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Faculty of Applied Science & Engineering
APS112: *Conceptual Design Specification (CDS)*

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- _X_ Introduction
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- _X_ Detailed Requirements (FOCs)
- _X_ Generation, Selection and Description
- _X_ Alternative Designs Selection Process
- _X_ Alternative Design Descriptions
- _X_ Proposed Conceptual Design Specification
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Executive Summary

Premuni is a snack shop in Zambia that sells frozen packaged goods and is experiencing challenges in distributing these items across rural regions while keeping them frozen. The company uses trucks and places food in unplugged freezers for transportation, which does not effectively maintain the temperature of the frozen foods. This project aims to design a viable solution that keeps the freshness and temperature of these frozen products during transport, without the need for refrigeration.

The current transportation method requires the use of freezers, frozen overnight with the food in it, unplugged then loaded onto trucks for delivery. This method is proven to be inefficient and unreliable as the grocery stores do not have access to lifts and the freezers do not maintain temperature well during the journey. There is a need for a solution that can effectively keep frozen goods at a cold temperature while using materials suitable for a project based in Zambia.

The proposed solution focuses on designing an insulated container that meets several critical requirements. Firstly, it must ensure the preservation of frozen goods at temperatures between -10°C to -18°C for periods ranging from 6 to 12 hours, addressing the primary function of temperature maintenance. Additionally, the design must be user-friendly, allowing for easy handling by two individuals, which aligns with the secondary functions of the project, including accessibility and mobility.

The project has a series of objectives that are based on the functions, stakeholder wants and constraints. These include objectives cost-efficiency by reducing expenses compared to the current method, ensuring durability to withstand the demanding conditions of rural Zambian roads, and adhering to environmental considerations by utilizing recyclable or biodegradable materials. These objectives are created to align with the overarching goal of the project, based on the client's wants while adhering to the constraints related to temperature control, weight limitations, non-toxicity, cost-effectiveness, and resistance to water damage.

The service environment is characterized by its hot climate and poor road conditions shape the design's constraints and materials. The service environment includes the different truck models used by Premuni within their specific dimensions and structural characteristics to ensure the proposed solution can meet the objectives. Additionally, the project recognizes the significance of various stakeholders, including delivery personnel, Premuni staff, local grocers, and the broader community, whose needs and impacts are carefully evaluated to guide the design process and its constraints.

1.0 Introduction

Located in Zambia, Africa, Premuni is a snack shop that sells frozen packaged goods. According to Premuni's partner, Suhail D'Souza, ensuring the high-quality arrival of imported frozen items is important. Our design developed an effective solution to be placed inside a delivery truck during transportation of the frozen foods. This document informs the bounds of the project, and proposes the design that satisfies the clients needs accordingly.

2.0 Problem Statement

Premuni Grocery is delivering frozen food items in rural towns across Zambia. Currently, food is being frozen in freezers overnight, then loaded in unrefrigerated trucks and unloaded at stops along the trip. Their supplies are limited thus there is little access to ramps and hydraulics, making this method of transport difficult. (Appendix A)

The client needs a durable solution that will store frozen food items while maintaining temperature in an unrefrigerated truck in Zambia. The current method is restricting as freezers are difficult to move and do not effectively regulate temperature without power. The client does not currently have an economically feasible, and renewable method of transporting frozen food across rural towns in Zambia while using readily available materials to maintain a safe temperature. The scope of the project is the design solution that will store the food within the truck. Figure 1 shows the space in which the solution will be contained. The truck, grocery store, fridges, and pick-up locations of the boxes are not within the scope of the project.

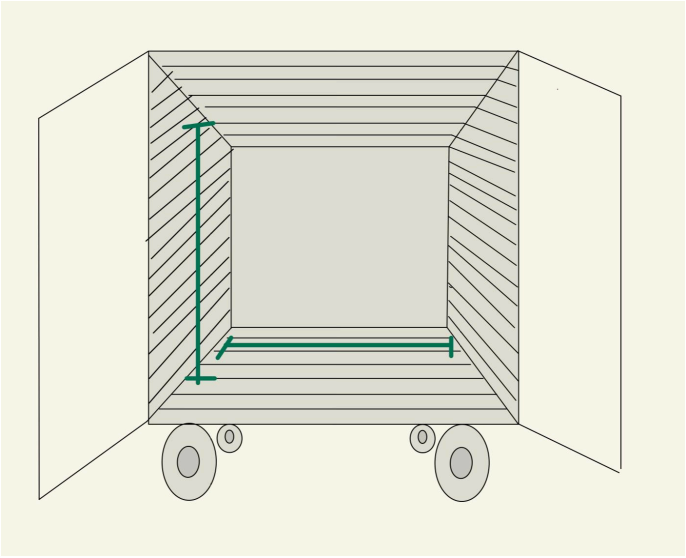

Figure 1: Sketch of the inside of the truck.

3.0 Detailed Requirements

Detailed requirements describe the functional and technical requirements of the project.

3.1 Functions

A function describes what a design must do to work. The primary functions listed in Table 1 and secondary functions listed in Table 2 were developed using the “black box” method in Appendix B.

3.1.1 Primary Functions

Table 1: Primary functions of the design.

Primary Function	Justification
1. Store goods	The items are stored and secured inside the design.
2. Maintain temperature of frozen foods	The items are received in a frozen state and they must stay frozen during the travel.

3.1.2 Secondary Functions

Table 2: Secondary functions of the design.

Secondary Functions	Justifications
1.1 Goods can be added and removed	To store packaged goods from one location to another, the design must be able to add and remove items.

3.2 Objectives

The objectives of this design measure its success using metrics. The objectives of this design along with their priority and metrics are listed below in Table 3.

Table 3: Objectives and metrics of the design.

Objective	Metric	Goal	Description	Priority
Keep items at low temperatures.	Degrees Celsius	-10℃ to -18℃	The safe temperature of the items is around -18℃. (Appendix A)	High
Keep items frozen for a certain period.	Hours	6 hours to 12 hours	The contents should maintain temperature for the duration of the trip (6 - 12 hours). Each extra hour can be measured as a 10% increase in success (Appendix A)	High
	RSI Value ($m^2 * K/W$)	R-Value of R-18 to R-30 [3]	The higher the resistance value, the slower the heat transfer rate through the insulating material [2]. Efficient insulators have a range of R-Value from R-18 to R-30 for temperature maintenance goal.	High
Be easily moveable by 2 people.	Kilograms	~46 kg	The average person can carry 23 kg, meaning two people would average 46 kg [3].	High
Be cost-efficient.	Percentage reduction in cost compared to current method.	30% reduction	The solution should be around 30% less costly than the current method as any more reduction would be unrealistic. (Appendix A)	Medium
Be durable and long-lasting.	Number of years of use before replacement.	13 years of use	Ensure the box has a durability of 13 years [4] or 4,500 delivery cycles which is one delivery per	Medium

			day for 13 years.	
Be environmentally friendly.	Percentage of recyclable or biodegradable materials used	95% recyclable or biodegradable	To minimize environmental impact, utilize 95% recyclable or biodegradable materials for the box. [5]	Low

3.3 Constraints

Constraints are the hard limits on the project that the solution must meet. It ensures the client and stakeholders' needs are satisfied while preventing legal and safety issues, as listed in Table 3.

Table 4: Constraints and Their Metrics.

Constraint	Metric	Limit
Must keep items frozen	Degrees Celcius	-8°C (Appendix A)
Must be durable with a decent product lifespan	Years	2 years without significant damage [7]
Must keep items frozen for a minimum time	Hours	6 hours (Appendix A)
Must have a maximum weight that two people can safely carry	Kilograms	78.925 kg [8]
Must be non-toxic and food-grade		WHO and DFCL approved. Included in the FDA's inventory of Effective Food Contact Substance notifications database. [9][10]
Must be reusable within a certain timeframe	Hours	12 hours. (Appendix A)
Must be able to hold multiple items	Centimeters Squared	Volume of 800 cm^3 [1] [11]
Must be cost-effective to produce	Canadian Dollars	Maximum of CA$20,000 for a truck's worth [12]
Must avoid water damage (Appendix A)		

[1] Assuming one box of samosas is 400g, ie 400 cm^3, and at least 2 boxes are packed.

4.0 Service Environment

The service environment provides factors in which the design must work with. Here, it is the interior of a delivery truck traveling through Zambia, experiencing varying climate and road conditions.

4.1 Physical Environment

The physical environment consists of various factors where the solution operates. The climate is cool from mid-May to mid-August, hot from September to mid-November, rainy from mid-November to March and dry from April to mid-November [13]. The different seasons cause the average temperature to sit between 14 - 35 ℃, however, the all-time high is 44 ℃ [14]. Below, Figure 2 provides a temperature graph of the temperature throughout the year.

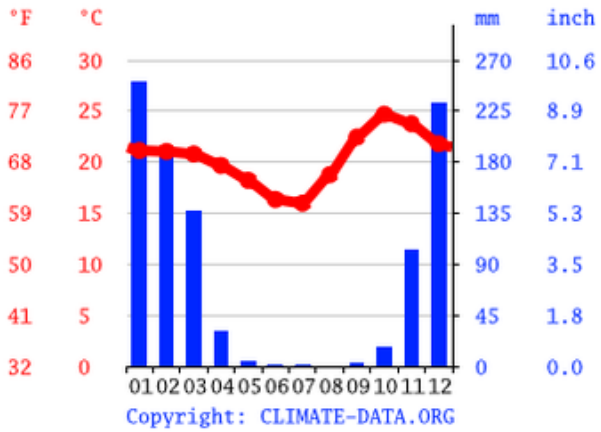

Figure 2: Yearly Temperature and Rainfall in Lusaka, Zambia [15]

The roads in rural communities are in poor condition, oftentimes unpaved dirt roads, as seen below in Figure 3. [16] This coupled with the rainy season leads to muddy conditions.

