1.1 Table Of Contents

2 Contents

1 Problem Formulation

1.1 Introduction

This section will discuss the project that Team TBD 215 has taken on with a client from Zane Middle School. This school is the largest middle school in Humboldt County; as well as the largest middle school between the Bay Area and Eugene, Oregon. Students and their families will have the opportunity to be affected by our creation at their school. This project is projected to help raise school spirit, increase funds for Zane Middle School, while focusing on safety and functionality.

1.2 Objective

The objective of this project is to design and build an easily movable food cart with the ability to lock and store various items, while also being large enough to accommodate the large number of people who will visit the cart. It will be sturdy and robust enough to withstand long term use by those that will handle the cart. The concessions cart will be a part of many athletic events and will be designed to also add school spirit to the games with the Zane Middle School's colors and mascot.

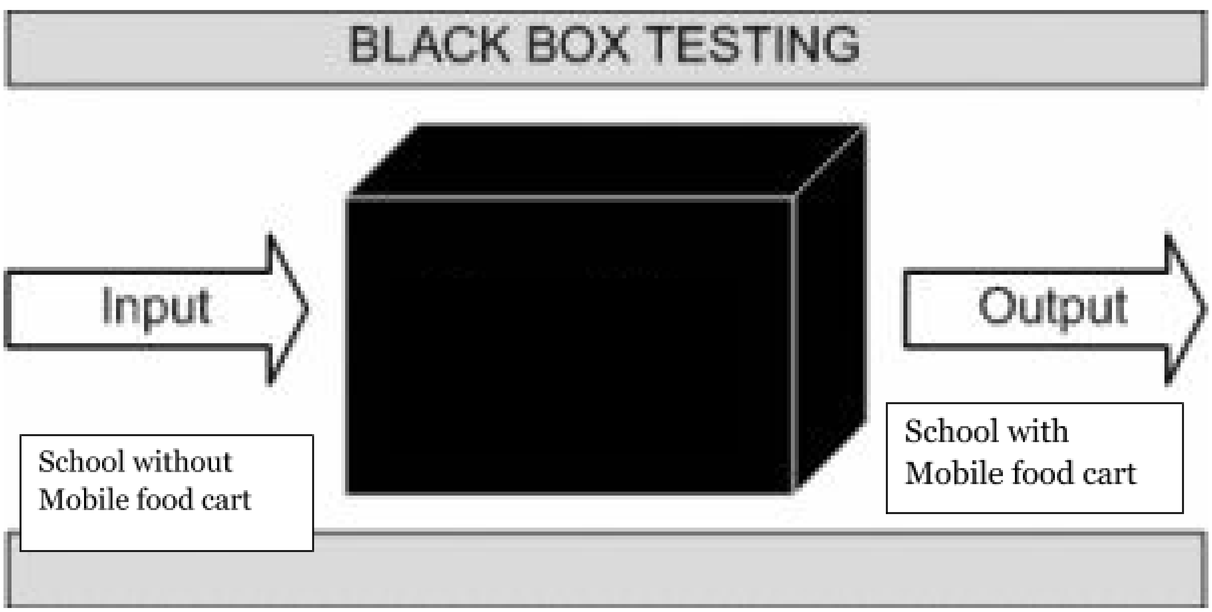


Figure 1-1: The black box model gives a simple overview of what the project will accomplish after the implication of a Mobile food cart.

2 Problem Analysis and Literature Review

2.1.1 Introduction

Section II Problem Analysis provides an analysis of the problem defined in the objective statement. The problem analysis consists of design specifications and considerations, criteria and constraints, as well as usage and production volume

2.1.2 Specifications

The specifications of the Concessions cart project are the needs of the project required to fit the parameters outlined by the client representative. These include dimensions of (60cm X 100cm) while allowing the capability of having two operators, the potential to be locked if needed, as well a being sturdy of long-term use and safe.

