while the remainder supports the operation. In fact, a car's design weight affects the fuel economy directly, albeit in a nonlinear way, ranging up to 0.4 L/100 km for every 100 kg of weight reduction.

Figure 5: EU CO2 emission standards for passenger cars and light commercial vehicles



Source: International Council of Clean Transportation

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Battery-powered EVs are rapidly emerging as natural alternatives to conventional gasoline/diesel engines because of the apparent reduction of vehicular emissions. As a result, almost all volume OEMs have started shifting to all battery-powered vehicles by phasing into mild hybrids, semihybrids, and pure hybrids. By 2030, EVs (hybrids and pure BEVs) would constitute approximately 23% of all passenger vehicles sold in the European Union. The growing impetus on joining the EV bandwagon in growing markets such as India and China, which are coming with specific EV policies, means EVs are strong contenders for the future of mobility.

However, EVs require the chassis to support a considerable amount of battery weight, an addition to the total vehicle weight. The weight of additional electric motors and electric drivetrain components makes this significant, even after the removal of the conventional powertrain. Lightweighting steps in to solve this problem for the future mobility business and will thus be an important partner to the development of EVs to make them lighter, more viable, and futuristic for consumers of tomorrow.

Restraints to lightweighting

Lightweighting has its own set of restrictions that have traditionally led to volume OEMs still not going all out on its application in their product portfolio.

Higher material costs and limited scalability of some advanced materials, such as CFRP and high-performance composites, have limited the use of these new materials in the mass vehicle and mid-premium segments. Although aluminum is increasingly finding its place in selective components across vehicle segments, the cost to totally replace steel with aluminum is still on the higher side. Hence, its usage and the phase-wise shift to lighter materials are limited.

A lot of upfront **investment** is required to use some of the materials, in terms of replacing the prevalent assets and technology with the current breed of materials. In many cases, this requires investment in a new technology; in other cases, a change in platform or component design may be required.

There is also the issue of **structural integrity and crashworthiness** for some alternative materials to meet the stringent passenger safety norms. Therefore, usage of materials such as magnesium, CFRP, and other plastics is limited, unless accompanied by excellent designs or redesigns of vehicle systems. Magnesium is especially tricky as it is flammable and possesses limited friability with respect to manufacturing processes.

The **concerns around the recycling** of specific composites and plastics such as CFRP are another restraint. This creates compliance issues for OEMs to have proper scrappage and reclaiming processes in place. Add to this the **limited willingness to pay** for costlier lightweighting initiatives by consumers, especially in the mass segment, and we have another blockage that needs to be handled for pushing lightweighting wholeheartedly.

Therefore, lightweighting initiatives should be taken with specific consumer and product segments in mind. Volume OEMs have their job cut out to use lightweighting with a great focus on their current and future product portfolio.

OEM Strategies around lightweighting—The premium & volume OEMs' way

Lightweighting definitely has its advantages, as discussed in the previous sections. However, it brings a cost and effort factor with respect to the materials, design constraints, and manufacturing technology available. Not surprisingly, the OEMs have their own targeted ways of bringing about lightweighting in their products based on their total portfolio and consumers' willingness to pay.

In general, the premium and luxury OEMs have been following a different lightweighting strategy as compared with mass or volume OEMs. Within the premium sections also, there are varied approaches to cater to lightweighting by individual OEMs depending on their current and future product focus and requirements. The usage of extremely light and costly materials in this segment is done with a dual aim of improving upon the final vehicle performance as well as ensuring the user feel of the material is not sub-standard at any point. Thus, the premium OEMs are hedging on futuristic material and adhesive technologies to cut down weight from the car and compensate for the increasing connected and safety features in the vehicle cockpit. Bespoke designs allow for niche component & vehicle designs without worrying for mass manufacturability of the material. Hence while a few premium and racing/luxury OEMs are betting huge on pure aluminum and pure carbon fiber body designs, others like Audi and Daimler are increasingly moving to multi-material strategies for their body structure to optimize the material performance and cost factors. OEMs are also entering into joint ventures/technical collaborations with raw material as well as component suppliers to fast-forward the technology and manufacturing adoption of new and alternative light weighting materials.

Volume OEMs however have a constraint on the final cost of the vehicle. Therefore, they have traditionally not adopted exotic alternative materials for lightweighting. There is also concern around mass scalability for some material automotive solutions as well as requirements of total component redesign to accommodate a material change. As a result, most volume OEMs have been focusing on first, cutting down any unnecessary weight in the component area. However, in the medium-to-long term, pure steel configurations are expected to give way to a material mix of steel and aluminum across component areas. The next stage therefore is to use the mix-material or multimaterial approach to gradually phase in alternatives such as aluminum and magnesium, without completely removing or reducing usage of cast iron and steel. However, most volume OEMs have their future strategy chalked out in terms of changing to aluminum and magnesium gradually for specific components. In terms of carbon fiber, few volume OEMs are prepared in terms of research and manufacturing, and it is going to be a very big advantage for them in terms of technological advancement. The cost will also come down automatically for these OEMs because of the larger scale.

IHS Markit is also conducting research on the penetration of different materials in these premium OEMs for the current and future market scenarios. This takes into account the actual vehicles in production and their expected year of launch, and the corresponding introduction of alternative materials across these vehicles. The early trends of this research have been shared in the detailed "Premium & Volume OEM light weighting Strategies" reports for each of the OEMs, which provides a more quantitative outlook on the use of these materials across OEMs, component areas, and some components

Component System-wise Global Lightweighting trends

The components and subcomponents in a car can be broadly differentiated into five component areas, namely powertrain, body-in-white (BIW), chassis, interiors, and exteriors. This categorization helps in grouping the components by function and technology, and allows for a holistic approach to lightweighting.

Interiors component area

The global automotive market is moving toward improved and more interactive user experience, along with increased safety and NVH regulation requirements. As a result, more features are being added to interior component systems to provide enhanced user comfort and safety. While this means fancier features are making their way to mid and mass-segment vehicles with time, it also forces premium carmakers to integrate new, more comfortable, and plush features in their cars. All this means added weight in the interior component area. Therefore, OEMs as well as suppliers are putting in a lot of effort toward lightweighting to counter the effect of added weights on fuel efficiency and vehicle performance. Also, the materials should have similar or even better user feel so that user experience should not go south. Hence, the industry needs wholesome new innovations instead of incremental weight reductions if the interior component area must balance feature weight addition with total component area weight. A reduction in the total component area weight can only be achieved thereafter.

Seating

The seating subsystem accounts for nearly 40% of the weight of the interior component area and around 5–6% of the total vehicle weight. Thus, it provides the biggest opportunity for lightweighting for both the interiors and the total vehicular weight. The front-row seats are typically heavier than the rear passenger seats, with the former claiming more than 53% of the seating system's weight. Thus, targets for maximum lightweighting impact are set on reduction of weight from the front seats.

The seat frames (back and base), reclining components, the mounting track, and rails for the front seats are the focus of lightweighting because they comprise 60% of the seat-weight in general. From plastics to steels, aluminum, magnesium, and CFRP, different OEMs and vendors are using varied options for their seat frames because each one of these has its own limitations and advantages. Apart from that, seat foams are also in focus for lightweighting as proprietary products for respective OEM-vendor combination.

For seat frames, magnesium is quickly becoming the *de facto* option for the front seats and has been making inroads in most of the new vehicle options in the premium OEM category. The BMW M-Series has already taken huge steps toward the usage of magnesium for seat frames and BMW is expected to have more of such lighter frames across its models. Other OEMs, such as JLR and General Motors (GM) are also targeting the introduction of magnesium seat frames in their premium vehicle segments. Aluminum is also making good inroads for the rear seat frames, where weight reduction requirements are less stringent. On the other hand, the need for lighter frame options for F1 and hypercars is driven by an inherent desire to improve vehicle performance. Hence, the cost and mass manufacturability factors become less important to them, which explains why most of the F1 and hypercars are shifting to the usage of carbon fiber seat frames with integrated seating structures. CFRP-based aesthetic optional content has already made a niche for itself in performance-oriented vehicles.

The volume OEM game relies on the economies of scale and hence seat frames for this segment are largely inclined to use steel. With technological developments, lighter and low-alloy steels are being used for lightweighting and thinner frame options are being considered to ensure reductions of weight wherever possible. Certain volume OEMs are also using a combination of aluminum and steel through their multimaterial approach. Wherever possible, plastics are also used in subcomponents to further lighten the seats without adversely affecting the final cost.

Adient, for example, claims to have knocked off the weights of its vehicle seats by 20–30% over the last decade, and is aiming to knock off a further 22 pounds by 2020. The same can be seen in its concept and product launches over the last few years. The focus has clearly shifted to the increased usage of die-cast magnesium for seat frames, and multimaterial lightweight structures. It showcased a glass fiber–reinforced plastic front-seat backrest concept at the 2018 North American International Auto Show (NAIAS 2018). The company claims that the slim and modular-design backrest saves up to 30% of weight, compared with other standard metal options. Adient is also focusing on the top-premium vehicle segment and F1 race cars through its RECARO brand. The RPSP (RECARO Performance Seat Platform) aims at having a thin frame structure by using a composite material seat structure, along with a carbon fiber braided backrest structure. The thin IntelliTech™ foam used is light, rigid, and 50% thinner compared with the standard polyurethane foam, giving 40% weight savings.

