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IIT Bombay

Storage Solution to Reduce Post-harvest losses of Vegetables

Project III

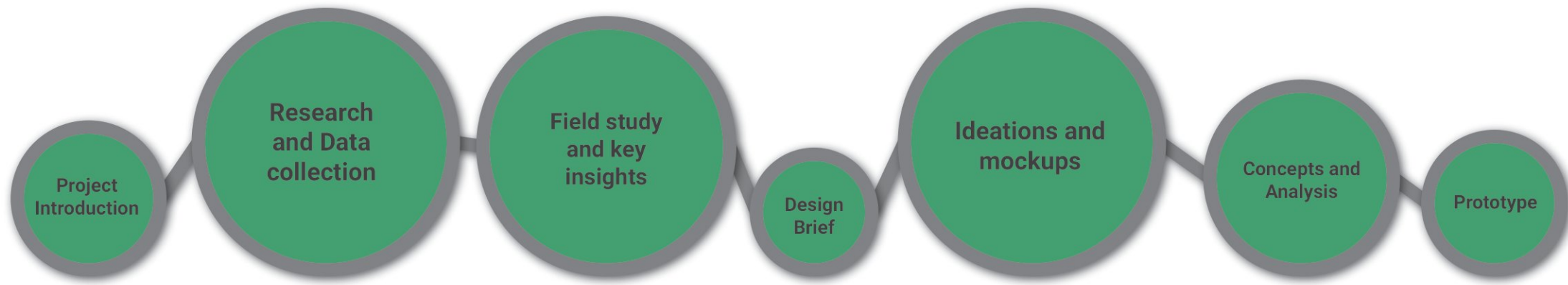
Guided by
Prof. Avinash

by
Arunprakash E (196130005)

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Methodology



Timeline

Jan

Feb

Mar

Apr

May

Jun

Jul

Project Introduction

Research & Data collection

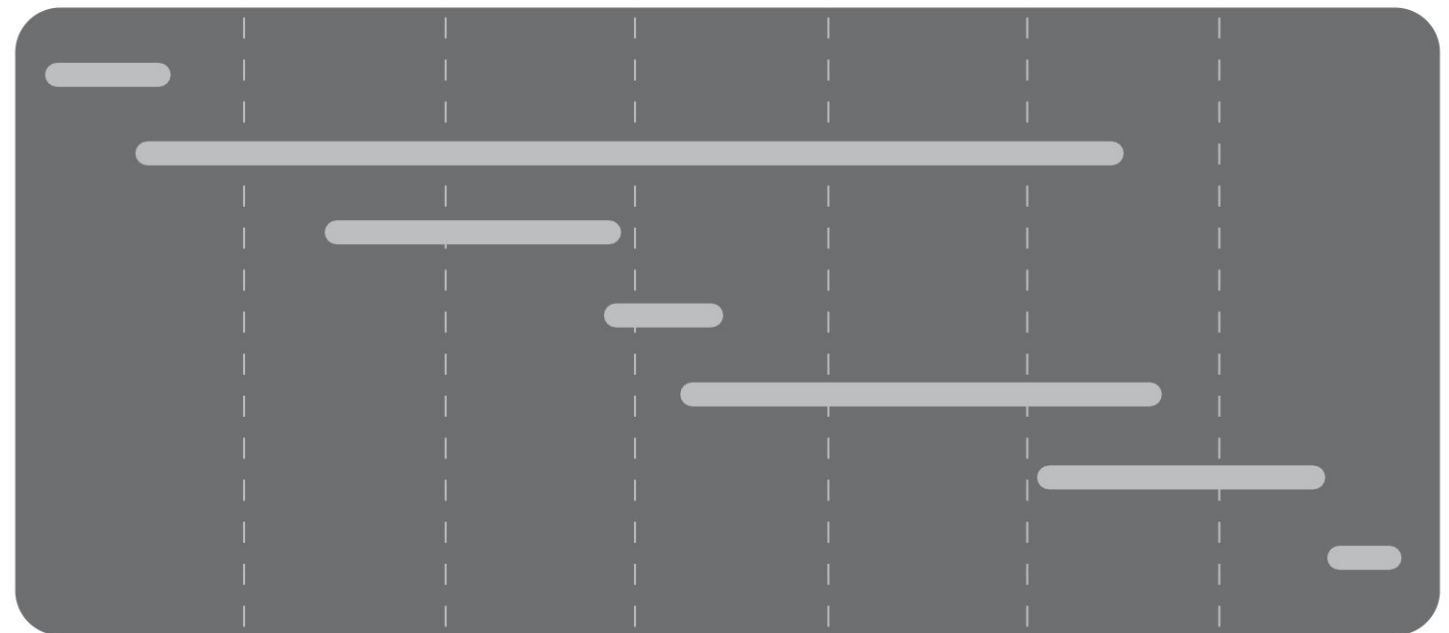
Field study & Key insights

Design Brief

Ideations & Mockups

Concepts & Analysis

Prototyping



Introduction



Fig. 1.1 Brinjal thrown away at Koyambedu market.

Over the past two decades or so, India's food system has been transitioning with a declining demand for cereals and pulses and increases in the demand for high value horticulture and livestock products with rising incomes, urbanisation, and female labour force participation.

Even in this demand led system, heavy losses occur because value chains remain poorly developed, in terms of transportation, handling methods, storage facilities. The losses are not addressed because of it occurring at small quantities compared to the huge transactions being done routinely. If it is accounted collectively the resulting loss and wastage are very huge. This is mainly because of two reasons, the perishable nature of the vegetables and the handling of the vegetables across different stages. The project focuses on addressing and giving a practical solution to reduce the losses.

Introduction

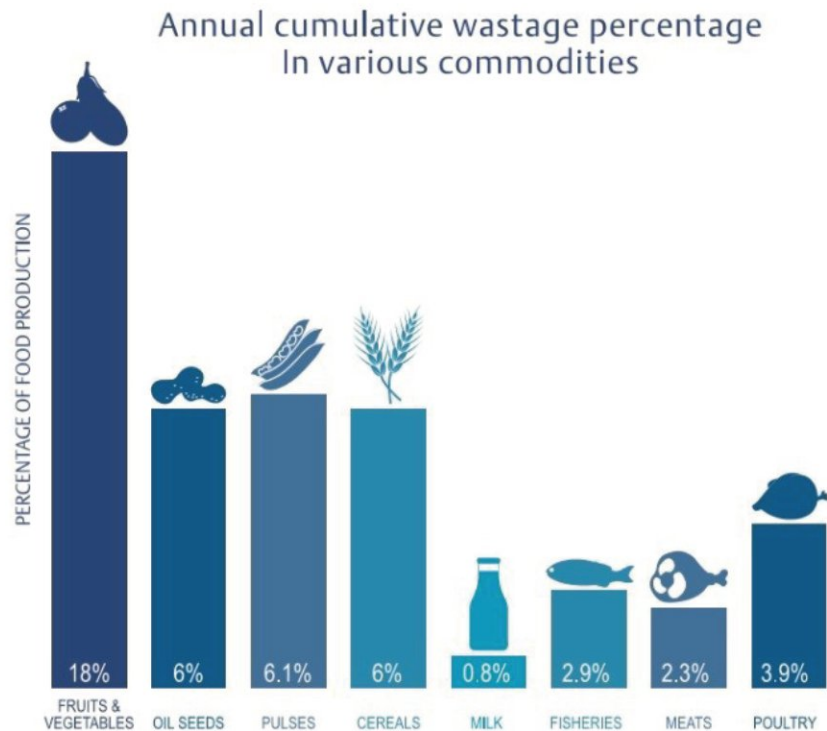


Fig. 1.2 FOOD WASTAGE ACROSS COMMODITIES

Source : Central Institute of Post Harvest Engineering and Technology (CIPHET), Ludhiana

Rationale

Need

Annually 18% of vegetables are wasted due to lack of a proper organised system and products to handle it.

If this percentage is monetised (i.e Rs. 63k crore approx.), the crisis of farmers can be readily solved

Opportunity

Intervention in the storage solution aspect will solve most of the problems.

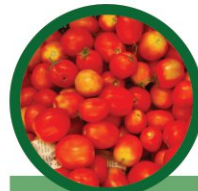
Till now, there are no adaptive storage containers designed for the evolved needs.

Research

Choice of Vegetables

The number of vegetable types available in the market are very large, including the hybrid types. Each and every vegetable has different shelf life, different nature of perishing, different adaptability conditions.

Only certain vegetables are chosen for this project which are listed here. The vegetables are chosen based on the most commonly available nature and distinct characteristics of the vegetables.



Tomato



Potato



Brinjal



Leafy Vegi



Carrot



Onion



Broad beans



Lady's finger



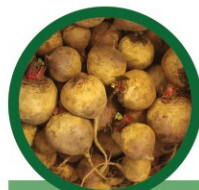
Bottle gourd



Pumpkin



Cabbage



Beet root



Elephant yam



Cauliflower



Bitter gourd

Fig. 2.1 Choice of Vegetables List.

Stakeholders

A stakeholder is a party that has an interest in a company and can either affect or be affected by the business. Every possible stakeholder has to be properly identified to address the grassroot level concerns/problems.

The stakeholders involved in this business are identified and listed based on their priority below. The Government is included because the business is mostly indirectly and sometimes directly affected by the government policies.



Fig. 3.2 Priority list of stakeholders.

User study



Karthik
Farmer - selling to
Local Market
retailers
Medium size Harvest
Land

Tomatoes are not harvested at full rippen stage.

The Packaging of vegetables is based on their value.

Lady's finger - decision on maturity to weight loss has to be taken.

local markets have certain prices, special occasions have special rates, and wholesale markets have a constant rate.

Leafy veggie - no special packaging is available.

Daily usage vegetables are prone to less wastage.

Summer - vegetables have less problem in transportation

Rainy - most vegetables are prone to become waste.

Rag sacks, bamboo baskets, leaf layers, wet rags, white washed roofs



Surya prakash
Farmer - directly
sells in farmers
market
Small size Harvest
Land

Aluminium containers are mostly used to transport.

Self handling of transportation of vegetables leads to almost no loss.

No storing is needed since it is a routine business.

Limited harvest pre-planning also leads to less wastage.

Bulk purchase (catering, Functions, hotels) reduces the loss to farmers very much.



Venkatesan
Farmer - Exporting to
Big markets.
Large size Harvest
Land

Manpower to machine harvesting - cost of labour is more than cost of damaged vegetables.

Rucksacks to plastic trays - rent of trays is more since large no of trays are needed (i.e 1 - 50kgs rag = 5 trays).

Retaining the freshness and less damaging aspect of trays is overcome by manpower required in rucksacks.

Gourds are transported in corrugated boxes because of their shape.

leafy vegetables are packed such that the leaf portions are wrapped inside the wet rags and the roots are exposed to air.

Most vegetables need airflow to avoid spoilage.

6-7 rows are stacked one above for bulk transport.

Processing stage - vegetables categorised - good and bad - sold accordingly.

summer - dry - good for vegetables
winter - moisture - bad for vegetables



Manickam
Wholesaler
2nd big shop in the
largest market of India

Rucksacks, plastic trays, corrugated boxes, Plastic mesh bags, plastic containers are handled.

No preserving methods are followed since mostly it is 8 hours business.

Mostly wastage is due to visual rejection of damaged goods.

Excessive goods are thrown because the supply chain is happening daily and there is very less space to handle.

10-15 people do business at peak hours.

Common cold storage is available and mostly monopolised by people who use it for cost fluctuations.

User study



Vijay
Retailer in local market
Above average size
shop in market.

No cold storage is available even in busy markets.

Only shade is created with a tarpaulin sheet to protect from summer and Rain.

Occasional water sprinkling other than that no prevalent preservation methods are followed.

Most vegetables go to waste due to loss of water content from vegetables leading to drying & shrinkage.

In 90Kgs , 5-6 Kgs goes to waste.

In peak hours, max 3-4 people buy at a time.

Bamboo baskets with wet rags layering.

Onions, potatoes, and cabbage are bought in large quantities.

Bitter gourd, leafy veggie, capsicum are bought in less quantity.

In the rainy season, vegetables tend to spoil more than shrinkage loss in summer.



Sumathi
Retailer
Small vending cart

Bought in Trays and plastic sacks, then piled on the cart without any containers.

Water is sprinkled occasionally.

Loss in terms of monetary is there, but unsold vegetables are used by themselves or to neighbours.

It's a stable business because Limited vegetables are bought and sold.

3-5 people buy at peak hours

Vegetable study

Shelf Life: ~ 1 month

Containers used: Mesh bag, Plastic trays, simple pile up

Reasons: Air flow is needed to keep it dry

Preserving method used: Keeping it dry as much as possible.

Reasons for wastage: High moisture in room leads to spoilage.



Onion



Potato

Onion bags are loaded on lorry



Onion bags are stacked outside wholesale shop



Wasted onions are thrown outside on the grounds



Wasted potato are thrown outside on the grounds



Onions in plastic mesh bags



Shopkeeper piled up onion and potato for sale



Potato bags are stacked outside wholesale shop

Vegetable study

Shelf Life: ~ 1-2 days

Containers used: Plastic trays, Bamboo basket, Rope supported plastic bag, Mesh bag.

Reasons: Fits more quantity

Preserving method used: Sprinkling water at the retail point.

Reasons for wastage: Shrinkage of skin due to loss of water content, visual rejection.



Beet root



Brinjal



Carrot



Bitter gourd



Bottle gourd

Bitter gourd are packed in bamboo basket and carton boxes



Carrots are packed in gunny bags for transport



Wasted carrots are thrown outside



Spoiled brinjal are thrown



Shrunken skin brinjal



Brinjal are being packed to transport



Huge container carried by 4 people



Bottle gourds are piled outside wholesale market for sale



Labour carrying beetroot filled bag maintaining his balance.



Skin of carrot and beetroot showing signs shrinking.



Vegetable study

Shelf Life: ~ 1-2 days

Containers used: Mesh bag, Plastic trays, Bamboo basket, simple pile up.

Reasons: Air flow is needed to keep it dry

Preserving method used: Keeping it dry and under shade as much as possible.

Reasons for wastage: Presence of water leads to insect infection, Transportation and handling damages, Visual Rejection.



Tomato



Cauliflower



Broad beans



Lady's finger

Broad beans in aluminium container



Layer damage on tomato



Rejected tomatoes are thrown outside



Shopkeeper piled up tomato for sale



Cauliflower packed in plastic bags and stacked



Tomatoes in plastic tray are loaded on lorry.



Tomatoes in plastic tray



Okra being shipped in plastic tray



Cauliflower turning yellow and shows signs of spoiling



Cauliflower packed in plastic bags



Infected broad beans are thrown

Vegetable study

Shelf Life: ~ 5-10 days

Containers used: Bamboo basket, simple pile up, Mesh bag

Reasons: Fits more quantity.

Preserving method used: Keeping it under shade as much as possible.

Reasons for wastage: Shrinkage of skin due to loss of water content, Transportation and handling damages, Visual Rejection.



Pumpkin



Cabbage



Elephant yam

Stacked elephant yam without container



Back view showing the complete stacking



Labours piling up pumpkin in wholesale market for sale.



Damaged pumpkins are thrown outside



Cabbage are packed and stacked in plastic mesh bags

Vegetable study

Shelf Life: 1 day

Containers used: Plastic trays, Wet rag sacks.

Reasons: Cooling & Air flow to retain Freshness.

Preserving method used: Sprinkling water at every stage.

Reasons for wastage: Drying of leaves due to loss of water content, visual rejection.



Longish leafy veggis are unwrapped from gunny bags and kept outside.



Normal size leafy veggis are kept in the plastic trays



Roots and leafs coming out through slots in plastic tray



Leafs got stuck and coming out in stacking of plastic tray

Marketing Channels

The Vegetables after harvest pass through different channels to reach the customer. The channels are categorised based on how many stages it passes through to reach the customer.

Four channels are identified and categorised from the insights from user study and evidence from the literature survey. The channels start from farmers, then wholesalers who acquire bulk quantities for distribution. There are pre-harvest contractors in some channels and sometimes farmers directly sell by themselves through farmers markets either wholesale or retail which is shown in 2nd channel. then it passes through retail to reach the consumer.

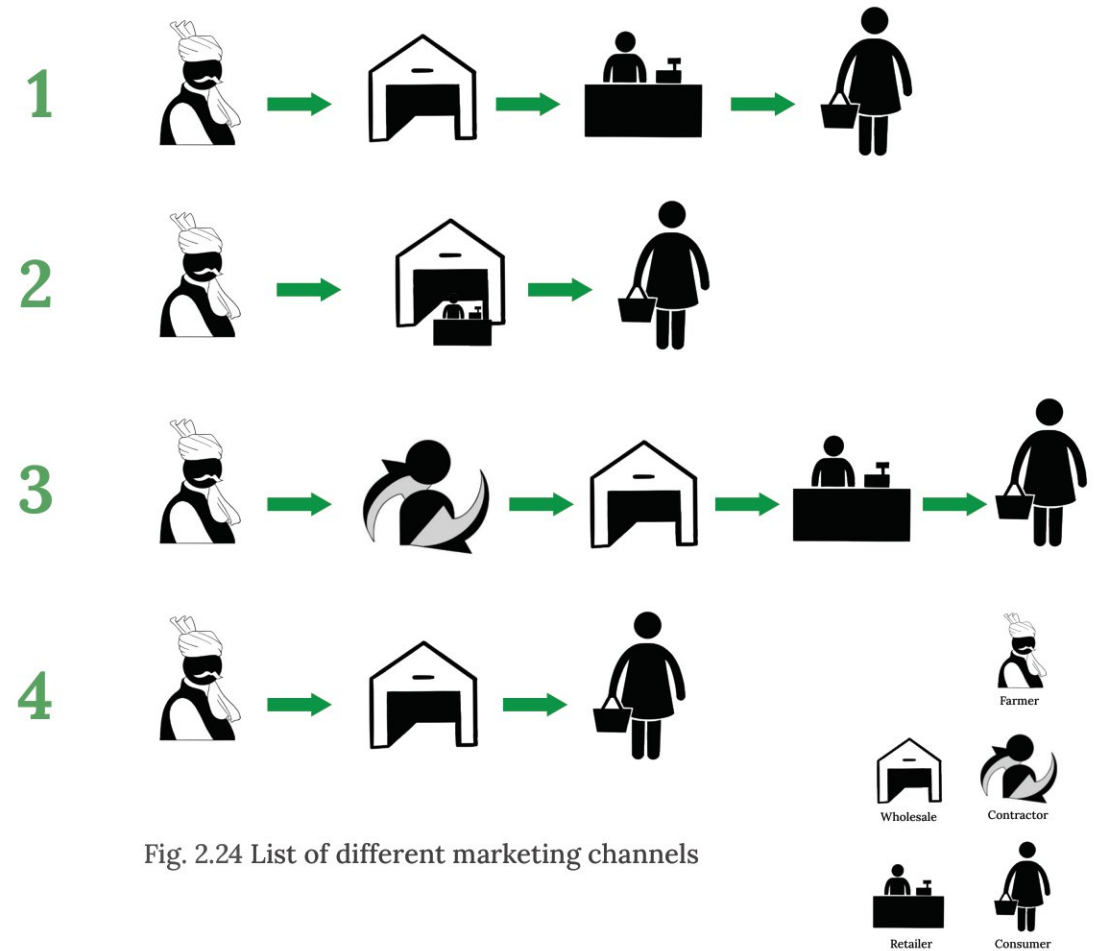


Fig. 2.24 List of different marketing channels

Loss Identification

Inefficiencies in Logistics Chain

The main challenge in realising higher farm level productivity is post production market linkage than can economically connect the produce to gainful end-use. The Need to connect the entire quantity of farm production to various markets or avenues of monetisation is important for farmers to recover full value of the quantity produced.

Any cost mark up or the losses that occur in the logistics chain to market, impacts upon the overall price discovery mechanism. The inefficiencies are loaded onto the final price including the hidden cost of physical loss of the produce and it is recovered from the weakest link in the value system, the farmer.