Figure 3: Roads in Rural Zambia [17]

As the scope is limited to the internal trailer of the truck, the specifications of the model are required for the design. Truck trailers are usually composed of steel or aluminum, impacting the internal temperature and the transported products[18]. Aluminum has a specific heat capacity of 0.921096J/gC and steel at 0.510796 J/gC, impacting the radiative heat inside the trailer [19].

As per client, the truck models in use are the Eicher PRO 2110 6s and the Hyundai HD78 GT (Appendix A). The Eicher PRO 2110 6s, shown in Figure 4 below, has four models, while the Hyundai HD78 GT, shown in Figure 5 below, has three models [20] [21].

Figure 4: Image of Eicher PRO Truck Model [20]

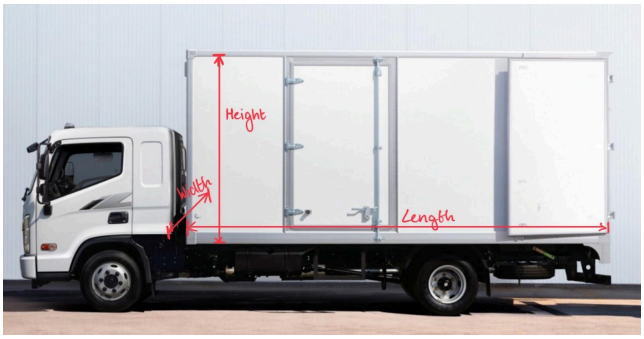

Figure 5: Image of HD78 GT Truck Model [21]

The two truck models have different dimensions according to their sub-models as provided in Appendix C.1. The two trucks have different box dimensions:

- Eicher Pro
  - Length: 5.5m
  - Width: 2.2m
  - Height: 2.3m

- Hyundai
  - Length: 4.8m
  - Width: 2.06m
  - Height: 2.4m

The different service environments posed by the truck models introduce the challenge of creating an adaptable design.

4.2 Living Things

The living things shape the use of the solution. The two categories of people involved are the delivery and stock personnel. The delivery drivers control the truck's (storage of solution) speed and stability, whereas the stock personnel handles the solution.

Many insects must be considered in case they get into the trucking trailer. The most common bugs in Zambia are beetles, true bugs, ants/bees/wasps and butterflies [22], see Appendix C.2 for examples.

4.3 Virtual Environment

The virtual environment highlights available resources for the solution. In the trucks there is radio access, thus the drivers can receive important news updates regarding the weather and emergencies [20] [21].

5.0 Stakeholders

The stakeholders are other entities that are affected by and affect the design whose perspectives are important. The primary stakeholders are listed below in Table [5].

Table 5: Project Stakeholders

Stakeholder	Affected since:	Affect the design since:
Delivery Drivers - High influence, high interest	They deliver the food items to the suppliers or customers.	Drivers transport items and want an efficient and lightweight solution
Premuni Staff - Low influence, high interest	Premuni can deliver to more places, generating more income.	They will be packing the products and working with the solution.
Grocerers in the area - Low power, high interest	They could stock more products if more food can be transported.	They make Premuni's products available to the communities in rural Zambia
Communities of rural Zambia - Low influence, low interest	They will have more food available and heavier traffic due to further shipping	They are Premuni's primary customers and source of income.
The Food and Drugs Control Laboratory - high influence,	They are not affected by the design.	They are the primary food regulatory agency in

low interest		Zambia. [9]
Other companies that deliver food - Low power, high interest	The design enables them to transport frozen food, meaning Premuni could sell the design solution to them	They do not affect the design.

6.0 Generation, Selection, and Description of Alternative Designs

The development of the project contains two phases of idea generation and selection, giving us the final three solutions. The comprehensive flowchart is included in Figure 6.

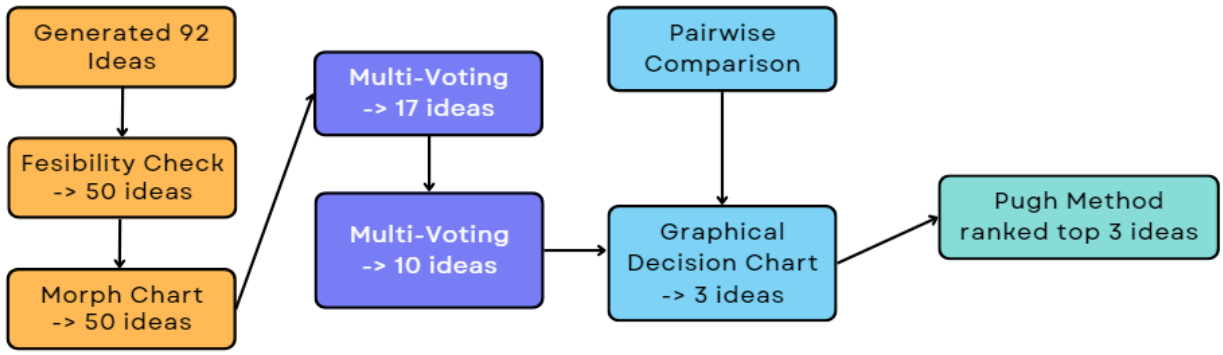

Figure 6: Ideation process flowchart

6.1 Generation

Members of our group individually came up with ~20 ideas, totalling 92 ideas. Through consolidation, repetitive ideas were eliminated. These ideas were generated based on the primary functions: to maintain the temperature of frozen foods, and to store goods. They also fit our secondary functions of adding and removing goods.

6.2 Selection

Idea selection was developed based on the objectives of the solution:

1. Feasibility Check: Narrowed ideas from 92 to 50 using constraints [Appendix D.1]
2. Morph Chart: developed 50 well-developed ideas from feasible ideas [Appendix D.2]
3. First Round of Multi-Voting: Each member submitted 5 votes, narrowing ideas from 50 to 17 [Appendix D.3]
4. Second Round of Multi-Voting: Each member submitted 2 votes, narrowing ideas from 17 to 10 [Appendix D.4]

5. Graphical Decision Chart: We ranked the objectives through pairwise comparison, then weighed objectives to pick the final three solutions: The VIP Insulated Aluminium Box, Aerogel Insulated Box, and Aluminum Plated Box [Appendix D.5]
6. Finally, we used the Pugh method to compare the solutions to the original method. [Appendix D.6]

6.3 Description of Alternative Designs

The alternative design solutions were developed based on the constraints of the service environment. For a detailed explanation of how each design meets the functions and constraints, see Appendix E. The minimum dimensions of the truck are a length of 4.3m x 2.3m x 2.06m. Using this we calculated a box size of 0.90m x 0.75m x 1.65m, shown in Figure 7, allowing 15 boxes in the truck while providing space for workers to grab boxes.

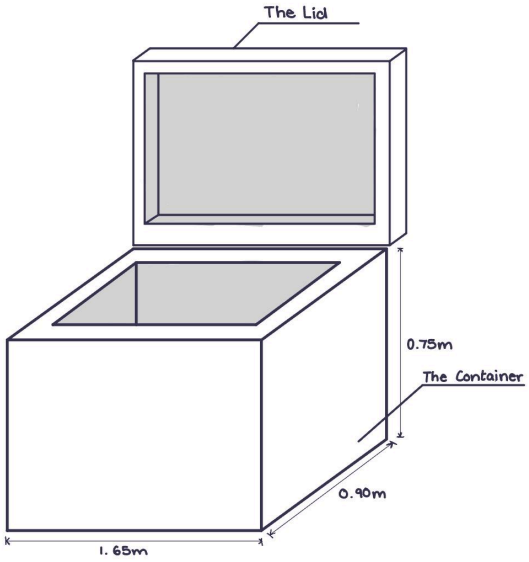

Figure 7: General Layout of Design

6.3.1 Design #1: VIP Insulated Box

The container is made from aluminum with an aluminum oxide coating for heat elimination. It is insulated with Vacuum Insulation Panels (VIP). As seen in Figure 8, the handles on the side facilitate mobility. A detachable compartment within the container holds a frozen cooling agent gel, choline chloride, [25]. It can be removed and frozen overnight, making it renewable.