The other major player in seating solutions—Faurecia—has its eyes firmly set on the volume OEMs and other high-number players in the automotive OEM market. Therefore, its solutions and innovations are rooted with lightweight steel options, while also scoping out magnesium applications. In fact, in 2013, the company partnered with FAW—one of the largest suppliers in China— to secure die-cast magnesium solutions for its lightweight seat structures.

Figure 6: Seat Metal Techno Show concept by Faurecia

Source: IHS Markit © 2019 IHS Markit

On the other hand, the Seat Metal Techno Show concept (above) by Faurecia aims at minimizing weight through thinner and lighter structures from existing material solutions. The modular structure is made of highly resistant steel alloys, along with composite materials and seating mechanisms that are more than 30% lighter than existing solutions and is mounted on lighter rails, bringing the overall weight down by 1 kg. The company is also aiming at new lightweight plastics in collaboration with BASF; the ultra-strong polyamide plastics will be used to create seat structures that are both stiff and strong, and can eliminate metal content even further. BASF is also working on new-generation foams that are both lighter and environment-friendly. The Elastoflex® W produced by BASF is an example of a new seating foam solution; it is 15% lighter and hence can be a boon for lightweight seat structures.

Other automotive suppliers, such as TATA steel are working on varied ways to keep the seat structure light. A research by TATA steel on the "Future Steel Vehicle" seat frame has suggested possibilities of reduction of up to 30% of weight by using TATA Steel's advanced high-strength steel. Similarly, Johnson Control's CAMISMA (carbon-amide-metal-based interior structure using a multimaterial system approach) aims at reducing steel and other light metal content from seat structures by using a multimaterial approach, saving up to 40% in weight compared with conventional steel structures. The project involves usage of fiberglass-reinforced plastics, steel, carbon fiber nonwovens, and thermoplastic tapes made of carbon filaments.

Figure 7: Johnson Control's CAMISMA concept

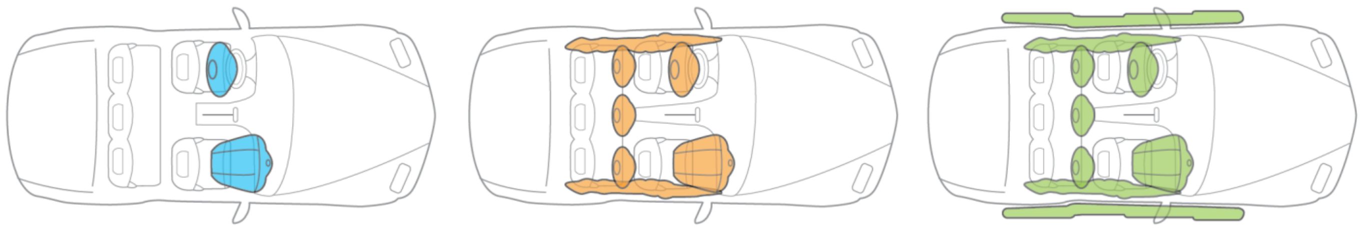
Source: Johnson Control © 2019 IHS Markit

Going forward, the general strategy for lightweighting in terms of seat structures will be a combination of material substitution and reduction in frame thickness, and hence weight.

Airbags

In line with the improving global safety norms, the number of airbags in a vehicle is increasing by vehicle segment to provide additional passive safety options to occupants. In addition, a higher number of airbags are slowly becoming a standard feature in mid-segment vehicles, and the feature is approaching mass-segment penetration soon. Lightweighting efforts in airbag modules are focused on the usage of lighter fabrics and alternative materials for airbag housings.

Figure 8: Evolution of airbag placement



Source: IHS Markit

Nowadays, airbags have become a common feature from C-segment onward, while also seeing quick penetration in the B-segment and may become common in the A-segment vehicles in the future. This presents an enormous business opportunity, as well as challenge in terms of sales number, costing, and final car pricing. However, the addition of airbags brings extra weight to the interior component systems. Airbags could weigh up to 24 kg in a seven-airbag system. This is critical in terms of vehicular weight, especially for the lower-segment car models, and puts additional pressure on the vehicular performance metrics. While it is sometimes difficult to decide between the essential driver and passenger safety features versus fuel mileage, safety is becoming the priority option across the globe. Therefore, specific lightweighting initiatives are required to provide balance to the equation, and both automotive OEMs and suppliers have been striving continuously over the years on this front with innovations and technology disruptions.

Instrument panels and cross-car beams

Instrument panel housings are dominated by various grades of plastics with varying look and texture. CFRP options are also used in premium vehicles. This affects the final cost and hence may vary across vehicle segments. The future trend comprises usage of proprietary foamed plastics to increase cross section while reducing weight. On the other hand, material options for cross-car beams vary from pure metal to hybrids of glass fibers, plastics, and metal skeletal.

Instrument panels of today are made from advanced plastics, such as acrylonitrile-butadiene-styrene (ABS), modified polyphenylene ether (PPE), styrene maleic anhydride (SMA), polycarbonate (PC) and polycarbonate alloys, polypropylene (PP), and polyurethane (PU) resins. These advanced plastics not only allow to avoid placing the structural support steel beam at the back, but also provide the option of producing an integrated instrument panel. The requirements of the current market for dual-tone interiors and housings in varied complex and close tolerance shapes have led vendors such as Faurecia, BASF, Hyundai Mobis, and many others to develop innovative materials, as well as production processes that help them tie up with OEMs. Hyundai Mobis, in fact, had suggested the usage of PP material filled with 3M iM30K additives to achieve more than 16.5% weight and 50% cost reduction, compared with PC/ABS instrument panel cores, more than a decade back. Since then, the mass-segment industry has progressed even further on usage of PP-based products and additives for instrument panels, along with other advanced plastics. Faurecia, on the other hand, has been working on its proprietary materials and innovative production processes, such as in-mold pigmentation process that help it create two-tone instrument panels with visible separation between colors. Faurecia is aiming to bring this process to every vehicle segment because of the considerable design latitude it offers to instrument panels, along with high user quality perception, by offering the separating lines even in raised 3D.

BASF showcased one of its innovative material solutions for instrument panels at the Detroit Auto Show 2018. The material allows for an instrument panel with a cross-sectional thickness of as low as 4 mm and a weight savings of up to 40% compared with traditional instrument panels. The material foam has a biobased content and hence recyclable. Currently, the company is discussing a possible collaboration with the IAC Group for making this into an instrument panel structure.

Figure 9: Cross car beam

Source: Kirchhoff Automotive

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Metal cross-car beams have excellent crash resistance, but are traditionally heavier and require a lot of welding and joining applications to bring the various subcomponents together. The usage of lighter metals, such as aluminum and magnesium, brings in additional costs and is not easily implementable on mass-segment vehicles. Therefore, vendors are working on hybrid and new-material cross-car beams that not only cut off weight, but are easily implementable on a greater scale. Faurecia has come up with a hybrid cross-car beam made up of metals, composites, and glass fibers that weigh only 3.6 kg, compared with over 6 kg for full-metal beams. The hybrid beam comprises a skeletal steel beam with integrated glass fiber composites, providing up to 43% weight reduction, and is slated for the mass market by 2020. The instrument panel carrier of the 2017 BMW MINI Countryman was attained through innovative processes and a new material from SABIC that allowed more than 15% weight reduction compared with other hybrid solutions. The material is injection-molded, and then the mold is opened to allow for foaming on the core side of the mold. This foaming increases the wall thickness of the part from 1.9 mm to 4 mm, thus providing the strength and rigidity characteristics without adding any weight.

The premium vehicle segment is facing the maximum pressure on interior lightweighting because the features and user experience requirements are quite heavy, and the plush experience cannot be compromised at any cost. Similar features are now trickling down to the mid segment because of rise in disposable income and accompanying customer expectations. However, there is a huge underlying innovation current across this component area and it is expected that lightweighting will be able to make a significant impact to vehicle interiors in the future.

Chassis

Analogous to the skeleton of a body, the chassis acts as the base to all the other component areas, and prevents any torsional deflection in the vehicle. The chassis supports sprung and unsprung mass, dynamic and static loadings, movements and stoppages—in short, a wide variety of critical vehicular functions. Hence chassis design, both in terms of shape/form and materials, must be carefully planned. Due to the complexities involved in a new chassis design, OEMs prefer to use a basic chassis structure across their models with some other common component systems. The resulting "skateboard structure", or platform, serves both the strategic and design aims of an OEM across multiple models and on a global basis.