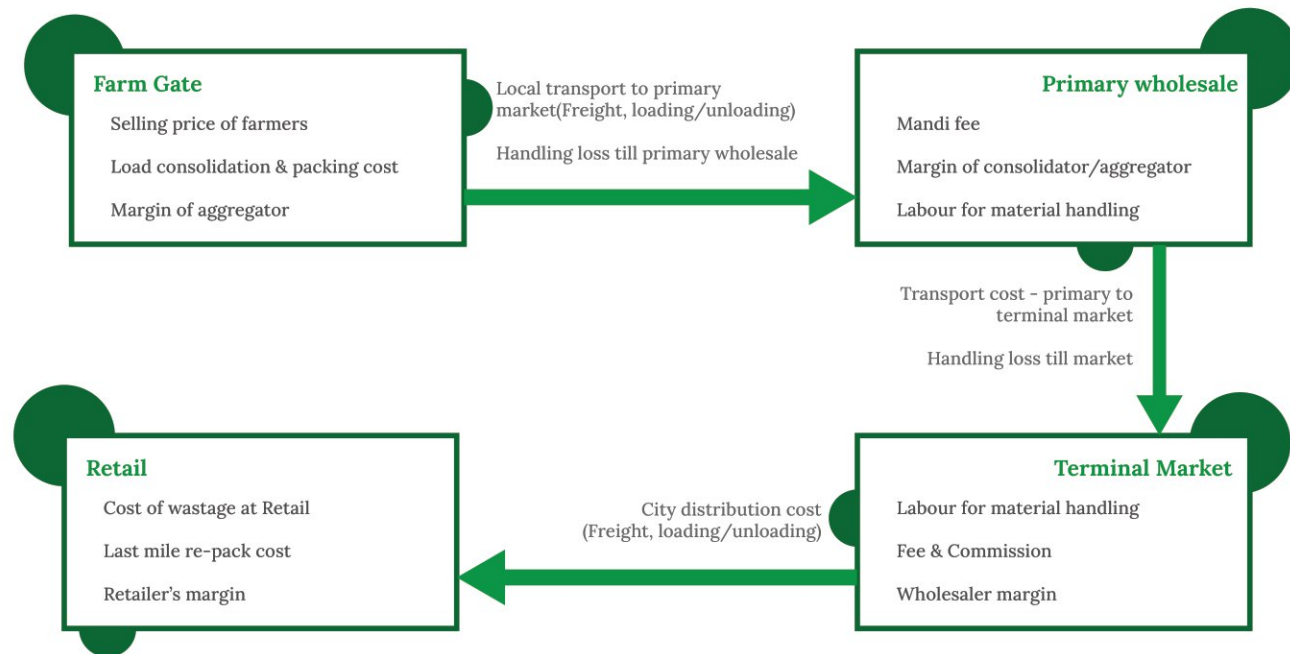


Fig. 8.1 Block diagram showing inefficiencies at different stages.

Loss Identification

Stage wise loss measurement

The data shows the minimum to maximum loss occurs at different stages of the channel of each vegetable. The physical losses (weight loss and discards) were appraised at varied stages of movement to market of the selected vegetable. Each stage of measure was where a change in custody occurred and the product entered the next step in its post-harvest journey to market.

Inclement conditions and poor handling results in loss of saleable quantity from farm to market. The losses beyond the point of wholesale or the waste in hands of the consumers were not assessed in this study.

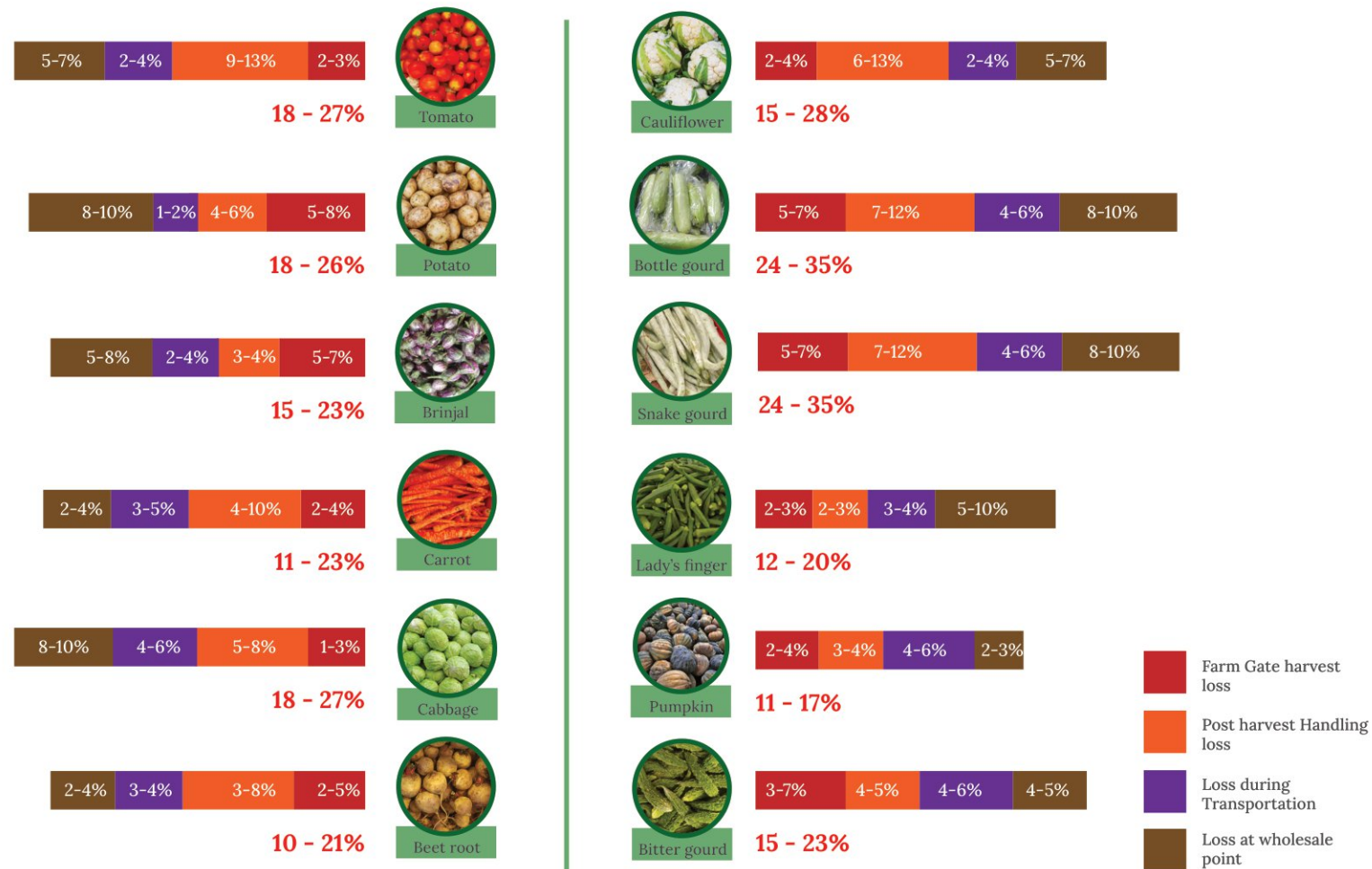


Fig. 8.2 Loss measurement at different stages Graph.

Data source: Doubling farmer income - vol. III



Plastic mesh sacks

Plastic mesh sacks are two types: woven and non woven. woven mesh bags usually bear more load. These bags are the evolved version of the gunny bags. It is lighter than the gunny bag and yet is durable and strong as almost equal to a gunny bag. The disadvantages of a mesh bag are it gets easily damaged and restitching is difficult. It can absorb water and provide cooling like a gunny bag, lifetime is very less since it gets deteriorated easily but it is cheap. It can be handled at all 360 degree sides. Using a hook tool for gripping is not possible.



Coir rag sacks

Coir rag sacks or Gunny bags have been in existence since ancient times. Still now there is no permanent replacement for this product. It is made up of coconut fibre and woven into bags. Humans are adapted to this bag rather than the opposite way because of its very long existence. So, the way of handling this product changed various times mostly in the aspect of comfortness and productive work flow. The only disadvantage in the gunny bag is, it doesn't have structural support.

Storage Containers



Plastic Tray

Plastic trays have been in existence since the mass manufacturing industrial revolution came. Plastic has almost completely replaced traditional materials like wood, bamboo, coir based and metal for the manufacture of containers because of its price, moldability, durability and lightweight. The disadvantage in plastic tray is, it's not flexible hence the handling aspect is restricted only to certain positions which leads to restriction of carriable weight. Since it is small and costs more to buy than a gunny bag, users prefer gunny bags except for certain vegetables.



Plastic sack

Plastic sack/bag is another evolution of gunny bags. It has more strength than the woven mesh bag, because it is completely sealed. It is best used for vegetables which does not require ample air (which is not the case). Users use this because it is cheaper and serves the purpose of transferring. The disadvantage is that grip hook tools cannot be used as it will tear the bag and since it is plastic having hand grip hold is also difficult so the handling methods are restricted to certain extent.



Corrugated Box

Corrugated box is mostly used to carry longish vegetables such as drumsticks, snake gourds, etc. Corrugated boxes are structurally strong when loaded in certain directions and it is also slightly flexible to accommodate such longish vegetables. The disadvantage is that it is mostly used upto 3 times because it easily absorbs water and becomes weak. But the corrugated boxes used are mostly general purpose boxes so addressing it as weak is unjustified.



Bamboo basket



Thin Plastic Bags



Reinforced bamboo basket

Bamboo basket is a brother to gunny bag because it has also been in existence since ancient times like the gunny bag. These baskets come in different sizes and shapes depending upon their purposes like for showcasing, for carrying more vegetables placed on the hip or head, for carrying to steep places by placing it on the back. They are structurally rigid and slightly flexible also. The main disadvantage is, it is not suitable for stacking when it is loaded with vegetables.

Thin Plastic bags are being used to carry vegetables nowadays. They are mostly used to make small batches of big vegetables and stacked which earlier has been simply piled up. Vegetables like cauliflower, pumpkin are made into small batches using thin plastic bags. The advantage is that it is helpful in making small batches rather than throwing single vegetables and piling it up, other than that it doesn't serve any purpose as a storage container.

Reinforced Bamboo Basket is the outcome of the Indians' amazing jugaad mindset. To carry more than 100 kgs, the container will become huge. Making a structurally rigid container for that size will result in handling problems and making flexible bags for that size will result in strength problems. To solve this structurally rigid bamboo basket is made as a bottom and flexible plastic sack reinforced with ropes as a net is used.

Cooling Methods

Room cooling - produce cools passively inside a cool room. Temperatures can take hours or days to approach the room setpoint.

Room cooling minimises re-handling. Slow cooling rates can increase weight loss and cause condensation.

Forced air-cooling, air is pulled rapidly through bins or cartons of vegetables. This increases the effective surface area from that of the bin or carton to that of the produce inside. This increases the rate of cooling and avoids condensation.

Hydrocooling can provide fast cooling so long as the water chiller has enough capacity to remove the heat from the dip or drench water.

It is not suitable for all products, and it is important to include a sanitiser to avoid spreading human or plant pathogens.

Vacuum cooling involves reducing pressure inside a sealed chamber. Water inside the vegetables turns to vapour, absorbing heat energy. Vacuum cooling works best - products lose water easily. Hydro-vacuum coolers add a misting system to avoid moisture loss from the product



Fig. 10.1 Room cooling.

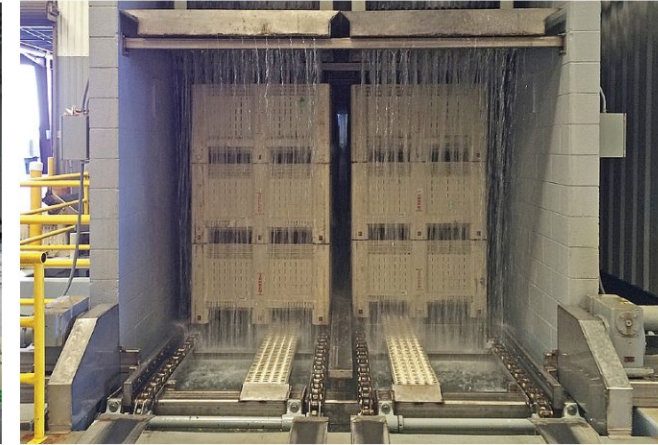


Fig. 10.2 Hydro cooling.

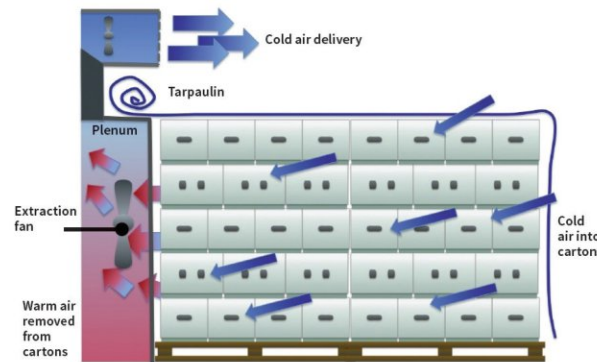


Fig. 10.3 Forced air cooling.

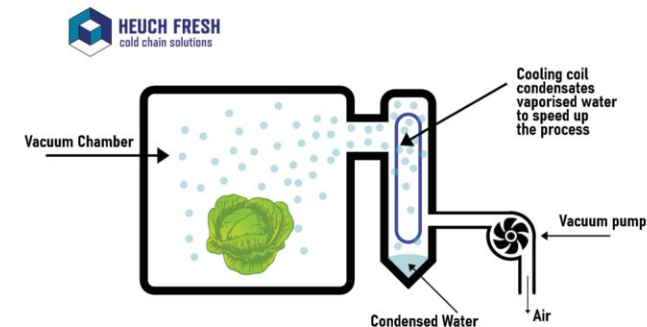


Fig. 10.4 Vacuum cooling.

Funnel cooling is devised based on the air expansion concept. When the air passes through a smaller cross section and lets it expand suddenly, the frequency of atomic collisions decreases as air expands, therefore the air gets cooler. Temperature is just the average heat of a substance. For a certain amount of air, the particles have a fixed amount of heat and if the air expands, the temperature decreases.

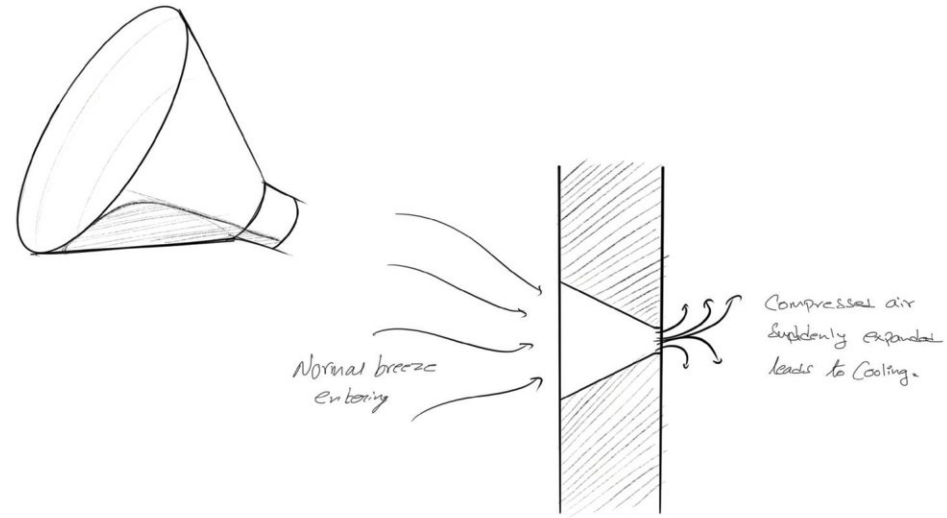


Fig. 10.5 Funnel cooling

Wind catcher is a traditional architectural element used to create natural ventilation and passive cooling in buildings. The wind catcher functions by directing airflow using the pressure of wind blowing into the windcatcher and it pushes the hot air which is present inside to top since hot air is lighter thus maintaining a cool environment inside.

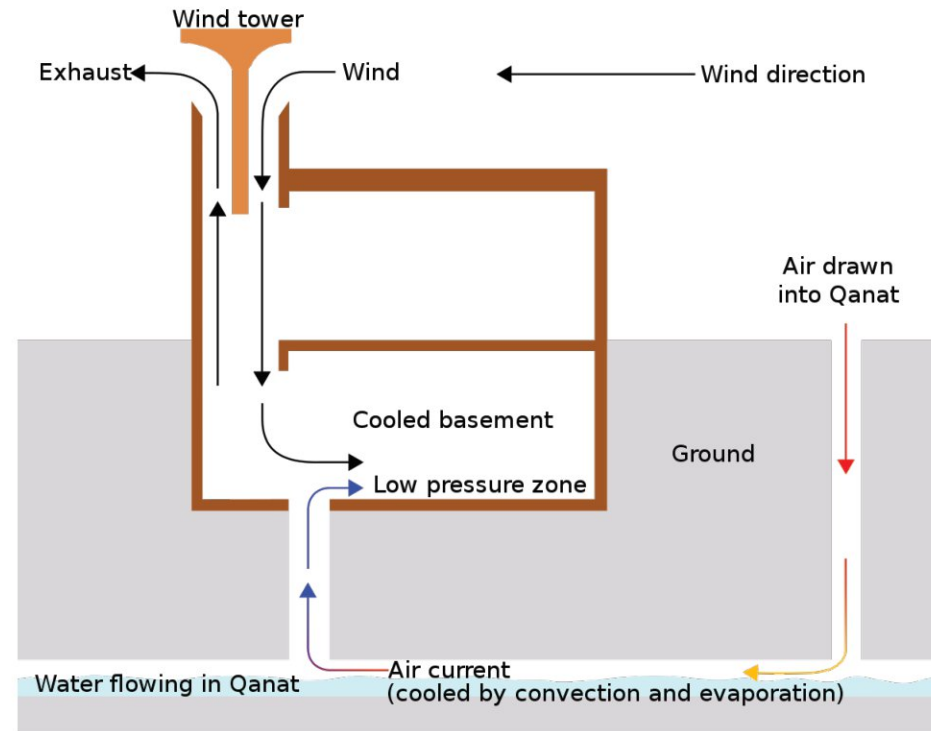


Fig. 10.6 Wind catcher

Posture study

The study of postures while carrying a heavy load is crucial for this project. Since, heavy loads cannot be handled just like that, if it's not assessed properly accidents from small muscle sprain to bones breaking will happen.

Since ancient times users have adapted themselves to the handling posture of containers based on their comfortness. Instead of changing the product they changed their way of handling depending upon the usage. Mostly heavy loads are carried on the head, on the back or on the shoulder where the hand position is just to support and balance while the load is transferred through the body. When heavy loads are carried in front of the body like carrying a plastic tray, the entire load is held by the hands and it will easily wear out the hand muscle and it is difficult to hold such big volumes with just hands only. The best position to carry heavy loads is to rest on the back and support it with your hands.

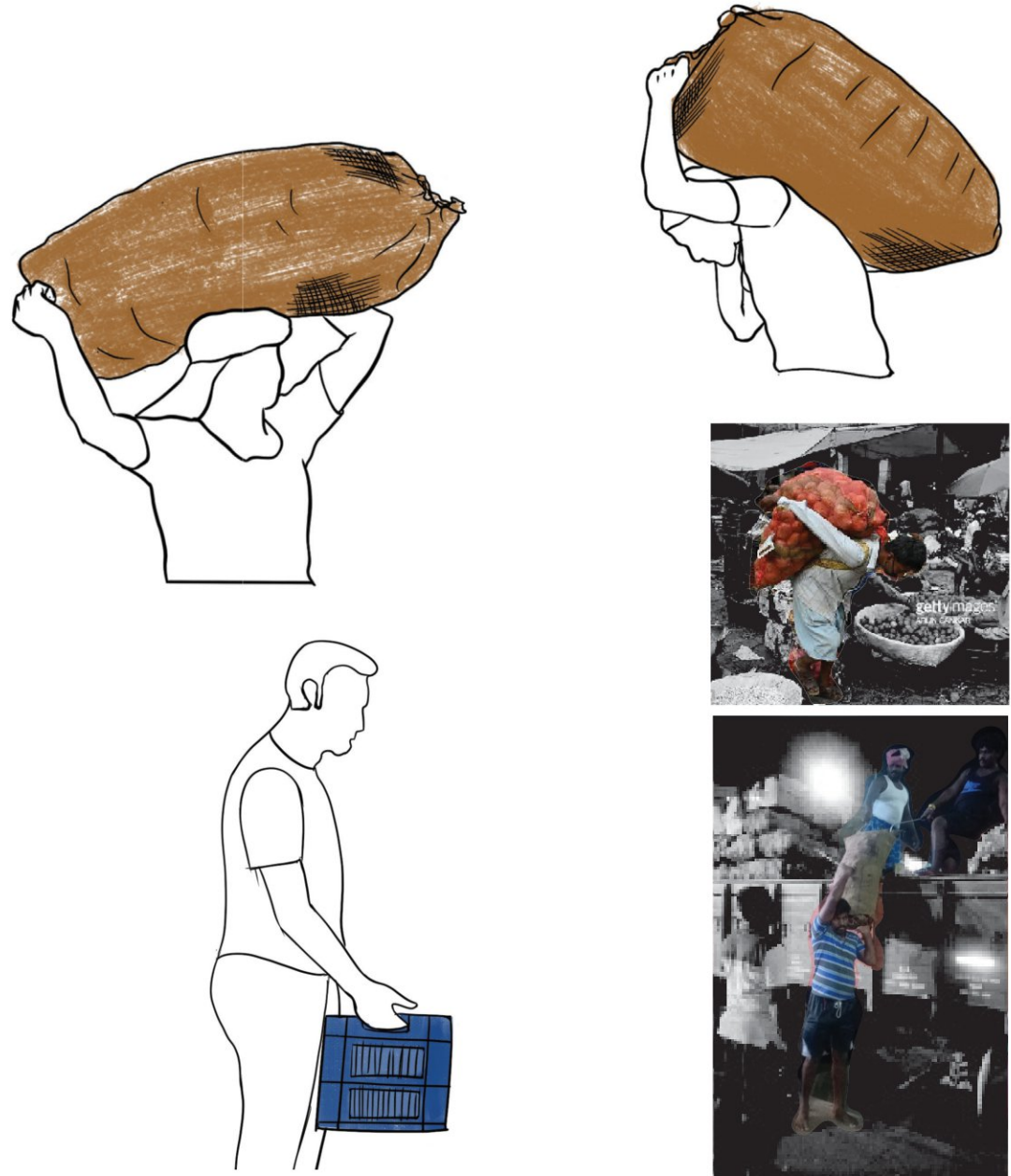


Fig. 11.1 Different postures of carrying

Key Insights

Preference of rucksacks over plastic trays for handling convenience and money saving .

