EDSGN 100
Design Project #2
ALCOA Aluminum Redesign
Introduction to Engineering Design
EDSGN 100 Sec 024

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Abstract:

The objective of this project was to redesign a product with aluminum in a fashion that benefits Penn State's University Park campus by increasing sustainability and eco-friendliness. After analyzing the customer needs of ALCOA, the project sponsor, CATA, and Penn State, research was conducted in order to implement aluminum into the redesign of a CATA bus. Aluminum with EcoClean was used throughout the frame and excess parts of the bus to reduce the overall bus weight and emissions. As a result of this redesign, the bus consumes less fuel and has a lower negative environmental impact.

ALCOA Aluminum Redesign

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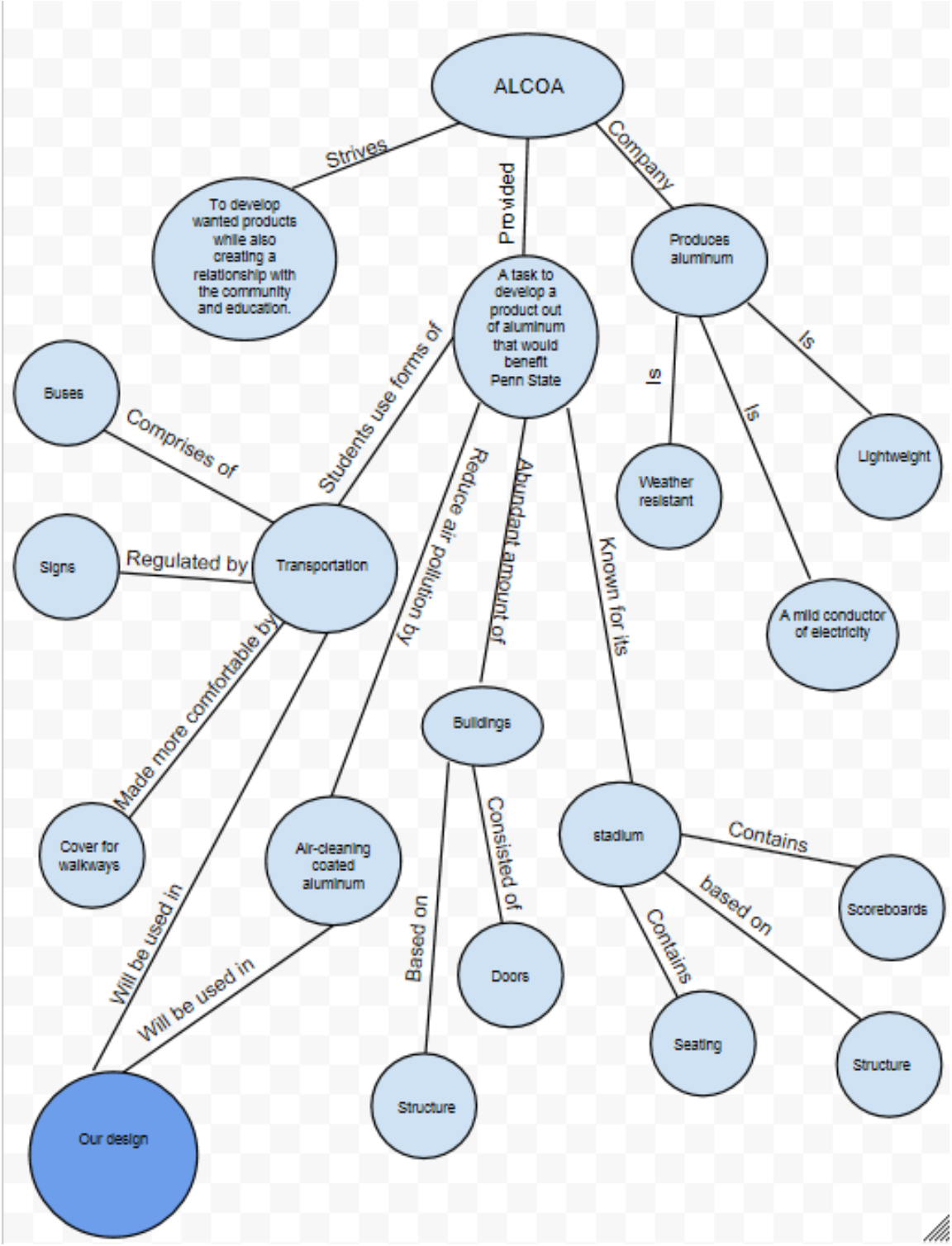
1.0 Introduction