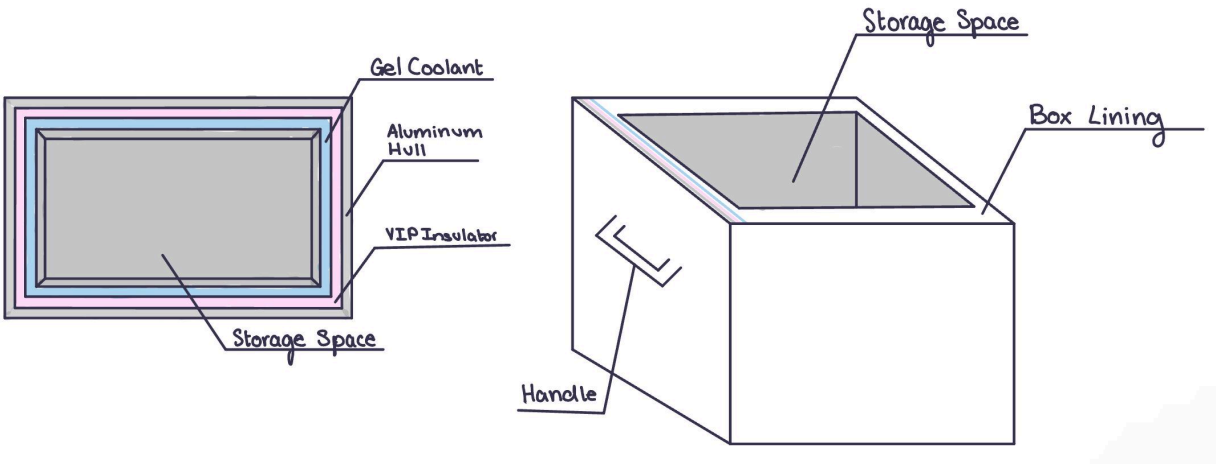

Figure 8: Design #1 Sketch

Table 6 shows how this design meets the project's objectives:

Table 6: VIP Insulated Box Objective Satisfaction

Objectives	How Objectives are Met
Keeps Items at low temperature	The VIP has an extremely low thermal conductivity (0.006 W/mK) minimizing heat transfer into the container. [3]
Keeps Items frozen for some time	The combination of VIP insulation and a pre-cooled cooling agent gel compartment keeps the container's temperature stable for at least 12 hours. [44]
Be easily moved by 2 people	The handles and lightweight materials like aluminum allow for easy lifting.
Be durable and long-lasting	Aluminum is highly durable and resistant to corrosion when coated with aluminum oxide
Be cost efficient	Aluminum is a readily available material, and the VIP's efficiency allows for thinner insulation layers. The production costs are kept low without compromising the performance.
Be environmentally friendly	VIP is more sustainable than traditional insulation materials due to its longer lifespan. Aluminum material and the reusability of the container reduce waste and lower the demand for raw materials.

6.3.2 Design #2: Aerogel Insulated Box

A dual-compartment box storing the food made of stainless steel and aerogel-insulated within its walls. Shown in Figure 9, there are carrying straps on the sides and rubber edges on the box. A temperature monitoring unit is inside, where the internal temperature is tracked via mobile apps. Table 7 shows how this design meets the objectives.

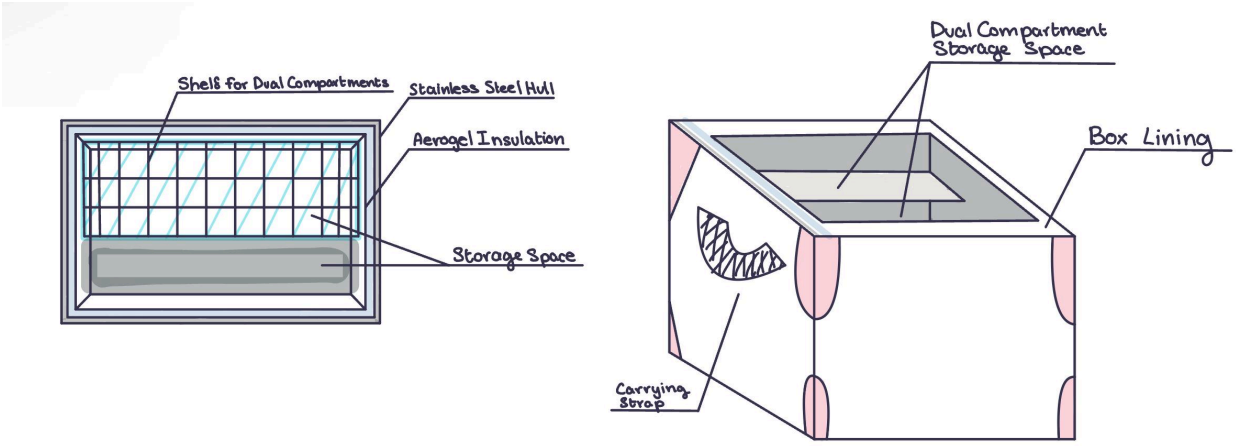

Figure 9: Design #2 Sketch

Table 7: Aerogel Insulated Box Objective Satisfaction

Objectives	How Objectives are Met
Keeps Items at low temperature	The low conductivity of aerogel insulators (0.015 W/mK) [27] ensures effective temperature maintenance. Stainless steel has a reflective surface that prevents heat from compromising the internal temperature of the box [28].
Keeps Items frozen for some time	The temperature monitoring unit records the internal temperature, and if the desired range is not maintained, the user is notified [30]. The aerogel insulation ensures a long freezing time.
Be easily moved by 2 people	Carrying straps make it easy to move and load the boxes onto the truck. Aerogel is a lightweight insulator as it has low density [27].
Be durable and long-lasting	Stainless steel is strong and durable [28].

	Rubber edges minimize damage in case of trauma to the box. The aerogel insulation can last for over a decade [27].
Be cost efficient	Aerogel's insulation properties minimize the need for additional cooling properties within the box[27].
Be environmentally friendly	Aerogel is made from silica aerogels, which come from sand [27]. Stainless steel is a recyclable material [28].

6.3.3 Design #3: Aluminum-Plated Box

The box is covered in aluminum, as seen in Figure 10. There are two handles on the exterior, and insulated dividers within the storage space. Inside the walls, there is a fluid-cycling mechanism. A pump is attached for the constant circulation of the fluid. The smart temperature monitoring system makes adjustments to the distribution of the cooling fluid as needed. Table 8 shows how this design meets the objectives.

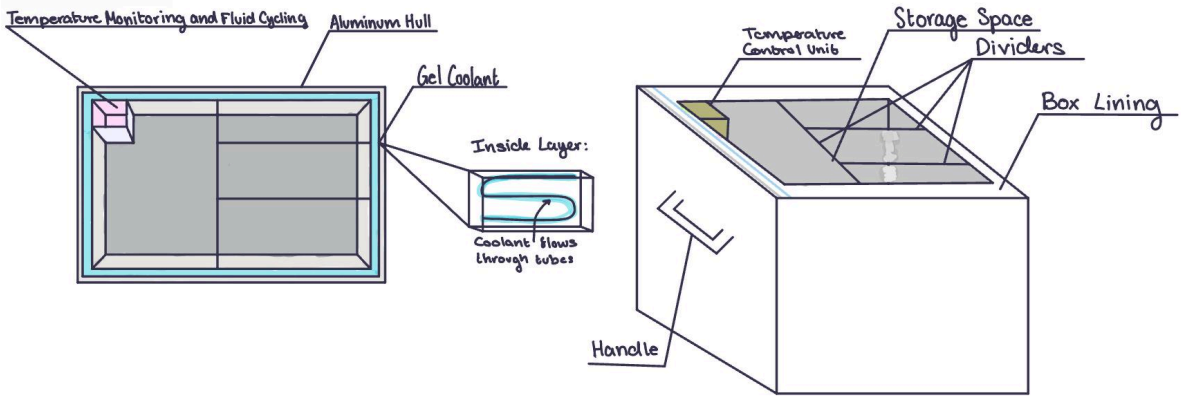

Figure 10: Design #3 Sketch

Table 8: Aluminium-Plated Box Objective Satisfaction

Objectives	**How Objectives are Met**
Keeps Items at low temperature	Aluminum with its reflective properties prevents heat absorption, while the cycling fluid mechanism inside the insulated walls maintains a constant temperature of -8°C [29].
Keeps Items frozen for some	The cooling system, composed of a cycling fluid

time	mechanism and smart temperature monitoring, consistently maintains temperatures below -8°C for the required time.
Be easily moved by 2 people	The two handles on the sides allow easy lifting and transportation. Its dimensions provide storage while ensuring mobility.
Be durable and long-lasting	Constructed from aluminum, the box is lightweight and tear-resistant. This material combined with the cooling and temperature regulation systems ensures the box's longevity [29].
Be cost-efficient	Aluminum is a readily available material, and the smart temperature monitoring system optimizes energy use, reducing operational costs [29].
Be environmentally friendly	Aluminum is recyclable. The cooling system and smart temperature monitoring reduces unnecessary energy consumption [29].

7.0 Proposed Conceptual Design Specification

The client wants an economically feasible and renewable method of transporting frozen foods across rural Zambian towns. To solve this problem, idea generation was iterated several times to develop three solutions. A Pugh chart was used to compare the alternate designs against the current method (a freezer freezing food overnight, placed in the truck unplugged). The Pugh method revealed that the best solution of the three alternates was solution #1 with a score of 11, while solutions 2 & 3 had scores of 7 and 9 respectively [Appendix F.1]. Table 9 provides a side-by-side of the designs and how well each meets the objectives. For a more detailed explanation of materials and the Pugh Chart, see Appendix F.1.

Table 9: Comparison of Objectives

Objective	Design #1	Design #2	Design #3
Keeps Items at Low Temp.	VIP Insulation	Aerogel Insulator	Aluminum Plating
Extends Time Item is Frozen	Gel Coolant	No additional coolant	Cooling Fluid

Easily Moved by Two People	Easy Carrying Handles	Easy Carrying Straps	Easy Carrying Handles
Cost Efficient	Inexpensive Materials	Expensive Materials	Some Expensive Materials
Durable & Long Lasting	Lasting Materials	Lasting Materials	Some non-lasting Materials
Eco-Friendly	Recyclable Materials	Recyclable Materials	Some Non-Recyclable Materials

Although all solutions can fulfill the main objectives of keeping a low temperature and extending the time it stays cold, the solutions differ in efficacy. Design 1 excels in all categories as it exceeds each objective. As seen in Table 9, Design 2 lacks a cooling agent and uses expensive materials. Although Design 3 surpasses the benchmark in the Pugh Chart, Design 1 outperforms it in cost-effectiveness, durability and eco-friendliness. The Figure below shows the 3D Model of the design solution. For more information on the model see Appendix F.2 or visit.

