



BACKGROUND

Cost is an issue in every material decision made on an automobile. When making a material substitution, cost can be viewed as a simple part-by-part substitution, a manufacturing and product system cost, and/or increasingly as a lifecycle cost analysis (LCA).

As automakers (OEMs) apply aluminum to lightweight their vehicles, the focus is increasingly directed toward the system cost and LCA to obtain the desired outcome of an improved driving performance, reduced fuel consumption or reduced emissions. The OEM is increasingly considering how to fully exploit the weight reduction in one or more parts, and allow this weight reduction to offer further weight or cost savings in other vehicle components.

The Aluminum Association conducted an objective analysis of the overall cost of manufacturing and operating an aluminum-intensive, four-door passenger car versus a conventional steel car, considering the total manufacturing and operating costs of passenger vehicles. The target was a conventional, mass-produced, mid-sized, four-door passenger vehicle, using conventional internal combustion engines (ICE) and powertrain components. The vehicles were matched in size and performance (acceleration and driving range).

The Association commissioned IBIS Associates, an independent consulting firm specializing in technical and economic analysis of materials in manufacturing technology, to analyze the cost-benefit of material choices in high-volume vehicles and the economics of vehicle design in a future state.

IBIS set out to analyze vehicle costs assuming a high-volume manufacturing system. This system is optimized in terms of manufacturing equipment for both vehicles. Additional costs for manufacturing the aluminum are included, recognizing some forming and joining disadvantages. The aluminum vehicle had more stampings and joints and also had some steel components where they were particularly beneficial. The powertrain was resized to match the performance requirement. The cost of the resized powertrain was determined by reviewing a large number of powertrain components of various power or torque outputs. (The analysis fit a regression from small to large ICEs.)

Note: In practice, due to the common approach of “carrying over” components from model to model, not all sizes might be readily available, but are considered available in our high-production end-state approach.

- ▶ Cost-effective solutions exist with aluminum intensive cars and trucks
- ▶ Aluminum-intensive automobiles can be very practical as a cost-effective alternative for improving fuel economy
- ▶ A cost premium of \$630 can be partially offset by secondary cost savings of \$527 if the smaller driveline components are chosen, resulting in a total cost premium of only \$103
- ▶ For every kilogram taken out of the structure, another 0.68 kilograms in secondary weight savings can be taken out as well

METHODOLOGIES

The study was based on an average, mid-sized family sedan that was designed to be an aluminum-intensive, safe and highly fuel-efficient automobile. It was a component of a new generation vehicle program, in part with the Department of Energy. The model car used in the study was a real vehicle, not something that was designed specifically for this study.

The stamping and assembly challenges associated with aluminum were not ignored; they were considered a part of the future cost analysis. The capital required to build this type of vehicle was also taken into account. All of the economics associated with the fuel economy were discounted at a 7 percent rate to determine a net present value figure for fuel economy. Fuel consumption was calculated on an equivalent acceleration and size basis, so only the mass and the powertrain are changing with the use of aluminum.

The cost used for aluminum in the study was \$1.50 per pound, which was taken directly from the midpoint of the project in order to avoid any future cost assumptions. The cost used for the steel comparison was \$0.35 to \$0.37 per pound, which was a mid-range price from the time the study began, therefore using neither a peak, nor a low value.

STUDY FINDINGS

FIGURE 1

	Baseline Steel		Baseline Aluminum	
	Mass (kg)	Cost (\$)	Mass (kg)	Cost (\$)
Vehicle	1564	\$14,871	1288	\$14,974

Figure 1 shows the mass of the baseline steel car of 1,564 kilograms would decrease to 1,288 kilograms in an aluminum intensive car, meaning a reduction of 275 kg curb weight or about 17.6 percent.

The primary weight saving – including the parts that are actually changing to aluminum in this analysis such as the body-in-white, cradle, and aluminum wheels – was 163 kilograms. However, when this weight is taken out of the structure, there are also secondary weight savings that are possible by downsizing other components. For every kilogram taken out of the structure, another 0.68 kilograms in secondary weight savings can be taken out as well – or a total of 112 kilograms.

A cost premium of \$630 was incurred when manufacturing the aluminum structure and closure panels. However, this cost penalty can be partially offset by secondary cost savings of \$527 if the smaller driveline components are chosen.



“Aluminum-intensive automobiles can be very practical as a cost-effective alternative for improving fuel economy.”



FIGURE 2

	Baseline Steel	Baseline Aluminum
Calc avg mpg	21.7	25.1
Fuel NPV Cost	\$9,342	\$8,071

Figure 2 shows the savings in mass and powertrain resizing translates to more than a 15 percent increase in average miles per gallon. (For a 10 percent mass reduction, the mpg was improved by 9 percent.) The estimated mileage of the vehicle jumps from 21.7 miles per gallon to 25.1 miles per gallon.

Net present value of the fuel was determined by assuming fuel cost at \$2.50 per gallon on a vehicle traveling 10,000 miles per year over a 12-year period, resulting in approximately \$1,300 savings in fuel over the life of the vehicle.

FIGURE 3

Only Structure and Closure Differences	
Cost of mass savings (BIW only) (\$/kg)	\$3.51
Secondary Mass Savings, but no Secondary Cost Savings	
Cost of mass savings (vehicle) (\$/kg)	\$2.03
Cost of mpg improvement (\$/mpg)	\$163.67
Secondary Cost and Mass Savings	
Cost of mass savings (vehicle) (\$/kg)	\$0.37
Cost of mpg improvement (\$/mpg)	\$30.09

When considering the cost to substitute aluminum for steel with no offsetting considerations, the cost of mass savings was \$3.51 per kilogram (\$1.59/pound saved).

When the weight savings of the engine and other components are included, but not considering any cost savings, a cost premium of \$2.03 per kilogram (\$0.92/pound) was incurred.

Finally, if both the weight and cost savings of the engine and other components are considered, the cost premium reduces to \$0.37 per kilogram (\$0.17/pound) for an aluminum intensive vehicle. This brings the cost to improve the car 1 mpg down to \$30.

CONCLUSION

This research shows that cost-effective solutions exist with aluminum intensive cars and trucks. Under the right conditions, these vehicles can be economically viable for high-volume vehicles. Further, the fuel savings can be significant and offer a real benefit to the consumer.

As OEMs look for cost effective solutions to reduce the fuel consumption and emissions of their vehicles, light weight, high strength aluminum vehicles with appropriately sized powertrains are very attractive.

For more information, visit us online at AluminumInTransportation.org