The focus of the redesign project is to apply aluminum to a current feature of Penn State University Park campus. This selected feature should be more environmentally friendly in a way that is valuable to Penn State because of the aluminum. The redesign will involve an evaluation of the current market situation to determine factors that will arbitrate the success of the redesigned product and applying that knowledge to the generation of new concepts and, eventually, the selection of an appropriate alternative to the current product. The following sections will explain the path to choosing an applicable and relevant substitute for the current product on campus.

1.1 Project Focus

In order to narrow the scope of possibilities Alcoa presented with such an open-ended task, a concept map was generated to assist in brainstorming a focus to the project. The concept map (appear below) looked at various components of Alcoa as a whole and created branches that eventually turned into concept ideas.

Figure 1.1: Project Brainstorming Concept Map



After the idea map was generated, main concepts were chosen and split into categories that define what the main concept is composed of.

Broad Concepts:

1. Clean Air
    a. Exhaust pipe lining
        i. Cleans bus emissions
2. Reynobond EcoClean™ aluminum siding
    a. Cleans surrounding vehicle emissions
3. Transportation
    a. Buses
        i. CATA bus
    b. Signs
    c. Cover for walkways
4. Buildings
    a. Doors
    b. Structural
5. Stadium
    a. Structural
    b. Seating
    c. Scoreboard

Out of the four broad concepts, we determined that the CATA bus affects the college campus through transportation but also through air emissions. These emissions can be reduced through the use of Alcoa's recently developed Reynobond EcoClean Aluminum, which clean the air in its vicinity. The possibility to combine both the transportation and clean air concepts through the redesign of the CATA busses makes the busses the clear favorite for the focus of the project.

1.2 Mission Statement

During a recent project launch, Alcoa tasked teams with using aluminum in an innovative fashion to improve the impact a system at Penn State University Park has on the environment. To reduce the amount of air pollution on campus and the quantity of gas consumed, the CATA Buses will be targeted in the redesign, with aluminum being used to clean the air and reduce the overall vehicular weight.

2.0 Customer Needs Statement

To provide a basis for brainstorming redesign concepts, an online survey was created at project inception that asked consumers their thoughts on what can be improved on campus with aluminum. This survey was largely unsuccessful, mainly due to a lack of response and knowledge on the topic. Following this failure, an idea to redesign the CATA buses was generated, providing CATA as a new source for customer needs.

Since the mission of the redesign project is to convince Alcoa, Penn State, and the manufacturer, in this case CATA, to implement the redesign, it was fitting that the customer needs should come from these three entities. An examination of the Alcoa website provided insight to Alcoa's mission to "[partner] to create innovative and sustainable solutions that move the world forward," ("Vision and Values" 2013). Alcoa approaches their mission statement through the development of lightweight alloys, such as aluminum, and the application of these alloys in such a way that it promotes sustainability. Penn State and CATA are jointly pursuing ways to increase sustainability in the CATA buses, thus saving both money in the long run, as well as a way to decrease emissions on and around campus.

From the examination of these three entities, it was determined that emissions, gas usage, cost, and safety are the four most important features of the buses to the entities, therefore providing the main parts of the customer needs.

2.1 Revised Mission Statement

In order to incorporate aluminum on the Penn State University Park campus, the CATA Buses can be redesigned to decrease the amount of emissions produced by the buses. In addition, fuel usage can be decreased through the weight reduction provided by the use of aluminum over steel.