For most vegetables, Cold storage enabled vehicles are not needed if the travel distance is less than 300Kms or 24 hours travel (it wont get completely spoiled but perishing will happen).

There is no organised supply chain which leads to lots of inefficient losses.

Wastage of vegetables due to Transportation & Handling is almost equal to wastage due to its perishable nature.

Wastage of vegetables almost becomes nil the more it is distributed to multiple stakeholders.

The more the routine of frequent vegetable transactions happens, cold storage is needed less.

People are used to the concept that it is necessary for some quantity of vegetables to get damaged for transportation to happen.

Post harvest loss at stages

After analysing the primary research and secondary research datas, the Cause and effects of the post harvest loss at all the stages have been listed out.

During harvesting the vegetables get damaged due to machines, the way crops are grown and season miscalculation. The storage, processing and packaging applies differently to different vegetables. for example, root based vegetables need to be cleaned so that the vegetables are stored in the harvest land for a certain period of time, then it is processed, packed and transported. In all these 3 stages, the transfer of vegetables is happening. Loss due to those transfers is equal to loss due to perishable nature. The shrinkage and spoilage mentioned in these stages is due to lack of cold storage. In the sales stage, it covers both wholesale and retail points. Failing to assess the correct supply and demand which leads to improper portioning and poor inventory management leads to loss.

Consumption stage is solely based on the consumer mindset; a lot of variables play a role in this stage.

In Stage 1 and in stage 6 there are more variables and uncertainties to control compared to the other stages. So, the scope of this project lies between the stage 2 to stage 5

Stage: 1 harvesting

Harvest Mechanisation
Production practices
Season

Stage: 2 Storage

Insects
Shrinkage
Spoilage
Damaged vegetables

Stage: 3 Processing

Visual based rejection
Shrinkage
Poor handling
Package failures
Transportation Issues

Stage: 4 Packaging

Package failures
Transportation issues
Lack of packaging

Stage: 5 Sales

Improper portioning
Poor inventory
Seasonal items
Temperature

Stage: 6 consumption

Leftovers
Impulse Buying
Infrequent market visits
Poor portioning

Scope and limitations

Scope

This project tries to provide a solution to reduce the loss due to damage of vegetables without causing additional difficulties to the stakeholders. There were no products till now designed to carry heavy loads by humans specifically for this purpose, so people assume the loss happens is necessary for profit. This project tends to change that mindset by showing how much amount of vegetables can be saved.

Limitations

This project is limited only to the focused area from farm land to wholesale point whereas other general purpose containers are used from the start to the end of the market channels.



Design Brief

To design a storage solution to reduce post harvest loss due to handling and transportation which will be used till wholesale point, with Size adaptability, Cooling enhanced and easy to handle.

Objectives

Space adaptable nature according to the scenarios.
Efficient air flow and cooling effect.

Reduce Mechanical loss, Physical loss and physiological losses of vegetables in every scenario.

User- centric (Stakeholders) approach.

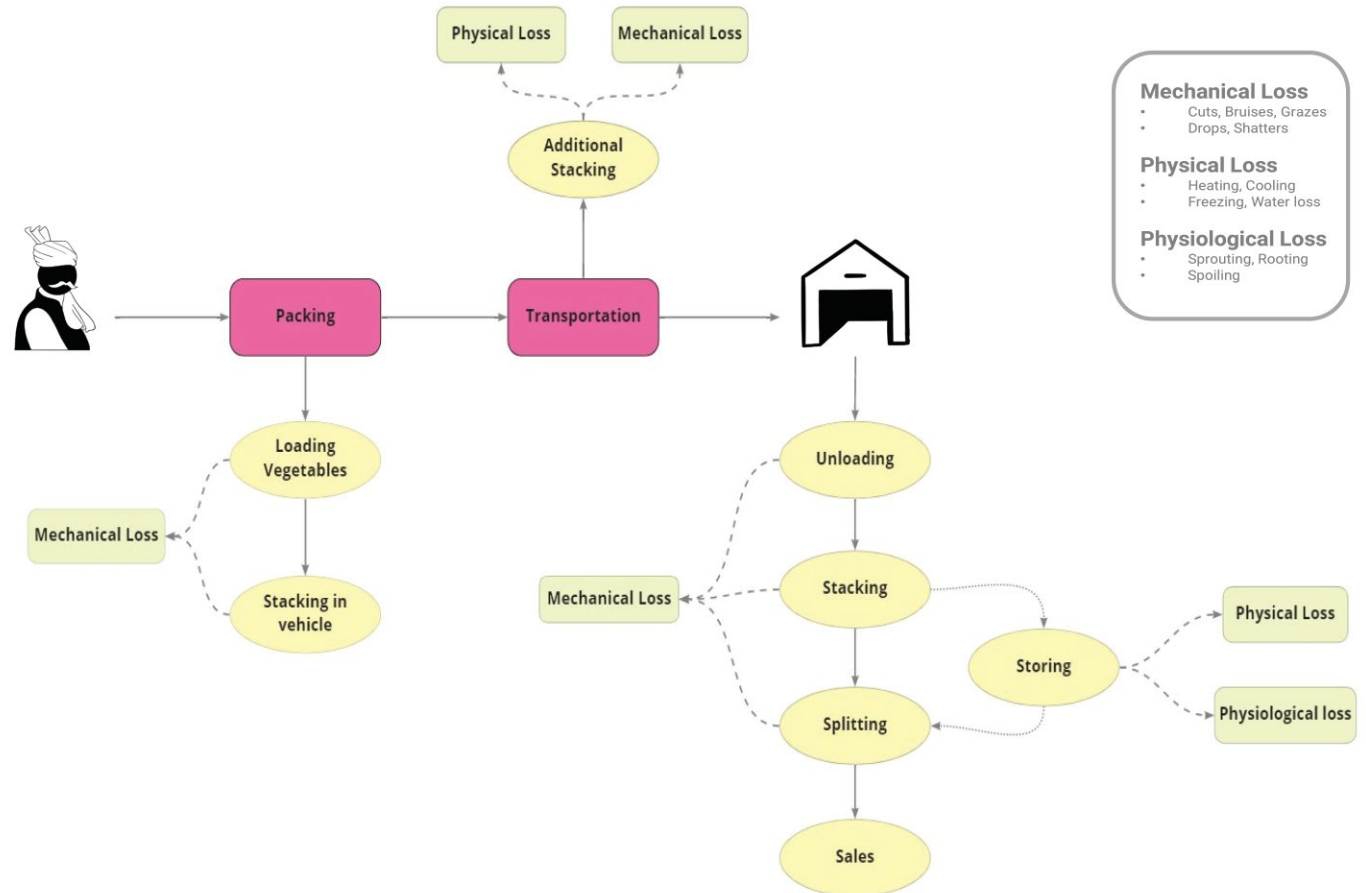
Should invoke desirability for effective reach of the product.

Should be sustainable and long-lasting.

Focus Area

To achieve the objectives, analysing and understanding the steps and processes happening in the focus area is crucial, so that the design directions align with the design brief.

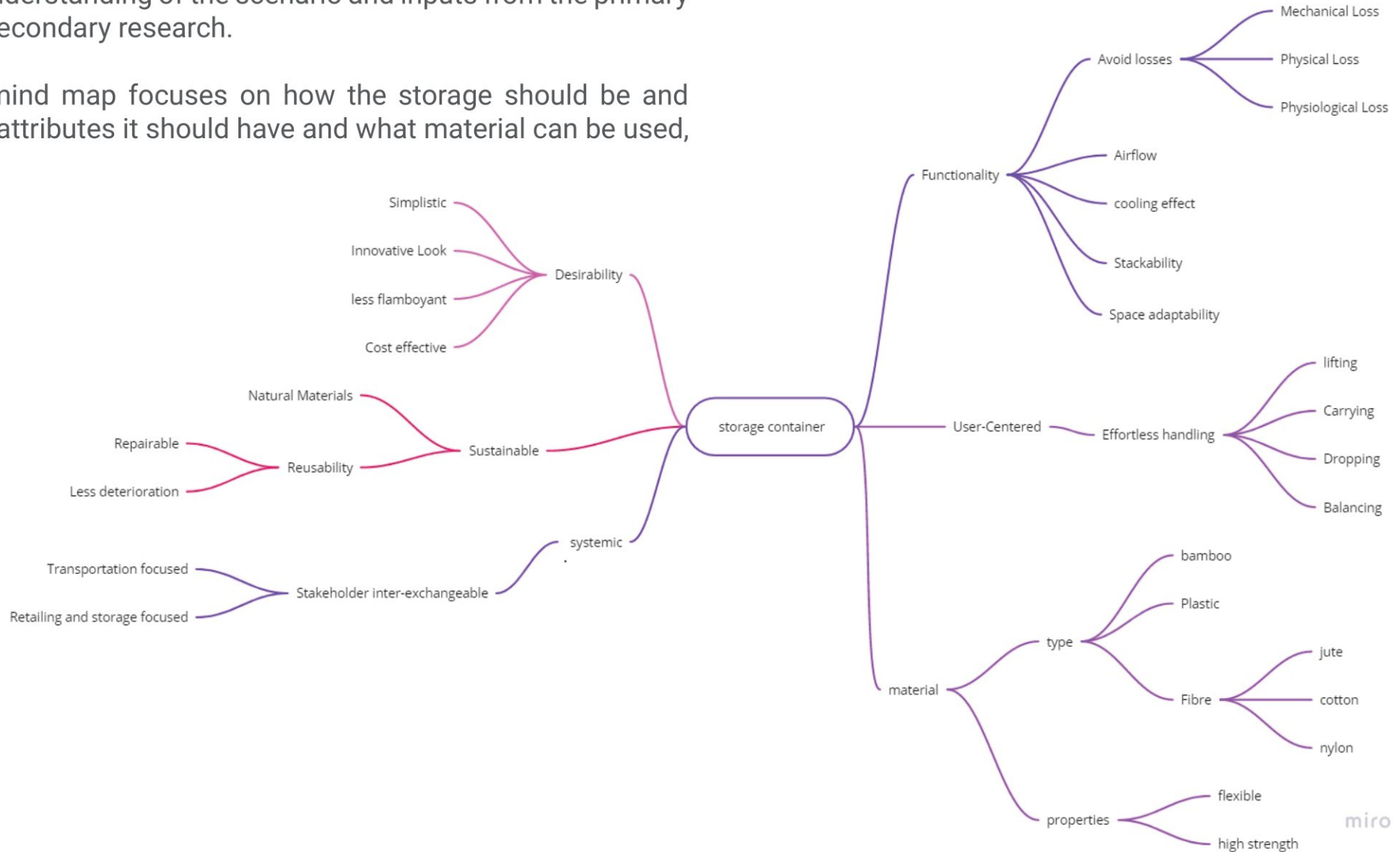
The flow chart shows the steps and processes happening between from farm land to the wholesale market. It also shows the types of losses happening at each step and each process.



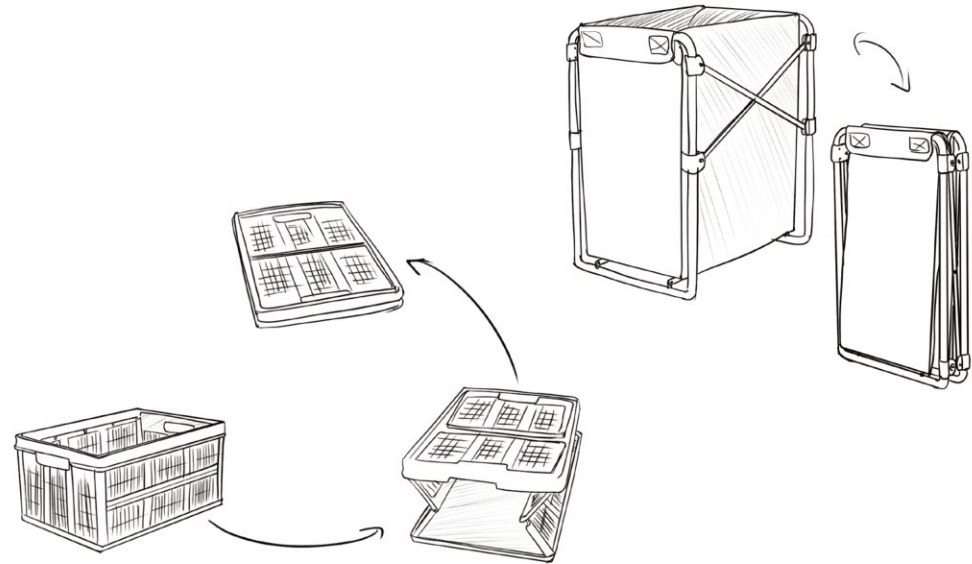
Mind Map

After analysing the focus area and stages where losses occur and what type losses occur, a mind map is derived based on the understanding of the scenario and inputs from the primary and secondary research.

The mind map focuses on how the storage should be and what attributes it should have and what material can be used, etc

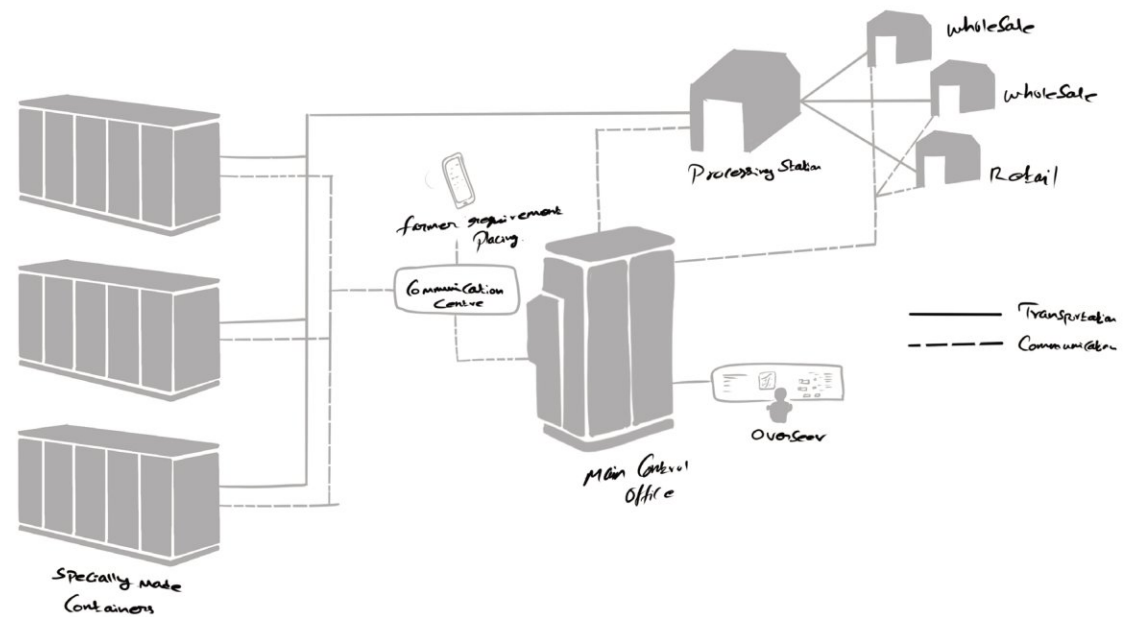


Design Direction 1



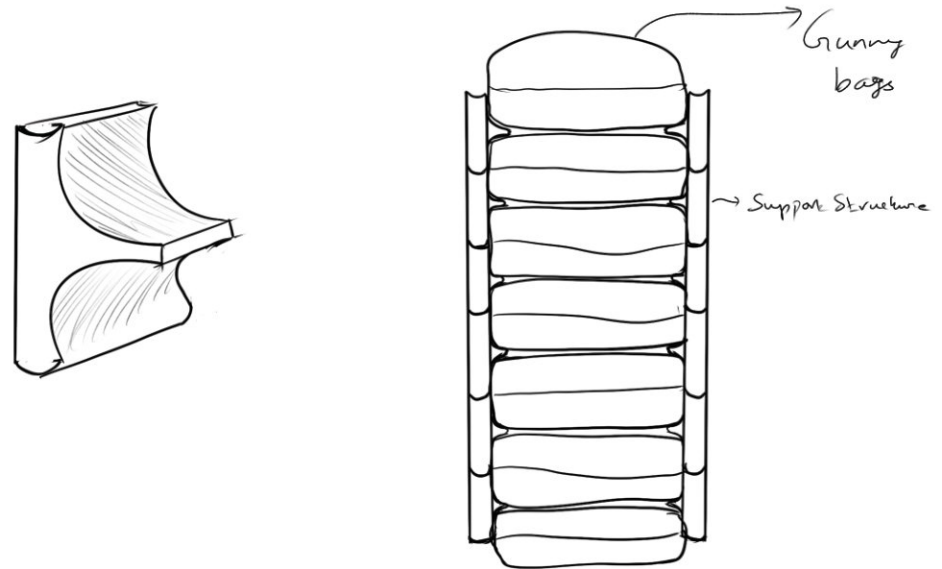
A Range of containers as a product to replace the existing containers which should be desirable and affordable by the stakeholders who have minimum purchase capacity.

Design Direction 2



System level Organised solution which involves Govt intervention or private organisation for the Orderly distribution and maintenance of storage containers.

Design Direction 3



An additional attachment-like product for the most used existing storage containers.

Ideations

The design direction 1 is chosen for further ideations , the 2nd direction involves collection of more inputs which is not possible in this covid period and the 3rd direction involves usage of a lot of products to achieve the purpose which leads to various handling and storing problems.

This idea is an improved version of the reinforced bamboo basket. The bamboo baskets serve as the structural support and the jute sheet creates the volume to store.