2.1.3 Considerations

The considerations of a project are the factors that create context for the project and are influenced by the client. The considerations for the Cessions cart are that it will serve as a food distribution device primarily used by children with ages ranging from (K-12) and parents during sporting events.

2.1.4 Usage

This item will be used primarily for sporting events, parent teacher nights and school open houses.

2.1.5 Product volume

It is evident that only one cart will be needed in order to fill the requirements of the client.

2.1.6 Constraints

Criteria	Constraints
Functionality	To provide a place to sell and store goods
Storability	Must be able to fit in a space of (60X100)cm
Portability	Must be able to be manuvered by two adults
Cost	$100
Saftey	Must be safe for chidren between (k-12)

2.2 Introduction to Literature Review

2.2.1 Wheels

Mobility is accomplished in several ways, the most common way is through the use of wheels. This section will be exploring different wheels, their use, and benefits.

2.2.2 Swivel Casters

A swivel caster is an omni-directional wheeled device which is mounted to the bottom of objects to enable movement. A swivel casters pivots around a pin which enables it to rotate and roll.

2.2.3 Fixed Caster

This casters share all the same characteristics of a swivel caster except these casters are prevented from rotating through the use of side plates, locks, etc. The use of fixed casters is most commonly seen on the rear of wheeled systems. They are more stable than swivel casters, but lack in directional movement. Costs are usually the same as swivel casters.

2.2.4 Tires

Tires surround a wheel to provide traction, shock absorbency, pressure distribution and protection. Tire material usually consists of rubber, fabric, and wire. Tire durability allows them to go through terrain in in which average casters are unable to traverse. The shock absorbency of a tire also enable a much smoother movement of a system compared to casters. Tires hold many benefits, but tend to cost significantly more than average casters.

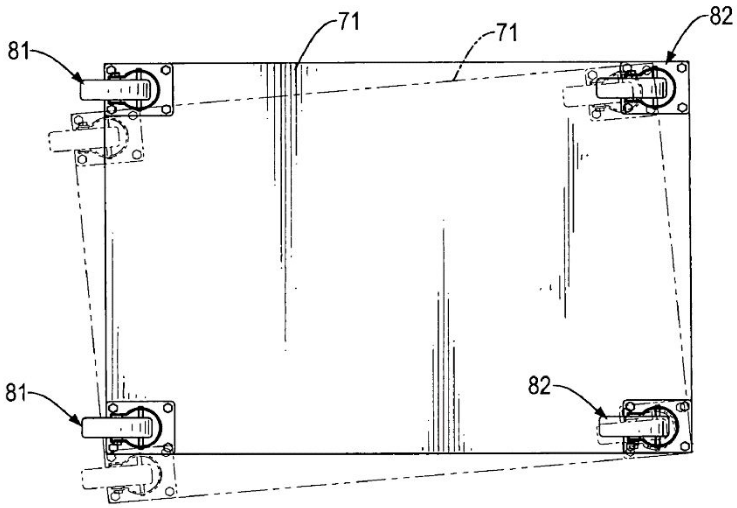
2.3 Maneuverability

2.3.1 Introduction

The system by which a cart is controlled and moved is critical to its design. There are several different methods by which maneuverability and movement of a system can be accomplished, each system verys in cost, stability and control.

2.3.2 Swivel Mechanisms

Maneuverability of a cart can be accomplished using swiveling wheels, which are omnidirectional and placed in all bottom corners of the frame to allow movement of a cart in all directions. This system is usually managed by an operator who provides a pushing force from the back of the system. Using a swivel mechanism provides independent directional movement for each wheel, allowing free and easy directional control of the cart (Liao 2009). These wheels which are free to swivel in any direction are normally called casters. Swivel systems tend to be more cost effective than other alternatives because of the simplicity of their design.



"The front swiveling wheels (81) are mounted respectively and rotatably at each side on the bottom of the front end of the platform (71). The rear swiveling wheels (82) are mounted respectively and rotatably at each side on the bottom of the rear end of the platform (71). The swiveling wheels (81), (82) are omni-directional and allow the cart to be moved in all directions" (Liao 2009).

