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# Adhesives in Transportation Series

## Part II: Adhesive Opportunities & Outlook in Light Vehicles

WHITE PAPER

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## Part II: Adhesive Opportunities & Outlook in Light Vehicles

**Light vehicle**

With over 17 million vehicles produced in the NAFTA region in 2015, the light vehicle segment represents the largest volume production in on or off-road vehicles in the region. The federal government classifies light vehicles as passenger cars and light trucks with a gross vehicle weight rating of less than 10,000 lbs. Therefore, crossovers, SUVs, minivans, and most pickup trucks fall into the light vehicle category.

**Light Vehicle Production Summary NAFTA 2015**

| | |
|---|---|
| United States: | 12.1 MM |
| Mexico | 3.0 |
| Canada | 2.3 |
| Total: | 17.4 MM |

Source: IHS, Ward's Auto, CBC

| Segment | 2015 NA Production (thousands) | Annual Market Growth 2015 – '19 | Adhesive Growth | Adhesive Growth Drivers |
|---|---|---|---|---|
| Light Vehicle | 17,400 | 2% | Above market | Fuel efficiency creating the need for lighter vehicles. Lighter vehicles achieved with mixed materials, which require adhesives to join. |

Source: Ducker Worldwide, ASC Growth Program Research, 2015; IHS, Industrial Market Insight

### Market Drivers and Trends

Because light vehicles are a consumer product in a highly regulated industry, manufacturers must balance consumer desires for comfort, convenience performance not only with household budgets, but also with ever increasing regulations on vehicle safety, emissions, and fuel economy. Consumer desires for larger, more comfortable, and safer vehicles generally require weight to be added to the vehicle in terms of electronics, reinforced body structures, and passive safety systems. As shown in the graph on the left below, the average weight of US light vehicles rose steadily from 1990 – 2003, while average fuel economy decreased over the same period. During that time, there were no incentives for vehicles to be more fuel efficient, as there were no changes in government regulations on fuel economy, and the low cost of gasoline allowed consumers to prioritize comfort, convenience, and performance over fuel economy when making purchase decisions.

**Figure 1: US vehicle weight, horsepower, and fuel economy**

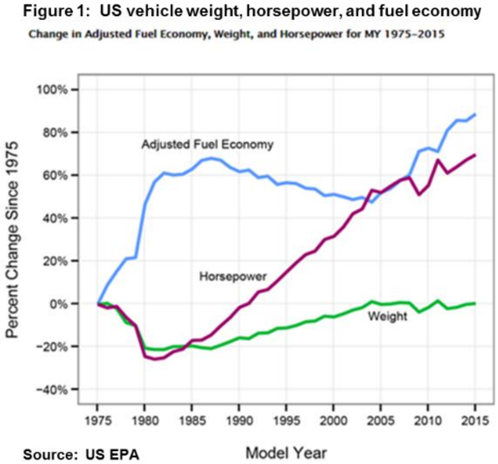
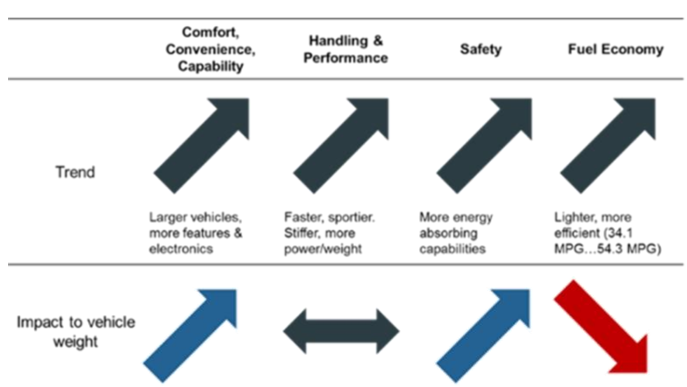


