Sustainability through Aluminum: Improving Pennsylvania State University's Public Transit System

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Abstract

This report details the process of designing or improving a facet of life on Penn State University campus to improve sustainability. The concept selection process is addressed resulting in selection of transitioning from steel public transit busses to aluminum. The effects on the community, profitability, and the environment are further discussed.

Table of Contents

1.0 Introduction……..1

2.0 Design Process……2

3.0 Conclusion……..5

4.0 Figures……6

5.0 References……..9

1.0 Introduction

Sustainability is the use of processes and materials that conserve the environment, energy, and resources. It entails maximization of reuse, recycling, and sound environmental practices. A process and its entailed practices can be improved by using resources that can be reprocessed and used for the same means over and over, vice resources that are used up in simply one period of use. In this matter, we found means of improving sustainability at Penn State University. The Catabus Transit system transports the majority of students on campus, as well as other citizens in the Centre County region, amounting to approximately seven million riders a year. The fleet of sixty-one buses are currently made out of steel and at the end of

their twelve year lifecycle, most are sold for very little capital or end up in the nearest city dump. By building the bus out of aluminum, the Catabus system could use the same aluminum continuously for each bus lifecycle, instead of trashing resources.

2.0 Design Process

Presented with the problem of increasing sustainability at the Penn State Campus, we immediately began brainstorming. After initially coming up with five ideas, the ideas were narrowed down to two through screening. These concepts were selected based on their ability to meet the intersection of the needs of people, affordability, and benefit to the environment. The first plan was new sectional receptacles to replace the large mixed trash cans found on the campus walkways. There are recycling bins outside but they do not coincide with every trashcan. The initial sketches showed sections with an aluminum sector that would also compact aluminum cans when placed inside. The second idea was to implement a new design for the public transit buses that serve the campus and surrounding towns. External research was conducted on the current bus structures and the Catabus representative was contacted in regards to the materials from which the busses are constructed. The representative was very informative and responded that the busses have steel frames and fiberglass panels on the outside. In selecting an idea, the group voted unanimously on the bus. The redesigned bus would give a great improvement to the environment, posed a sound investment, and would provide the same safety and reliability of the busses to the local community and university.

After selecting the aluminum bus as the focal point of the project, research became paramount. A number of models of aluminum buses have already been manufactured but all

had distinct difference in structure and composition. The next step in the design process was to sort, screen, and combine these different ideas to find the best optimization of functionality, reusability, and realistic affordability. The three main forms of aluminum buses currently in production are aluminum body, aluminum body and frame, and aluminum body, frame, and chassis. The group discussed the best fit for the metric and decided that by replacing the frame, side panels, and wheels with aluminum we would be able to make a significant weight reduction and thus substantially increase fuel economy and decrease carbon dioxide emissions. The final design of the product was based around these specifications and keeping the dimensions and passenger capacity identical to the former model (Figure 2 and Figure 3). The chassis and mechanical parts of the bus would remain steel due to the large change in capital it would cause for a comparatively small decrease in the total bus weight.

After selecting the general bus composition, we researched more to ensure we were meeting our needs of benefitting the people involved and the environment in an affordable matter. In regards to the consumer, aluminum buses cause no degradation in the quality of service to the bus passengers. Aluminum is increasingly present in the automotive industry (Figure 1), with safety tested cars, railcars, buses, and even semi-trucks proving the same safety is generated by aluminum as with steel or steel alloys. In this way, aluminum is an equivalent functional substitute to the steel. In terms of profitability, the aluminum is initially more expensive than the steel in a per ounce measurement yet it saves fuel costs and potentially extends the longevity of the vehicle (Chart 1). To decrease the initial capital and wastefulness of replacing all the buses immediately, a replacement plan was constructed. At the end of

each steel buses functionality, the bus would be refurbished or replaced with the aforementioned aluminum parts.

In terms of the cost of each individual bus, it was found that in the long run many of the aluminum benefits would counteract the initial higher cost. In the Alcoa aluminum bus project, the engineers designed an aluminum space frame that caused a 1.2 ton reduction in the bus's total weight (forty percent less total body weight) leading to a 6% reduction in fuel usage. A 6% reduction in fuel usage would save $14,651 per bus during its lifetime (Chart 2). Applied to a 61 bus fleet, the use of aluminum would save $893,702 in fuel costs over one fleet lifecycle. These fuel savings, as well as increased period of use due to the corrosion resistance of aluminum, would make up for the initial capital costs of the aluminum.

Lastly, we examined the environmental impact of our project. The sustainability of the local transit system will be greatly improved given our design selections. At their end of their lifetime, many buses are sold at public auction. Due to constraints on buses, many of them sell for very little money since other government agencies cannot purchase them due to high government standards resulting in little salvage value for the transit company. The buses are often sold cheap for parts, with a large part of the bus either sold for scrap metal or taken to the junkyard. Steel is harder to recycle than aluminum, heavier to transport, and the process for recycling is more involved and costly. Using aluminum as a primary construction material for the buses will allow the old buses to be recycled and formed into new buses.