3.0 External Search

Following the customer needs assessment, an external search was performed to compare the aspects of current products on the market. This information was important to the redesign because it provided insight on the current position of products on the market, as well as allowed an exploration on current patents so that none would be violated in the creation of the redesign.

3.1 Literature Review

Literature on the web was utilized to examine companies and products throughout the redesign process, providing a database of information that conclusions could be drawn from.

"About CATA." *CATA*. CATA, 2009. Web. 15 Nov. 2013.
<http://www.catabus.com/AboutCATA/index.html>.

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"Welcome to New Flyer!" New Flyer, n.d. Web. 17 Nov. 2013. <http://www.newflyer.com/>.

3.2 Patent Search

A patent search was then conducted to examine the main components of a CATA Bus.. From this process, the four main components of the bus were determined and their functions explored as well.

Function		Art		
	Aluminum alloy wheels for minibus Airbus	Aluminum coating on exhaust piping for automobiles	Hollow frame member of aluminum alloy of vehicle body frame	Aluminum alloy bracket for vehicle seats
Wheels	CN202965795 U			
Exhaust Pipe		EP0705914 A1		
Vehicle Frame			EP1398247 B1	
Seats				CN201371828 Y

3.3 Benchmarking

In order to consider possible redesigns, the specifications of current CATA busses must be taken into account. After comparing the relative performances of the current fleet of CATA busses, including busses of multiple fuel types and producers, the current bus types were found to be relatively equal although some busses slightly stood out. After

full analysis of their performances, it was found that the New Flyer C40LF was the best model to work off of as an example due to low relative price with competitive specifications.

3.4 Global Considerations

Although this project is to be implemented on just the Penn State University Park campus, the technology created has the potential to be utilized around the world. Developing countries could use the buses' Reynobond EcoClean™ aluminum siding to filter their air since they typically don't have many eco-friendly options for creating power in their countries. On other campuses, it could be used in a similar manner to Penn State, filtering the emissions of other cars, while also using less gas themselves, saving the universities' money in the long run.

3.5 Product Dissection

While it was unfeasible to dissect an actual CATA bus for redesign, it was feasible to think through the general design of a bus and identify the main components that make it inefficient. From this examination, it was decided that there are three main components of the buses: siding, frame, and mechanical parts. While all of these components need to be functioning properly for the bus to work, they have a generally low level of interconnectivity, demonstrated by the fact that if one part is changed, it doesn't directly affect another component. For example, if the siding of the bus is changed to a lighter material than it currently is, neither the siding nor mechanical parts will have to drastically change to allow the bus to continue functioning in the same manner. The only slight impact of the lighter material would be that there is less stress on the engine since the bus would be lighter as a whole and, therefore, easier to propel.
The product dissection also determined that there were very few, if any, non-essential parts on the bus. Since the bus is already meant to be a cheap way for college students to travel around campus and the surrounding area, the bus companies seem to have already cut the unnecessary amenities that are normally in buses. This makes it easier to identify the exact places in the bus to redesign since there are no other distractions while evaluating the impact of each component.