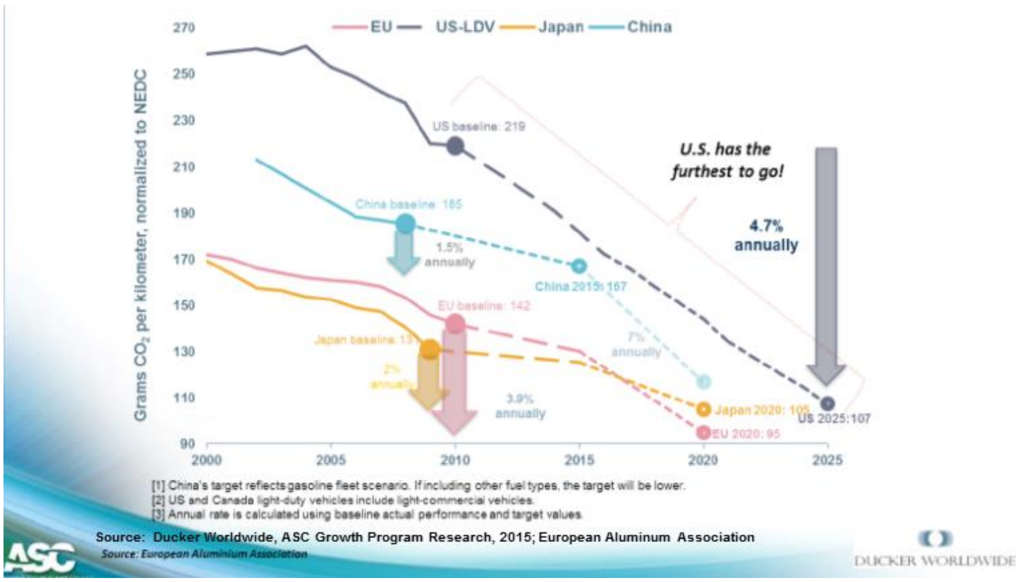

**Figure 2: Consumer & Regulatory Influence on vehicle weight**




Source: Industrial Market Insight

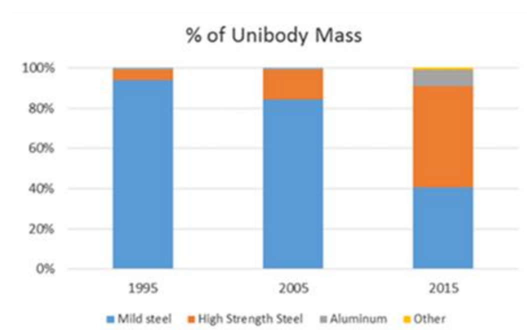
In the early 2000s, average fuel economy of US light vehicles began to increase for the first time in years. This was due to a rise in gasoline prices that led consumers to prioritize fuel efficiency in purchase decisions, as well as the first increases in federal fuel economy regulation in over a decade. In December 2007, Congress passed the first change fleet wide changes to fuel economy standards in nearly 20 years, requiring an improvement of about 40% by 2020. This has subsequently been accelerated, with a fleet-wide requirement of 35.5 MPG by 2016, and a pending increase to 54.5MPG by 2025. The intent is to reduce CO2 emissions per distance traveled in a manner that is consistent with the rest of the world. Figure 3 below shows a relative comparison of global regulations for CO2 emissions per kilometer traveled, which are all trending downward. In order to comply, auto manufacturers are using smaller, more efficient engines and transmissions coupled with lighter body structures. Reduction of the vehicle body mass contributes to fuel economy improvements, while also helping to satisfy consumer demands for nimble, quick, and fun-to-drive cars despite the use of smaller engines.

**Figure 3: Global CO2 Emission Regulatory Trends**




The desire of light vehicle OEMs to reduce weight has significantly changed the mix of materials used on body structures, as illustrated in Figure 4. Steel remains the material of choice in high volume passenger cars, which are typically designed with unibody construction. Manufacturers are familiar with steel, and it can be processed economically at high volumes using as stamping and spot welding operations. In the mid-1990s, mild steel won the overwhelming majority of body applications, with high strength steel limited to bolt-on parts such as bumper and door reinforcing beams. Through the early 2000s, high strength steel gained acceptance and began finding applications in mainstream vehicles. Coincidental with the revised fuel economy standards in the past decade, manufacturers began aggressively applying high strength steel to shed weight, and high strength steel accounted for nearly 50% of body mass in 2015. Despite its higher cost, aluminum has begun to gain market share, winning applications on parts such as hoods, doors, and tailgates, which are bolted on to the car and can easily be isolated from the steel body to prevent galvanic corrosion. These parts also tend to be above the center of gravity, so reducing mass improves handling and stability as well as increasing fuel efficiency.