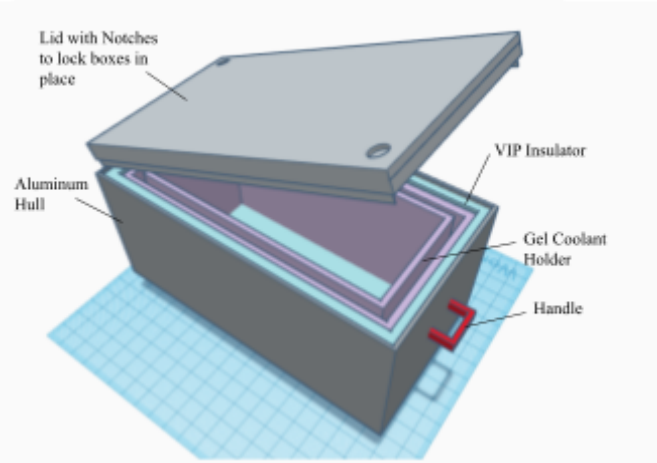

Figure 11: 3D Model of Selected Design

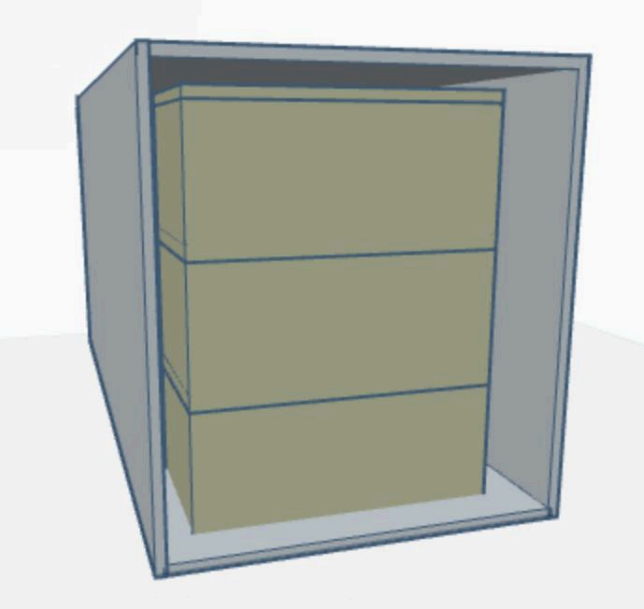

Figure 12: 3D Model Fit of Units Inside Trucks

Although all solutions addressed the client's basic needs, the client's wants such as durability, eco-friendliness and ease of use set Design #1 apart. Therefore, the chosen design solution will best fulfill the client's goals of keeping products frozen in transit for 10-14 hours without refrigeration.

8.0 Measures of Success

The primary objectives the team will be measuring are the internal temperature of the solution and the duration that the internal temperature is less than -8°C. To measure how long the solution can keep the client's food frozen, the team used modelling software to model the heat emission. The software used was *Energy2D*, where we created a 2D mockup of the design. [31] This is illustrated below in Figure 13. We assume that the internal ambient temperature of the box is -18°C from the frozen items. The team also chose choline chloride as the chemical compound within the cooling packs due to its widespread use for eutectic coolants and its non-toxic nature. [32] For more information about the values the team used, see Appendix G.

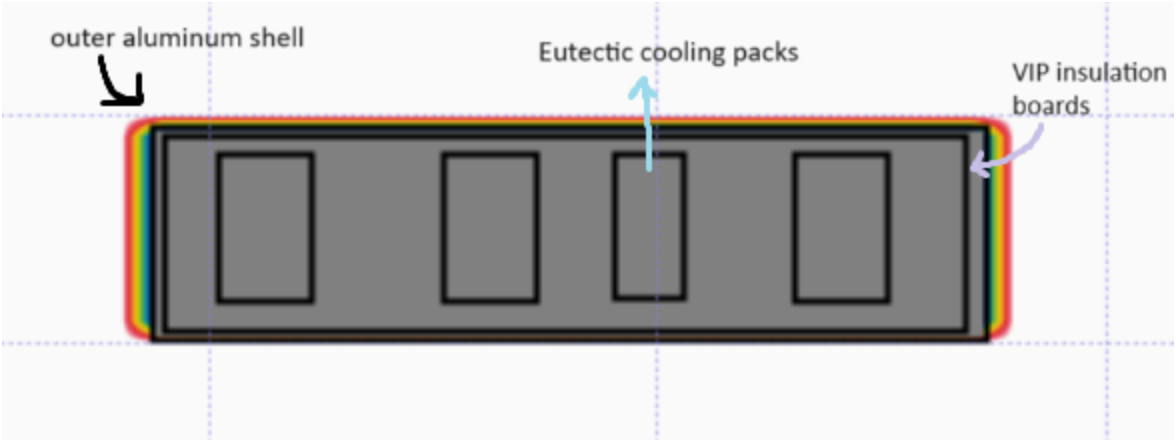

Figure 13: Energy2D Model of the Solution

This following model allowed the team to simulate and graph the internal change in temperature of the box over time, shown below in Figure 14. For further information on the data the team collected, see Appendix G.

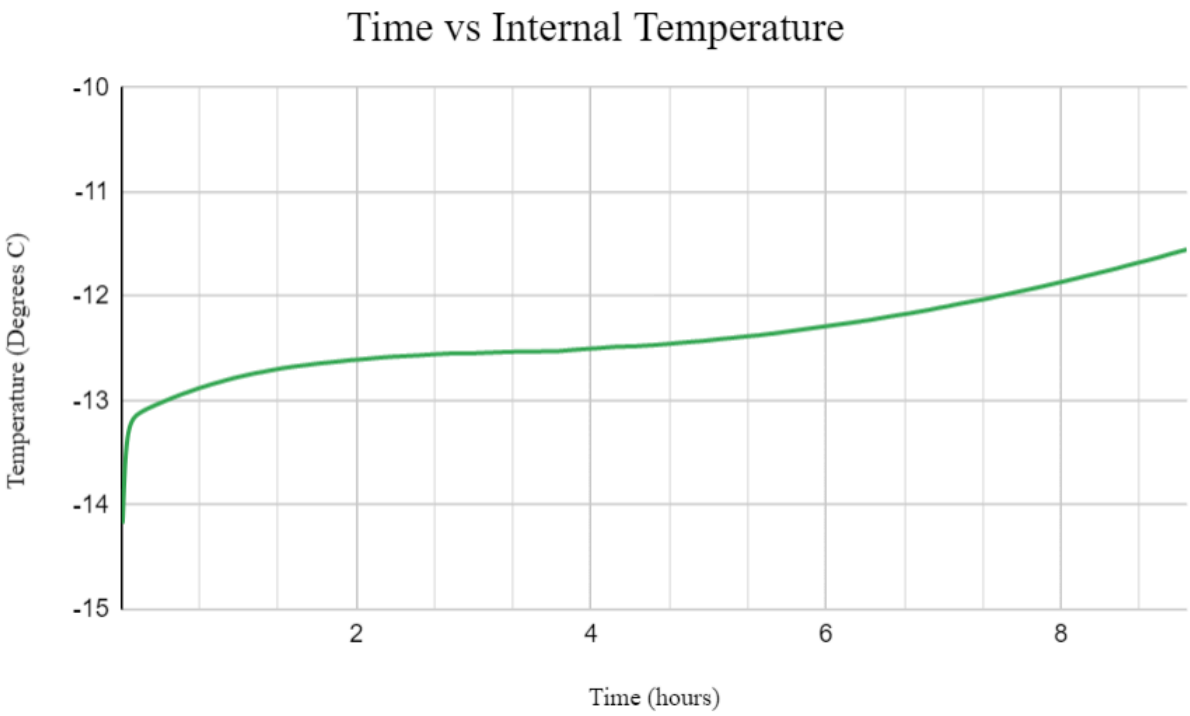

Figure 14: Graph of Collected Data

As shown in the figure and the chart in Appendix G, the box can keep an internal temperature of -8°C for 8 hours, meeting our objective.

We can extrapolate the temperature of the box at 10 and 12 hours using a linear trendline resulting in the equation:

$$f(t) = 0.138t - 13$$

The team extrapolated that the temperature at 10 hours is -11.62°C and the temperature at 12 hours is -11.34°C, meaning we meet the objective of 10 hours.

9.0 Conclusion

The final design solution incorporates the primary and secondary functions such as storing goods and maintaining low temperature, while enabling the stored goods inside to be added and removed. The solution is suitable for the client's initial need to transport frozen goods across rural areas of Zambia for over ten hours of travel time. The team will now proceed with building a physical prototype and will eventually require the client’s approval from the testing of the prototype.