Figure demonstrating placement and movement of swiveling system. Image from Liao, 2009.

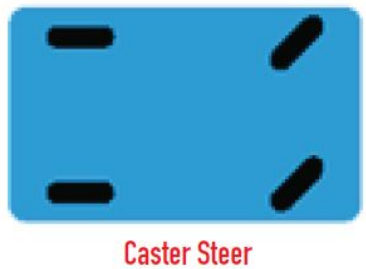
There are several advantages of designing a cart with free range omnidirectional wheels. Having a free moving cart allows for more effective maneuvering around areas like corridors, providing easy movement of an object (Aulik 1982). Omnidirectional movement also provides an advantage that fixed moving systems cannot by allowing the operator to effortlessly move the cart in any direction they want at any time. However, there are some disadvantages with swiveling wheels. If the cart is moved at a high speed, it may become difficult for the operator to steer, as momentum could keep the cart moving in a single direction, so even after an attempt is made to turn, it will just rotate. Swiveling wheels are also prone to deformities and often damaged due to excess weight (Liao, 2009). Swiveling mechanisms provide a great advantage in directional movement but usually provide the least stability in terms of linear movement.

2.4 Steering Systems

Maneuverability of a cart can also be accomplished through steering mechanics, where the operator controls the direction of a system through a pulling force. Steering mechanisms provide more control over a system, but lack free directional movement (Al-Eisawi, et al. 1999). There are a number of basic steering designs:

2.4.1 Caster steering

This mechanism uses two swivel casters at one end of the system and two fixed casters at the other end. This is one of the more simple and economic designs. It provides maneuverability through directional movement from the front (Lippert. and Yater 2013).



(Figure of steering system) Image from HamiltonCaster.com

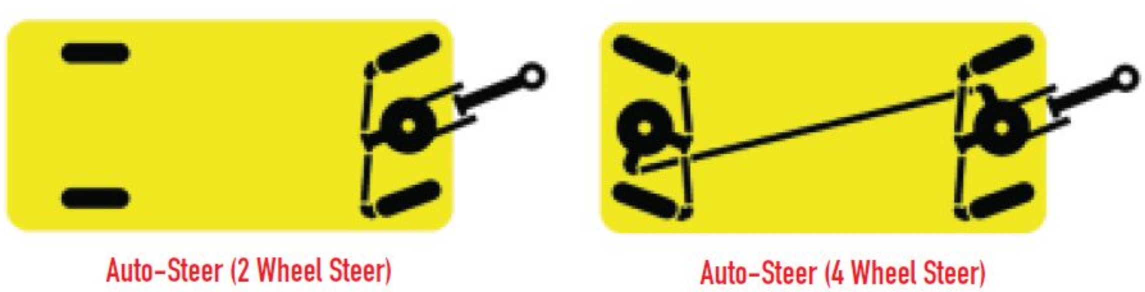
2.4.2 Fifth Wheel Steering

This design uses a single pivot point for the front fixed axle (no free range movement) and has two fixed rear wheels. This steering assembly is placed at the front center of the system which uses a plate assembly (fifth Wheel) for directional movement. This plate assembly typically has boundaries which only allow a certain degree of steering; this gives the operator more control than a fully independent swivel systems, but usually require wider aisles for turns (Lippert and Yater 2013).

(Figure of steering system) Image from HamiltonCaster.com

2.4.3 Auto-Steering System

This system of maneuvering mimics that of an automobile, which provides additional steering stability compared to fifth wheel steering. In the two-wheel system, the rear wheels of this system are fixed and do no steer. There is a four wheeled system which enables both rear and front steering. The front and rear systems are connected by a steering rod to allow coordinated turns. This four-wheel system allows for tighter and more accurate turns, while providing stability. These four wheel steering systems usually cost two and a half more times that typical caster systems, but provide great advantages to the operator. (Lippert and Yater 2013).