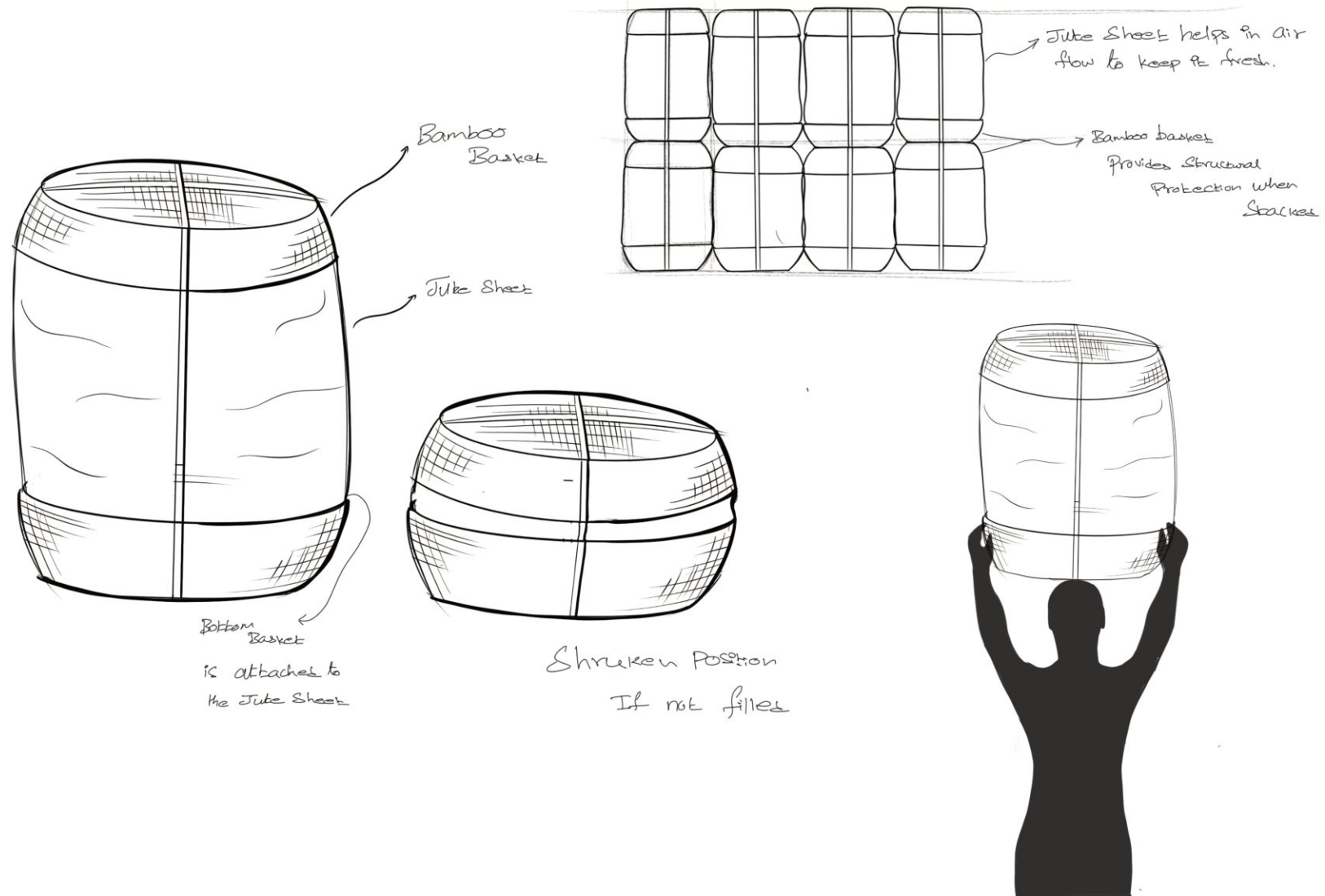
Pros

- Light weight
- Complete customization
- Repairable

Cons

- Load is directed on the vegetable
- balance while handling

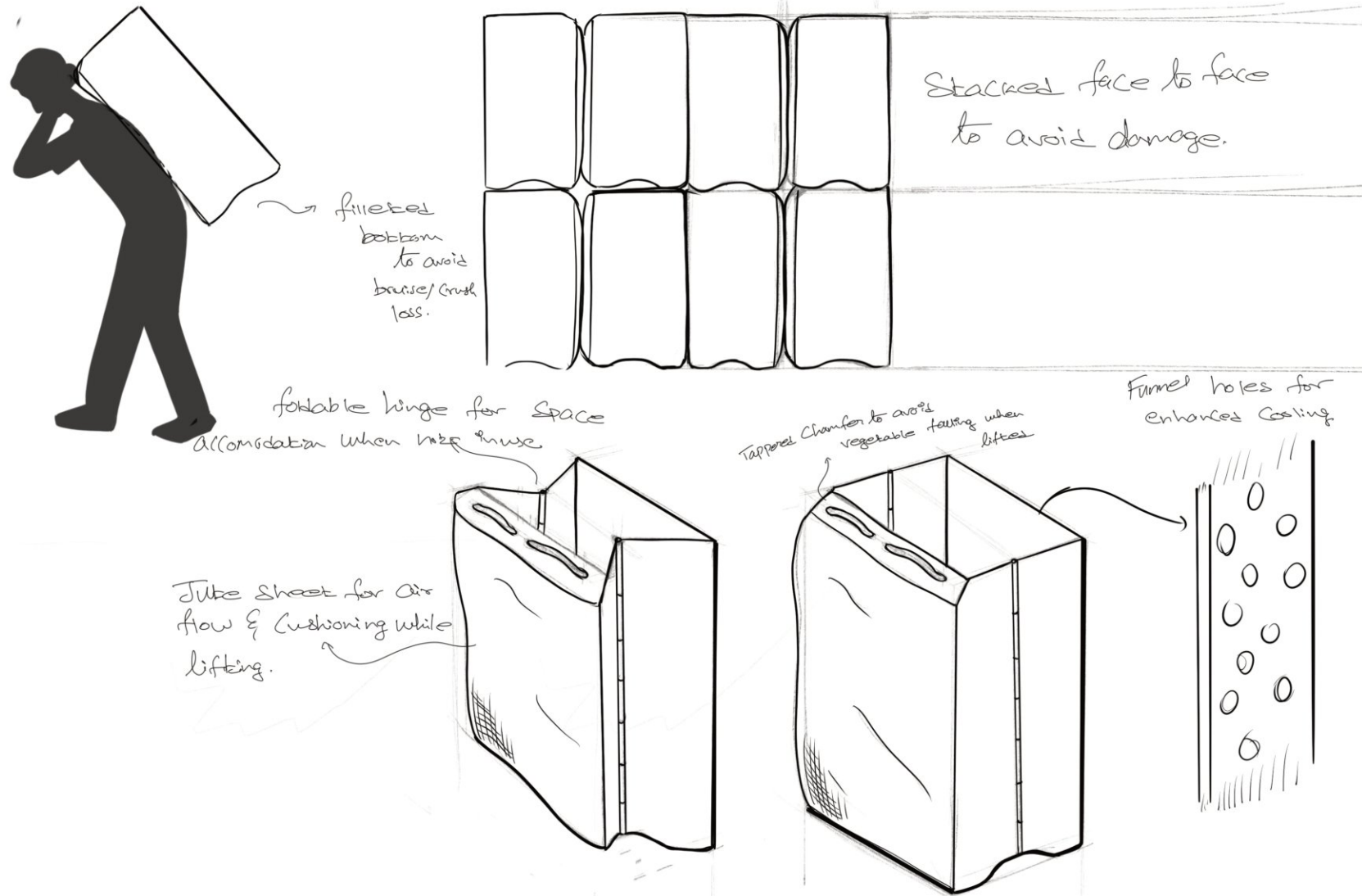
Idea 1



Ideations

This idea is a combination of a gunny bag and plastic tray, it gives the comfortness of a gunny bag and structural support of plastic trays. This idea uses the gunny bag carrying posture which is the most suited for heavy load carrying purposes. The slots will give an ample cooling effect.

Idea 2



Pros

- Light weight
- Repairable
- space saving

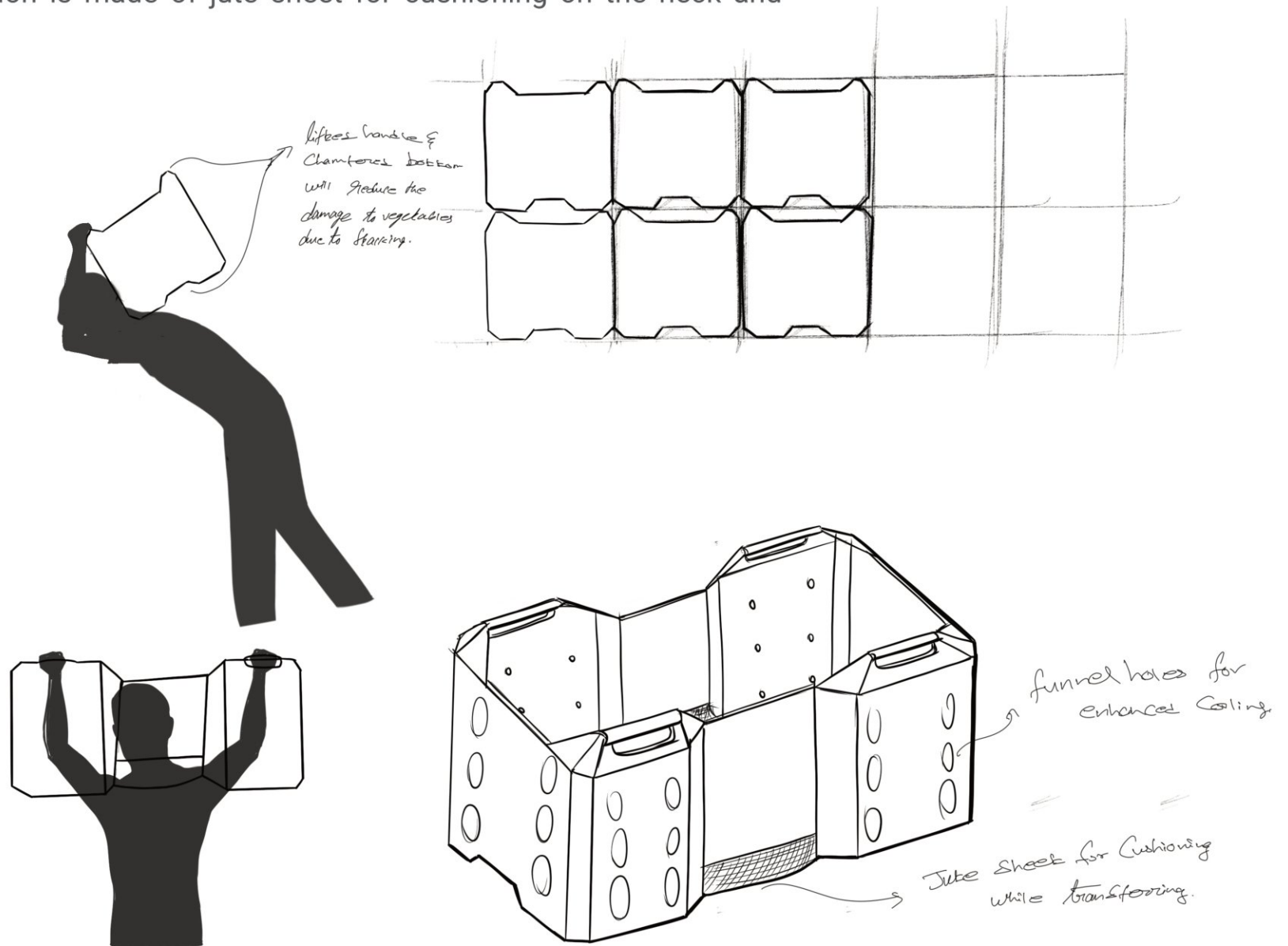
Cons

- Imbalance while stacking
- hinge becomes weak

Ideations

This idea is inspired from the 90's trend where people carry audio speakers on their shoulder, and this is also one of the preferred positions of carrying a gunny bag. The bottom of the middle portion is made of jute sheet for cushioning on the neck and shoulder parts.

Idea 3



Pros

- Stylish
- ease of handling

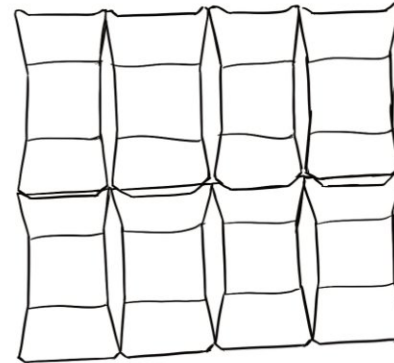
Cons

- Space occupying when not in use
- weak middle part

Ideations

This idea is the evolved version of the gunny bag. It is handled just like a gunny bag because of the flexible middle part and it also has the structural strength of the plastic trays. When not in use it can be compressed and stored.

Idea 4



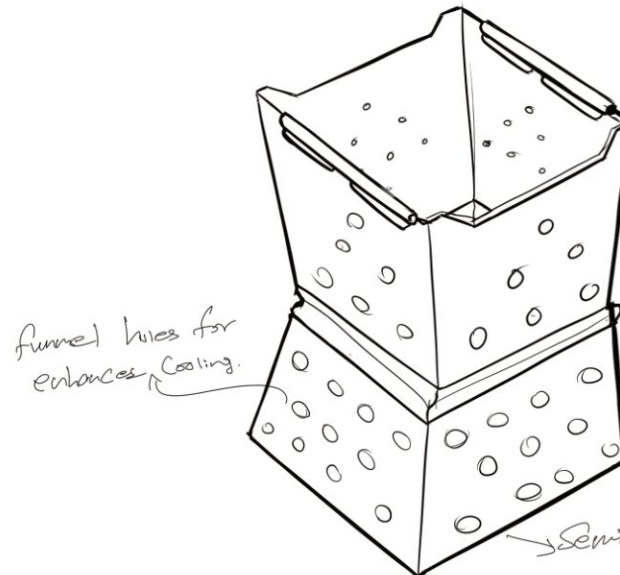
Chamfered & Projected handle to reduce loss due to piling & give comfortness while lifting.

Pros

- Adjustable storage volume
- space saving
- ease of handling

Cons

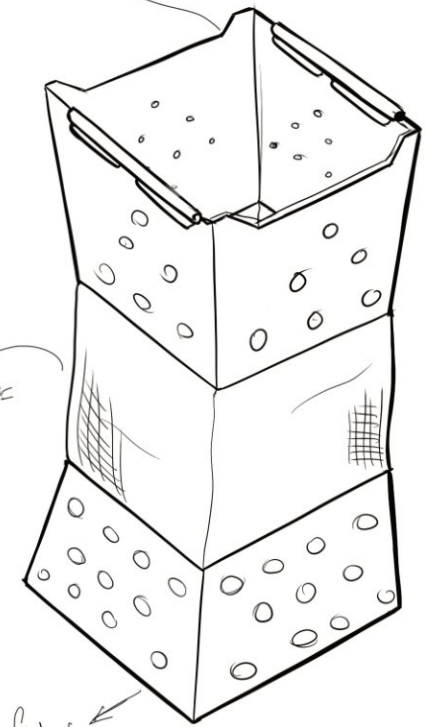
- heavy



funnel holes for enhances cooling.

Tube sheet for size adjustment & cushioning effect for back while lifting

Semi filled or empty state.

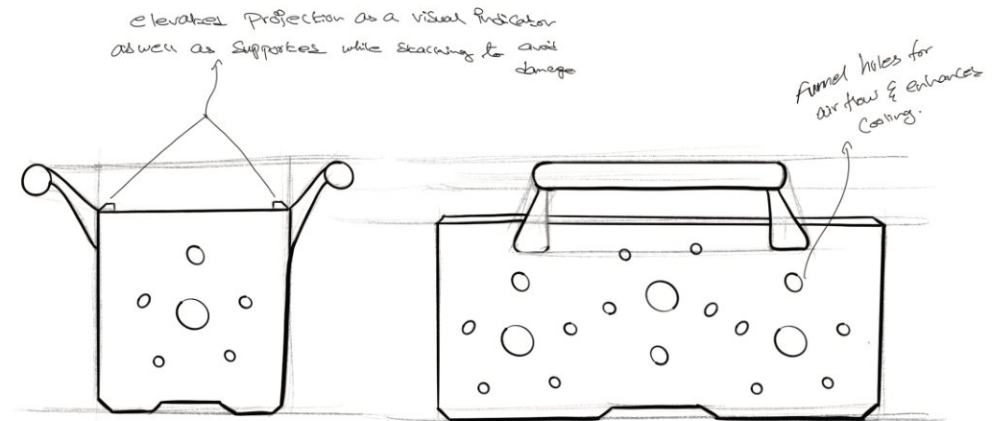
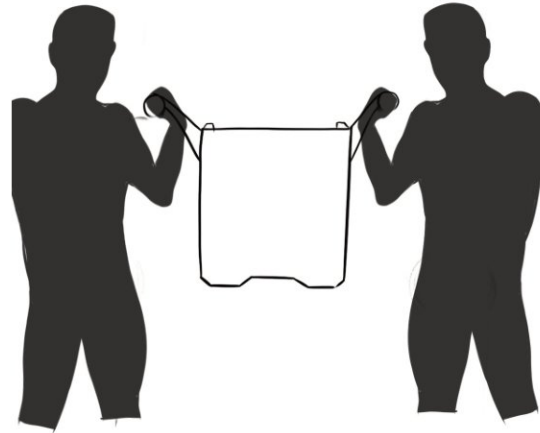


filled state

Ideations

This idea is designed by making the plastic tray bigger in size and letting 2 people carry it. This solves the renting large number of small tray problems. This sturdy structure reduces all the losses caused due to physical and mechanical aspects for vegetables.

Idea 5

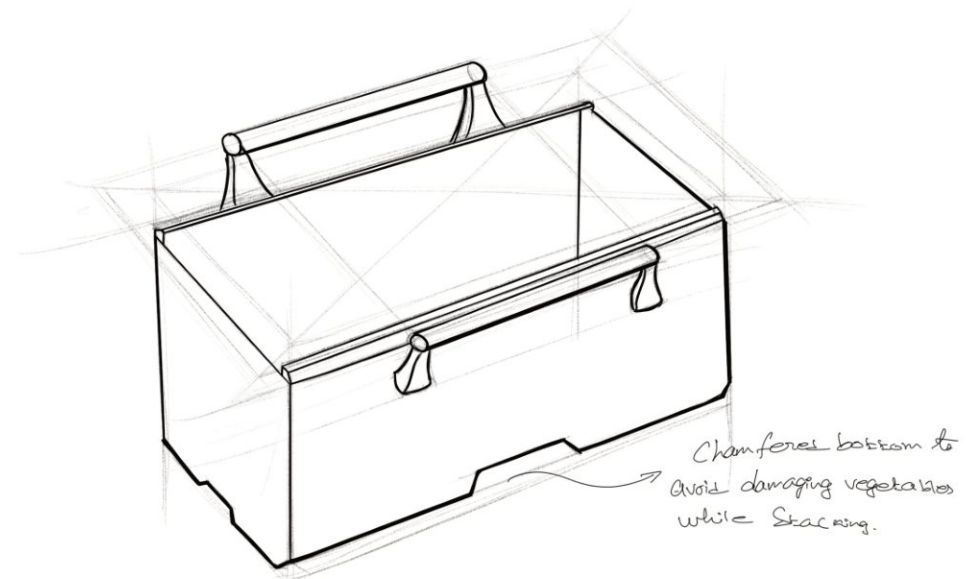


Pros

- Big storage volume
- sturdy

Cons

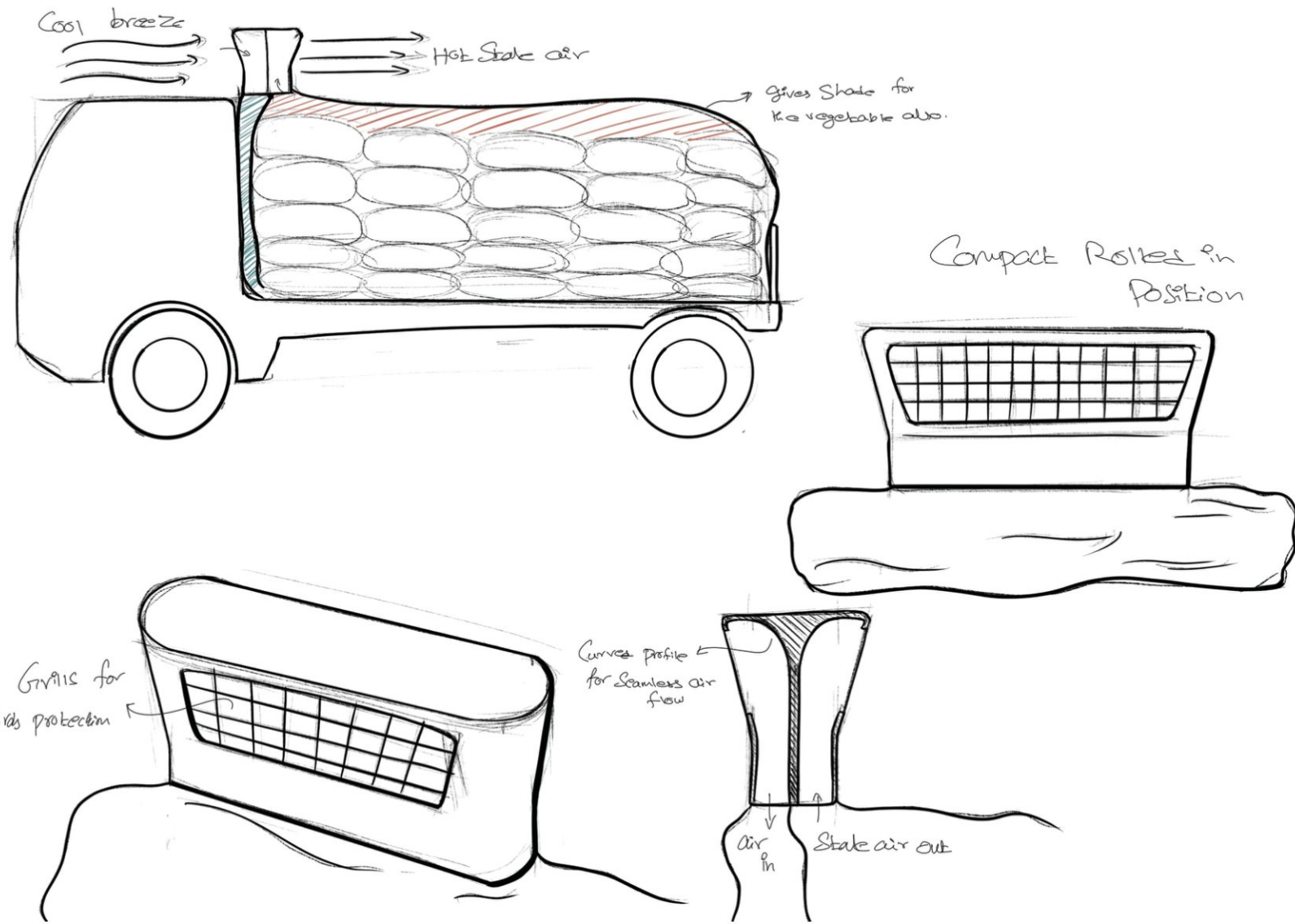
- heavy
- occupies large space when not in use.