3.0 Conclusion

Sustainability in local communities has the potential to make worldwide impacts. The more people, campuses, and organizations that brainstorm and develop improvements to their ways of life, the lesser the sum of irrevocable damage caused to our environment and resources. Taking a mundane part of everyday life and slowly transforming it to make it profitable for the business owner, comfortable to the consumer, and less harmful to environment is a small step in the right direction. It is important in the design process to consider all of the externalities of the decisions made and to be conscientious in all steps involved. Aluminum provides the perfect example of a resource that can be cannibalized over and over to serve the same purpose without needing to deplete more of the earth's resources. Through extensive use of the design process, the modifications of our Aluminum Catabus meet all the goals of a sustainable endeavor. The bus company maintains its income, the bus passengers are safe and travel efficiently, and the environment faces less negative impact from a bustling transportation system.

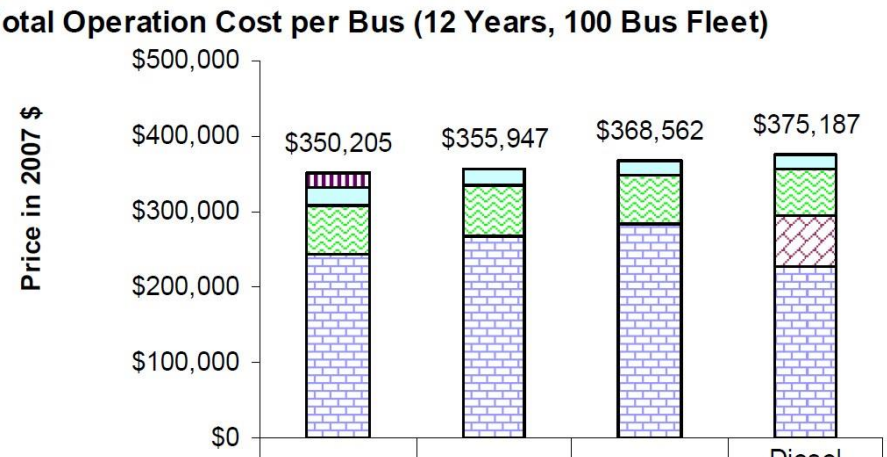
4.0 Figures and Tables

Figure 1: Growth of Aluminum in Passenger and Commercial Vehicles in 2012. (Brodrick 2012)

Comparison of Common Structural Shapes and Grades of Three Metals

Property	Aluminum 6061-T6	Carbon Steel A36	Stainless Steel 304, Cold-finished
Extrudability	Very Good	Not Practical	Very Limited
Weldability	Fair, But Reduces Strength	Good, No Strength Reduction	Good
Cost by Weight	$1.50 / lb.	$0.30 / lb.	$1.40 / lb.
Cost by Volume	$0.14 / in.^{3}	$0.084 / in.^{3}	$0.42 / in.^{3}
Cost Index	2.5	1.0	4.7
Corrosion Resistance	Good	Fair	Very Good
Tensile Yield Strength	35 KSI	36 to 50 KSI	45 KSI
Stiffness	10,000 KSI	29,000 KSI	27,000 KSI
Elongation	8 to 10%	20%	30%
Density	0.098 lb. / in.^{3}	0.283 lb. / in.^{3}	0.284 lb. / in.^{3}
Strength-to-Weight Ratio	2.8	1.0 to 1.41	.2

Chart 1: Comparison of Aluminum and Steel Basic Structural Properties (Kissell 2002)



	CNG	ULSD	B20	Diesel Hybrid
Total	$350,205	$355,947	$368,562	$375,187
Compression Electricity	$19,003	$0	$0	$0
Facility Maintenance	$24,433	$20,723	$21,039	$17,470
Propulsion-related System Maintenance	$62,588	$66,394	$62,706	$63,589
Battery Replacement	$0	$0	$0	$67,500
Fuel Costs	$244,181	$268,830	$284,818	$226,629

Chart 2: Distribution of Costs per Bus in a Public Transit bus fleet (Nigel 2007)