(Figure of steering system) Image from HamiltonCaster.com

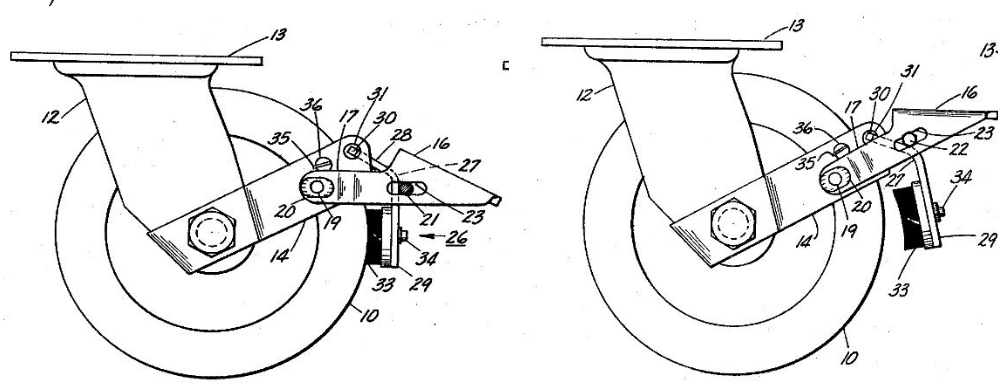
2.5 Brakes

Making a system able to move is an advantage which makes the transporting of goods relatively easy. It is important to consider how the system will become stationary once it arrives to its destination. The following systems explore ways a wheeled system can become stationary through the use of several different brake systems.

2.5.1 Locking Caster Brake Assembly

Applying locking caster brakes on any swivel movement system is an effective way to stabilize and prevent movement. A wheel brake oproble by a foot lever is common in swivel systems which use casters. This brake system is put into effect when the operator applies downward pressure (typlicy by stepping) on a lever which causes a brake to apply pressure against the tread of the caster wheel. This locks the wheel into place and prevents any further movement. The same lever can be turned upward to release the brake (Libhart 1970).

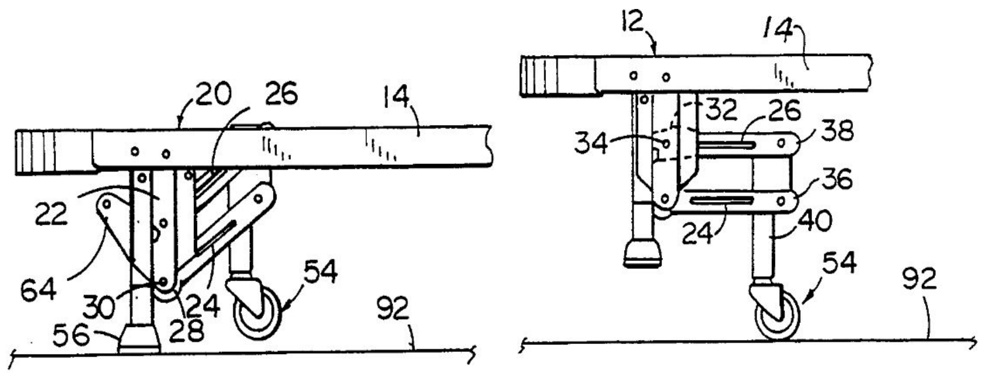
This brake system is particularly simple and cost effective, but it carries a disadvantage. The brake is normally not adjustable to compensate for the wear of the caster wheel tread or brake (Libhart 1970).



Left: Caster wheel with brake applied. Right: Caster with without brake applied. Image from Libhart, 1970.