10.0 References

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11.0 Appendices

Appendix A: Client Meeting Notes

Feb 01, 2024

Team Number	088
Project Title	Eutectic cooling for Cold Chain in Sub-Saharan Africa
Meeting date	Thursday, February 1st, 2024: 10:00 am.
List of people attending	All team members
Team members	Eika Go Ali Jaouni Shreya Perumal Gamze Ugur Dooyeon Yeom

Client Introduction

He wants to be referred to as Suhail
For short distances, they use a freezer to freeze overnight, and then they transport the freezer
Products start frozen → they can also freeze the eutectic plates
Cannot freeze once they leave the supplier
Renewable solution is preferred

Problem:

- Business in Africa
- Logistics are not straightforward
- Food business
- Frozen products from one location to another
- It is economically unfeasible for frozen trucks to be used; goods do not justify the cost
- The solution to keep frozen items frozen without big fridge trucks

Any current prototypes:

- No prototypes with the company → no prior work
    - Poor man's version is a cooler box
    - CANNOT be filled with ice → water damage is something to keep in mind
    - Needs a more effective solution
    - Keeps things frozen -> does not need to refreeze items
- Eutectic cooling → technical word → very technical meaning
    - Not looking for something Eutectic in engineering terms
    - Basically like an Ice pack
- Modular:

- More rural African communities will be using the product
    - Lacks loading ramps, etc
- Reasonable for 2 people to lift
- Stackable and modular is highly preferred → higher efficiency

Measures of success

- 1) Time period of keeping frozen
    - Only way to refreeze the cooling packs is back at the source
- 2) Keeps temperature the same -18C → universally accepted frozen item temp
- Approx failure range: -8C to-10C → limit -8 to -10 is the standard for energy efficiency
- The solution should be safe for humans (ideally nontoxic)
    - PRIMARILY Packaged foods
    - Not fish and meat → frozen packaged products in boxes
        - Range of weights
    - Dimensions and weight range will be sent later over email
- Heavy emphasis on the ability of people to lift and carry the boxes by themselves

Constraints

- Primary goal → Maintaining temperature
- Secondary goal → Packing efficiency
- No budget for now → most cost-effective way possible
- Material constraints → No absolute wants/don't wants
    - Factor that it should be accessible to people in Zambia
    - Readily material available materials would be highly preferred
    - Ideally, we can make the boxes in Zambia
    - We want durable boxes or if it's a local solution they can easily be fixed
- We need to get a frozen item from one place to another in increments of 2 hours (6-10 hours of fridge) 14 hours is the stretch goal
- The solution doesn't have to protect the product but it should be reasonably durable

Service Environment

- Closed truck → midsized Uhaul
    - Send truck sizes and photos
    - Trucks can be modified → can build new trucks possibly
- Through a few towns in Zambia
- Usually just one main road
- In theory, we want the ice packs to reset overnight

Appendix B - Black box method

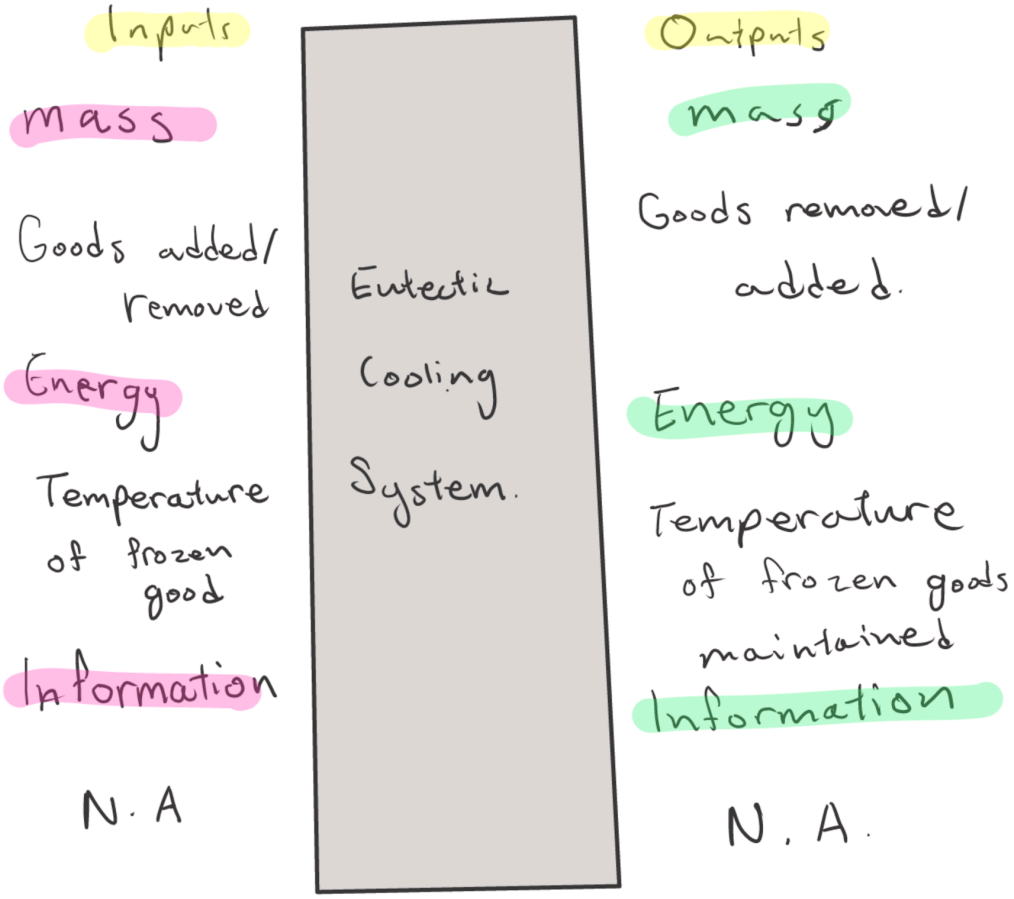


Figure 1: Use of the black box method to determine functions

Appendix C - Service Environment

C.1: Truck Models

Table 1: Dimensions of Various Truck Models

Truck	Specifications (m)
HD78 GT (MWB)	Height: 2.360 Length: 6.030 Width: 2.025
HD78 GT (LWB)	Height: 2.360 Length: 6.990 Width: 2.025
HD78 GT (ELWB)	Height: 2.360 Length: 7.455 Width: 2.025
Eicher PRO 2110 6s Wheelbase: 4300	Length: 5.811 Width: 2.125
Eicher PRO 2110 6s Wheelbase: 4400	Length: 6.112 Width: 2.125 - 2.287
Eicher PRO 2110 6s Wheelbase: 5150	Length: 6.756 Width: 2.125
Eicher PRO 2110 6s Wheelbase: 5150	Length: 7.364 Width: 2.287

C.2: Living Things

Below are a few images of the bugs and animals in the environment.

Bugs:

Beetles:



True Bugs:



Ants, Bees, Wasps:



Butterflies:



Appendix D - Idea Generation and Selection

1. Feasibility Check

Feasability Check:				
Functions:	Maintain Temperature of frozen foods		Store Goods	
Secondary Functions:		Constraint	Goods can be added/removed	Constraint
	Solar Powered Cooling Systems		Modular Insulation Crates	
	Insulated Blanket Wraps		Prism-shaped containers that can be stacked into each other to optimise space	
	Portable Freezing Units		slide-in shelving	1
	Vacuum Insulated Panels (VIP)		Adjustable Insulated Dividers	
	Aerogel Insulation		Quick Access Cooling Chambers	
	Rock Wool Insulation	non-toxic/ food grade	Collapsible Containers	
	Smart Temperature Monitoring		Interchangeable Cooling Systems	
	Clay wool insulated container	non-toxic/ food grade	Rolling Platforms	2
	Polystryene Insulation container		Conveyer on Truck to remove content	2
	Cellulose Insulation container	Avoid water damage	Box with bottom plate that cycles cooling fluid (battery powered)	
	Hemp Insulation container		Box with removeable lid that acts as a eutectic cooling plate	
	EPS insulation container		Small box units	
	~~Calcium Chloride cycling coolant system~~	6	Box with only insulation	1
	Choline chloride cycling coolant system		Lids like lego bricks that click together	
	~~Polypropylene Glycol cycling coolant system~~	6	Carrying Strap	
	Container insulated with aluminium		Straps over each box for durability	
	Automatic fan attached to the top of the container constantly blows out cold air		Box that is separable in a half and reattachable via magnets to make is easier to carry	
	~~Containers placed in gigantic freezing water tubs inside the truck~~	10	Rubber edges on container	
	~~Ethylene glycol cycling cooling system~~	6	Chain hooks to lock contianer	
	Mobile Freezer Unit		Latch/lock on box	
	Insulated Container		Large insulated bag as a container for food	6
	Thermal Packaging System		Dual Compartment Insulated Box	
	Refrigerated Unit with Enhanced Insulation		Wheels that lock	
	Insulated Cooler Bag			
	Temperature-Controlled Storage Container			
	Gel-insulated box			
	Container made of wood	6/10		
	Dry ice	10		
	Flash freezing products	3		
	Lining truck walls with fans	out of scope		
	Thermal box panels inside the box (padding)			
	Steel box			
	Fibreglass insulation			
	Box insulated with polyurethane foam			
	Holes in box to prevent condensation	1		

Constraint #	**Constraint**
1	Must keep items frozen (below -8C)
2	2 years w/o significant damage
3	6 hours frozen
4	less than 78.925 kg
6	non-toxic/food grade
7	resusable within 12 hrs
8	volume of 800cm3
9	cost effective (<20,000$)
10	Avoid water damage