Figure 10: Vehicle chassis

Source: Shutterstock © 2019 IHS Markit

The chassis component area consists of various subcomponent areas including the wheel system, the steering system, the chassis frame, the suspension systems, and the braking systems. Together, the components can weigh from 20% of vehicular weight (for basic frame chassis) to 40% or greater of vehicular weight (for a unibody or Monocoque frame chassis–design).

Plastic over molded steel–components are emerging as an effective solution to produce lighter moving arms at a reduced cost. Similarly, plastic over molded aluminum has emerged as a more efficient solution in brake master cylinders, in terms of weight, cost, and supply chain risk.

Carbon fiber is increasingly used in cars across all premium and luxury segments for chassis components, especially in frames and springs. The recycling of carbon-fiber products (of aerospace origin) will help to reduce the raw material cost and drive the penetration of carbon-fiber-reinforced plastic (CFRP) products in mass segment chassis components. These cost benefits justify the construction costs of several new recycling facilities. The processing costs of carbon fiber represent most of the price per piece, but new techniques, such as pultrusion, promise a large reduction in cost. Also, chopped-strand thermoformed sheets should emerge relatively quickly in the marketplace.

Hot stamped aluminum does not require the use of progressive dies thus removing them from manufacturing floors. Additionally, the final metal is stronger, compared to other methods, and the process allows for a thinner sheet. As a result, hot stamped aluminum sheets are becoming as cost-efficient across chassis component areas as HSS sheets, which explains their increasing penetration in chassis systems.

Wheels lightweighting

Steel wheels, historically the favored option owing to their lower costs and ease of manufacturability, are still popular with new micro-alloy steel grades. Aluminum alloy though has been gaining ground across segments as a top material of choice for wheels, whereas magnesium (the lightest option) is gaining popularity in the premium and race car segments.

In general, forged wheels are lighter and stronger than cast wheels and the variety of subprocesses involved—such as heating, rolling, high pressure application, and hammering—alters and strains the molecular metal–grain structure, to produce lightweight wheels. The only drawback of forging can be the cost of operations, which will eventually drop, with rising production scales, to match the cost of the casting processes.

Chassis frames

Unibody construction chassis frames are becoming the preference for mass models, with OEMs progressively pursuing the multi-material strategy with advanced and lighter HSS and new adhesive technologies. Monocoque chassis frames are preferred in premium and luxury vehicles, where lighter and costlier materials like full-aluminum, magnesium, or carbon fibers can be used.

In its simplest form, a monocoque design is a one-piece structure combining the base chassis and body together to give a complete outer shell-like structure. The design provides for lightweighting benefits due to the integration of the body and chassis base as well as the option of using lighter materials on the body skin and base platforms. The design is especially favored by SUVs who want to have a lighter overall frame without having to compromise on the tortional stiffness of the chassis base. The monocoque architecture has decent crash resistance due to crumple zones built within the frame through the combination of top and base frames.

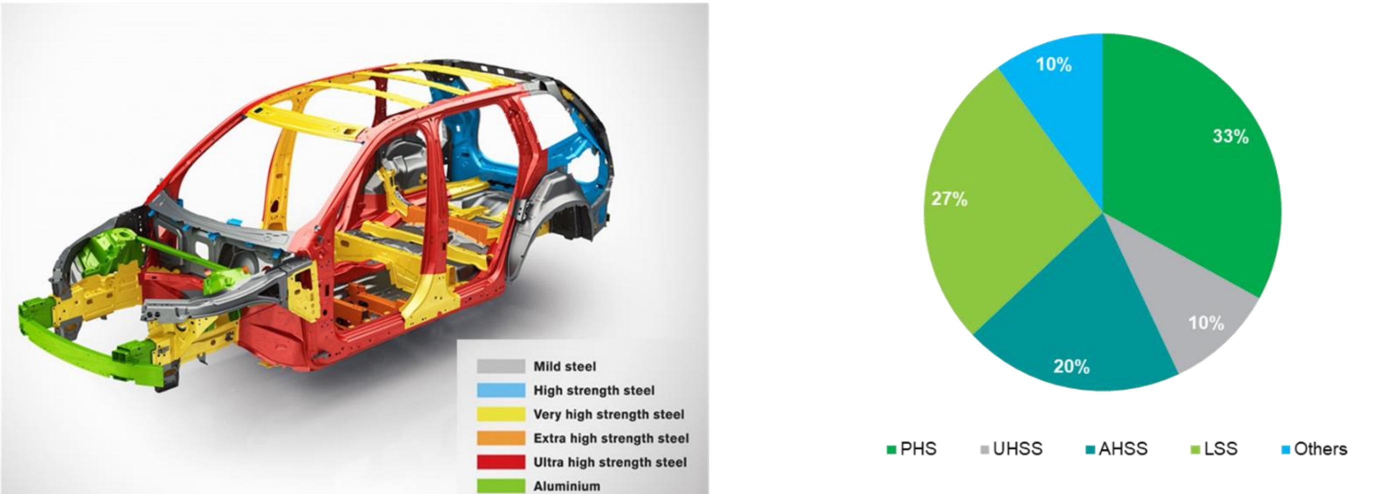
Figure 11: Vehicle monocoque chassis frames of Jaguar F PACE (L) and Range Rover

Source: Jaguar, Land Rover

© 2019 IHS Markit

Most of the passenger cars today use what is known as the unibody chassis frame. The unibody design is a unitary construction that combines the bulkheads and tubes with a system of box sections through ring like structures running across the body frame. The skins or sheet panels are then added to this base structure. As the unibody design is supported by this combination of stiff subsystems bound by the rings and pillars of differentiable strengths, the sheets are not required to add much stiffness or rigidity and can be designed of thinner or lighter materials. The integration of zones also allows for significant lightweighting. The unibody design allows for multi-material design frames, most prominently allowing for the joining of aluminum to steel through friction stir welding in low stress zones. The base platform can be made from hot stamped steels with molded ribbing to provide for additional strength while decreasing weights. The stiffness of the unibody can be further increased by using advanced adhesive methods and glues to produce continuous, stress-free joints with the addition of closed-tube sections and components. The addition of energy-absorbing deformation zones help to enhance safety through closed loops in the unibody structure. The resultant unibody structure is thus compact and spaciously configured and, not surprisingly, it is perhaps the most used chassis frame design across models. Conversely, a unibody design will be more difficult to repair from a collision owing to the elaborate interconnections.

Figure 12: Volvo XC90 unibody chassis contribution by material (%)



Source: Volvo, IHS Markit

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In general, two major factors are guiding chassis frames lightweighting: the use of AHSS and hot stamped high-strength steel (HSHSS) and the increasing usage of the multi-material concept across space frames, unibodies, and Monocoque frames in whatever way possible. The simultaneous surge for the multi-material approach in recent years has further helped the cause of lightweighting of chassis frames. By using a multitude of materials like HSS, aluminum, magnesium, and CFRP, OEM design teams are arriving at solutions that maximize combinations of optimum strength versus lowest possible cost and weight. BMW, Audi—and even volume players such as VW, FCA, and others—are pursuing this multi-material approach to decrease weight from the unibody, monocoque, and space frames.

Automotive OEMs are also designing for the allowance of battery weight and positioning along the base of the frame for even weight distributed. They are already designing compliant common platforms to prepare for the electric vehicle (EV) wave. The general principle of having a lighter top frame, while allowing for heavier base frames, is to keep the vehicle’s center of gravity low under the seat of the driver. This not only lowers weight and optimizes force, but also provides the stability and driving experience required for maximum performance and fuel economy from the vehicle.

Suspension systems

While the penetration of aluminum in suspension components (such as control arms, steering knuckles, and in some cases, axles) is increasing, companies like Hutchens and others are still banking on HSS for lighter and thinner suspension springs that have the same load carrying capacity and durability.

Glass-fiber-reinforced polymer (GFRP)—specifically in coil springs—is now seen in suspension systems. This suspension technology is becoming more widely accepted, owing to the decreased costs of active suspensions and the subsequent weight reduction it allows. The ZF Group is also using GFRP to reduce several components in the axle. The ZF team has replaced the complex control-arm-and-spring concept with a single-component wheel-guiding transverse spring. This component reduces the weight and complexity of the axle parts. ZF has also made a lightweight, MacPherson-integrated strut, with a wheel carrier made of GRP/GFRP, that reduces weight by almost 50% compared to conventional steel struts. This strut can be used for lighter vehicles of one ton and ZF is ramping up this technology for larger vehicles.

The Michelin Active Wheel, consists of a standard wheel that houses two electric motors. One of the motors acts as an active suspension system, while the other drives and brakes the wheel. This technology reduces weight by knocking off the gear box, clutch, drive shafts, and anti-roll bar through the usage of this active suspension system. The suspension system is controlled through a gear rack and pinion instead of a hydraulic shock absorber, another reduction in weight. Thus, the overall wheel weighs just 42 kg including a 25 kilowatt water-cooled drive motor.