2.5.2 Floor Brakes/Locks

Floor brake or Floor Locks achieve stability and stop any movement of a wheeled system by having two alternating systems. The first is the floor brakes, which are non-marking rubber pads that engage with the floor to create a stationary and stable frame. The other mechanism is made up of the caster wheels, which allow the system to move. These two systems are able to alternate through the raising and lowering of the cart system. The raising of the cart is done by a crank assembly. This assembly is connected to links, which when rotated by the crank assembly, cause the raising and lowering of a socket. This socket holds the wheels which come into contact with the floor when being lowered, lifting the frame and allowing movement in the process (Edgerton 1994).



Right: system is lowered, and floor locks are in contact with the ground while wheels are suspended. Left: wheels have been lowered and cause the floor locks to be suspended, allowing movement of the system. Images from Edgerton,1994.

A great benefit to this alternating system is that the sockets that hold the wheels/floor locks are able to release them, making Floor locks interchangeable with the caster wheels and providing two modes of operation (Edgerton 1994). In this way, the lifting of the frame will make it stable and the lowering will make it mobile. Systems like these are usually very reliable and an effective way to make a wheeled system stationary. Floor locks provide a more stable and stationary platform than caster brakes. However, the cost of these systems usually are much higher than caster brake systems.

2.6 Materials

Several different material choices are available for the use in this project, and this document will cover several of them with regards to durability, ease of use, and price.

2.6.1 Hardwood vs. Softwood

“The distinction between hardwood and softwood actually has to do with plant reproduction. All trees reproduce by producing seeds, but the seed structure varies. Hardwood trees are angiosperms, plants that produce seeds with some sort of covering. This might be a fruit, such as an apple, or a hard shell, such as an acorn.

Softwoods, on the other hand, are gymnosperms. These plants let seeds fall to the ground as is, with no covering. Pine trees, which grow seeds in hard cones, fall into this category. In conifers like pines, these seeds are released into the wind once they mature. This spreads the plant's seed over a wider area.” (What is the difference between a Hardwood and a Softwood 2001)

“The hardwood/softwood terminology does make some sense. Evergreens do tend to be less dense than deciduous trees, and therefore easier to cut, while most hardwoods tend to be more dense, and therefore sturdier. But, as the classification of balsa wood demonstrates, there is no minimum weight requirement to become a hardwood." (What is the difference between a Hardwood and a Softwood 2001)

2.6.2 Deterioration

"The factors that cause weather-induced deterioration of wood surfaces were determined by chemical and spectroscopic analyses. Albizzia (Paraserianthes falcata Becker.) and sugi (Cryptomeria japonica D. Don) were exposed to two temperate conditions of natural weathering with and without rainfall and to accelerated conditions of artificial weathering coupled with ultraviolet (UV) light irradiation and water flashing. Infrared spectroscopic analysis showed that the oxidative reaction of lignin was observed under all conditions of weathering for both wood species. However, a marked decrease in lignin and hemicellulose content were recognized when albizia woods were exposed to weathering with water. Lignin content in the softwood sugi did not decrease as much as in albizia even in the presence of water, but the modification of lignin macromolecules was assumed to be accelerated by water, as seen by electron spin resonance spectroscopy. These results showed that the presence of water promotes the weathering deterioration of wood under UV irradiation." (Sudiyani, Tsujiyama, Imamura, Takahashi, Minato, Kajita, 1999)

Hardwoods last longer, and while being mildly more difficult to use if we don't have the right tools, we do have the right tools, so we should use hardwood.

2.6.3 Metals

"Stress is often expressed in units of MPa (equal to 10 6 N/m 2) or ksi (equal to 10 3 lbs/in. 2). There are two general methods used to characterize the stress: engineering stress and true stress. Engineering stress is most often used in engineering design calculations, and is based on the original cross-sectional area, A 0 , of the part or component under consideration. Because engineering stress is based on the original cross sectional area, it does not take into consideration the fact that the cross-sectional area changes when a load is applied to the material. While the material is under load, the resulting change in cross-sectional area depends on the material properties and the magnitude of the applied stress. True stress is based on the instantaneous cross-sectional area under load and is therefore a more accurate method for characterizing the stress. Because the value of the true stress is typically more difficult to determine than the engineering stress, it is used less frequently in practice." (Reardon 2010)