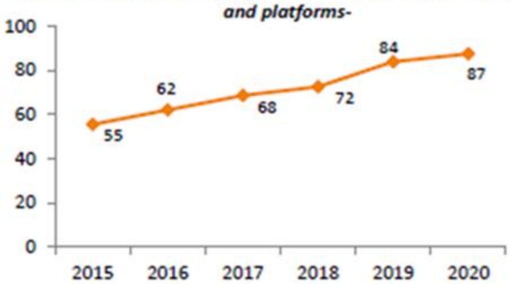
**Figure 4: Light Vehicle Body Material Trends**




Source: Industrial Market Insight

Structural adhesives have been a significant enabling technology in the industry's move to high strength steel. Because the density and elastic modulus of high strength steel is the same as mild steel, reduction in panel thickness, which is required to reduce weight, is accompanied by a decrease in stiffness. Structural adhesives have provided a solution

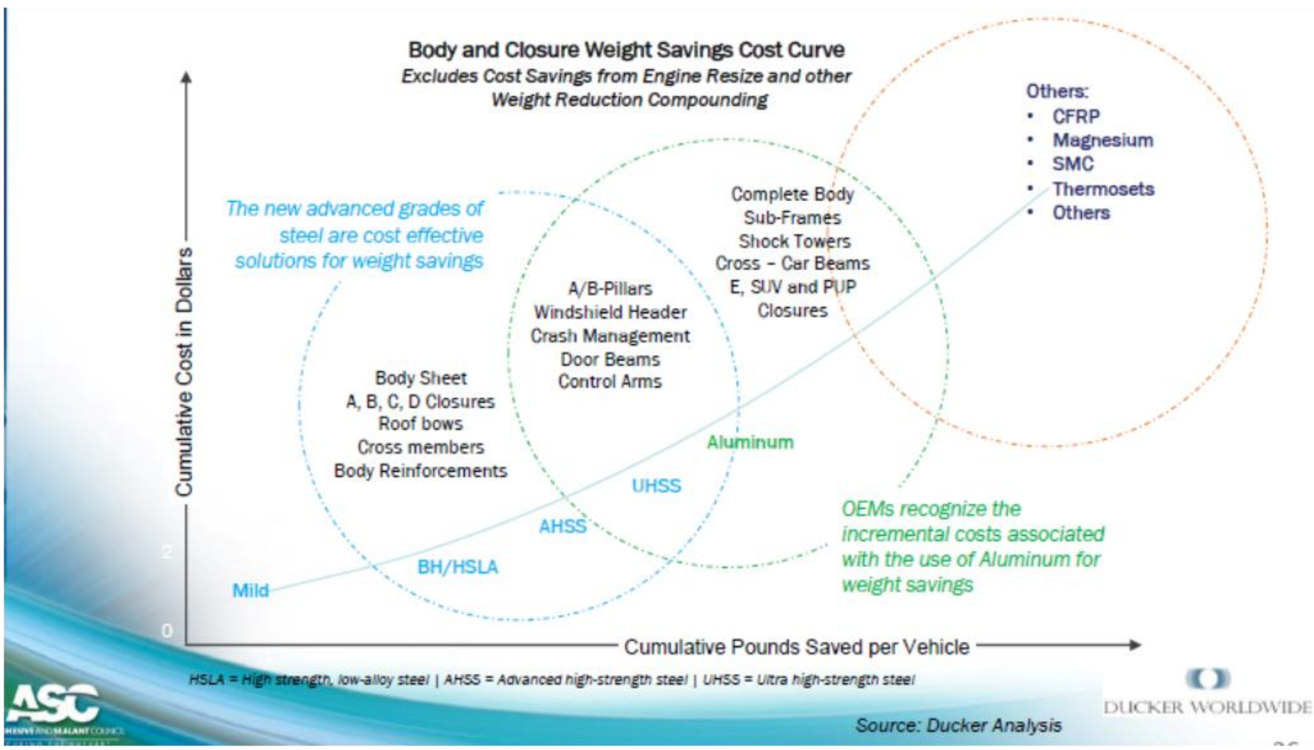
**Figure 5: Average Feet of Structural Adhesives per Vehicle**
***-Based on the overall aggregate adhesive use across all vehicles and platforms-***




Source: Ducker Worldwide, ASC Growth Program Research, 2015 to this problem, as the addition of structural adhesives to weld lines and seams stiffen the entire structure. Furthermore, the adhesive seals gaps, which can reduce the amount of noise, vibration, and harshness (NVH) in the vehicle cabin. As a result, manufacturers have been able to produce higher performing, quieter vehicles, while at the same time reducing weight. Due to the benefits structural adhesives provide, average bond length per vehicle is expected to increase 60% over the next 5years to an average of nearly 90 linear feet per vehicle.