Braking system

OEMs and vendors are making dedicated efforts to eliminate weight from the braking system. For instance, lightweight aluminum rotor discs have been designed with ceramic coatings to account for the thermal characteristics while reducing weight. The ceramic coating itself is applied in layers and patches to account for thermal expansion. Also, BMW’s new “slim rim” brake rotor design, is more than 10 pounds lighter than standard rotors although it appears larger. This is achieved using lighter aluminum on the rotor hats, with a larger friction surface across the circumference, and a shorter area from top to bottom. This allows for a weight reduction in the wheel disc, while providing for equivalent friction and braking control. BMW has also developed a slimmed-down, two-piston caliper, which knocks off another seven pounds from the brake assembly at each wheel. Brembo has also developed a steel disc housing made of HSS that is just 2.5–3 millimeters (mm) thick (conventional cast iron housings are 7.5–9 mm thick), providing a 10–15% weight reduction. Brembo is also known to use carbon ceramic discs for premium segment cars and is the exclusive supplier for specific models of Porsche, Ferrari, Audi, and Bentley. Brembo has also integrated the parking brake unit with the main caliper with the use of aluminum to knock down the weight by more than one kg per caliper, especially ECS (electrically controlled secondary caliper). This technology is debuting with the Alpine A110.

Conclusion:

The prevalent trend today across all OEMs, premium and mass segment alike, is to keep the base chassis platform common across multiple models. This allows for ease of production and lower design costs by distributing the same chassis platform across models. Hence, chassis components are usually tied to global platforms and therefore are highly cost sensitive to car production. The design must be robust and high performing but also common and available across multiple locations—wherever the OEM has a chassis manufacturing plant. This creates a challenge for the material selection and research opportunities. Therein lies the opportunity for lightweighting—to provide relevant material options. Mass reductions in the chassis components will therefore rely on cheaper options to ensure that all variants can maintain a cost-competitive bill of materials. While premium, niche, or racing cars can afford to have selective material preferences for lightweighting—based on customer or performance preferences—it is critical for mass models to have common-component designs and material selections.

Exterior Systems

Weighing at up to 15% of the total weight of the car, the exterior component system also forms one of the major mass blocks, and considering the structural and torsional rigidity requirements of the component subsystems, it provides for a very interesting mix of materials to choose from. When considering the number of features and sensors that add weight to the exteriors, lightweighting becomes an important requirement for the exterior systems. The main challenge is achieving this goal while ensuring the safety structural requirements are not compromised.

Car doors

Figure 13: Car door frame

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With respect to the door component subsystem, steel is the preferred material in mass-segment vehicles, whereas aluminum is catching up fast on the mid-to-high-segment vehicle bracket. Press-hardened and ultra-high-strength steels (UHSSs) are also being used extensively to account for lower weights and costs. The combination of aluminum and steel for inner and outer panels has been, in fact, one of the most dominant material systems being used across door panel systems for some time now.The usage of aluminum sheets both on the outside and inside of doors, with additional bracing inner frames is known to drop the weight even further, in the range of 25% and upward, as compared with conventional all-steel door options.

Aluminum has gained a lot of ground in side impact beams owing to the design flexibility in their extrusion sections, ease of joining to an outer steel panel, and inherent light weight. However, the latest innovation in advanced steel chemistry is allowing thinner and stronger steel sections to compete with aluminum for this component. Weight is managed by using a combination of tubes and solid rods in the frame.

OEMs such as Audi, Land Rover, and Porsche are known to prefer all-aluminum door panel systems for lightweighting. On premium- and niche-segment vehicles, carbon fibers are being used in some cases for exterior body panels to provide for extreme lightweight door panels. The biggest advantage of having a lighter door system is that it shifts the center of gravity further toward the center of the vehicle, which improves vehicle maneuvering and handling.

Glazing solutions

The transparent components in automotive glazing include primarily the windshield, the rear hatch glass (backlight), the four side rolling windows, as well as the front and rear fixed quarter windows. These subcomponents are estimated to weigh more than 45 kg on average. This figure can be even higher in cars with a sunroof and more curved/canopy-type windshields.

Laminated glasses by themselves are known to be around 10% lighter than tempered glasses. Hybrid glass laminates that use the fusion draw process and ion exchange are known to be 30% thinner and provide equivalent NVH performance for large windshields etc. There are also developments around a bilayer windshield with only one layer of glass as the outer sheet, between 2–4 mm in thickness. Recycling of windshield components and reclaiming of plastic sheets are also becoming popular, which is making the laminate technology cheaper and hence more usable across segments. The use of dynamic tint technology for cars is also adding weight to the glasses, but this may become a popular choice for customers.
The usage of Gorilla Glass by automotive vendors/OEMs is one of the biggest push for glass lightweighting. Gorilla Glasses are only 3–4 mm thick; they are approximately 25–50% thinner than traditional glass laminates, which are between 4–6 mm thick.

In fact, Corning—the manufacturer of Gorilla Glass in smartphones—has partnered with automotive glass maker Saint-Gobain Sekurit to scope for mass production of Gorilla Glasses for the automotive industry. This is expected to help lower the cost of production further. The joint venture (JV) is supposed to manufacture windshields that are 30% lighter than the standard windshield mass of around 5.5 kg.

Polycarbonates (PCs) are also emerging as a viable option to glasses for glazing. PCs offer increased pliability and hence enormous styling and integration options. In fact, PC glazing allows for the integration of the roof module frame with the optical panel. Thus, PCs are expected to offer up to 40–50% weight reduction as compared with laminated glass. However, regulatory hurdles in the North American Free Trade Agreement (NAFTA) prevent PC use whereas Europe is allowing it. The major disadvantage of PC is its low UV resistance and low scratch resistance. To counter these, coating or layering of PC windshields is required, which kind of destroys the cost advantage of PCs vis-à-vis glass glazing solutions.
Going forward, PC solutions are expected to see improved penetration in mass-segment vehicles too, especially for lighter side fixed windows and rear hatch, as well as moon roof glazing.

Tailgates/Liftgates

Traditionally, tailgates have been made from thin metal sheets, preferably steel, to account for homogeneity in the exterior vehicular structure strength as well as appearance. Considering that tailgates are probably the lowest-risk component in times of crashes, the structural and torsional strength requirements from them are relatively not high. As a result, tailgates are probably the low-hanging fruits at the moment in terms of lightweighting by using alternative materials. A number of materials are currently being considered for making tailgates, including sheet-molding compounds (SMCs), thermoplastics, PCs, as well as composites, apart from the metallic sheet tailgates for mass-model items. In fact, many OEMs are progressively phasing out metallic tailgates even in their high-volume vehicles in favor of lighter, nonmetallic alternatives mentioned above.

SMC is being used massively across OEMs and especially in tailgate panels because of the light weight as well as structural integrity opportunities. The weight of the component made from SMC is more than 30% lower than those made from advanced steels and provides tremendous opportunities for integration of parts, leading to further lowering of mass.

Roofs/Sunroofs

Roof systems made of thin steel sheets and accompanying subsystems are known to weigh in the range of 10–15 kg for a normal mid-segment car. The usage of aluminum in the same provides additional weight savings of up to 30%. However, the use of aluminum in roofs with a steel body calls for addressing the fusion and joining of the two materials at joints. Many advanced welding and adhesive bonding technologies have been developed for this purpose, and hence lightweight aluminum roofs on steel BIW have been finding their way into many models such as the Range Rover Evoque and Maybach luxury cars. Another major issue with using aluminum roofs on steel BIW is the difference in thermal expansion between the two materials, which makes fabrication difficult especially during painting and curing. There may be distortions leading to unacceptable surface finish normally. Hence, special aluminum alloys are being used, which are not only stronger but have matching thermal expansion coefficients.

Figure 14: Car sunroofs

Source: Shutterstock © 2019 IHS Markit

In fact, Novelis has especially developed a high-strength aluminum alloy Anticorodal®-600 PX with excellent formability, for the roof of the Evoque, owing to the abovementioned reasons only. Novelis has also recently announced the usage of hot-quenching technology for the aluminum pillars that support the roof and roof bracing. This is being achieved by hot forming aluminum sheets and then quenching them in the die at one of their UK partners. This will open the floodgates for low-weight aluminum roof structures with strength properties that approach the ideal temper while being an efficient forming process. The roof rails have also become an attractive option for the usage of lightweight extruded aluminum technology. The usage of extruded aluminum rails also eliminates the need for extra cast supports because the rails are integrated through hydroforming.

Front and rear bumpers/Fascia

OEMs have followed disparate strategies for material selection as well as load design for bumper beams. There is the strategy for load transfer from the bumper to structural members, and then there is the beam crush or self-crumple strategy leading to a crumple zone and absorbing energy in the front itself. However, considering the repair and aftermarket implications of these designs, this decision point means quite a lot to consumers, insurance providers, and repair shops.

The use of plastics in front fasciae/bumpers allows designers a lot of freedom both in shape complexity as well as integration. Hence, the plastic bumpers of today have active grill shutters or headlamp slots and designs integrated with them, allowing for a smooth and one-piece surface finish. However, when considering repair and aftermarket implications of these designs, this decision point means quite a lot to consumers, insurance providers, and repair shops.