Ideations

This idea is for providing a cold storage kind of experience without using electric power, just by redirecting the air which passes over the vehicle and letting it pass to the bottom of the payload area and pushing the hot air inside upwards and then outwards.

Idea 6



Pros

- single part
- easy to mount

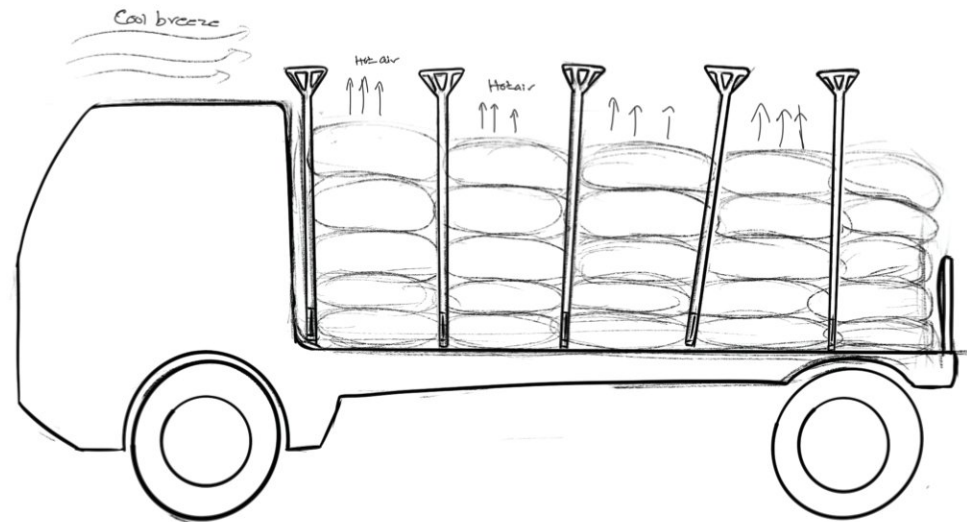
Cons

- Space occupying when not in use
- air doesn't reach till the end of payload area

Ideations

This idea is a stick-like version of the wind catcher. it can be inserted in between the gaps of the containers. it pushes the air downwards uniformly in all parts of the payload area.

Idea 7

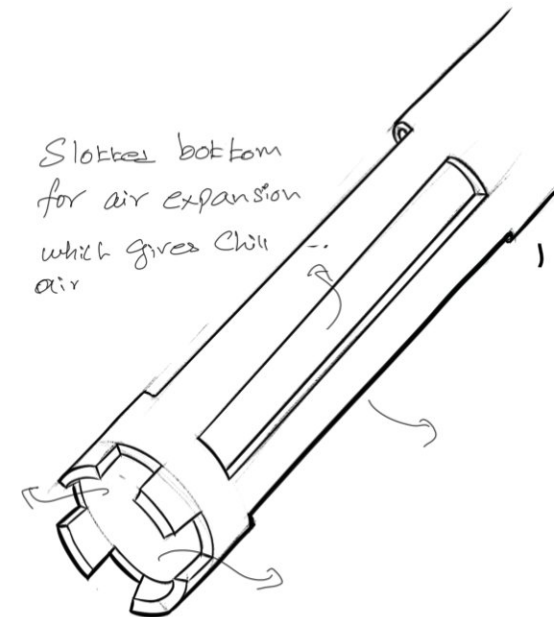
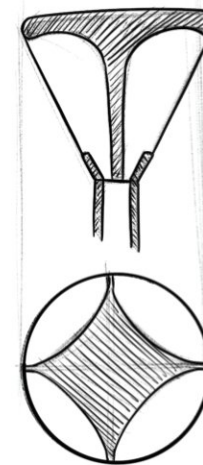
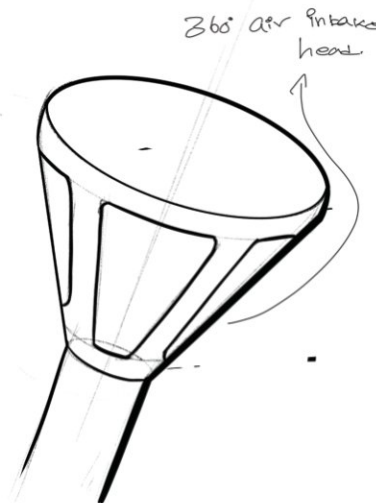
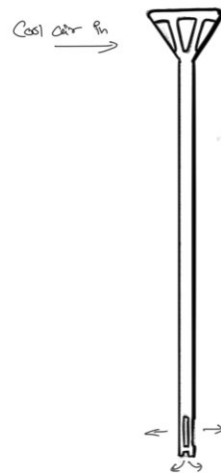


Pros

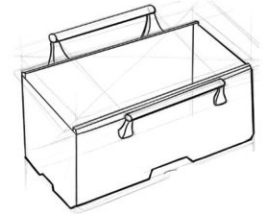
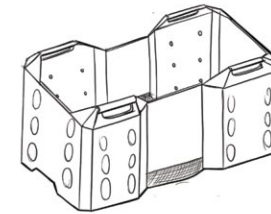
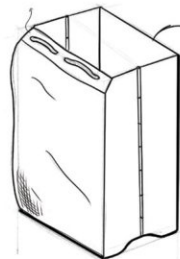
- easy to handle
- no complicated mechanisms to mount

Cons

- too many products to achieve the purpose.
- prone to get damaged.



Evaluation



Stackability

8

8

9

10

10

Posture

8

10

9

7

8

Balancing

6

9

9

7

8

Space saving

10

10

9

5

5

Adjustability

10

9

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Handling

7

9

9

7

8

Desirability

7

9

9

9

5

Strength

7

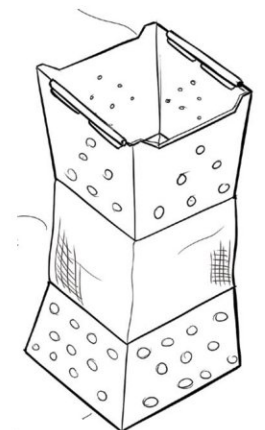
7

9

10

9

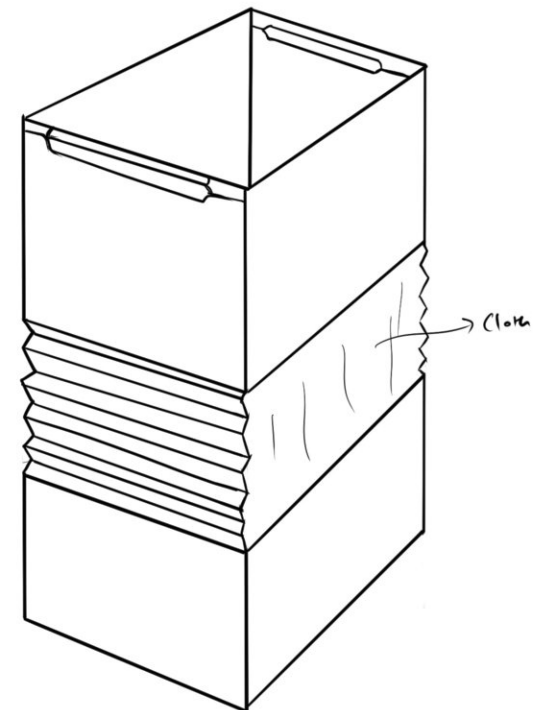
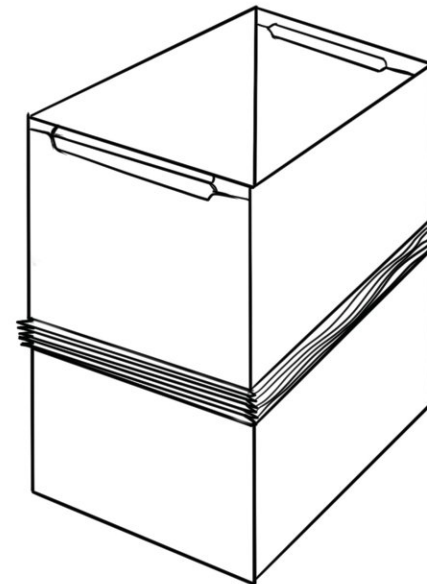
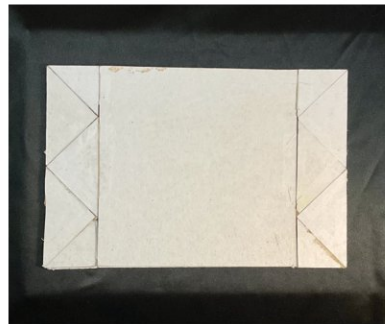
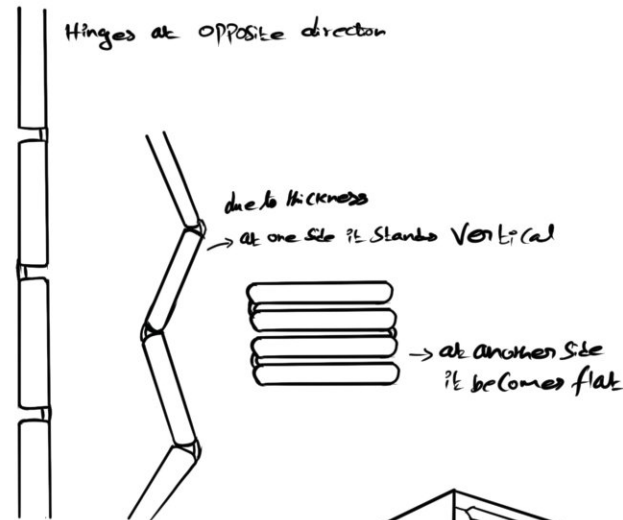
The ideation in the middle scores highest among the others and it scores balanced highest in all the parameters. So, that is selected and taken further for concepts development.



Concept Development

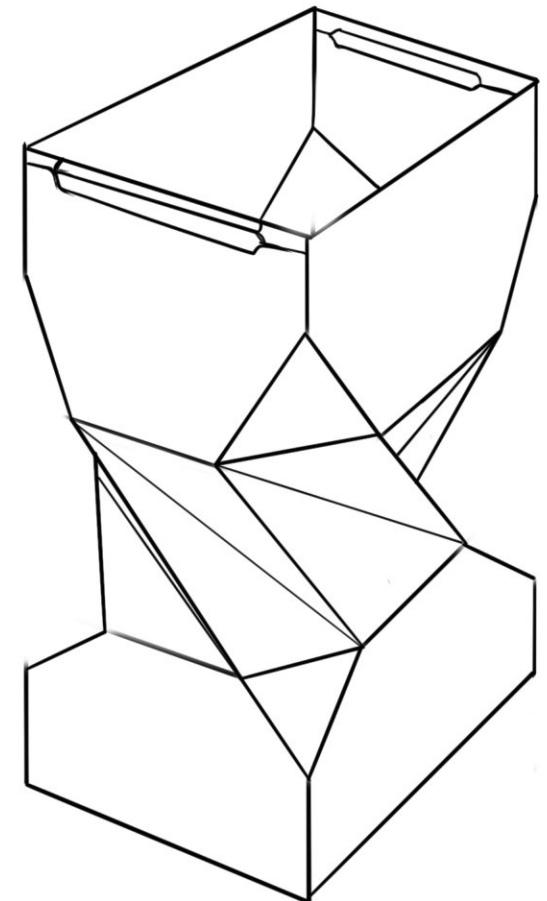
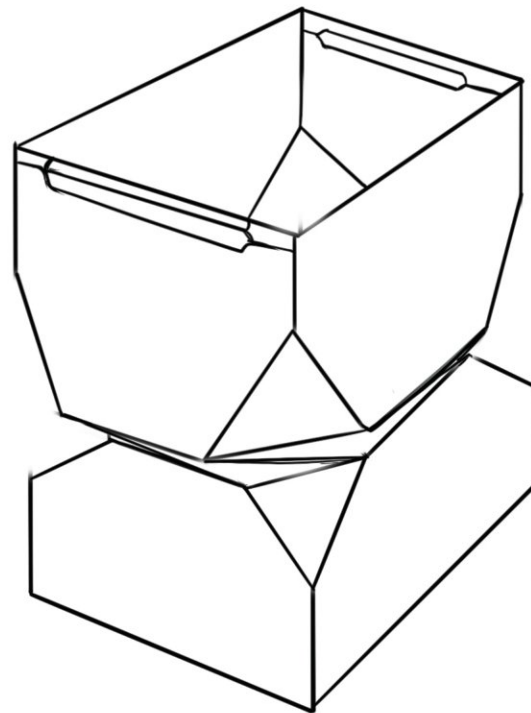
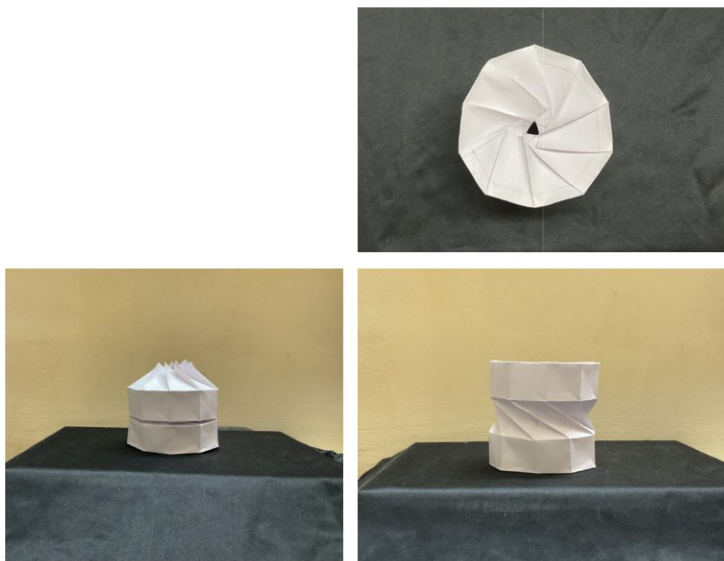
This concept is based on a wave pattern formed through origami. Folding paper resembles the hinge. with 2 thick sheets, if it is connected to one surface, it will act as a hinge in one direction and the motion will be constrained in the other direction. So implementing this concept in the wave pattern forms the mechanism for our idea. The disadvantage is, it is easily triggerable and collapses which was found in doing a quick mockup with box board and scotch tape.

Concept 1



Concept Development

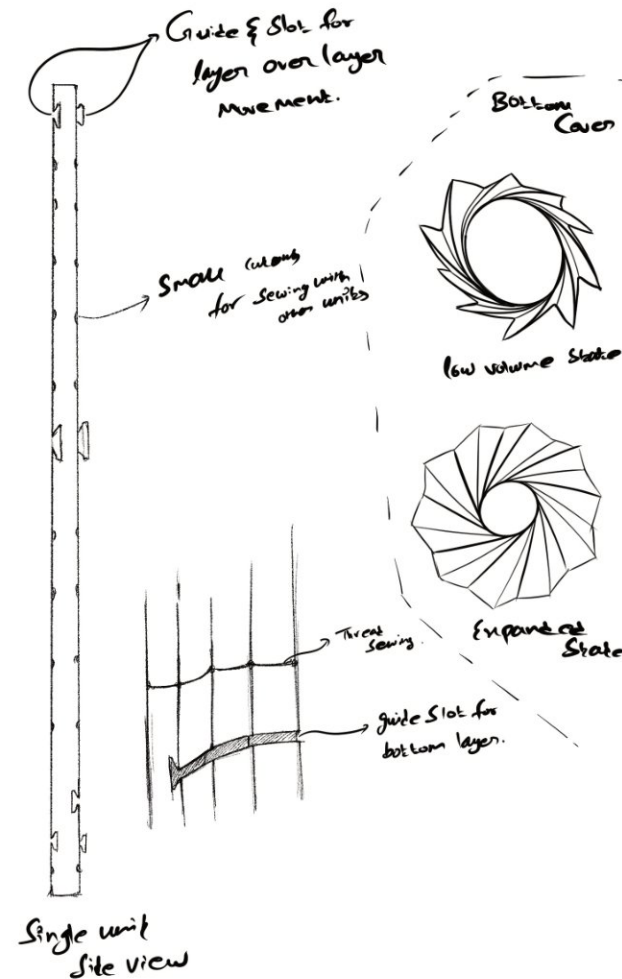
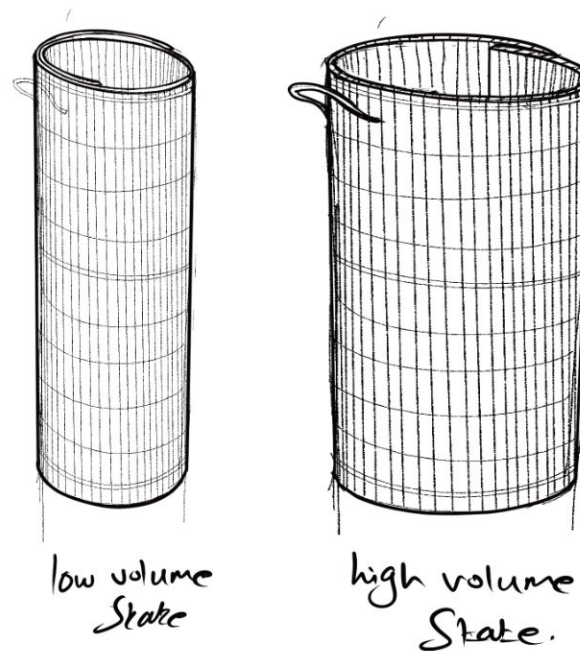
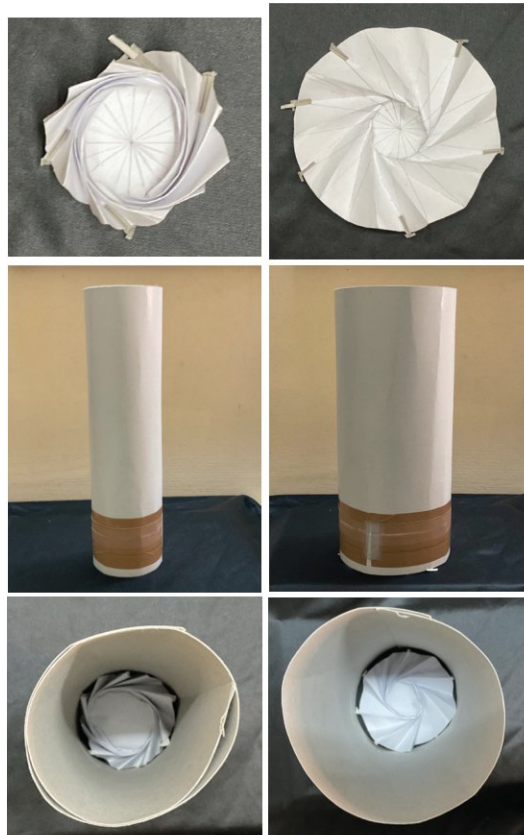
This concept is based on the twist pattern of origami. This concept will only work if the top and bottom part has more than 6 faces for the twisting action to take place. Having more than 6 sides will complicate the overall design. But this compression and expansion action happens in a poetic way. The concept is verified by making a quick mockup using paper and glue.



Concept 2

Concept Development

This concept is done with a different approach, instead of vertical compression. What if the product will look like when it is twisted inside itself like rolling a paper. The two main problems in this design is guiding the layer over another layer and the bottom cover should be such that it should change dimension as well as not be stuck between layers. For layer over layer guiding each pieces are made with slots and for bottom cover the inspiration is taken star shade model of NASA. But because of the slot the entire structure get weakens.