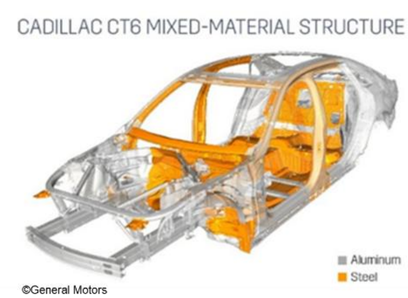
As fuel economy requirements continue to rise over the next decade, automakers will need to continue to find ways to make vehicles more efficient. This will require an ongoing effort to reduce weight, despite the remarkable progress in the recent past. The graph below shows an array of weight savings options available to automakers. The options are progressively more beneficial in terms of weight savings moving from left to right, and more costly moving from bottom to top. OEMs have been following this progression as they have looked to reduce weight. With high strength steels accounting for 50% or more of many vehicles' body weight, the least expensive opportunities have been exploited. As OEMs consider more expensive options, they will selectively use materials such as aluminum, magnesium, and composites only where they provide the greatest return on investment. This will mean greater numbers of multi-metal and multi-material vehicle platforms that will rely on adhesives as a joining technology.

**Figure 6: Relative Cost and Weight Savings Potential of Automotive Materials & Applications**




Source: Ducker Worldwide, ASC Growth Program Research, 2015

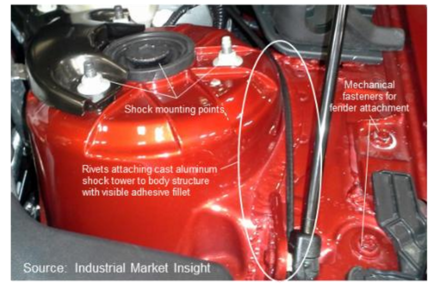
There are several examples of how adhesives are already playing a role in this transformation in both multi-metal and multi-material vehicles. Since these approaches are more costly, yet yield more significant weight reduction, they are currently found in luxury vehicles. Examples can be found in offerings from Cadillac, Lexus, and BMW. Cadillac's 2016 CT6, a new, flagship sedan, is built on a new platform that consists of a steel passenger compartment joined to aluminum front and rear ends. This allows Cadillac to take greatest advantage of both materials, and build a lighter vehicle than could be achieved with either material on its own. The body contains over 180m of structural adhesives that serve to reinforce, stiffen, and quiet the vehicle. According to Cadillac, the multi-material



approach, enabled by adhesives and other advanced joining technology, was 250 pounds lighter than the base model, a savings of 7%.

An application that is quickly finding its way into platforms from multiple OEMs is the replacement of multi-piece steel assembly with a cast aluminum shock tower. Cadillac features this on the steel intensive ATS and CTS, as well as the aforementioned multi-metal CT6. On the ATS and CTS (ATS shown at right), the aluminum casting is rivet bonded to the steel frame rail. The shock tower receives many high load input cycles over the vehicle's life, and the adhesive spreads the load over a much larger area, eliminating stress concentrations at the rivets, and extending the fatigue life of the assembly. On multi-metal assemblies, galvanic corrosion can be a risk, and adhesives or sealants can be used to prevent the metallic surfaces from touching and causing galvanic corrosion. The ability to both bond and isolate materials with an adhesive or sealant eliminates the cost of manufacturing and installing an isolator that would be required with mechanical fasteners.