Table 3.1 Mechanical properties of selected metals at room temperature

Metal	Young's modulus, *E*, GPa	Shear modulus, *G*, GPa	Poisson's ratio, n	Yield strength, MPa	Tensile strength, MPa	Elongation, %
Aluminum	67	25	0.345	15–20	40–50	50–70
Beryllium	303	142	0.07	262–269	380–413	2–5
Cadmium	55	19.2	0.43	...	69–83	50
Chromium	248	104	0.210	...	83	0
Cobalt	211	80	0.32	758	945	22
Copper	128	46.8	0.308	33.3	209	33.3
Gold	78	27	0.4498	...	103	30
Iron	208.2	80.65	0.291	130	265	43–48
Lead	26.1	5.6	0.44	9	15	48
Magnesium	44	16.3	0.35	21	90	2–6
Molybdenum	325	260	0.293	200	600	60
Nickel	207	70	0.31	59	317	30
Niobium	103	37.5	0.38	...	585	5
Silver	71.0	26	0.37	...	125	48
Tin	44.3	16.6	0.33	9	...	53
Titanium	120	45.6	0.361	140	235	54
Tungsten	345	134	0.283	350	150	40
Zinc	69–138	...	...	...	...	...
Zirconium	49.3	18.3	0.35	230	...	32

Source: Ref 3.1

Prices

Exclusive **Everbilt** 1-1/2 in. x 96 in. Zinc-Plated Slotted Angle
Model# 800117
(17)
$31.70

Exclusive **Everbilt** 1-1/2 in. x 96 in. Aluminum Angle Bar with 1/8 in. Thick
Model# 802617
(9)
$37.08

Exclusive **Everbilt** 1-1/2 in. x 96 in. Aluminum Angle with 1/16 in. T
Model# 802597
(11)
$18.54

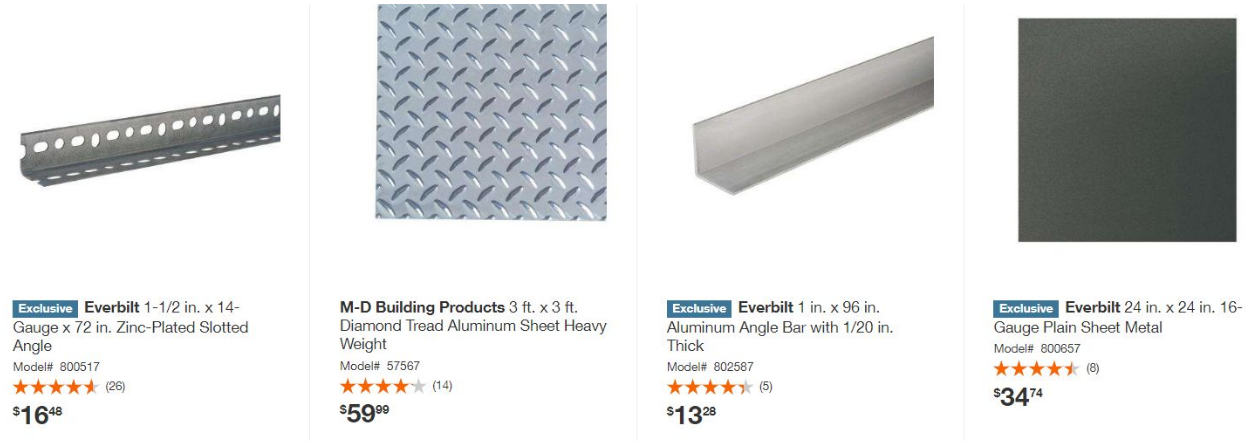
Exclusive **Everbilt** 1-1/2 in. x 60 in. Zinc-Plated Slotted Angle
Model# 18240
(16)
$13.78