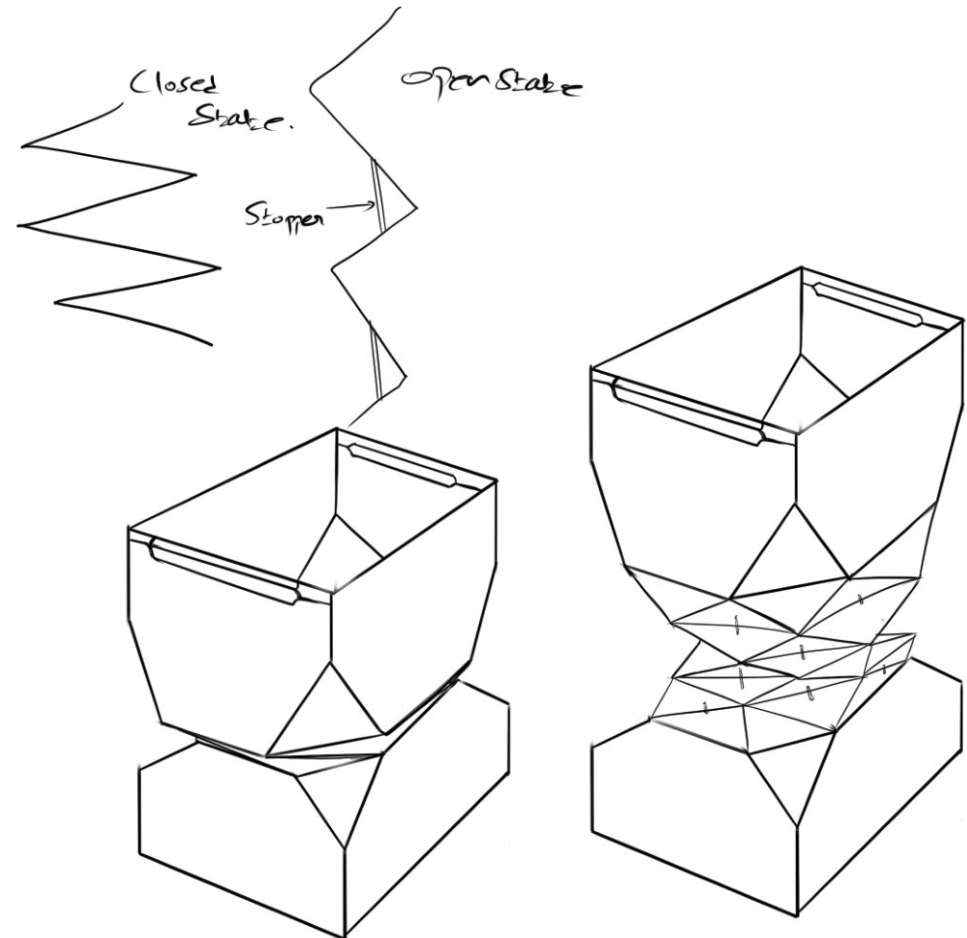
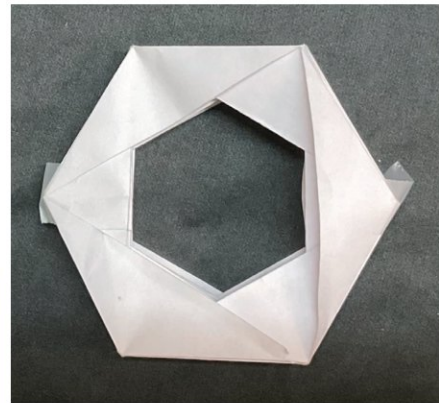


Concept 3

Concept Development

This concept is inspired from the bellows and using origami to form a rigid structure. Yet this incorporation once again requires more than 6 sides to work. Quick mock up is done to check the feasibility of the concept and it is found that it requires an additional component to keep it in the expanded position.

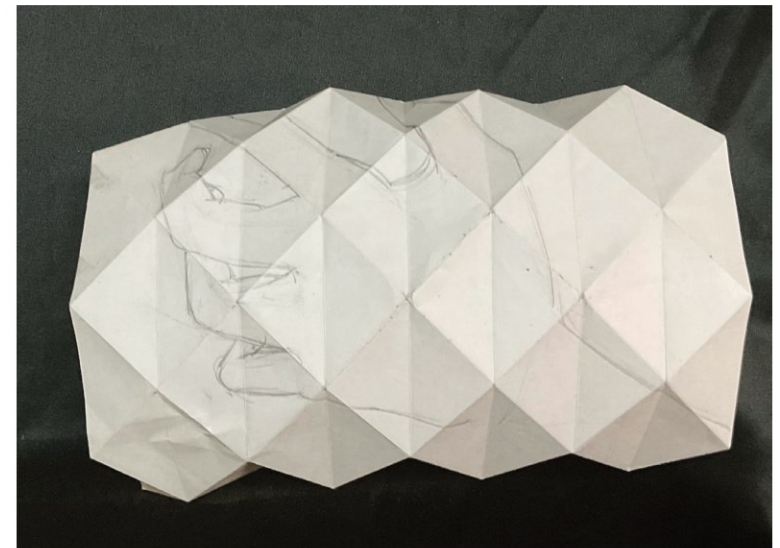
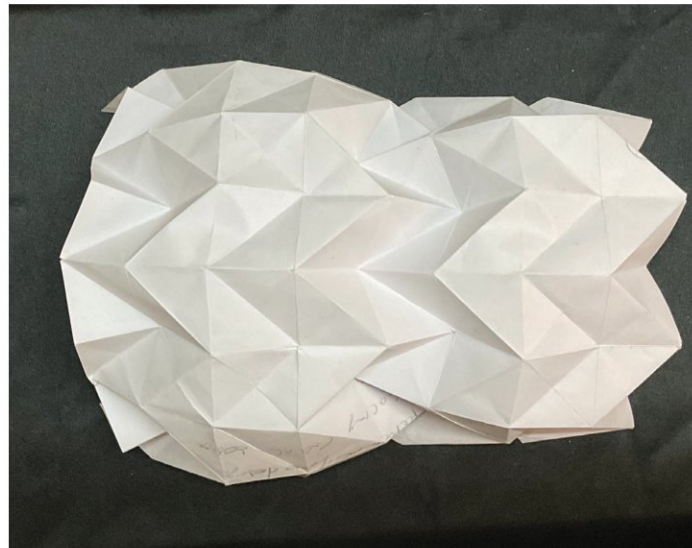
Concept 4



Concept Development

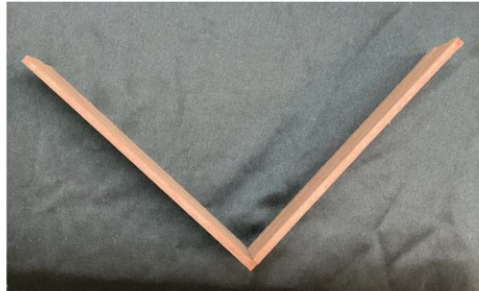
In this concept, the approach is made to work at the individual surface level instead of having a connected four sides. but the structural rigidity cannot be achieved and it requires a thicker section to work which will abruptly increase the weight of the actual product. Quick mock up ideations are done for surface patterns.

Concept 5

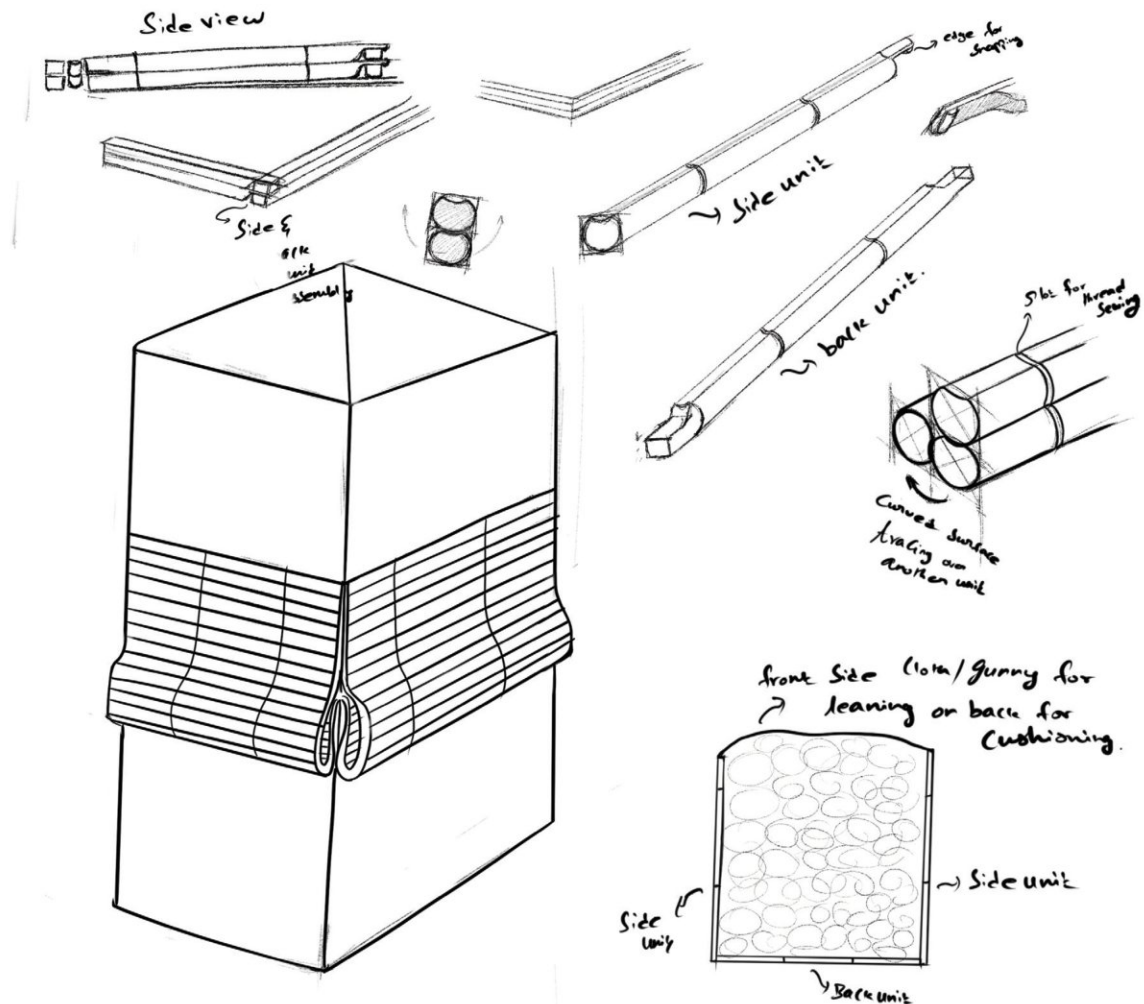


Concept Development

This concept is developed after taking insights from the previous concepts and it is inspired from window bamboo blinds where individual blinds are connected with ropes which makes it easy for sliding and the idea is when these blinds are held together in a single plane it becomes a solid rigid structure. This idea is verified by doing a quick mock up with a mdf sheet and it is load tested with a heavy book. This concept is finalised and taken further for product detailing.

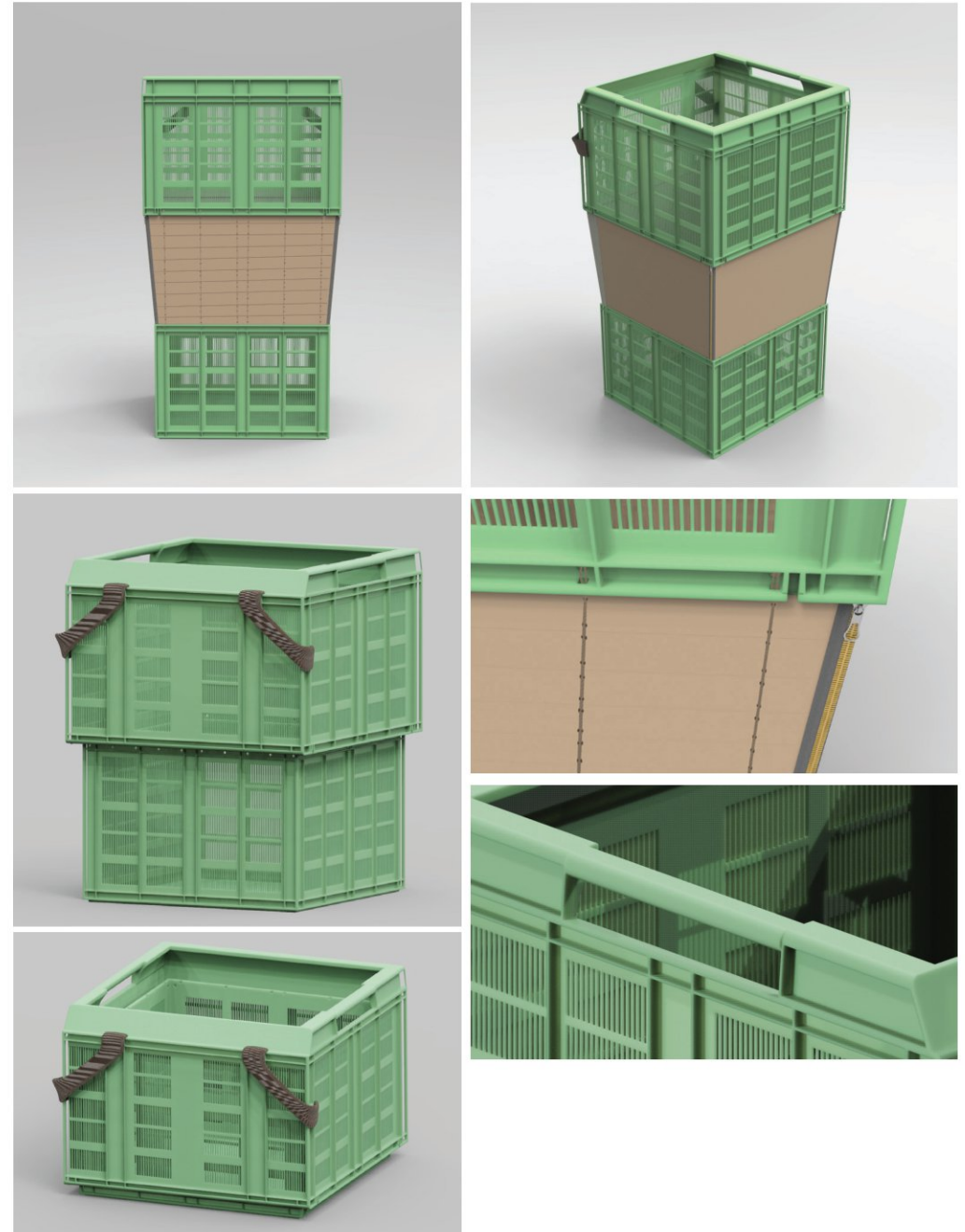
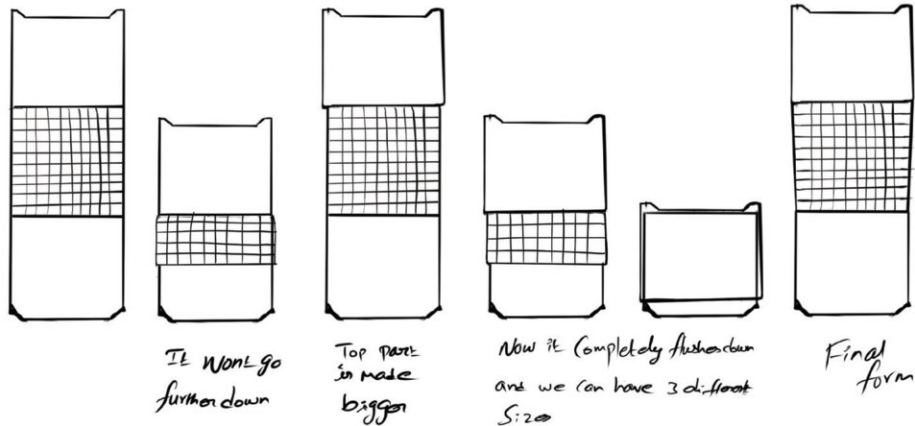


Concept 6



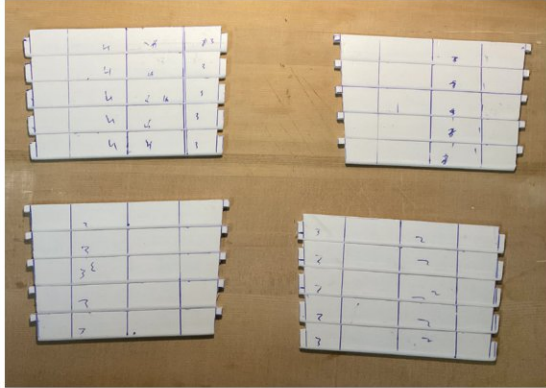
Final Concept

The window bamboo blinds mechanism is made as the functional mechanism for the final product. Then the feasibility is checked for that with sketching the dimensional aspect of the product and it is found that it is compressed till the top surface of the bottom part and if we increase the top part dimension it can be completely shrunken to the height of the bottom part and space is greatly reduced and it can have three different weight options. The form of the product is visualised by making 3d models and renderings. The zipper detail is given to hold the corners in position when it is in full erect mode.

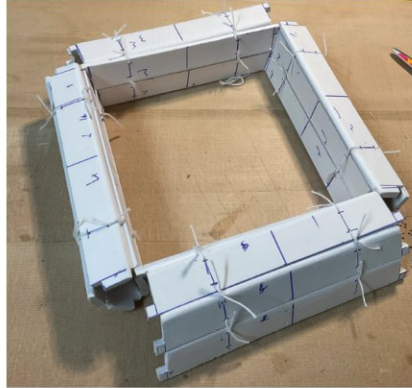


Mockup Test

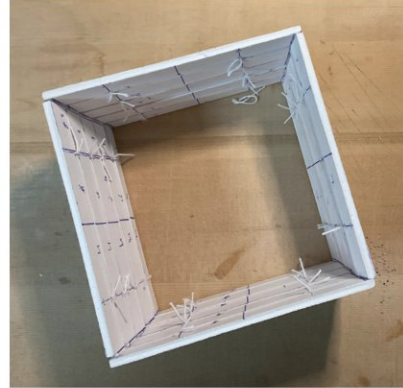
The difference in top and bottom box dimension are calculated and taper is cut on the blinds



Blinds are holed and tied together and tested



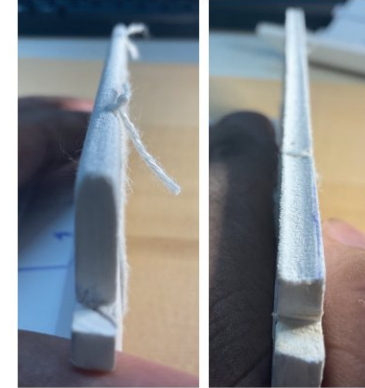
The blinds forms a perfect trapezium and stands rigid



Corner detail which keeps the trapezium in position



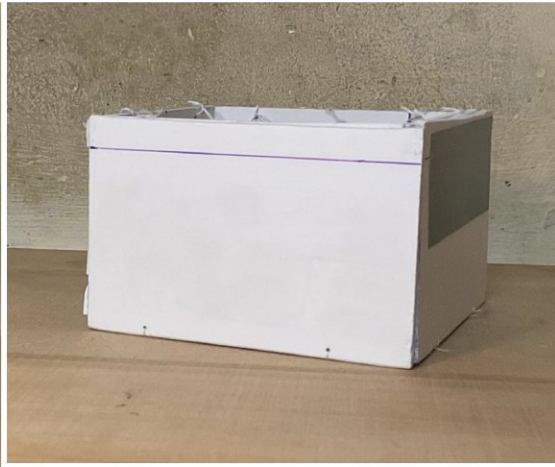
Semi-circle shape crest and trough keeps the blinds in perfect position



Assembled to form 1st configuration



Pushed down to form 2nd configuration



Further pushed down to form 3rd configuration



In 3rd configuration all the Blinds are perfectly flushed within gaps

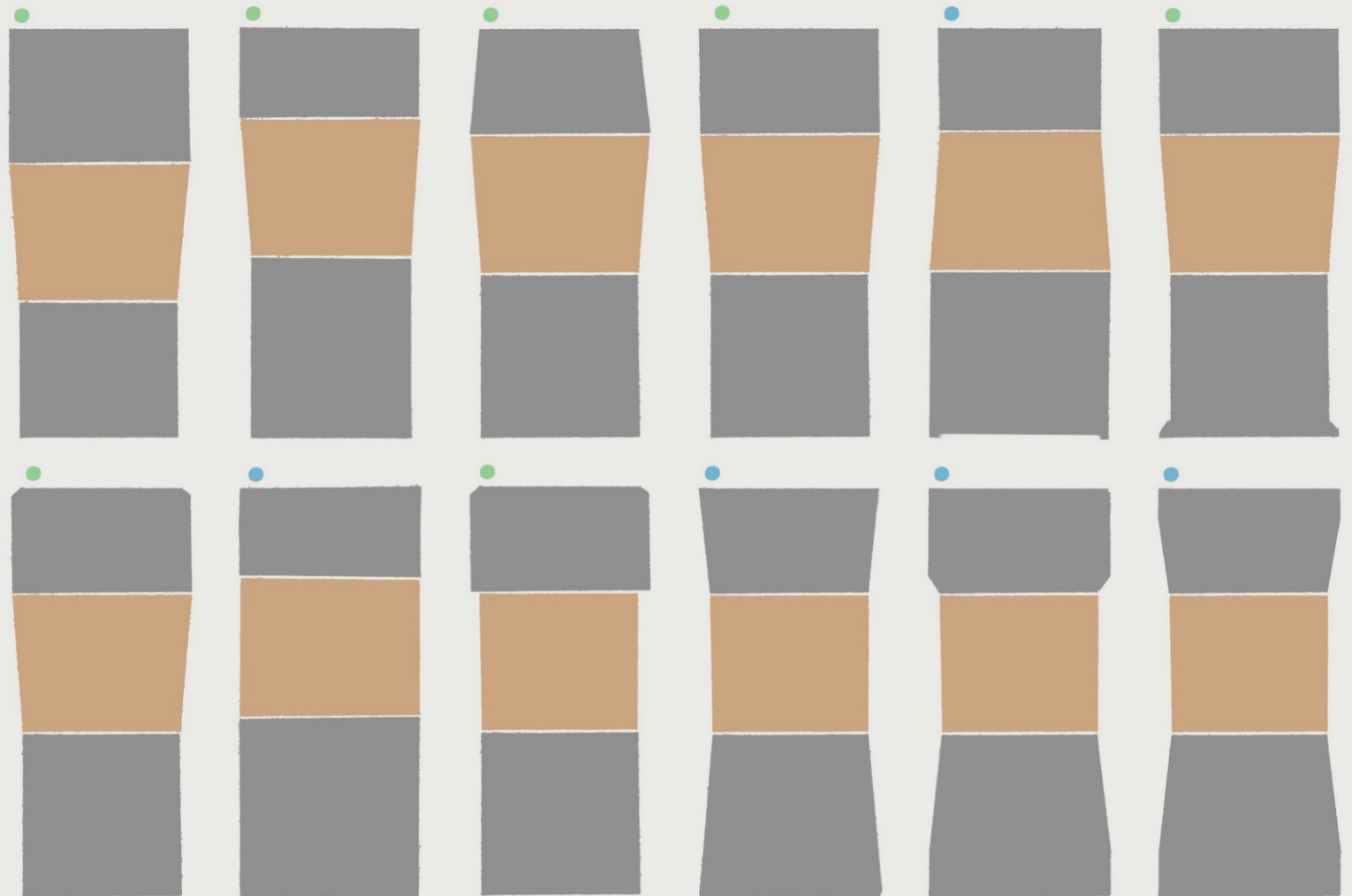


The assembled mockup is load tested with 6kgs dumbbell on top of it.