Going forward, for these lighter components to be sustainable across models, OEMs would need to balance the extremely low weight and ease of manufacturing with the costs and difficulties associated with the replacement of the bumper components. There is a fine line between lighter components and consumer apprehensions, even more so for bumpers, and OEMs need to keep that in mind when considering any material change.

Powertrain - Engine

The powertrain system can weigh up to 20% of the entire vehicle weight on average. Within this system, the engine itself contributes anywhere between 10% and 15% of the vehicle weight.

Figure 15: Disassembled car engine

Source: Shutterstock © 2019 IHS Markit

Because the engine also serves as the power source of the vehicle, it is even more important that the weight of the entire powertrain system be optimized/minimized so that it is not overly feeding on its own generated power; subsequently, more power would be available for movement of vehicle. The Brake Mean Effective Pressure or BMEP is an important indicator of engine efficiency, indicating the average effective pressure of all the stoke cycles. BMEP is dependent on the temperature of the combustion chamber or the burning of the fuel. Less emissions or better fuel mileage means a higher BMEP, which leads to higher torque or power for the engine. A lighter engine means less emissions and more torque. Thus, lightweighting plays a vital role in increasing the overall efficiency and power of the engine. The aim of lightweighting is to improve upon the maximum torque per kg of the engine weight. This can be achieved by downsizing the engine completely and supplying higher torque through turbocharging or efficient burning from a comparatively smaller-volume engine. Another way is reducing the weight of subcomponents in an existing engine, which will provide similar benefits.

Engine Valves

There are a number of materials and alloys that can be used for the manufacture of valves, including low-carbon steel alloys, austenitic and martensitic stainless steel, titanium, and nickel-chromium-iron alloys. While titanium valves are 40% more lightweight than steels and offer high-temperature strength and corrosion-resistant properties, they are costly when compared with steel options, and as a result, their use is limited to high-performance and luxury vehicle engines. In general, silicon-chromium steels are used to make inlet valves because they can provide strength as well as reasonable high-temperature strength, whereas austenitic chromium-nickel steels and Nimonic nickel-based alloys are used for exhaust valves owing to their extreme-high-temperature-strength and corrosion-resistance properties. These alloy steel valves are still considerably lighter and better-performing than the low-carbon steel alloys of earlier generations.

However, the choice of materials is not the only way of lightweighting the valves. Many companies are making the head, stem, and tip of the valves from different materials to save costs as well as weight. The disadvantage with a two-piece valve is the slower cooling than a one-piece valve. Another way of lightweighting the valve while maintaining the cooling parameters is to make a hollow-stem valve and fill it with sodium for better cooling. Hollow-stem valves are known to be more than 18% lighter than solid-stem valves of the same length. MAHLE, in fact, has come up with a stem made from a precision steel pipe. The valve cone and disc are also made from metal sheets in a multistage metal-forming process. They are all joined by laser welding and the hollow stem is filled with sodium. MAHLE claims that this new valve is up to 55% lighter than conventional solutions. Another 8–10% of the valve's weight can be reduced by making it a bit shorter, or undersized. In terms of mass, all these savings may be low, but in terms of effect they are tremendous considering the revolutions per minute (RPM) and opening cycle/frequency of the valves. Hence the focus on smaller details too.

Camshaft

Camshafts have been migrating from solid cast-iron rods to hollow rods made from steel for reducing the weight. In fact, emerging cylinder head technologies such as FreeValve, where the camshafts are replaced by electronic actuators for valve movement, can reduce the overall size and weight of the engine when compared with chain/belt-driven 4-valve engines. Compounding effects from a dimensional reduction of engine size also can further change the weight of a body-in-white (BIW).

The usage of such forged steel camshafts is costlier, and hence it is limited to higher-end cars with low production volumes. However, it is expected that with a rise in scale of steel and lowering of costs, steel camshafts will make their way down to mass-segment vehicles, providing up to 30% weight reduction as compared with cast-iron camshafts. Further developments in steel camshafts include making composite or assembled camshafts with steel pipes and separate lobes. This allows the optimum usage and mix of inexpensive and lighter components with high-performance materials/subcomponents.

Cylinder head

Common alloying elements for aluminum cylinder heads include copper and silicon. While silicon improves castability and abrasion resistance, copper helps in age hardening and reducing thermal expansion and contraction. Manganese and magnesium are known to increase the strength of alloys and are added in small quantities to the aluminum matrix. In general, the better the strength and thermal properties of the matrix, the thinner the cross sections across the ports and passage holes and hence lighter heads can be further designed. This can lead to downsizing of the heads and therefore, secondary lightweighting. Aluminum-silicon-copper alloys are used for cylinder heads in moderately loaded gasoline engines, while nickel and higher-copper-containing aluminum alloys are being developed for the high temperature requirements of high-performance diesel cylinder heads.

IHS Markit's ongoing material research further laments the dominance of aluminum and aluminum-based alloys as preferred materials for cylinder heads. The usage of cast iron is very limited. It is however interesting to note the progress of specific alloys, such as the A319 and A356, as cylinder head materials, owing to the design developments at raw material companies that are targeting cylinder head usage and material requirements with innovative alloying solutions across OEMs.

Cylinder block

In cylinder blocks, weight reduction is happening by reducing the wall thickness, as well as total height, of the block through stronger alloy chemistries. The transition from cast iron to aluminum cylinder blocks is happening across the board with development of special aluminum alloys. In fact, Fiat Chrysler Automobiles (FCA) has recently developed a high-temperature alloy for the cylinder head, which may also be used for cylinder blocks, even for diesel engines. Coated cylinder walls replacing steel liners have a huge potential for weight reduction and would be heavily preferred because they provide

We have found that a number of OEMs have decided to use a common cylinder block for both gasoline and diesel engines, which further leverages economies of scale. Considering that engine blocks can weigh around 3% or more of the total vehicle weight, using an aluminum cylinder block provides tremendous lightweighting benefits. Historically the cylinder block liners were made of cast irons, steels have taken over recently because of better thermal characteristics, therefore resulting in reduced weight. Nitrided steels have been found to be particularly successful as liner materials. However, going forward, coatings in the cylinder bores are providing avenues to the total removal of cylinder liners. These coatings are not only thermally stable, but they provide better surface properties in terms of optimum oil retention and fluidity for the movement of pistons. But above all, this means tremendous opportunities of cutting down weight directly in the combustion chamber, which can have compounding effects. Heller Machine Tools has, in collaboration with Daimler AG, developed a similar coating technology for aluminum blocks, called the Heller Cylinder Bore Coating (CBC).

Early results from an ongoing material research by IHS Markit also suggest that aluminum will remain the preferred material for cylinder blocks, followed by cast iron; aluminum is expected to gain further penetration. There are very limited use cases of aluminum-magnesium cylinder blocks currently, but this is expected to increase slightly over the next five years. However, it is even more interesting to note from the above graphs that within aluminum cylinder blocks, steel liners are expected to be declining consistently over the next five years. This means more cases of coated cylinder bores and lighter cylinder blocks with time across OEMs.

Pistons

Aluminum alloys are preferred for their high thermal conductivity and easy machinability, along with the lower density and easier manufacturability for near-net-shaped components. Hence, aluminum pistons are vastly used across gasoline as well as diesel engines. The alloy composition contains aluminum with up to 12% silicon, along with varying proportions of copper, nickel, and magnesium, which helps in the high temperature strength, wear, and fluidity characteristics. Cast pistons are generally made from eutectic alloys whereas forged ones are made from hypereutectic alloys as well to allow for the higher strength requirements. As discussed earlier, forged pistons are known to have a finer grain as well as microstructure that provides higher strength in lower temperature ranges as well as reduced wall thickness, resulting in reduced mass of the pistons. Future research into varying aluminum alloy metal matrix composites and powder metallurgy are expected to further lower the weight of the final component with equivalent or better material characteristics.

Additive manufacturing is making a foray into engine component systems. There are use cases of 3D-printed pistons to provide complex customized designs at extremely light weight, with Ferrari taking a lead on this in the F1 racing circuit. 3D-printed pistons can have a definite business case in the heavy-duty marketplace, where lower volumes thrive and weight savings could be large

Crankshaft

The strict fatigue and tensile strength requirements mean that the material alloying as well as grain structure need to be perfectly fine tuned. steel-forged crankshafts are mostly preferred by all OEMs. Forging ensures excellent grain flow and strength, which further help in improving fatigue strength. The different alloying elements help in increasing the hardenability as well as maintaining a softer core. This again leads to higher surface strength and fatigue life.

The grain size and structure are also found to be better in such low-alloy, high-strength steels. Molybdenum steels are preferred for forged crankshafts, along with alloying additions such as manganese, chromium, nickel, and vanadium to achieve the balance between hardness and grain structure in forged crankshafts. The use of such advanced microalloyed steels does help in reducing the weight of the component for equivalent strength and hardness. Most OEMs are working on such specific grades of steel to help them knock some weight off crankshafts.