Exclusive **Everbilt** 2 in. x 72 in. Plain Steel Angle with 1/8 in. Thick
Model# 42110
(5)
$24.97

Crown Bolt 1-1/2 in. x 96 in. Aluminum Flat Bar with 1/8 in. Thick
Model# 56900
(6)
$21.89

Crown Bolt 1-1/4 in. x 96 in. Aluminum Angle with 1/8 in. Thick
Model# 56830
(6)
$29.90

Exclusive **Everbilt** 1/2 in. x 96 in. Aluminum Angle Bar with 1/20 in. T
Model# 802677
(9)
$6.64



2.6.4 Finishes

"Although the necessity for mass production is a primary consideration, the finish, nevertheless, must conform to certain minimum requirements:

1. The surface should be protect and sealed against heat, dirt and abrasions, and insulated from the ingress and evaporation of moisture, which would cause dimensional change in the timber.
2. The finish should be clear (clouded) and smooth to enhance the natural beauty of the figure and the grain.
3. The finish should maintains its appearance and the adhesion and protect given by the film should not seriously diminish during the life of the article" (Book BJ 50).

A proper finish on any surface will conform to the following and with the proper research, some proper finishes will fit a certain purpose better than others.

2.6.5 Wood Finishes

There are two popular types of wood finishes in French polish and cellulose nitrate. Before the increased popularity of these two finishes styles, a type of finish known as shellac. Shellac is increase falling out of importance for the following reasons (Book BJ17-18).

French polish dates back to 1823 when featured in the *Mechanics Magazine* where it was praised for its effectiveness (Book BJ 17). French polish was an improvement from shellac in regards to both speed and quality, but the real improvements were how easy it could become a large factory process, how quickly it set and how well it resisted oils, greases, and hydrocarbons. French polish also showed excellent adhesion to wood and metal and gave an unparalleled clear finish when properly applied. (17-18)

"The advantage of cellulose nitrate in wood finishes far outweigh the disadvantages. Its stability, hardness, easy solubility and wide compatibility with natural and synthetic resins, plasticizers and matting agents, make it possible to produce a comprehensive range of quick-drying finishes for industrial purposes. It imparts toughness, hardness, durability and polishability to the film" (18).

2.6.6 Metal Finishes

Organic finishing is one of the most popular and most widely practices methods for finishing metals. Organic finishes allow for a considerable number of variations, thus a multitude of uses (142). "Industrial uses of organic coating can be classified as follows:

1. External work on girders, bridges, gasholders, pylons and petroleum storage.
2. Boat top and upper works of ships.
3. Special chemical-resistant paints for internal protection of tanks, tankers, chemical factories, bottling and bottle-washing machines.
4. Industrial finishes for manufactured commodities. These cover the field of automobile, domestic equipment, instrument and machinery manufacture in cellulose, stoving synthetic and air drying and catalyzed cold-cure finishes" (142).

"The selection of a coating for a specific purpose from a hundred or more polymers which may be chemical and wear resistant, is a difficult task. The commonsense principles which must apply are: suitability, functionality, practicability and last but not least, cost. Cost can only be established soundly, not on nominal price per gallon but by a factor compounded of the summation of labour plus material per unit area, divided by the length of life of the finish, where maximum length of life is a requisite" (144).

"Red lead in linseed oil has still retained its position against the multitude of synthetic sessions available, because the was majority of these resins have shown no fundamental increase in length of life. Their cost per unit of area is not cheaper and convenience of application no better. Red lead protective systems, even under the drastic condition of gas works pollution, give two to three years life, and many more expensive systems five much worse results" (144). Some other stand-out qualities of red lead and other lead pigments include its superior weathering properties on galvanized iron, its outstanding resistance to salt spray, humidity, and accelerated weathering, its decreased tendency to blister, and its lifespan of upwards of four years.