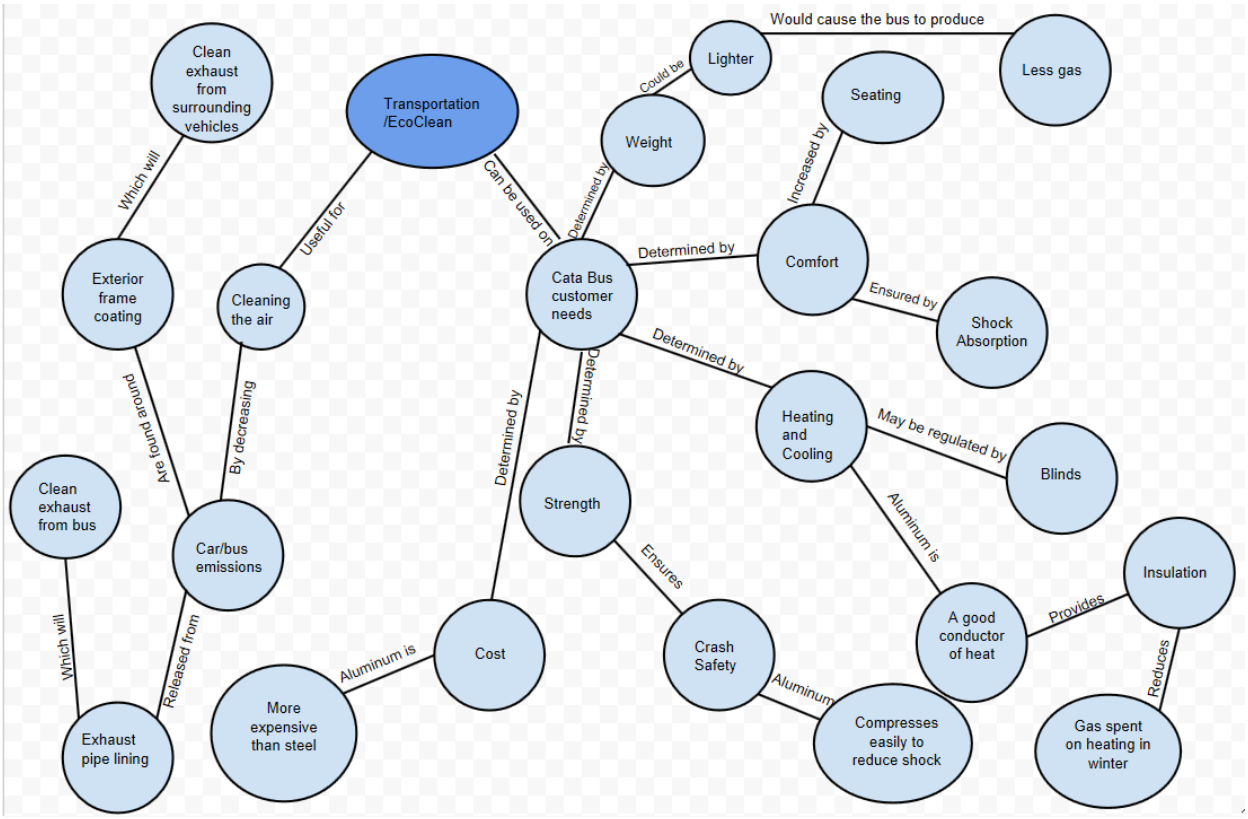
4.0 Internal Search

After finding information about bus companies and the vehicles used through external search, an internal search must be led in order to determine how to generate the best product. This allows the ability to pick out factors that will suit best for the bus companies and also determine factors that would not be favorable in the companies' eyes.

4.1 Concept Generation

Following the external search, a new idea map was generated in order to organize the conclusions drawn from the previous processes. It divides the redesign into two phases: the clean air initiative and the CATA bus efficiency. From these, concepts were generated on how to maximize success, thus creating multiple branches that represent potential new concepts. The idea tree is as follows:

Figure 4.1: Concept Generation Concept Map



The key components of the concept map are listed below and comprise the list of possible options to include in the redesigned CATA Bus.

1. "Clean Air" Aluminum
    a. Exhaust pipe lining
        i. Cleans bus emissions
    b. Reynobond EcoClean™ aluminum siding
        i. Cleans surrounding vehicle emissions
2. Strength
    a. Crash safety (weaker than steel) (Aluminum infrastructure)
        i. Compression to absorb shock
3. Heating and Cooling

    a. Aluminum insulation
        i. Conductor of heat
        ii. Less energy used on heating in winter
    b. Cooling blinds
        i. Less energy used on air conditioning in summer
4. Weight
    a. Aluminum = low weight
        i. Less fuel used/ emitted

These options were chosen in concept generation since they seem to have the highest level of impact on either the quality of air on campus or on the efficiency of the busses on campus. Choosing these options and applying them to the CATA busses will make them more environmentally friendly, thus fulfilling the mission statement.