Apart from the material choice, there are few other ways of lightweighting a crankshaft. Some engineering designs prefer a smaller journal diameter, wide enough for the connecting rod’s bolting and strength requirements. There are also use cases of decreasing the size/width of the flanges to attain substantial weight savings. One of the largest passenger vehicle manufacturers from India is known to use a combination of both to obtain close to 2–3 kg weight reduction from the forged crankshaft and more than 0.5 kg from the final machined crankshaft.

Exhaust manifold

Historically, SG cast iron has been the preferred material for exhaust manifolds because of its low cost and easy castability into the required complex shapes. However, SG cast iron manifolds are considerably heavy and are also brittle and prone to impact crack. There is also the tendency of having surface and subsurface defects, which are generally higher for cast iron and can be critical for component failures.

As a result, steel is the next preferred material for exhaust manifolds. While it is a little costlier than cast iron, it more than makes up in its better resistance to corrosion and light weight as compared with cast-iron manifolds. Steels are used in the form of tubings and castings for making the exhaust manifold’s complex structure.

One of the interesting design developments for the exhaust manifold is the integrated component within the cylinder head, called a “headifold.” New engine architectures, such as those seen in the Honda Civic Type R and VW Jetta,have this integrated exhaust system, and the trend is expected to continue with the newer-generation architectures across OEMs. Not only does this save considerable weight owing to the integration of components, it also promotes better heat exchange and less thermal loss through the exhaust system, allowing for faster and better reheating of air/fuel mixture and hence improved fuel combustion and economy. In addition, emissions go down because of better fuel burning, making integrated manifolds look even more attractive. The only issue that remains is to fine tune the cooling system of the vehicle to take off this extra heat load from the manifold to the coolant, and hence, some design interference is required for this technology to take off.

Early indications from the ongoing research at IHS Markit regarding exhaust manifold material choice suggests that steel may become the major material preferred for exhaust manifolds, and integrated manifolds will also increase their share in the near to middle term. Cast iron technologies are expected to slowly give way to these two in the long term but may still be around strongly for the next five years or so while the design teams at OEMs come out with new cooling and exhaust architectures for improving the overall efficiency of engines at equivalent cost.

Indian Automotive Industry – Lightweighting scenario

The Indian Automotive Industry has traditionally been a mass market segment especially in the A & B segment cars. For decades, the largest selling cars in India were the entry segment cars and were aimed at a customer segment which was mileage hungry. The result of this combination has been that the OEMs churned out extremely light vehicles with turbocharged engines that made the final kerb weight of the vehicle to stay well below 1000 kgs for long. Not surprisingly, lightweighting per se was not a separate requirement for the Indian Automotive Industry and weight reduction was therefore seen mostly as a Kaizen activity once the initial car was launched. The philosophy of 1 part– 1gram weight reduction ingrained deeply in the vendor development thereafter was the major driving force towards knocking off mass sequentially.

However, the past 3-4 years have led to the rise of optional content in the cars. This is partly being driven by the rise of dispensable income in Indian customers and the rise in expectations in terms of the features from the car. The launch and growth of MPV segment is another driver where customers are now expecting the cars to be bigger, feature rich and with better driving experience. All this while the mileage expectations of the customers have not gone down and the emissions and safety standards have grown even tighter along the global norms. The cost vs weight vs features vs norms conundrum is what is making the Indian Automotive market a true mystery and Lightweighting can be a true hero to the rescue.

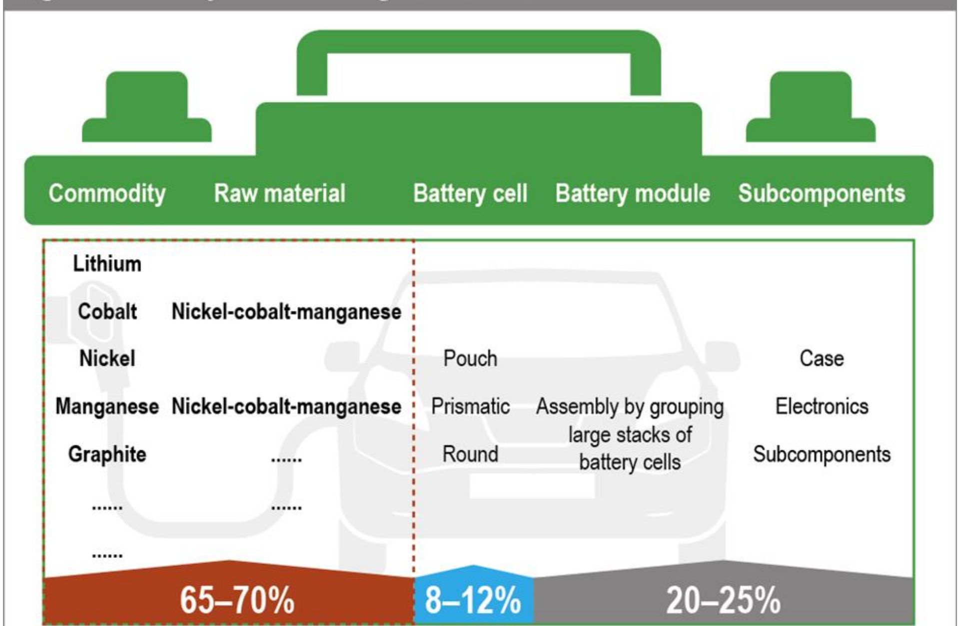
Currently the Indian Automotive Industry produces passenger cars majorly in the weight range of 700kgs to 1700 kgs. This shift within this weight range to upwards of 1000 kgs is coming straight from a shift in the popular segment and the introduction of heavier, feature rich cars. The most popular segments of cars are now in the compact sedan segment and UVs. Instead of downsizing the engines and using sub 1.2 litre engines majorly, the industry is shifting to 1.3, 1.5 and 2.0 l engines for better power and emissions as and when required. Further in the Indian market, value for cost is a deciding factor for customer buy and hence margins run really low. This puts extra pressure on the final pricing increase despite feature additions. Lightweighting is further helpful in identifying synergies through both primary and secondary weight reductions and thus decrease the input costs to balance out the spectrum. Quite clearly, intelligent light weighting can even serve as a competitive advantage for the OEMs as well as suppliers.

The opportunities for the vendors in India market are significant. In terms of materials of choice, high strength steels, aluminum and plastics/polymers are clearly the frontrunners for automotive here. While cast iron has enjoyed a typically large share especially in the powertrain and chassis component areas for Indian cars, it is giving way to steels and aluminum at an increased rate owing to both the lighter weights and equivalent cost to weight advantages. Especially the cast-iron heavy engine area is getting disrupted by aluminum and high strength steels in terms of steel camshafts, steel block liners, aluminum cylinder blocks, aluminum heads and a lot many others whereas microalloy (and lighter) steels are cutting down weight from the connecting rods, crankshafts, piston pins, bearings etc which are the moving parts and hence have manifold effects on the efficiency of the engine.

It is also important for OEMs and Vendors to use the principles of lightweighting as a primary design tool to counter the costs and weight right from the conception stage. Considering that the Indian market is seeing a slew of new products and the product life cycles are becoming progressively shorter, it is imperative that the players look at weight reduction from various component areas as part of the design DNA itself. Considering that the penetration of plastics/polymers in the car is reasonably high currently, one may think that potential for lightening may be limited. However, Indian plastic suppliers can really turn a corner by concentrating at various non-thermal zones in the powertrain areas as well as various integration possibilities. Plastic thermostats, intake manifolds, clutch master cylinders amongst others are some of the very interesting use cases of cutting down weight with innovative uses of plastic/polymer chemistry and molding methods. Interiors are another potential component area for increased use of plastics which give premium feeling. This is both a possibility for advanced chemistry and improved margins for the plastic/polymer players. Material substitution is not the only way of reducing weight from the component. Vendors can look at various options like integrating of components, plastic mold over metal component, novel joining techniques, stamping and punching methods as well as thinner cross-sectional parts as various modes of cutting down weight from the component. However, the requirements of mechanical strength and allied torsional rigidity etc must be taken care of in every case.