Aside from lead pigments, Silicones also have proven themselves as an effecting finishing among metals. Silicone resins brought about the first organic compounds that could withstand temperatures of up to 1000°F, allow organic compounds to challenge the inorganic. "Silicones, in addition to their permanence and heat resistance, have remarkable anti-foaming and surface tension effects among which is outstanding water repellence. Straight silicones unmodified with alkyd resins will withstand temperatures of 500°F indefinitely, and alkyd co-polymers with 25% of suitable alkyd with withstand such temperatures for long periods without discoloration" (147). Silicons have made many new things possible like permanent protections of metal chimney stacks and electric rods and protection of turbo jet engines. Silicones have even more potential when mixed with other ingredients like aluminum powered, as it often done.

2.6.7 Insulation

"A range of packaging solutions exists for products that must be kept within a specific temperature range throughout the supply-and-distribution chain" (journal).

3 3 Search for Alternative Solutions

3.1 Introduction

Brainstorming sessions where held in order to generate alternative solutions for our project. These designs are made with the criteria and specifications in mind while offering feasible options for concession carts.

3.2 Brainstorming

Three brainstorming sessions were held within the library. Utilizing whiteboards, a peg board, and dowels to construct the general shape of the concession carts. Using notecards to incorporate new ideas.

3.3 Alternative Solutions

The following pages are have 6 alternative solutions that were developed in the brainstorming sessions. Each of the alternative solutions is described in the following paragraphs.

Plastic

Instead of using wood for the exterior of the cart, we could use polypropylene plastic sheets. It is a strong material that is still flexible enough to handle any stress we would put on it. It is durable, flexible, heat resistant, and acid resistant, although I don't think we are ever going to need that last part, but you never know. Materials are relatively cheap, although nowhere near as cheap as wood paneling is.

Glass

Instead of using plexiglass or just having a hole in the top of the cart, we could use glass for our display. Glass is relatively cheap and easy to come across, and it's easy to cut and shape if we have the right tools. It would be durable and stay clean and clear for a long time if it is properly maintained. On the other hand, if it does break, it's not going to be good for anybody, as it's usually pretty sharp, and all of the pieces have to be cleaned up.

Bryce, I'm doing the same with yours.

4 4 Decision Phase

4.1 Introduction

4.2

4.3 Criteria Definition

4.4

4.5 Decision Process

4.6

4.7 Final Decision Justification

5 5 Specification of Solution

5.1 5.1 Introduction

5.2

5.3 5.2 Solution Description

5.4

5.5 5.3 Cost Analysis

Cost analysis

Over the course of this project, we have accrued a number of expenses, which itself is not that surprising. However, what was slightly alarming was just how much each and every part of our project would cost. Buying in bulk would have probably been cheaper, but seeing as we are not really looking to mass produce our project, we had to make do with the prices we were given for individual pieces and materials.
8x4x0.5 plywood boards: $47 each
Metal frame L bars: $22 each
Studs 6x: $20
Plexiglass: $17
Screws: $12
Casters: $8 each
Hinges: $8 each
Each of these materials on their own isn't really that bad, but after adding them all together, and needing duplicates of even the more expensive parts, such as multiple plywood boards and L bars, the cost really starts to add up.

Time Analysis

The most progress made on this project has mostly been outside of class, which isn't surprising considering the nature of our project. While class time has been useful in teaching the design process, there really isn't that much room in the classroom to work on construction. And seeing as there are very few tools available from the school, we have had to find another place outside of campus to construct our project, which currently is Bryce's garage. Overall, we have spent ⅓ of our time working on the project in-class, and ⅔ of our time working on the project outside of class. This comes to around 10 hours in class, 20 hours out of class. This is not counting the time spent at Zane Middle School looking at prototypes, but if that is included, that probably adds another 2-3 hours to our time spent on the project.

5.6

5.7 5.4 Design

5.8

5.9 5.5 Construction

5.10

5.11 5.6 Maintenance

5.12

5.13 5.7 Implementation Instructions

5.14

5.15 5.8 Prototype Performance

6 6 Appendices:

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