This is a rough mockup model to check the working of mechanism. Sunboard is used to make the mockup, the scale of the mockup is 1:3. The blinds works perfectly as conceptualized in the sketching phase.

Concept Detail

After confirming the working of the mechanism through a rough mock up. Series of ideations are made for the proportions of the overall form. The forms with green dots are more feasible to make while blue are less feasible and more complicated. These form ideations are made by keeping the insights from the mockups and posture in mind.



Concept Detail

Handle Design is also one of the crucial parts of this product. since, it is a longish form when it is full erect mode and it is heavily loaded. Centre of gravity plays a huge role as to get a balance while carrying the product. The first concept is by holding the product near the ear level and it is held on the top part, this position makes the C.G to fall exactly at the centre of the body. The second is a backpack-like handle where both the top and bottom parts are connected. in this because of the longish form, the C.G falls way off. The third concept is inspired from the meghalaya people who carry heavy loads in steep mountains by holding the handle on their head. In our product to have such a handle design, the handle should be kept as a separate tool and this becomes a problem when unloading from a completely stacked vehicle. So, the first concept is chosen.

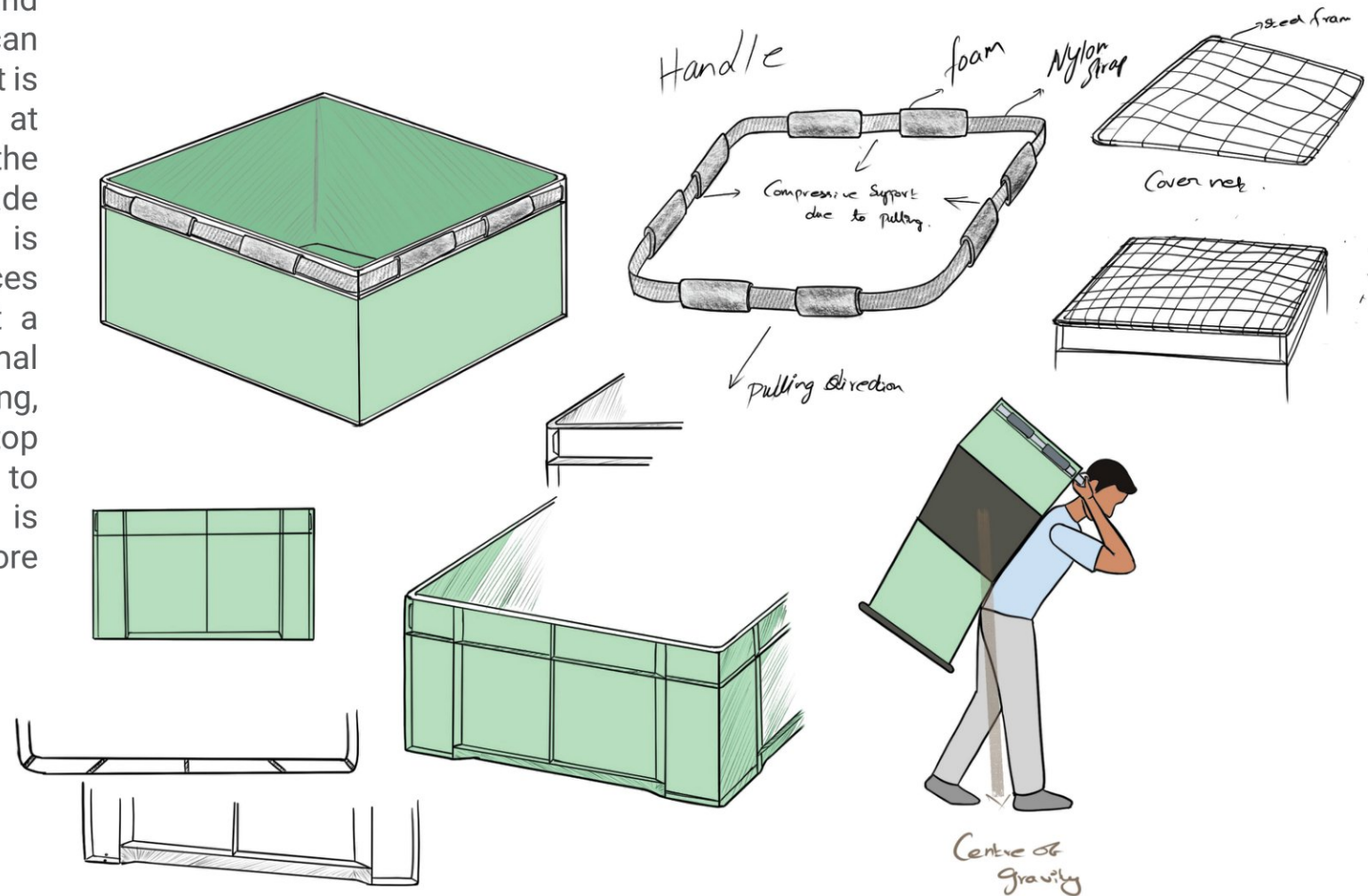
Handle design concepts

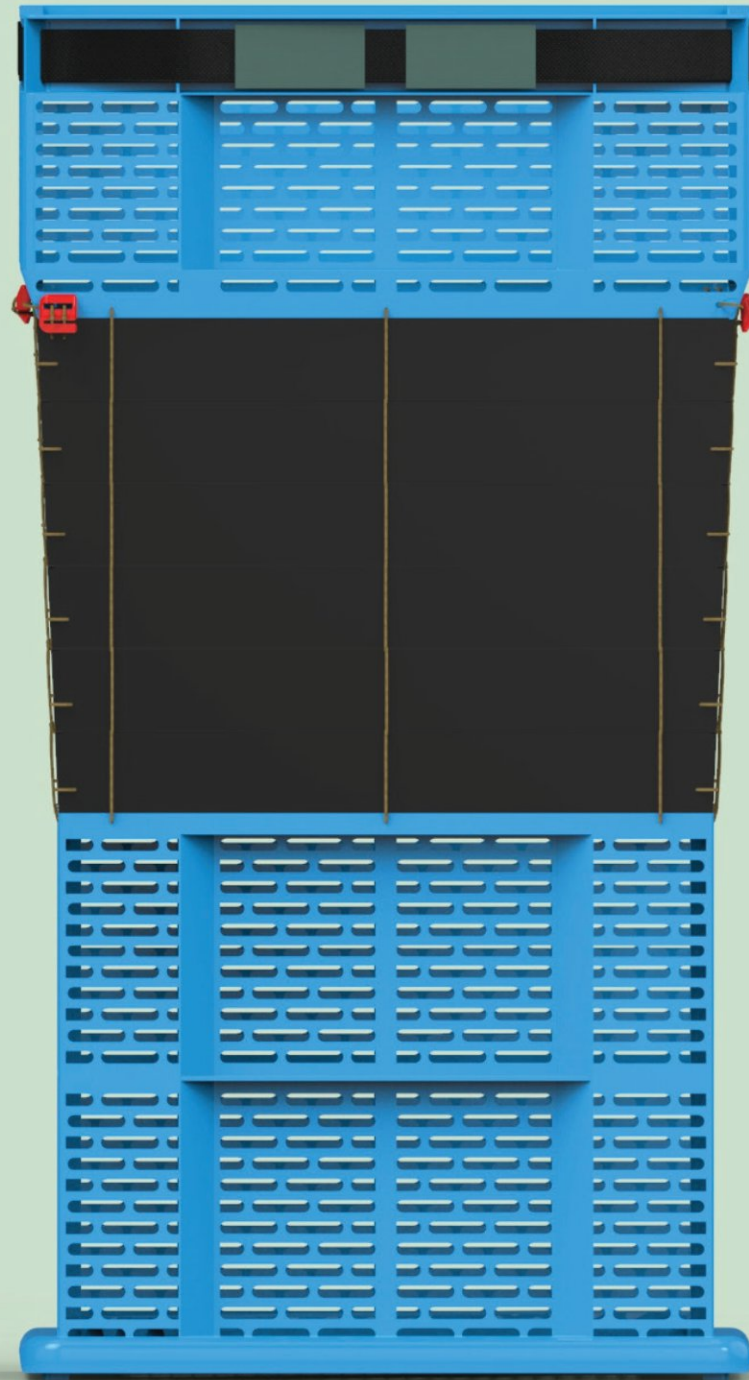


Concept Detail

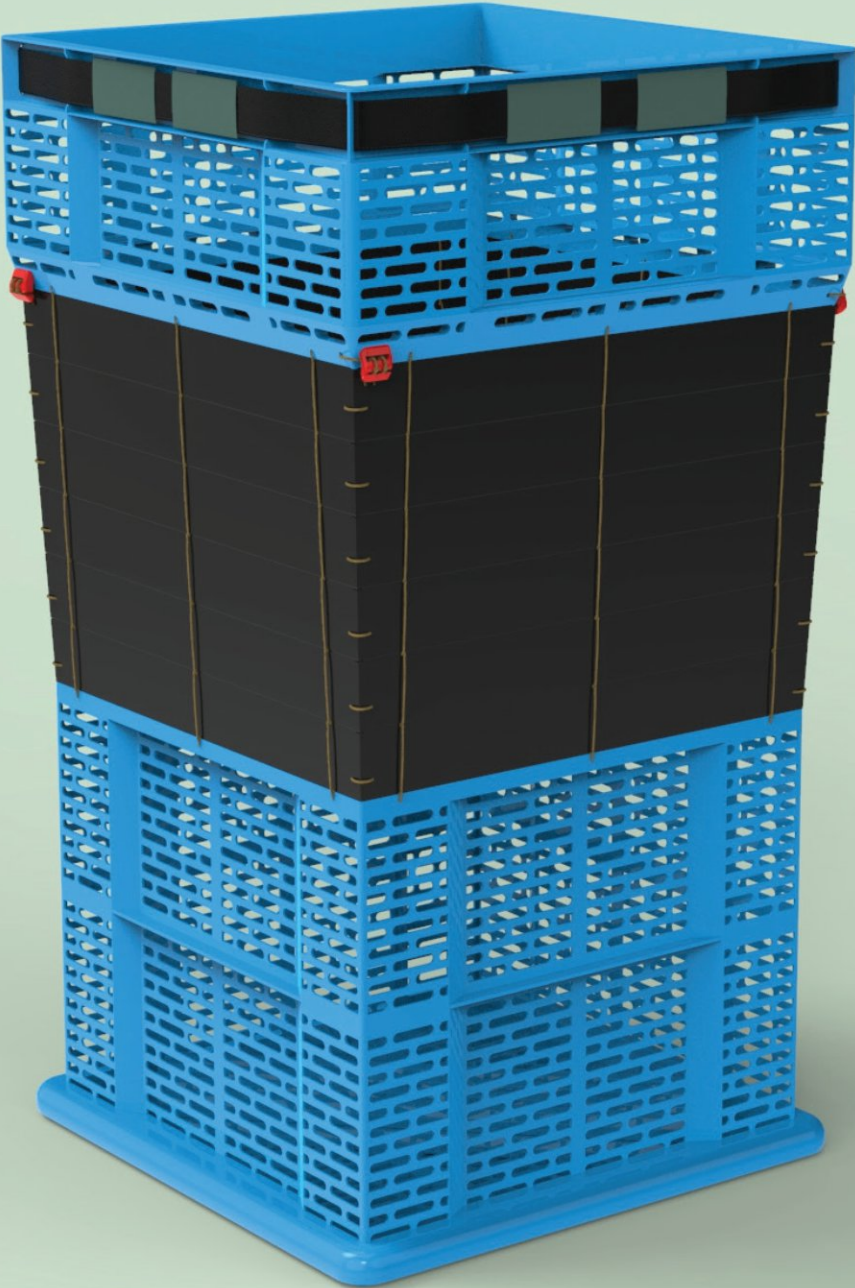
The top part of the product is further detailed for the chosen handle concept. The handle is proposed to be made of nylon strap and foam for grip. The nylon strap loops around all four sides of the top part, so it can be lifted from any position. When it is being carried the pulling action at one side leads to compression of the other three sides because it is made of a single loop, Thus the load is evenly distributed over the surfaces of the three sides unlike not at a single which are seen in normal handle designs. While lifting, because of the slant angle the top layer vegetables tend to slide to avoid that a separated net like is used to cover the product before lifting.

Detailed Handle design





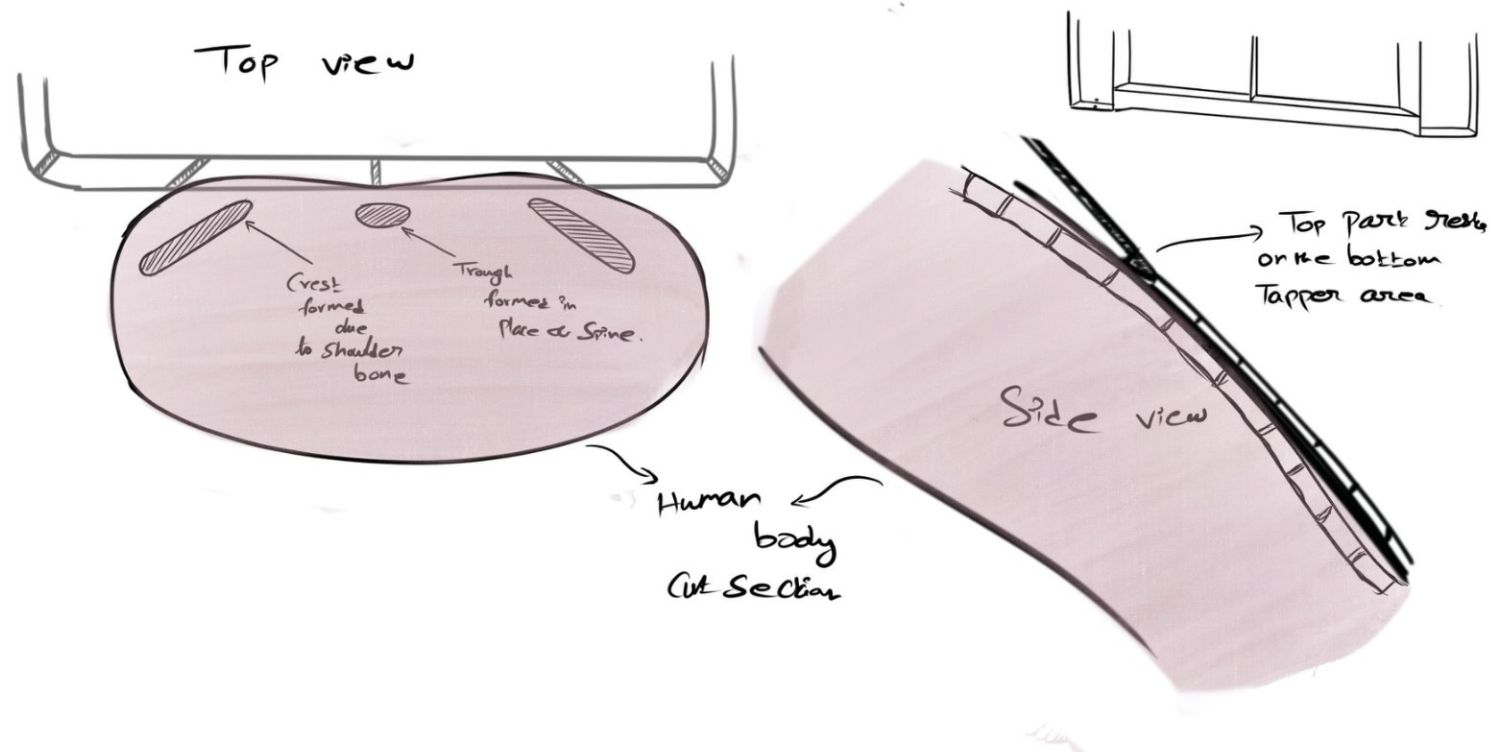
**Flexi
Crate**



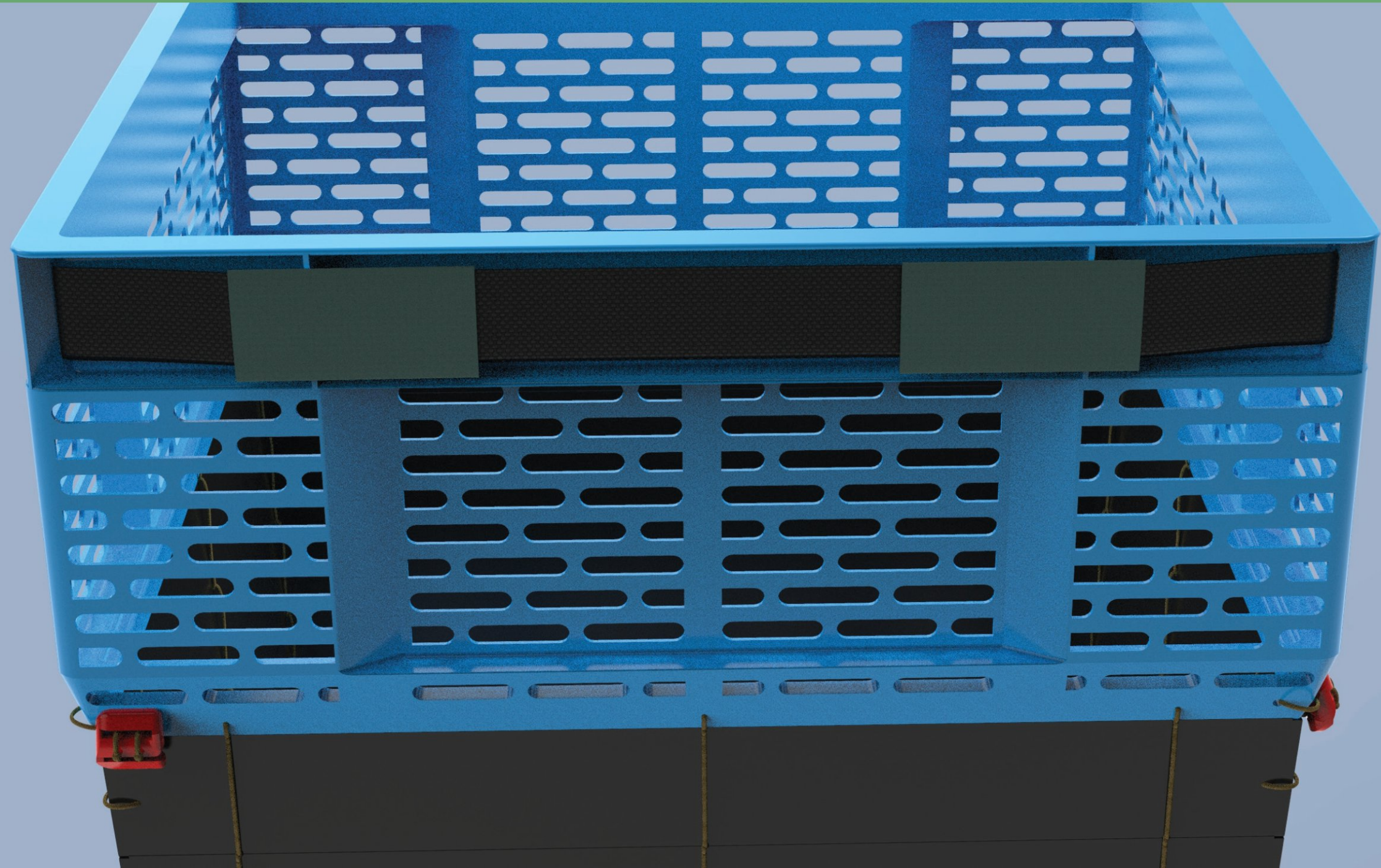
Concept Detail

The top part of the product is further detailed for the human body interaction while carrying. The top part and blinds are the ones which come in contact with the human body. The blinds which are specifically used because of its flexibility for smooth interaction with the body. Now the top part, Generally in plastic trays the ribs are kept at right angle to the surface. Here certain vertical ribs are made slanted to accomodate a smooth effect for the crust formed by the shoulder bone (Scapula bone). The middle one is kept as it is since there will be a trough formed by the spinal cord place. The bottom edge of the top part is made into a chamfer to avoid load concentration at the edge and hurting the back.