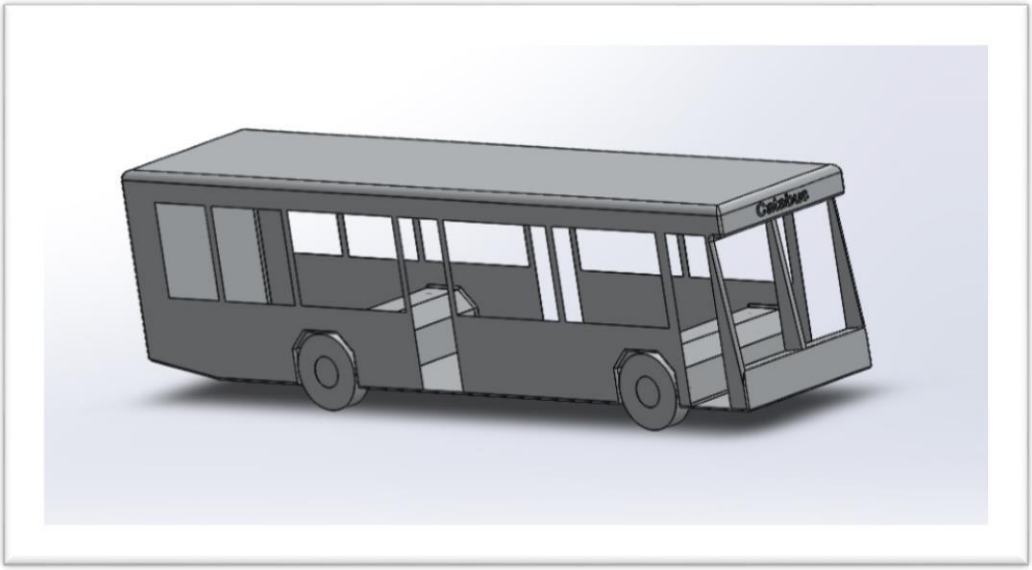


Figure 2: Catabus Solidworks Model

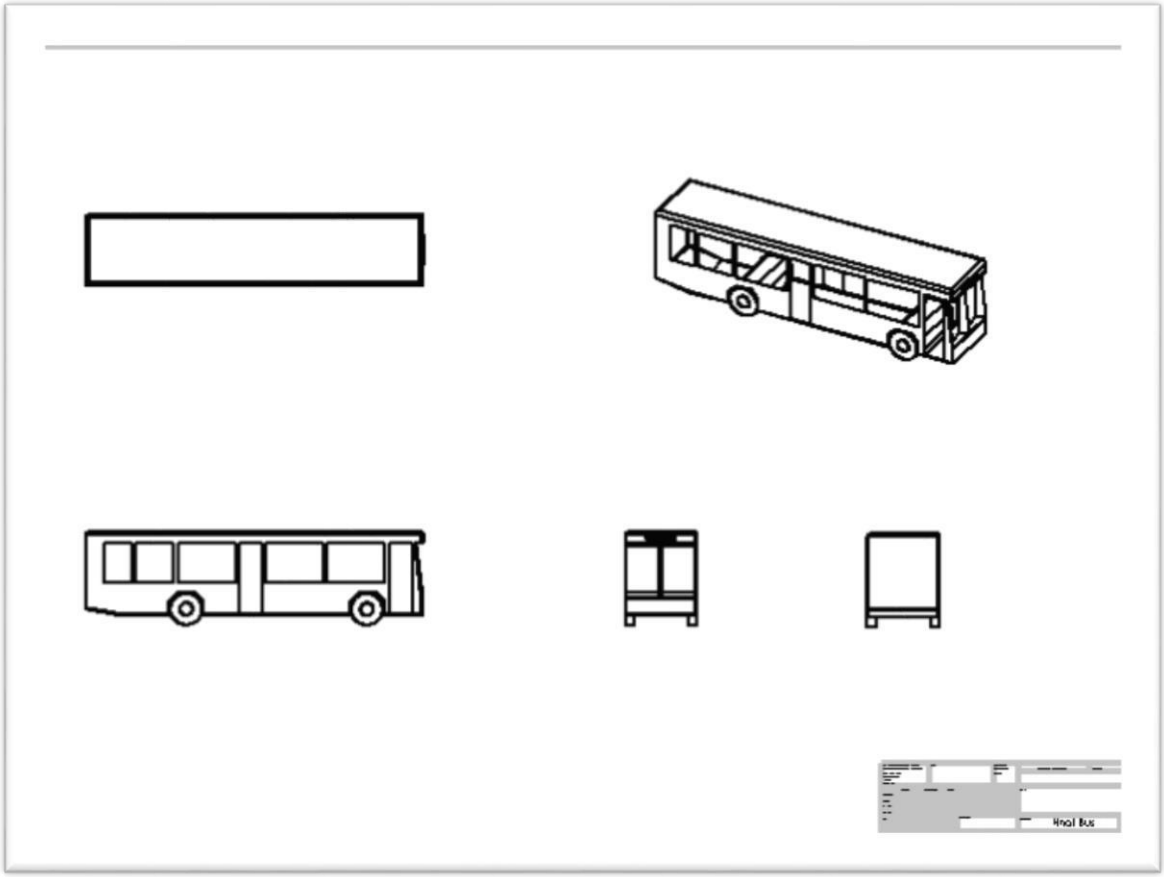


Figure 3: Catabus SolidWorks Drawing

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