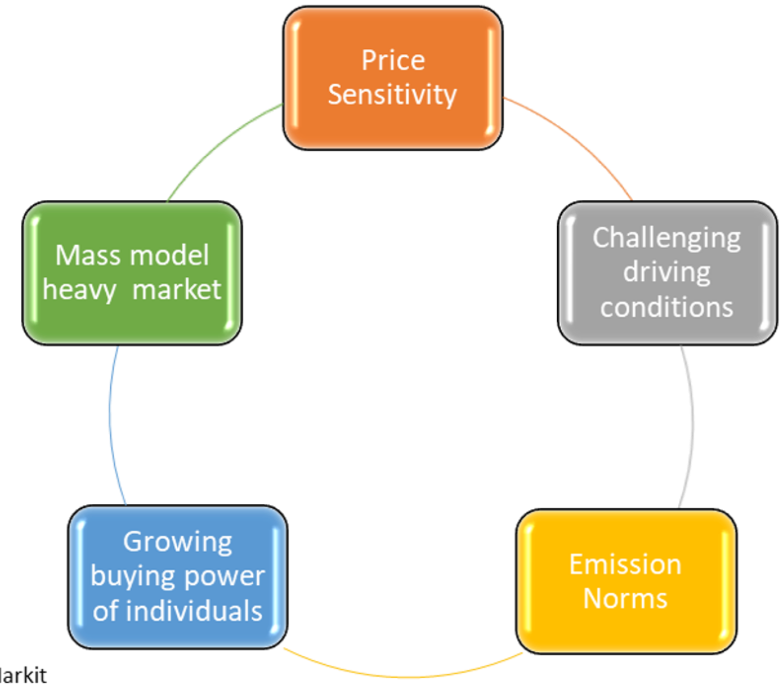
With the government giving increasing attention to Make in India and EV2030, Indian Automakers have a huge potential to scale to global level and standards while retaining their inherent USPs. Lightweighting is a global phenomenon and Indian players have an opportunity to not only match up to the global requirements and technology in this regard but infact use their inherent knowledge of lighter parts and cars as well as the manufacturing processes to match the curve. They can infact enter into JVs with global giants as well as have global footprints while embracing the material choices and possibilities. It is to this fact that many Indian suppliers are researching into lighter AHSS, High temperature aluminum alloys, magnesium manufacturing and scalability as well as carbon fibers towards the needs of automotive industry. Since the EV leap in India will be a customized approach there is a huge opportunity for Vendors and OEMs to design lighter and safe components and batteries which will enable a higher driving range and hence increased penetration in the Indian market for these electric vehicles. The EV battery manufacturing industry itself provides for many opportunities for the traditional component manufacturers to scope and enter the market at various levels of the value chain as below. Indian auto-component manufacturers need to align themselves accordingly

Figure 16: Battery manufacturing value chain



Source: IHS Markit © 2019 IHS Markit: 1737683 to similar other technological opportunities so that they do not miss out on the EV bandwagon.

Figure 17: Factors affecting materials and lightweighting in India



Source: IHS Markit © 2019 IHS Markit

However, all the automotive players must keep the quality and feel perceptions of the consumers in mind while designing for lighter components. Lighter parts in general are not looked at very kindly by consumers unless they are costly alternatives like carbon fiber. It is imperative therefore to use design philosophies that do not deteriorate user experience. Body color components are therefore used whenever plastic components replace metal ones, especially in the exteriors. For the interiors, also color and texture designs need to complement the enhanced feeling. Another threat to Indian Suppliers may be to miss the global technology caravan around lightweighting and its usage towards future EVs as well as ICE vehicles if they are not aware enough. They can be disrupted by start-ups as well as external suppliers from China and South Asia with lighter as well as cost and functionally effective components. The push to BS6 is another impetus for vendors to actively use lightweighting principles to stay ahead of the norms.

As the automotive industry in India faces the disruptions above, players who make an early and informed move towards the principles of lightweighting will have a big advantage.

Conclusion

It is interesting to analyze in totality how various materials are gaining penetration across the component systems in premium OEMs as well as Volume OEMs. This provides for a roadmap for suppliers as well as OEMs to strategize for their overall lightweighting strategy. Premium OEMs are looking to alternative materials like aluminum, HSS, magnesium, advanced plastics, carbon fiber, and composites for lightweighting initiatives.

Volume OEMs are primarily looking to increase the usage of various grades of HSSs in place of conventional steels. However, aluminum is also increasingly becoming affordable and hence is being targeted for lightweighting initiatives by volume OEMs. The most favored alternative, however, is the mix-material approach, combining steel and aluminum wherever possible to keep the benefits of lightweighting as well as structural integrity. This is particularly important for volume OEMs, which generally do not have any additional, high-cost safety features. It is therefore expected that with time, pure steel configurations will give way to such mix-material usage.

IHS Markit is conducting research on the penetration of these materials across vehicles of premium as well as volume OEMs, in terms of usage in the number of vehicles sold. This research aims to establish in detail the effect of specific material usage on the lightweighting strategy of the OEMs, and when fully complete, it will be a true referral index for tracking the lightweighting path of all OEMs.

It is interesting to see some early trends coming out of the IHS Markit Lightweighting Forecast report. We will look at some of the major takeaways for chassis, powertrain, interior, and exterior component areas across Volume as well as Premium OEMs quantitatively, while the research on the BIW is currently on a qualitative basis only.

Chassis

For both Volume as well as Premium OEMs, the chassis area is seeing a decrease in the use of conventional materials like cast iron and steel in favor of lighter alternative materials, mainly aluminum and aluminum alloys. As per the IHS Markit preliminary research report, aluminum penetration in the chassis of premium OEMs is expected to grow at a CAGR of around 13.5% per year during 2018–23, whereas for volume OEMs' vehicles this is expected to grow at a CAGR of around 18.5% per year during 2018–23. Additionally for volume OEMs, the aluminum and steel mix-material configurations are expected to rise at a CAGR of 11.2%.

Correspondingly, cast-iron penetration is expected to decrease at a CAGR of over 8% while steel penetration will decrease around 1.3% during 2018–23 for premium OEMs. Simultaneously, in Volume OEMs cast iron will lose penetration at a CAGR of almost 17% and the penetration of pure steel configuration is estimated to decline at a CAGR of 8 % during this same period.

Composites and magnesium, which have minimal penetration as of now in the chassis components across vehicles, are expected to more than double their footprints by 2023—an indication of the technological advancements expected in these materials' processing and manufacturing for automotive solutions.

Powertrain

Powertrain was probably the most significant area where premium OEMs still preferred cast iron to some extent albeit very low, because of its excellent thermal and shock-absorbing properties. However, cast iron is losing out significantly even in powertrain components to other alternatives, with the usage penetration expected to decrease by a negative CAGR close to 2 % during 2018–23. The beneficiaries here are aluminum alloys and HSS whose penetration is expected to increase at CAGRs of 6.8 % and 4.3%, respectively. Magnesium is another material that is expected to gain significant penetration in powertrain with its increasing use in cylinder heads as magnesium alloys.

The powertrain component area for volume OEMs does not see any rapid change in material selection. Pure aluminum alloy penetration is expected to increase at a less than 1.4 % CAGR during this period, while cast iron penetration is going to decrease at a CAGR of -0.5%. Pure steel configurations are also expected to decrease, albeit at a very low CAGR of -0.2% in 2018–23. Thus, the powertrain area is expected to retain its major component materials. Again, the mix-material approach is favored by volume OEMs for reducing weight as well as aiding downsizing by integrating components wherever possible, without disturbing the combustion chamber components too much. The steel and aluminum alloy mix is again able to gain, with an increase in penetration of an approximately 8.5% CAGR in 2018–23.

Magnesium is expected to gain significant penetration in powertrain for both volume and premium OEMs with its increasing use in cylinder heads as magnesium alloys.

With other, nonthermally active areas, like thermostats and intake manifolds, plastics are expected to increase their foothold considerably over that time period. However, it is yet to be seen as to which components finally are overtaken by plastics and through which grades, as the technology is progressing at an astonishing pace.