2. Morph Chart

Morph Chart		
Functions:	Maintain Temperature of frozen foods	Store Goods
Secondary Functions:		Goods can be added/removed
1	Vacuum Insulated Panels (VIP)	Adjustable Insulated Dividers
2	Aerogel Insulation	Box with bottom plate that cycles cooling fluid (battery powered)
3	Smart Temperature Monitoring	Box with removeable lid that acts as a eutectic cooling plate
4	Container insulated with aluminium	Lids like lego bricks that click together
5	Mobile Freezer Unit	Rubber edges on container
6	Insulated Container	Chain hooks to lock contianer
7	Refrigerated Unit with Enhanced Insulation	Dual Compartment Insulated Box
8	Temperature-Controlled Storage Container	Modular Box Units
9	Gel-insulated box	Handles
10	Thermal box panels inside the box (padding)	Wheels that lock
11	Steel box	

3. First-R

ound Multi-Voting

	Formed Ideas		Votes:	5 votes per person
1	Vacuum Insulated Panels using in a Modular Box with Handle Bars, with rubber edges to protect contents (1, 5)		S, G A	E - Eika
2	Vacuum Insulated Panels in an Aluminum plated box with adjustable insulated dividers (1,4,1)		SA	S - Shreya
3	Smart temperature monitoring in a unit that cycles cooling fluid at a bottom plate when the temp is too high (1,2)		S	G - Gamze
4	Mobile freezer unit with a bottom plate that cycles cooling fluid with wheels that lock (5,2)		G	A - Ali
5	Steel box with aerogel insulation with wheels that lock (11, 2,10)		d	D - Dunny
6	Handles on a Aluminum plated box with lids that click together with gel-insulation (9,4,9)		S, D	
7	VIP box with removeable lid that acts as cooling plate with lids that click together (1,3,4)			
8	Polystyrene Insulated container with lids that click together (4)		s	
9	Gel-insulated box with chain hooks to lock container in place (9,6)			
10	gel-insulated box with adjustable insulated dividers (9,1)			
11	Thermal box panels to insulate container with rubber edges (10,5)		d	
12	Aerogel Insulation in dual compartment insulated box (2,7)			
13	VIP box with dual compartment insulated plated with aluminum (1,4)		E, G	
14	Smart temperature monitoring in a dual compartment box with fluid cycling through walls		E, D	
15	smart temperature monitioring in a temperature-controlled storage container with gel insulation			
16	thermal box panels in stell box with wheels that lock		D	
17	VIP panels in box with bottom plate that cycles fluids		E, A	
18	Aerogel insulation in box with removeable lid that acts as eutectic plate			
19	aluminum plated box with lid that acts as eutectic plate			
20	aluminum plated box that cycles cooling fluid			
21	mobile freezer unit with adjustable insulated dividers			
22	mobile freezer unit with smart temp monitoring and wheels that lock			
23	areogel adjustable insulated divders in polystyrene box			
24	modular box units with insulated dividers & dual compartments			
25	gel-insulated box with lids that click together like lego bricks			

26	VIP insulated steel box w/ dual compartment		
27	Temp controlled dual compartment box that cycles fluid if temp too high		G
28	thermal box panels insulated container with removable lid that acts as eutectic plate		
29	steel box with smart temperature monitoring and dual compartments		
30	aluminum box w/ thermal box panels and handles		
31	mobile freezer units with lids that click like legos		
32	temp controlled container with adjustable insulated divider		
33	gel-insulated box with dual compartments		A
34	Aluminum container with temperature monitoring system, with locking lid		
35	Steel box with aerogel insulation, rubber edges and handles		
36	Aluminum box with temperature control unit in the lid that cools the box		
37	Aerogel Box with temperature control unit inside, rubber edges and dual compartments		e
38	smart temp monitoring gel insulated box with chain hooks		
39	thermal box panels in dual compartment box with handles		
40	thermal box panels with box w bottom plate that cucles cooling fluid		
41	steel box with bottom plate that cycles cooling fluid		
42	steel box with lid that acts as eutectic cooling plate		
43	aluminum dual compartent box with divider that cycles cooling fluid and smart temp monitor		E,G
44	aluminum plated box with thermal box panels and insulated dividers		
45	gel insulated box with bottom plate that cycles cooling fluid		
46	gel insulated box with lid that acts as eutectic cooling plate		
47	thermal box panels as adjustable insulated dividers		
48	thermal box panels in steel box with lids that lock		
49	smart temp monitoring fridge unit with dual compartment that cycles fluid		
50	Steel Box with vacuum insulated panels, smart temperature monitoring and adjustable insulated dividers		a

4. Second Round of Multi-Voting

	Formed Ideas		Votes:	2 votes per person	
1	Vacuum Insulated Panels using in a Modular Box with Handle Bars, with rubber edges to protect contents (1, 5)		A		
2	Vacuum Insulated Panels in an Aluminum plated box with adjustable insulated dividers (1,4,1)				
3	Smart temperature monitoring in a unit that cycles cooling fluid at a bottom plate when the temp is too high (1,2)		S		
4	Mobile freezer unit with a bottom plate that cycles cooling fluid with wheels that lock (5,2)		G		
5	Steel box with aerogel insulation with wheels that lock (11, 2,10)				
6	Handles on a Aluminum plated box with lids that click together with gel-insulation (9,4,9)		G		
7	Polystyrene Insulated container with lids that click together (4)		A		
8	Thermal box panels to insulate container with rubber edges (10,5)		D		
9	VIP box with dual compartment insulated plated with aluminum (1,4)				
10	Smart temperature monitoring in a dual compartment box with fluid cycling through walls				
11	thermal box panels in steel box with wheels that lock				
12	VIP panels in box with bottom plate that cycles fluids				
13	Temp controlled dual compartment box that cycles fluid if temp too high				
14	gel-insulated box with dual compartments		E		
15	Aerogel Box with temperature control unit inside, rubber edges and dual compartments		D		
16	aluminum dual compartent box with divider that cycles cooling fluid and smart temp monitor		E		
17	Steel Box with vacuum insulated panels, smart temperature monitoring and adjustable insulated dividers		S		

5. Graphical Decision Chart

Ranking	Objective	Weight (out of 21)	Percent
1	Keeps Items at low temperature	6	29.00%
2	Keeps Items frozen for time period	5	24.00%
3	Be easily moved by 2 people	4	19.00%
4	Be durable and long-lasting	3	14.00%
5	Be cost efficient	2	9.00%
6	Be enviromentally friendly	1	5.00%

Design #	Solution
D1	Vacuum Insulated Panels using in a aluminum Box with Handles with adjustable insulated dividers (1, 5)
D2	Polystyrene Insulated container with lids that click together (4)
D3	Smart temperature monitoring in a unit that cycles cooling fluid at a bottom plate when the temp is too high (1,2)
D4	Mobile freezer unit with a bottom plate that cycles cooling fluid with wheels that lock (5,2)
D5	Handles on a Aluminum plated box with lids that click together with gel-insulation (9,4,9)
D6	Thermal box panels to insulate container with rubber edges (10,5)
D7	gel-insulated box with dual compartments
D8	Aerogel Box with temperature control unit inside, rubber edges and dual compartments
D9	aluminum dual compartent box with divider that cycles cooling fluid and smart temp monitor
D10	Steel Box with vacuum insulated panels, smart temperature monitoring and adjustable insulated dividers

	Targets	Weight	D 1	D2	D3	D4	D5	D6	D7	D8	D9	D10
OBJECTIVES	Keeps Items at low temperature	0.29	2	2	1	2	2	2	2	2	2	2
	Keeps Items frozen for time period	0.24	2	1	2	1	1	1	1	2	2	1
	Be easily moved by 2 people	0.19	2	1	1	2	2	1	1	1	1	1
	Be durable and long-lasting	0.14	2	0	1	1	2	1	1	2	2	2
	Be cost efficient	0.09	1	2	0	1	1	2	1	1	0	1
	Be environmentally friendly	0.05	1	0	1	1	0	1	1	1	1	1
Total Scores **max score = 2			1.86	1.19	1.15	1.48	1.57	1.38	1.29	1.67	1.58	1.43

2	Targets directly
1	targets indirectly
0	does not target

* insulated keeps it at low temp, cooling/a coolant extends the time

6. Pairwise Comparison

Checking (column)	Keeps Items at low temperature	Keeps Items frozen for time period	Be easily moved by 2 people	Be cost efficient	Be durable and long-lasting	Be enviromentally friendly	Score
Keeps Items at low temperature		1	1	1	1	1	5
Keeps Items frozen for time period	0		1	1	1	1	4
Be easily moved by 2 people	0	0		1	0	1	3
Be cost efficient	0	0	0		0	1	1
Be durable and long-lasting	0	0	0	1		1	2
Be enviromentally friendly	0	0	0	0	0		0

Ranking	Objective
1	Keeps Items at low temperature
2	Keeps Items frozen for time period
3	Be easily moved by 2 people
4	Be durable and long-lasting
5	Be cost efficient
6	Be enviromentally friendly

7. Pugh Method

Objectives	Benchmark (current method)	Alternate #1	Alternate #2	Alternate #3
Keeps Items at low temperature	0	2	2	2
Keeps Items frozen for time period	0	2	1	2
Be easily moved by 2 people	0	2	2	2
Be cost efficient	0	1	-2	1
Be durable and long-lasting	0	2	2	1
Be enviromentally friendly	0	2	2	1
Score Totals (max score = 12)	0	11	7	9

Benchmark: putting a freezer, frozen overnight inside of a delivery truck and then running the delivery route

Alternate Designs - highest to lowest grade in pairwise with details added in colored font		
1	Vacuum Insulated Panels using in a aluminum-plated box with Handles with adjustable insulated dividers that have eutectic cooling packs	A
2	Aerogel-insulated Box with temperature monitoring unit inside, rubber edges and dual compartments, stainless steel exterior, carrying straps on sides	G
3	Aluminum-plated dual compartent box, insulated dividers and smart temp monitor to cycle fluid to cool, handles on sides,	A

* insulated dividers are the eutectic cooling packs

Appendix E:

VIP Insulated Aluminum Box

Functions:

1. Maintain temperature of frozen foods:

The container utilizes Vacuum Insulation Panels (VIP) to maintain a consistent internal temperature. These panels, with their ultra-low thermal conductivity of (0.006 W/mK), effectively prevent heat transfer, keeping the internal environment below -8°C, which is crucial for storing frozen foods.