**Aluminum shock tower joined to steel body rail with rivets and adhesives in Cadillac ATS**

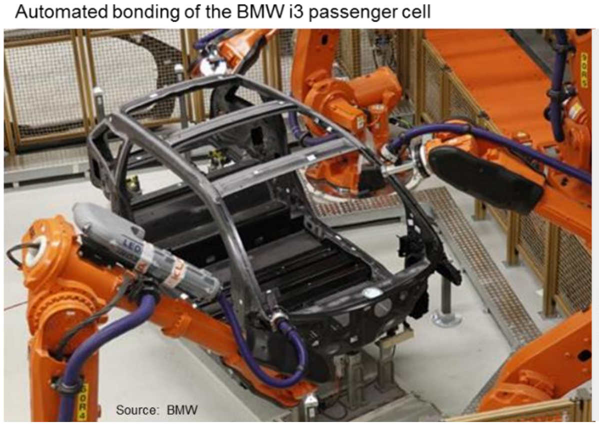


Source: Industrial Market Insight

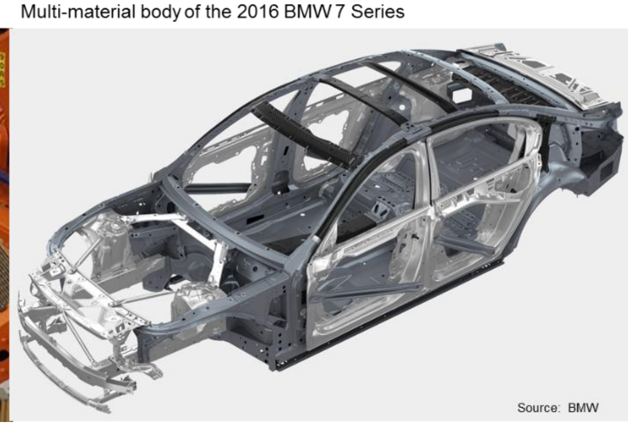
When manufactures put the highest premium on weight savings, carbon fiber composites are selected for use. Although the price is several times that of a steel or aluminum assembly, the weight savings offered by carbon fiber composite is unparalleled, which why the material is used prominently in aerospace, racing, and sporting goods, where performance is paramount. In the automotive market, BMW has taken the lead with the use of carbon fiber composites in mass production with the groundbreaking application of carbon fiber composite to the i3 and i8 hybrid electric vehicles. BMW was the first automotive manufacturer to experiment with composite intensive vehicles at mass scale. With production of about 30,000 units a year and a price tag of about $45,000 USD, the i3 is a niche vehicle, but represents the largest volume production of a carbon fiber composite vehicle to date. Since composite materials cannot be welded, structural adhesives are relied upon to bond most of the passenger compartment. Adhesives are applied robotic dispensing equipment, as shown in the figure at left, below. The automation of adhesive application can improve consistency and vehicle quality, as well as eliminate repetitive stress injuries that can occur with manual operations.

Although the i3 is a benchmark achievement in the use of carbon fiber composites in volume production of light vehicles, perhaps more indicative of the future of automotive design is the 2016 BMW 7 Series. With production of 60,000 units a year, and with a price tag starting at two times the price of the i3, the BMW flagship design is built for customers who want no compromises in luxury and performance. However, economics do factor into material selection, and BMW elected to place lightweight materials only where they provide the most benefit. The passenger compartment is primarily steel, married to an aluminum front end that features cast aluminum shock towers. Carbon fiber composite is added to stiffen and reinforce areas of the car critical to safety and performance. The material applied above the beltline, along the roof rails and cross members, which serves to lower the center of gravity, improve handling, as well as to stiffen the overall structure. Carbon fiber composite is present in the A, B, and C pillars, where it improves stiffness and provides protection to occupants in the event of an accident at a fraction of the weight of equivalent steel parts. BMW's confidence in adhesives as a primary joining method allows the use of composite in a metallic structure in a manner that is truly revolutionary for the industry.

Automated bonding of the BMW i3 passenger cell


Source: BMW

Multi-material body of the 2016 BMW 7 Series


Source: BMW

**Summary**

Adhesives provide multi-functional solutions to light vehicle manufacturers seeking differentiation in a highly competitive global market that is faced with increasing regulatory and consumer demands. For years, OEMs have relied on adhesives to bond dissimilar materials in safety critical applications such as windshields, and composite body panels, among others. Adhesives that provide strong, durable, and reliable bonds of dissimilar materials are enabling innovative approaches to vehicle weight reduction today, and will be even more important in the future. In addition, the fact that adhesives can create barriers to corrosion and the transmission of sound and vibration increase the value as an engineering material. Finally, the fact they can be dispensed in both automated and manual processes enables adhesives to be an economical solution at nearly any production volume.

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