By combining these options, concepts can be generated for the new CATA bus. Each prototype bus would have its own objective, such as being more environmentally friendly or more cost efficient. The prototypes generated are as follows:

1. Emission Reducing Bus
    a. EcoClean exhaust pipe lining
    b. EcoClean aluminum siding
2. Gas and Cost Efficient Bus
    a. Regular aluminum siding
    b. Aluminum infrastructure
    c. Aluminum insulation
    d. Cooling blinds
3. Gas Efficient Bus
    a. EcoClean aluminum siding
    b. Aluminum infrastructure
    c. Aluminum insulation
    d. Cooling blinds
4. Cost Effective Bus
    a. Aluminum infrastructure
    b. Aluminum insulation
    c. Cooling blinds
5. Environmentally Friendly Bus
    a. EcoClean exhaust pipe lining
    b. EcoClean aluminum siding
    c. Aluminum infrastructure
    d. Aluminum insulation
    e. Cooling blinds

4.2 Concept Selection

Following the creation of the key, a concept matrix was created to evaluate each design. The designs created in concept generation were placed in the matrix and rated in comparison to the baseline, which is the current CATA bus design. The matrix
The designs were evaluated in four different categories: cost, safety, gas usage, and emissions. Each individual category was then weighted, providing more power in the concept selection to the more important categories. Gas usage and emissions were clearly the most relevant categories to the mission statement of making CATA busses more environmentally friendly, causing them to receive 35% weightings, while cost received a 25% weighting and safety a 5% weighting. Cost was rated above safety since the targeted entities were interested in creating a sustainable and eco-friendly bus system that is also cost efficient.
Each concept was graded on a scale from 1-5, with 1 being the worst and 5 the best. The ratings were based off of what concept 'E' received, since it served at the current CATA bus benchmark. After each concept was rated, it was determined that the environmentally friendly bus was the best option. No combinations were considered because the concepts were already so closely related that any combinations would have resulted in an overlap in ideas and would have been unnecessary.

Figure 4.2: Concept Selection Matrix

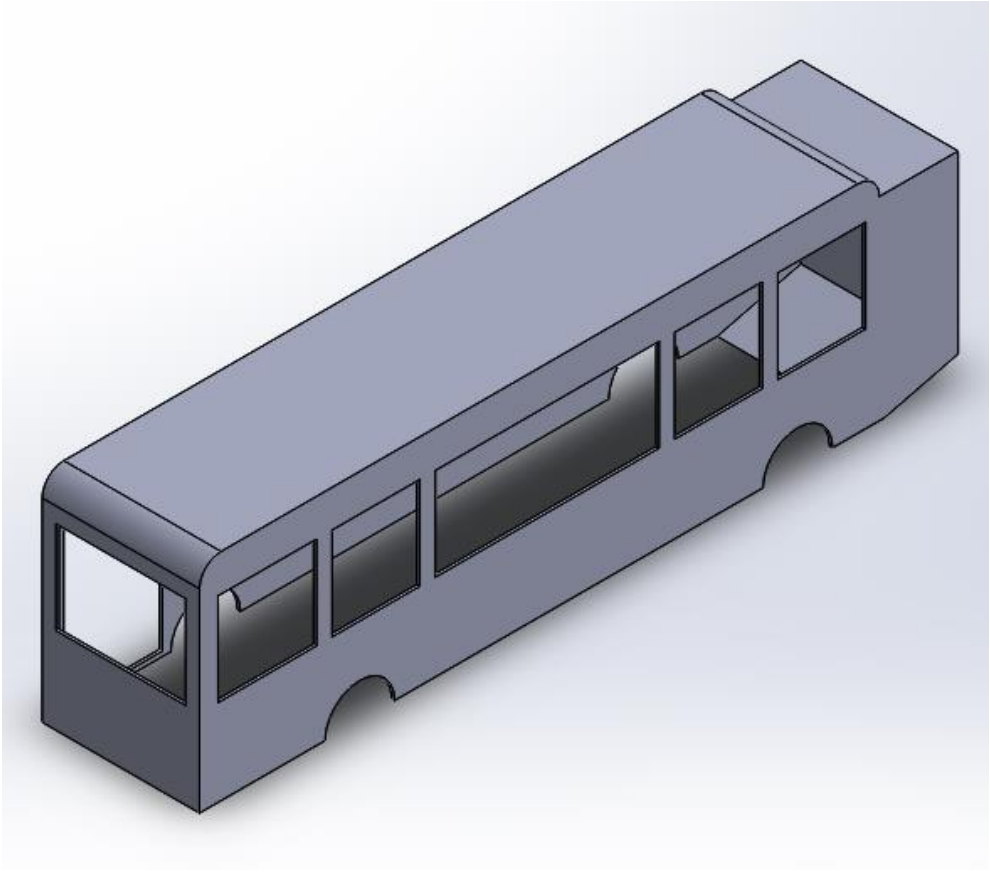
		Concepts															
		Emission Reducing		Gas and Cost Efficient		Gas Efficient		Cost Effective		Environment Friendly		Original CATA Bus		x x		x x	
Selection Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Crash Safety	5%	3	0.15	2	0.1	2	0.1	3	0.15	2	0.1	5	0.25		0		0
Cost	25%	3	0.75	2	0.5	1	0.25	2	0.5	1	0.25	4	1		0		0
Gas Usage	35%	2	0.7	5	1.75	5	1.75	5	1.75	5	1.75	2	0.7		0		0
Emissions	35%	5	1.75	3	1.05	4	1.4	3	1.05	5	1.75	2	0.7		0		0
			0		0		0		0		0		0		0		0
			0		0		0		0		0		0		0		0
			0		0		0		0		0		0		0		0
			0		0		0		0		0		0		0		0
			0		0		0		0		0		0		0		0
			0		0		0		0		0		0		0		0
	Total Score	3.35		3.40		3.50		3.45		3.85		2.65		0.00		0.00	
	Rank																
	Continue?	No		No		No		No		Yes		No		x		x	