2. Stores Goods:

With dimensions of 0.75m x 1.65m x 0.90m, the container is designed to optimize storage space, allowing a significant quantity of goods to be stored. The interior is also configured to maximize space efficiency, facilitating the organization and accessibility of stored items.

Constraints:

1. Must keep items frozen (below -8C):

The container's insulation's low thermal conductivity (0.006 W/mK) is optimized to maintain temperatures lower than -8°C, ensuring the contents remain frozen. The inclusion of a pre-cooled cooling agent gel compartment further enhances its ability to sustain low temperatures over extended periods.

2. 2 years w/o significant damage:

Durability is achieved through the use of high-quality materials like aluminum, which is known for its strength and longevity. The container is built to withstand regular use and environmental stressors, ensuring it remains functional without significant damage for at least two years.

3. Non-toxic/food grade:

All materials in contact with stored goods are non-toxic and food-grade, ensuring that the container is safe for storing consumables. This adherence to health and safety standards is paramount in the container's design.

4. Avoid water damage:

The container is designed to be waterproof and resistant to condensation, protecting the contents from water damage. This is achieved through the use of water-resistant materials and seals, which prevent moisture ingress and ensure the integrity of the stored items.

5. Less than 78.925 kg:

Current manufacture of the box is designed to weigh less than 78.925kg.

$$[(75 * 90 * 165) - (74.7 * 89.7 * 164.7)] * 2.7/1000 = 27.44\ kg$$

6. Reusable within 12 hrs:

The design can be used several times within 12 hours without jeopardizing its capacity to maintain temperature due to its insulative properties.

7. Volume of 800 cm^3:

The dimensions create a volume of 1,113,750 cm^3.

8. Cost effective (<20,000$):

Assembling all materials in the design cost well below $20,000.
Total surface area of the box:

$4 * ((0.75m)(1.65)) + 2 * ((0.9m)(0.75m)) = 6.3m^2$

Weight of aluminum needed: 27.44 kg

Cost for VIP insulation: (6.3 m^2)($50) = $315
Aluminum cost: ($1.16)(27.44kg) =$31.8 [33]
Aluminum handles: $10 [24]
Choline chloride cooling gel cost for 1 liter: $30.95 [39]
Rubber edge protector: $20
Total cost of design: $407.75

Aerogel Insulated Box

Functions:

1. Maintain temperature of frozen foods:

Aerogel Insulation ensures a minimum of 6 hours of effective temperature regulation of -8 degrees Celsius within the box due to its low conductivity of 0.015 W/mK [27]. Stainless steel has a reflective surface, preventing the heat from compromising the internal temperature of the box by trapping the cool air inside. Stainless steel also has effective temperature-regulating properties, such as the lowest thermal conductivity of any metal: 15 watts per kelvin per metre [28]. This makes the material very capable at resisting temperature increase.

2. Stores Goods:

The large storage space of the box (1,113,750 cm^3) allows for several frozen food items to be stored and delivered to various locations. Dual compartments of the model allow for versatility as it adjusts and organizes the storage space within the box. Items can be organized based on perishability.

Constraints:

1. Must keep items frozen (below -8C):

The temperature monitoring unit ensures that the internal temperature of the box is always maintained within the desired temperature range [30]. The insulation has a very low conductivity of 0.015 W/mK, guaranteeing the maintenance of -8 degrees for a long duration [27].

2. 2 years w/o significant damage:

Rubber edges protect the box against significant damage during the transportation of the box due to its elastic component. They also seal the box to trap the air within the box and not allow mold to compromise the box.

3. Non-toxic/food grade:

Stainless steel is a corrosion-resistant material, making it safe to store food in [28]. None of the materials being used compromise the safety of the food, including the aerogel insulation, which is safe to use for storing food as it is chemically stable.

4. Avoid water damage:

Rubber edges can prevent moisture from getting in the box as it tightly seals the edges, preventing evaporation from occurring.

5. Less than 78.925 kg:

Current manufacture of the box is designed to weigh less than 78.925kg.

$7.75 g/cm^3 * [(75 * 90 * 165) - (74.9 * 89.9 * 164.9)]/1000 = 26.3\ kg$

6. Reusable within 12 hrs:

Design can be used several times within 12 hours without jeopardising its capacity to maintain temperature due to its insulative properties.

7. Minimum Volume of 800 cm^3:

The dimensions create a volume of 1,113,750 cm^3, well above the minimum requirement.

8. Cost effective (<20,000$):

Assembling all materials in the design cost well below $20,000:
Stainless Steel Cost: ($5.84)(26.3kg) =$153.6 [33]
Temperature monitoring unit: $70 [30]
Rubber edge protector: $20 [36]
Carrying Straps: $20 [37]
Aerogel Insulation: [34]
Volume of Aerogel Insulation = 66246.14cm3 [35]
Density = 1.5kg/m^3 = 1.5x10-4g/cm3
Weight = 9.94g
Cost = $91/g
Rough estimate = $91/g*9.94g = $904.54

Aluminum-Plated Box

Functions:

1. Maintain temperature of frozen foods:

The aluminium plating ensures that 95% of the light gets reflected off of the surface, minimizing the amount of heat that gets transferred into the box. It traps air within the box, maintaining the current temperature. The heat bounces off rather than being absorbed in the box [29].

2. Stores Goods:

The storage space being a box allows for many frozen food items to be transported to different locations. Insulated dividers are used to organize the storage of the food, where non-perishable and perishable items can be separated, as well as maximize the space.

Constraints:

1. Must keep items frozen (below -8C):

The insulated dividers ensure that each compartment of the box has consistent temperature and stays within the desired temperature range. The smart temperature monitoring also controls the flow of the cooling gel within the walls, according to the needed temperature for frozen foods to remain frozen [39].

2. 2 years w/o significant damage:

Aluminium is a highly durable and strong material that can withstand damage. Also, the insulation and temperature monitoring system are designed to be used on a regular and frequent basis without the risk of experiencing damage to the system [29].

3. Non-toxic/food grade:

Aluminium is a non-toxic material that often gets used to store food inside [29]. The insulation system meets food standards as it does not corrode the food in any way, or result in moulding.

4. Avoid water damage:

Aluminium stops evaporation and therefore eliminates the risk of moulding due to moist air [29].

5. Less than 78.925 kg:

Current manufacture of the box is designed to weigh less than 78.925kg.

$[(75 * 90 * 165) - (74.7 * 89.7 * 164.7)] * 2.7/1000 = 27.44\,kg$

6. Reusable within 12 hrs:

Temperature monitoring system guarantees that the design can be used many times within 12 hours without affecting its ability to maintain temperature [39].

7. Volume of 800 cm^3:

The dimensions create a volume of 1,113,750 cm^3.

8. Cost effective (<20,000$):

Assembling all materials in the design cost well below $20,000.
Aluminium Plating: ($1.16)(27.44kg) =$31.8 [33]
Handles: $8 [38]
Smart temperature monitoring with cooling fluid: $601[36]
Total cost: $640.8

Appendix F - Proposed CDS

F.1 - The Pugh Chart Explained

	Objectives	Benchmark	Alternate #1	Alternate #2	Alternate #3
1	Keeps Items at low temperature	0	2	2	2
2	Keeps Items frozen for time period	0	2	1	2
3	Be easily moved by 2 people	0	2	2	2
4	Be cost efficient	0	1	-2	1
5	Be durable and long-lasting	0	2	2	1
6	Be environmentally friendly	0	2	2	1
Score Totals (max score = 12)		0	11	7	9
Benchmark: putting a freezer, frozen overnight inside of a delivery truck and then running the delivery route.					
(1) Point for “Better Than” Benchmark (2) Points for “Targets Objective”					

Each objective was measured with respect to the measures outlined in the PR. While completing the Pugh Chart, the objectives were considered with respect to “how well” they were met in comparison to the current method. The way the objectives were measured compared to the benchmark are as follows:

1. How well heat is kept within the container
2. How well the container extends the period of time things stay cold for
3. If it is fit to be moved by two individuals
4. If it is a 30% reduction from the refrigerated truck
5. How close it gets to lasting 13 years
6. What percent of the design is recyclable

Below is the rationale for the score of each design for each objective:

Alternative Design #1: VIP Insulated Box

1. VIP is a strong insulator which keeps the cold inside the container
2. Eutectic cooling packs are a strong coolant that make the inside colder
3. Handles on the sides make the box easy to carry by two people
4. The materials namely aluminum, VIP, eutectic cooling packs, are relatively inexpensive
5. The materials are also relatively durable as they can survive some tumbling and force
6. All the components of the design are recyclable and easy to recycle, with the assumption that the eutectic cooling pack used is recyclable