Interiors

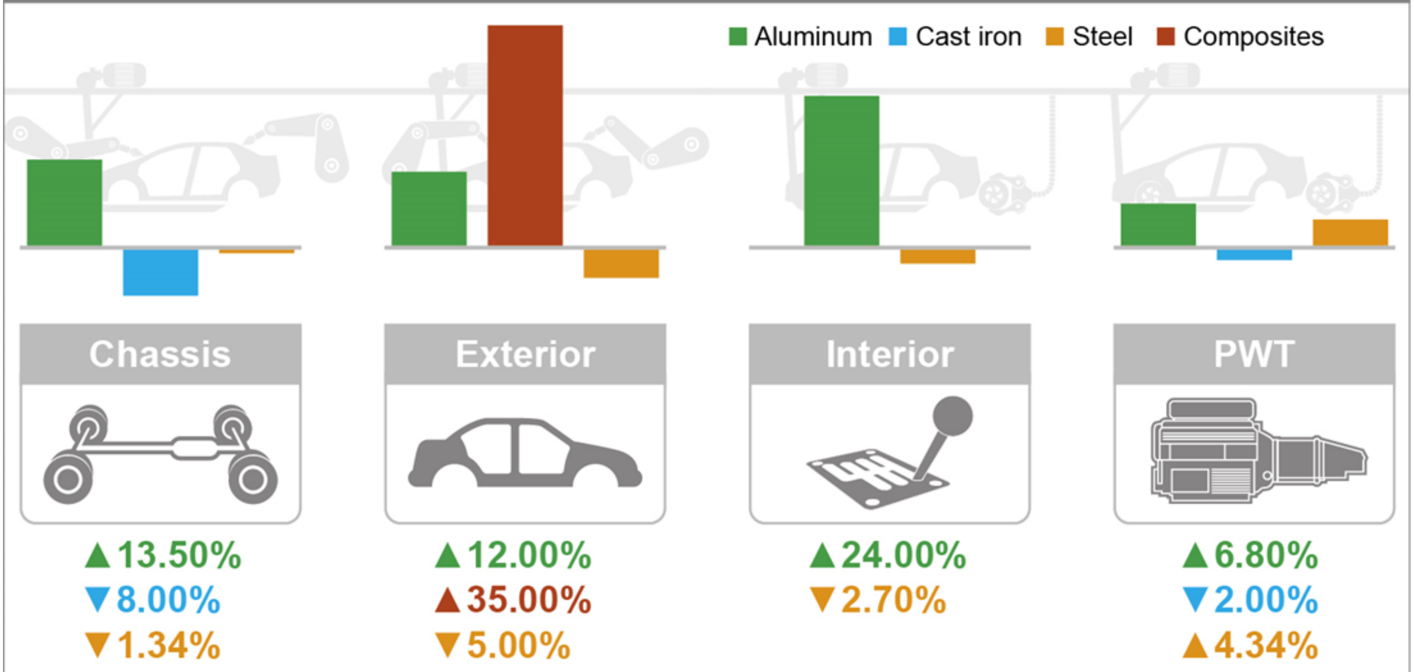
The interior component areas have been easily the showcase region for premium OEMs. The focus has been to introduce new materials while maintaining the luxury and richness of the aesthetics. Traditionally ruled by steel and plastics, the interiors are seeing increasing penetration by aluminum and magnesium for both premium as well as volume OEMs. Aluminum alloys are increasingly used around trims, display logos, and frames in the passenger and rear occupant cells apart from the steering components, with an expected CAGR of close to 24% in terms of vehicle penetration for premium OEMs and more than 27% for volume OEMs.

Magnesium is quickly becoming the norm for seat frames for all high-end models, replacing steel in many parts. New and advanced grades of plastics should replace existing ones in the automobile cockpit, increasing aesthetics while reducing weight, whereas carbon fiber is replacing normal plastics in many premium OEMs. The loser in this component area is steel whose penetration is estimated to decrease by a negative CAGR of 2.7% for premium OEMs and -4.4 % CAGR for volume OEMs during 2018–23.

Exteriors

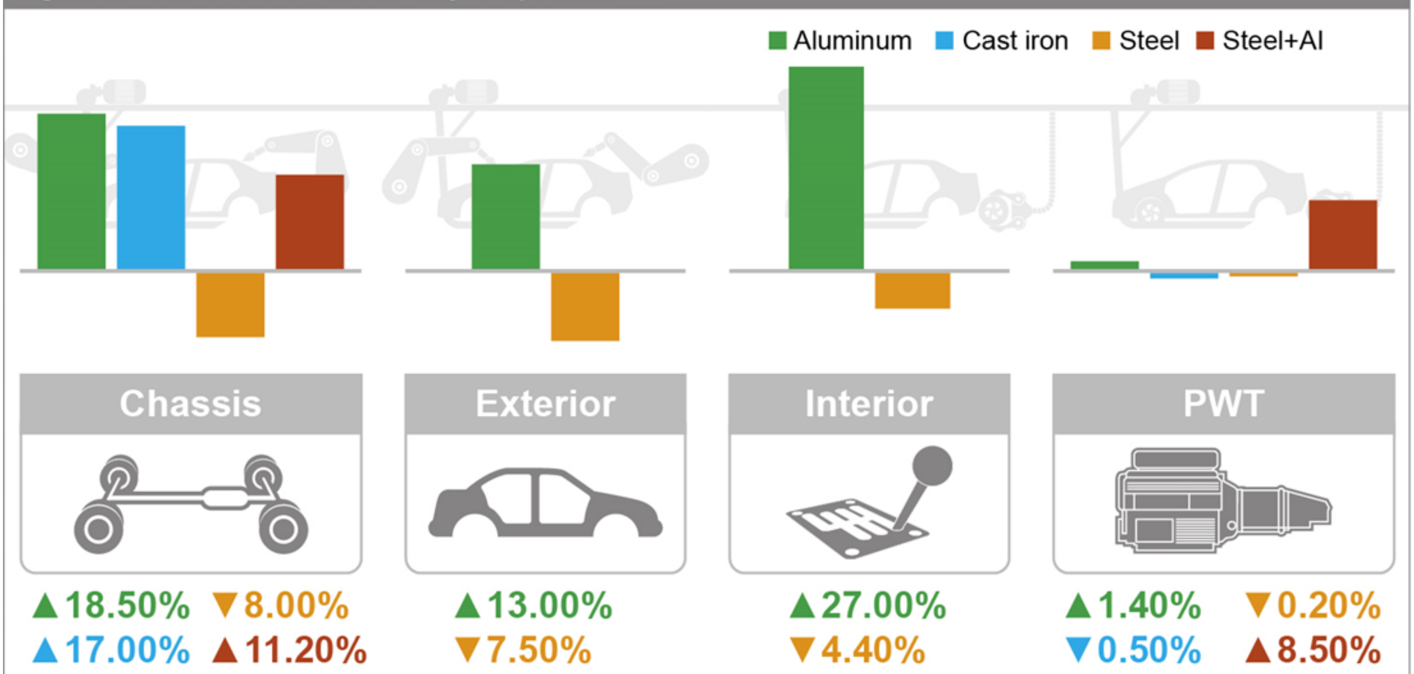
IHS Markit expects composites and CFRP materials to give exteriors of the premium OEMs a huge boost. A lot of research and existing products are also pointing towards the same. Unsurprisingly, penetration of CFRP and composites combined in premium OEMs is expected to grow at a CAGR of 35% in the exterior component area. Aluminum is also expected to grow at a CAGR of close to 12% for premium OEMs and around 13% CAGR for volume OEMs ,with increasing use around hoods, doors, and bonnets . The above lightweight components are steadily replacing steel from the exterior components, which is understandably showing a negative CAGR of more than 5% for premium and negative of 7.5% CAGR for volume OEMs between 2018 and 2023, among the total number of vehicles sold.

Figure 18: Premium OEMs—Material penetration by component area



Source: IHS Markit/Shutterstock

Figure 19: Volume OEMs—Materials by component area



Source: IHS Markit/Shutterstock

BIW

Although the current IHS Markit research does not quantitatively define the material penetration pattern across the BIW, it is understood aluminum and HSS are going to dominate the BIW for premium OEMs and primarily HSS only for volume OEMs. This is primarily due to the strength vs. weight requirements for the integrity of the BIW. Aluminum may find its way in the BIW in volume OEMs for specific regions only, with innovative joining technologies becoming available and scalable for mass manufacturing.

While composites and magnesium have found some scattered usage across a few models, their penetration is going to be growing sedately only for the BIW component area unless they make a technological leap in their strength parameters.

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Suman leads the Component Forecasting and Analysis India Team under the Automotive Supply Chain & Technology vertical. He has 9 years of work experience across supply chain and vendor development, strategic and operations consulting, market analysis and forecasting. He has worked at the largest Indian PV OEM and consulted for global automotive players in his previous roles. At IHS Markit, he is also responsible for the Materials & Lightweighting Sector.

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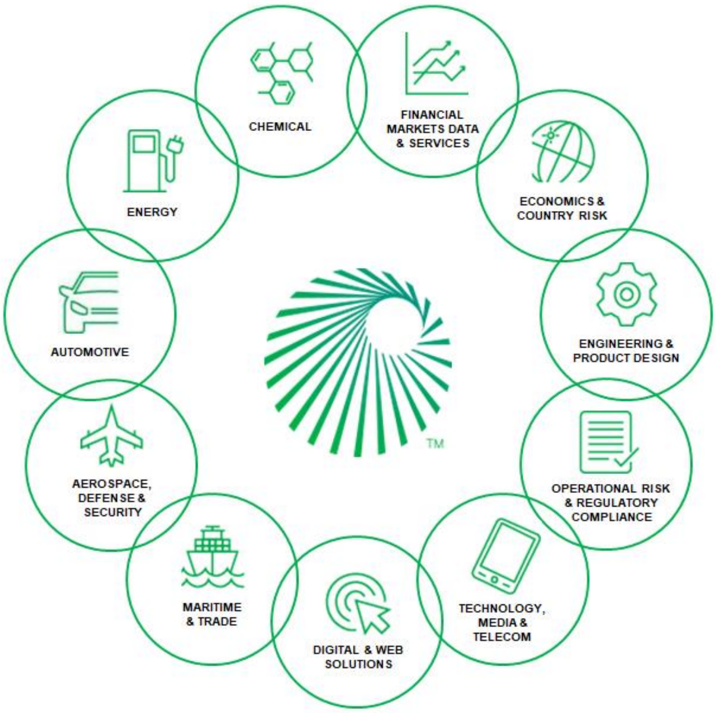

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