5.0 Review of Design Features

The final design for the CATA bus redesign will consist of an exhaust pipe lining, Reynobond EcoClean aluminum siding, an aluminum infrastructure, aluminum insulation, and cooling blinds. The exhaust pipe lining and Reynobond EcoClean aluminum siding will help reduce emissions from the bus and around the bus, while the rest of the structure being composed of aluminum will reduce the bus weight and allow it to be more fuel efficient, thus making it more eco-friendly. The cooling blinds and aluminum insulation will also help reduce the need for heating and cooling in the bus, reducing the bus's gas usage and making it more environmentally friendly. The advanced level of eco-friendliness makes the redesigned CATA bus unique, as it is the first of its kind to clean the air it emits, as well as the air that surrounding vehicles emit as well.

Figure 5.1: Physical Model of Redesigned CATA Bus

Figure 5.1: SolidWorks CATA Bus Redesign



The increase in environmental friendliness comes with weaknesses too. For example, the redesigned CATA bus will cost significantly more than current models, mainly due to the implementation of aluminum and EcoClean aluminum, both of which cost more than the current materials used to produce a CATA bus. This cost, however, can be offset in the long-run by the fuel efficiency of the bus, since fuel efficiency will save CATA lots of money in gas. In addition to the cost, the bus loses some strength with the addition of aluminum since aluminum is weaker than the current metal being used.

5.1 Design Drawings and Parts List

The bill of materials lists the parts essential to the redesign, including the Reynobond Aluminum with EcoClean, cooling blinds, an aluminum infrastructure, and aluminum insulation. The wheels and mechanical parts (engine) are included since they may have to be altered since the bus will drop weight due to the change in build material (aluminum to steel).

Bill of Materials

Part Number	Part Name	Qty	Function	Mass	Material	Dimensions	Cost
1	Reynobond EcoClean Siding	5 (One on each face)	Clean air around bus and seal outside of bus	1.12 lb/ft^2	Aluminum	41'x133"(long side) 41'x102" (top) 133"x102"(back) 44.3"x102" (front)	$0.85/lb.
2	Reynobond EcoClean Exhaust Pipe	1	Clean air emitted from engine in bus	1.12 lb/ft^2	Aluminum	5" diameter x 3' long	$0.85/lb.
3	Cooling Blinds	2	Cool bus	~167lb/ft^3	Aluminum	41' x 3'	$0.79/lb.
4	Aluminum Infrastructure	1	Support bus's structure	~167lb/ft^3	Aluminum	See Part #1 dimensions 41' x 1.5" diameter (x2) 6' x 1.5" diameter (x6)	$0.79/lb.
5	Aluminum Insulation	1	Hold in hot/cool air	~167lb/ft^3	Aluminum	See Part #1 Dimensions	$0.79/lb.