Alternative Design #2: Aerogel Insulated Box

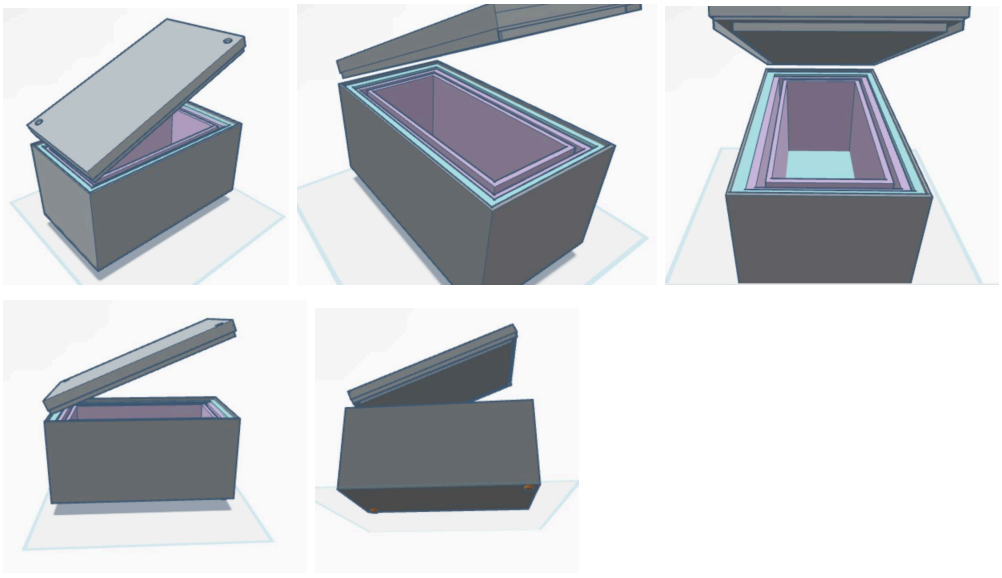
1. Aerogel is a strong insulator, that keeps cold inside the container
2. There is no coolant in the box, thus no additional cooling is introduced however the box will extend the period of cold temperature better than the benchmark
3. Carrying straps will enable it to be easily lifted by two people
4. The materials will be various metals and tech for temperature monitoring, rubber, aerogel, stainless steel and fibers. These materials are relatively expensive in comparison to the benchmark
5. The materials are very durable as they will survive a suitable amount of force
6. All the materials are recyclable

Alternative Design #3: Aluminum-Plated Box

1. Aluminum plated box with insulated dividers will be a strong insulator and retain cooling
2. A Cycling cooling fluid keeps the container cold very well
3. There are handles on the sides for easy two person handling
4. There are certain materials like the technology that are more expensive and may need to be regularly replaced
5. The materials are not entirely long-lasting, namely the smart temperature monitoring, coolant cycling system will have to be replaced every so often
6. The cooling fluid may not be recycled

F.2 - Images of the 3D Model

Link to TinerCad Model



Appendix G - Measures of Success

The numbers used for the Energy2D simulation are given below in Table A.1:

Table A.1: Material properties and temperatures:

Material	Initial Temperature [°C]	Thermal Conductivity [W/(m°C)]	Specific Heat [J/(kg°C)]	Material Density [kg/m^3]
Choline Chloride	-18 (Appendix A)	0.198 [40]	249 [40]	450 [41]
VIP Insulation	-18 (Appendix A)	0.004 [42]	0.80 [42]	160 [42]
Aluminum	-18 (Appendix A)	237 [43]	0.90 [43]	2810 [43]

A snippet of the data the team gathered from the Energy2D simulation is provided here, as the full quantity of data exceeds over 2,000 data points. See Figure A.1 below for the data.

*Note: continued on next page

Figure A.1: Data points from Energy2D simulation

Time (s)	Time (hr)	Outside Temp	Internal Temp	Eutectic Temp
10	0.002777777778	35	-13.84329	-14.6626835
20	0.005555555556	35	-14.129927	-14.657565
30	0.008333333333	35	-14.179124	-14.651872
40	0.01111111111	35	-14.13254	-14.6459
50	0.01388888889	35	-14.052146	-14.639756
60	0.01666666667	35	-13.964317	-14.633504
70	0.01944444444	35	-13.879725	-14.627157
80	0.02222222222	35	-13.802183	-14.620738
90	0.025	35	-13.732604	-14.614194
100	0.02777777778	35	-13.670716	-14.60761
110	0.03055555556	35	-13.615928	-14.60103
120	0.03333333333	35	-13.567371	-14.594406
130	0.03611111111	35	-13.524338	-14.587814
140	0.03888888889	35	-13.486157	-14.5811825
150	0.04166666667	35	-13.452227	-14.574676
160	0.04444444444	35	-13.422024	-14.568181
170	0.04722222222	35	-13.395037	-14.561552
180	0.05	35	-13.370839	-14.554958
190	0.05277777778	35	-13.349127	-14.548403
200	0.05555555556	35	-13.329652	-14.541968
210	0.05833333333	35	-13.3121395	-14.535483
220	0.06111111111	35	-13.296309	-14.529022
230	0.06388888889	35	-13.281966	-14.522604
240	0.06666666667	35	-13.2690525	-14.516257
250	0.06944444444	35	-13.257312	-14.509907
260	0.07222222222	35	-13.246596	-14.503596
280	0.07777777778	35	-13.227842	-14.4909935
290	0.08055555556	35	-13.2196455	-14.484735
300	0.08333333333	35	-13.212116	-14.478547
310	0.08611111111	35	-13.205154	-14.472395
320	0.08888888889	35	-13.198684	-14.466277
330	0.09166666667	35	-13.1926565	-14.460133
340	0.09444444444	35	-13.187027	-14.454

Appendix H - Attribution Table

Tutorial #:	0112	Team #:	088
Assignment:	Conceptual Design Specifications	Date:	March 24, 2024

The Attribution Table is a major resource used by your TA in determining whether there was equal contribution to the team assignment. If your TA determines that there was significant under contribution, then they may apply an individual penalty to the under contributing team members' grade. As a future professional engineer you should NOT sign any document you have not read and do not agree with.

The Attribution Table must be completed, signed by all team members, and included as an appendix of your assignment AND uploaded to your MS Teams team channel. Teams who do not submit a completed form, including those that submit an incomplete form, such as one missing a team member's signature, will receive zero on the assignment. The team may submit a petition to the ESP Office if they feel the lack of signature is through no fault of the team.

The Attribution Table should accurately reflect each team members' contribution to the document. Be sure to keep a copy of this form for the team's records.

If there are irreconcilable differences that are preventing all team members from signing the attribution table then each team member must write a letter (<one page) explaining their position on the difference and suggest a solution. These letters much be submitted to the TA.

As with any engineering statement this attribution table must be backed by credible evidence. In most cases this will be found either in the Google Docs document revision history, or your engineering notebook. Making fraudulent claims in an Attribution Table displays intent to deceive and is a serious academic offence.

Section	Student Names				
	Shreya Perumal	Dooyeon Yeom	Ali Jaouni	Gamze Ugur	Eika Go
Executive Summary	MR, ET		WD, ET	MR,ET	MR, ET
1.0		WD, MR		MR,ET, FP	ET
2.0	FP		ET, FP	WD, MR, ET	ET
3.1		WD, MR, ET, FP	ET, FP	ET, MR	ET
3.2		ET	WD, MR, RS1, RS2, ET	ET	ET

3.3	RS10	ET		ET	WD, MR, RS2, RS3, RS4, RS11
4.0	RS, WD, MR, ET, RS5, RS6, RS7, RS8, RS9 , FP		FP	ET, RS7	ET
5.0			ET	ET	WD, MR, ET, FP
6.0			RS1, RS2,WD,MR,ET, FP, RS13	RS1, RS2, RS12, RS13,RS14, WD,MR,ET	
7.0	WD, ET, MR, FP			ET	
8.0				ET	WD, ET, FP, RS12
9.0		WD, MR, ET, FP		ET	
10.0	WD, ET, RS5, RS6, RS7, RS8, RS9	WD, ET	WD, RS1, RS2, RS3,	WD, ET, RS1, RS2, RS4, RS12, RS13, RS14	WD, ET
11.0	WD, ET, FP	WD, ET, FP	WD, ET, FP	WD, ET, RS1, RS2, RS4, RS12, RS13, RS14, FP	WD, ET, FP

Fill in abbreviations for roles for each of the required content elements using the abbreviations found on the next page. You do not have to fill in every cell.

RS – Research (give details below) WD – Wrote Draft MR – Major Revision ET – Edited	FP – Final Proofread of COMPLETE DOCUMENT verifying for flow and consistency OR – Other (give details below)

If you put RS (research) please add a number identifier such as RS1, RS2, etc. Give the research question / topic:

RS1: What is an ideal R-Value for insulation of frozen food?

RS2: What defines a durable product?

RS3: What is the maximum weight an adult can carry safely?

RS4: What are non-toxic and food grade materials?

RS5: What is the climate in Zambia?

RS6:	What are the road conditions in Zambia?
RS7:	What is the range of temperatures in Zambia?
RS8:	What are the dimensions of the transport truck?
RS9:	What is the climate in Zambia like?
RS10	What is the cost of a refrigerated truck
RS11	What are the governing bodies in charge of food safety in Zambia
RS12	Specific heat capacities of Materials used as insulators
RS13	What is the cost of materials?
RS14	What is the weight of materials?

If you put OR (other) please add a number identifier such as OR1, OR2, etc. Explain the role below:

OR1:	
OR2:	

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Student #3 Name	Gamze Ugur	Student #7 Name	

Student #4
Name

Eika Go