6	Wheels	4	Move bus	133 lbs/wheel	Rubber	39.30in	$760/wheel
7	Mechanical Parts	3 main	Move bus	Same as current CATA bus	Varies	Same as current CATA bus	~$1700+

6.0 Analysis and Testing

Based on previously made designs of entirely aluminum busses designed by ALCOA and in use in China, converting a standard steel bus body to entirely aluminum can reduce weight from approximately 2.5 tons to 1.3 ton, and by effect, increase the mileage of one "tank" of fuel by 10%.. Using the New Flyer C40LF as the model to be modified, the mileage can be increased from 4.3016 MPGe (.76 mi/lb) to 4.73176 MPGe. If the standard CATA bus is constrained to the typical 250,000 mile lifetime (about 12 years of function before additional funding for new busses), the effective natural gas usage can be reduced from 58117.90962 GGe to 52834.46329 GGe, saving 5283.446334 GGe. Assuming fuel costs remain relatively stable and close to the current $3.30 per gallon of gasoline equivalent, the redesigned aluminum bus will save over $17,500 dollars on fuel. This surplus more than compensates for the increase in cost for the aluminum body and allow for even more improvements to be made on the bus aside from efficiency increases.

7.0 Description of Design Operation

The current CATA bus design simply transports passengers from one point to another in University Park and the surrounding area. The redesigned CATA busses will perform the same task, as that's what the bus system is in place for. In addition to this fundamental use, the new CATA busses will also filter the air surrounding the bus, reducing the busses' emissions, as well as the emissions of the cars near the bus, thus making the air cleaner for people traveling outside of the bus and helping the environment in general.

8.0 Life Cycle Analysis

Aluminum will be advantageous as compared to steel in terms of its lifecycle. Aluminum is inherently resistant to corrosion and rust so it would be a more weather resistant material for the body of the bus. Although the aluminum may lack the same strength as steel, its lower density allows for a lighter bus overall and will increase the mileage. This increase in mileage, along with the possibility of Reynobond EcoClean aluminum, will create an extremely efficient and clean bus, even compared to the already low emissions of a natural gas fueled bus. Along with the increases in environmental and economic efficiency, the bus will also be readily recyclable

and be able to maintain low costs for future busses produced. Overall, with its versatility for environmental benefits and its low density, aluminum is a superior alternative to steel.

9.0 Conclusion

The redesign of the CATA bus resulted in the development of a new model featuring design elements that either directly or indirectly contribute to improving the bus's eco-friendliness. Through the selection of Reynobond EcoClean aluminum siding and exhaust pipe lining, the bus is able to reduce the amount of CO_2 and other greenhouse gases in the atmosphere, while also reducing the overall weight of the bus by about 40%, or one ton, when compared to previous, steel-based models. The bus's weight is further reduced by the use of aluminum in the infrastructure, thus causing the bus to consume less fuel and, therefore, produce less emissions, making the bus more environmentally friendly. The addition of aluminum insulation and cooling blinds reduces the need to use fuel for the cooling or heating of the bus by either holding the heat in or preventing the sun from heating the outside of the bus. The conservation of fuel reduces emissions produced by the CATA bus, bringing the model into a new level of environmental friendliness that wasn't present in previous designs. Through the reduction of fuel usage, the bus has the potential to save about $17,000, thus taking turning the short-run disadvantage in cost and turning into it a long-term benefit of the bus being more fuel efficient. In terms of utilizing aluminum in the fashion that ALCOA tasked, the CATA bus redesign was a success and resulted in an overall better product than what was previously on the market.

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