Illustration of body interaction



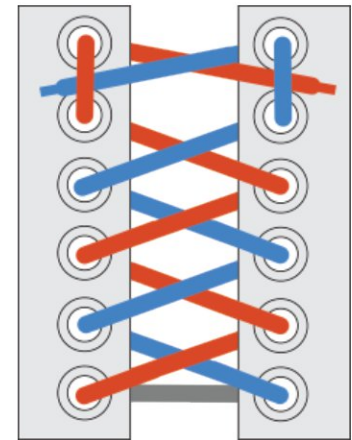
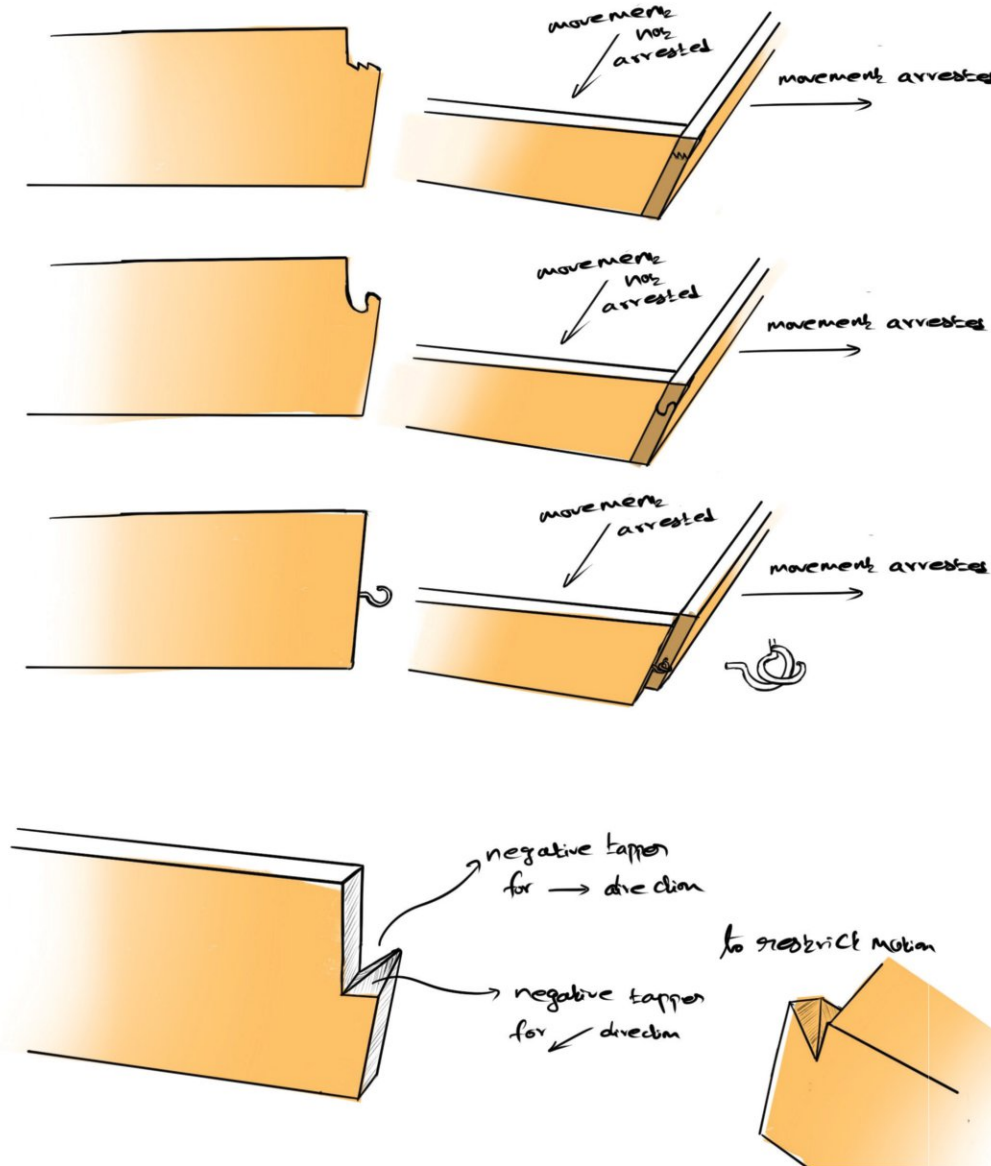
Concept Detail



Concept Detail

The corner joint is the most crucial part of the product, if it fails the entire product will collapse and since the corner is a small area and it has to withstand major load so designing it by properly considering the loading directions is of utmost necessity. The concepts shown here have different profiles to arrest the motion and ease of attaching also. But however when taking material out to make a profile in an already small area makes the section still too weak. so additional reinforcement is needed. For that either zipper or lacing can be used which is easy to remove and easy to make connections.

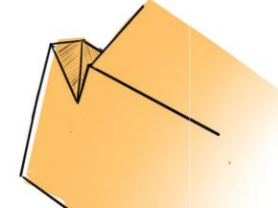
Blinds corner joint Design concepts



negative taper for → direction

negative taper for ← direction

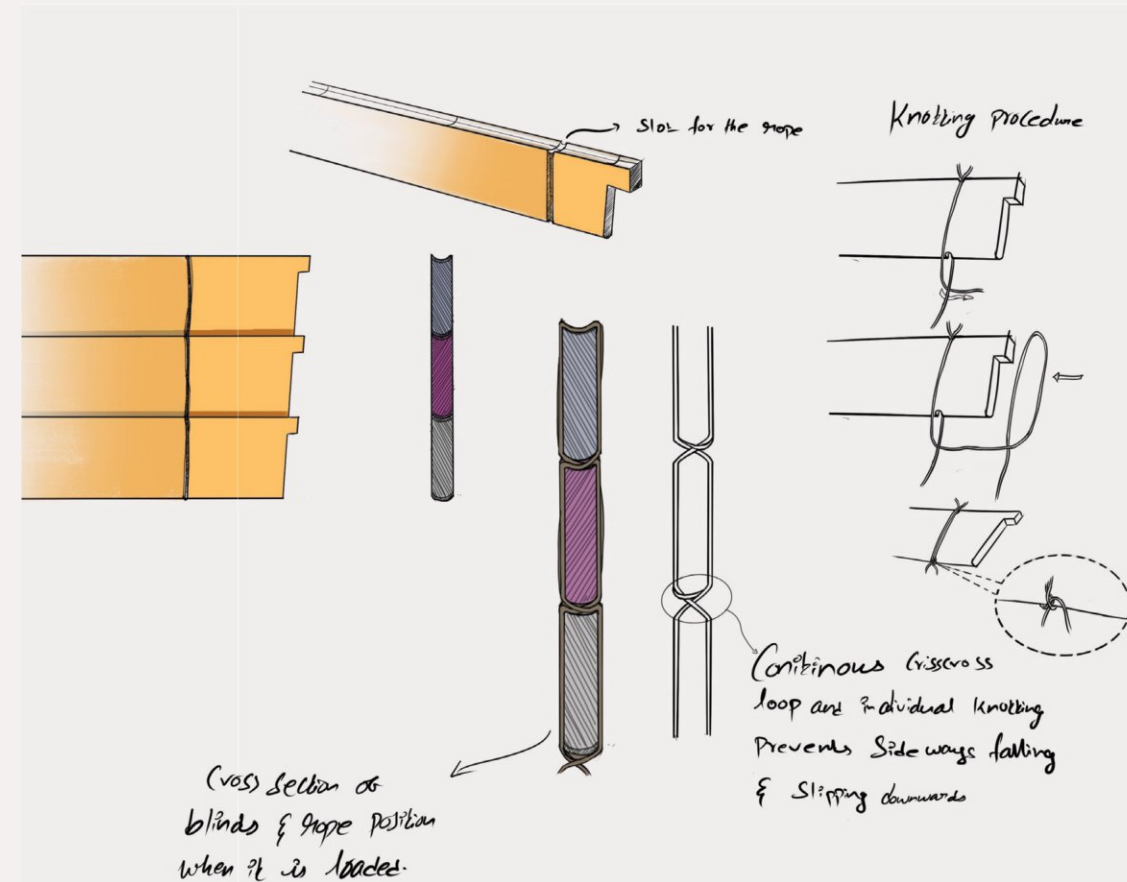
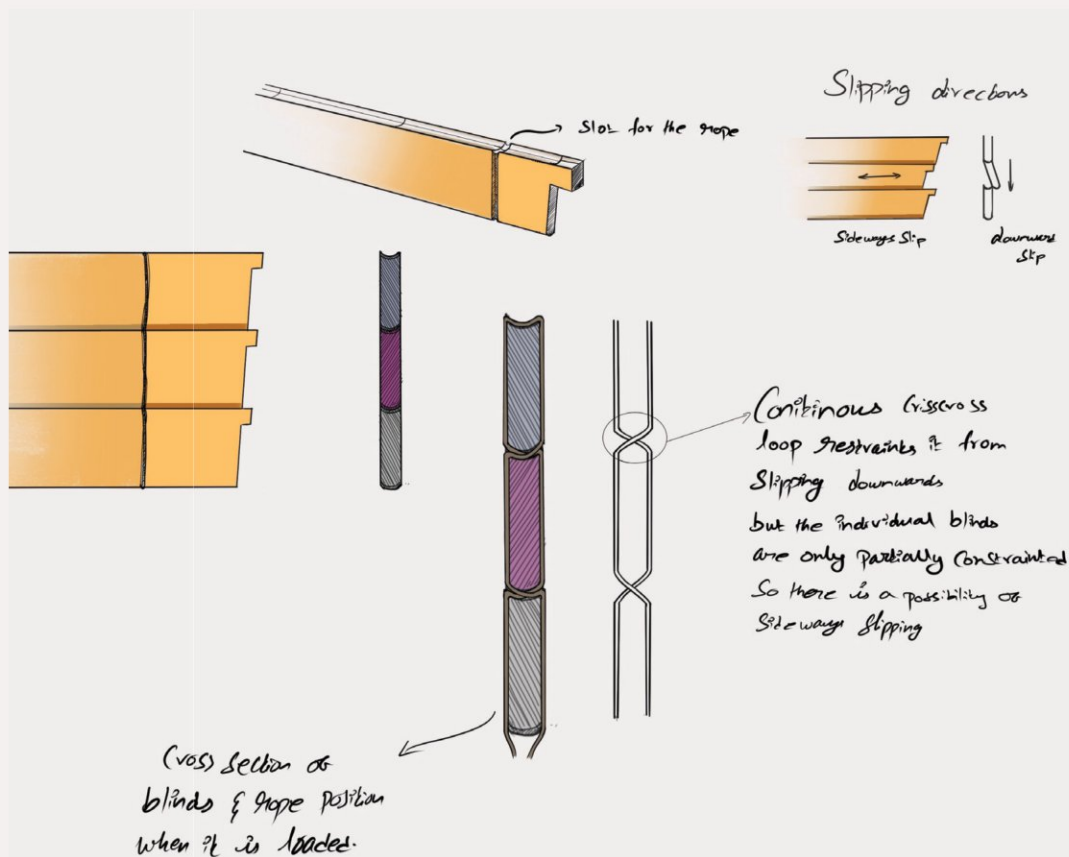
to restrict motion



Concept Detail

Blinds Knotting detail concepts

The next important detail is the connecting detail of individual blinds to one another. The connections should be such that when it is assembled it should retain all the blinds in a single plane. The connection of blinds has two slipping directions which was found when doing the mockup by just putting a holes and tying the blinds with each other. So, to solve that, different knotting techniques are referred and tested. In the first one, a simple criss cross loop based over the blinds and to keep the rope in position a small groove is carved on the blinds. This knot solves the downward slip but there is a sideways slip even with slots because each blinds is not individually connected with the ropes. The second concept solves this by using a special knotting technique which is illustrated below.



Concept Detail

The blinds are a crucial part of the product, it creates the flexibility and rigidity of the product, the flexibility is inspired from the bamboo window blinds and the rigidity is achieved by keeping the blinds in a single plane and supported by other two sides, like that all the four sides support each other. The top and bottom side of each blind has a negative and positive curve profile so that while sliding it acts as a pivot and while kept at a single plane it helps in aligning the other blinds in the single plane. The left and right side of each blind is cut out in order to form the corner with adjacent blind just like the curve profile; the corners have a negative and positive cut out which complements each other and forms a corner. The blinds totally have 2 different profile sets. Opposite facing blinds have the same profile and adjacent facing blinds have different profile sets.



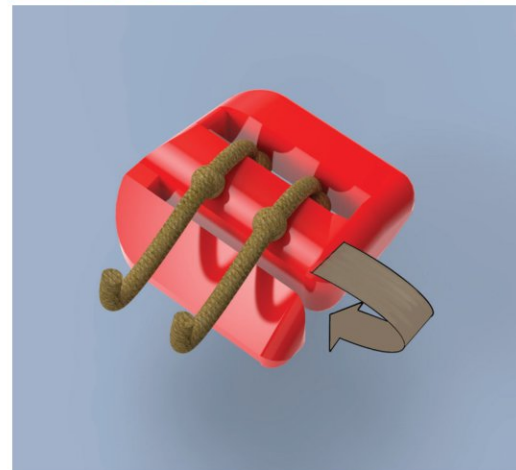
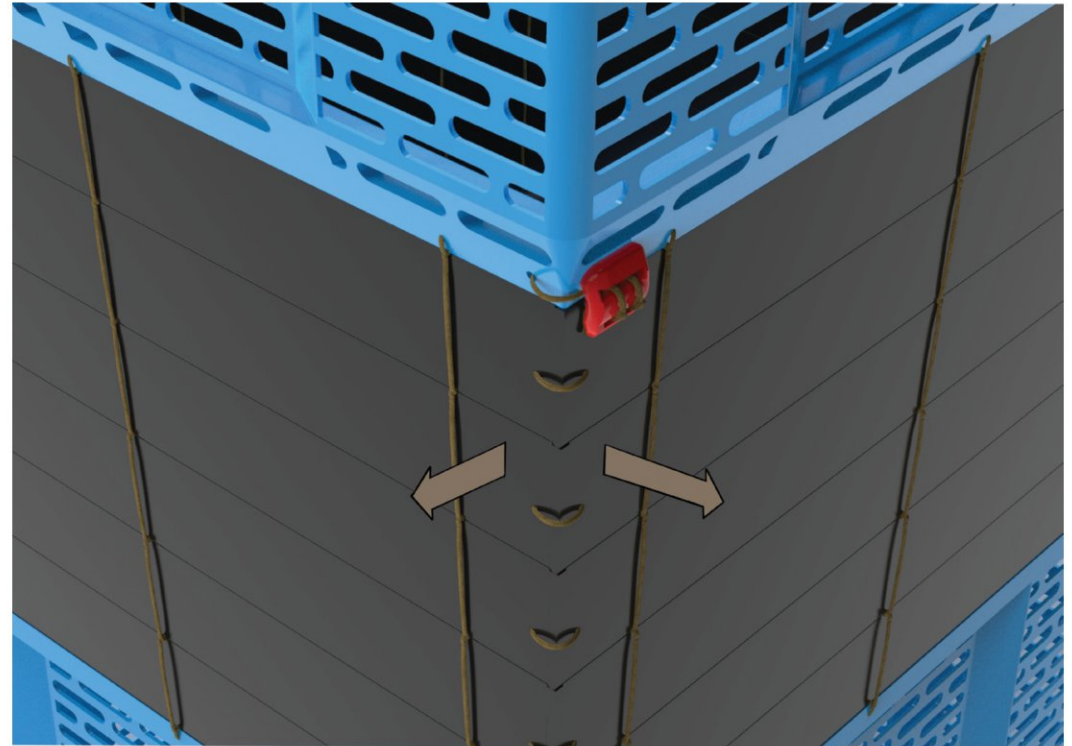
Concept Detail

The blinds will not collapse inwards because of the complimenting positive and negative profile of adjacent blinds but for it to collapse so as to form a different configuration, it collapses outward. To arrest this outward collapsing when it is loaded, the Lacing technique is used. The lacing method is a modified version of the ladder lacing method. In this method, the lace connects the two blinds of the corner by passing over it outside and holds the corner firmly. On the inside it is ensured to keep it on a single side. It is done because when collapsing the lacing should not interfere or get stuck in between the blinds. This will create chaos while assembling and it will deteriorate the strands of the rope.



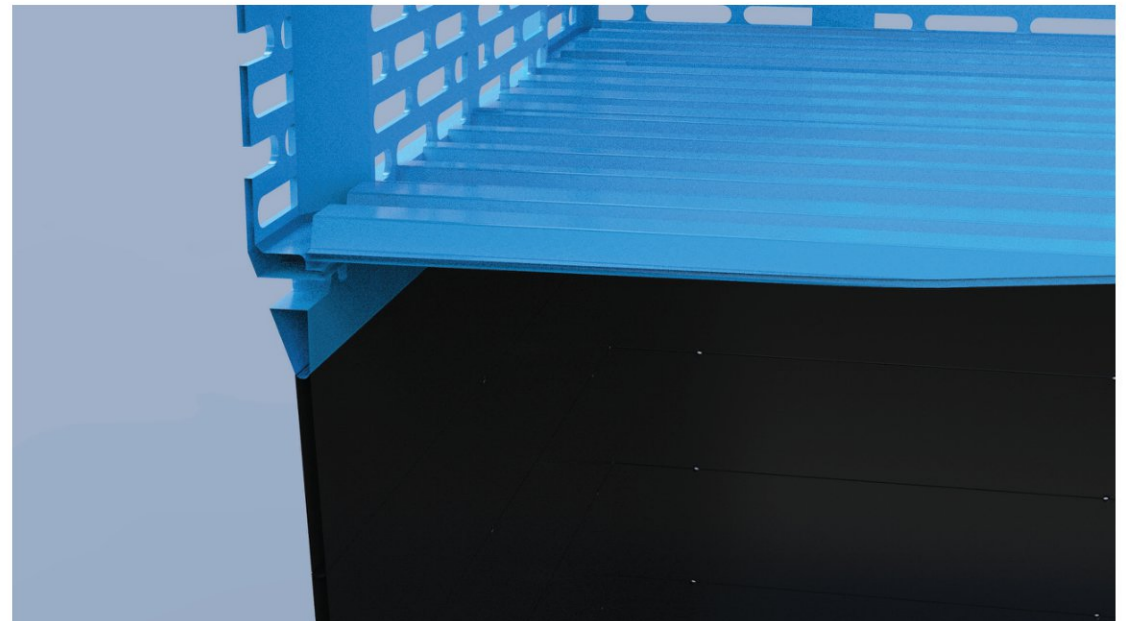
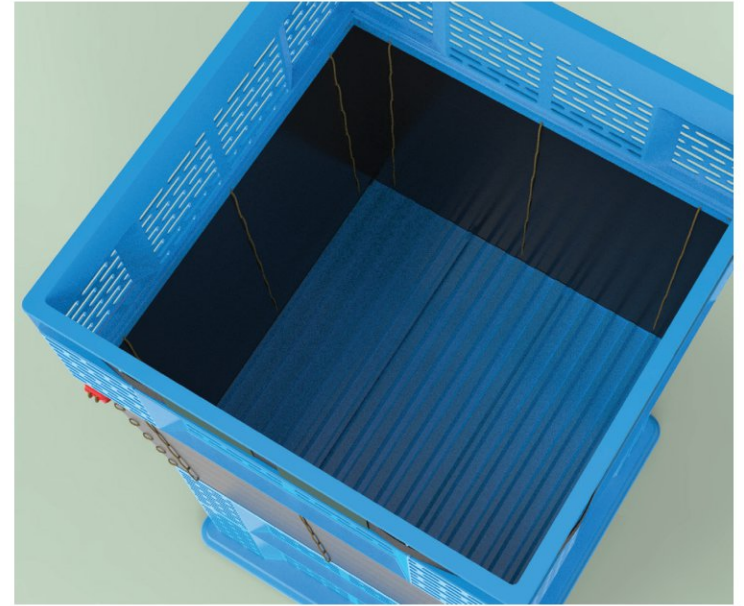
Concept Detail

The tying of lace is another crucial aspect of the product. The lacing method serves the purpose of holding the blinds in position and ensures it from not being collapsed and getting tangles in between the blinds. But to hold the lacing, it has to be tied at the ends. If normal tying methods is used, quick deployment and usage of product becomes questionable. For that a quick locking method is thought out. The concept is inspired from the buckles used in bags and belts. The two slots in the buckle have different dimensions. One has large slot and another has small slot. The knotted thread passes through the large slot and when it is slided into the small slot it gets locked.



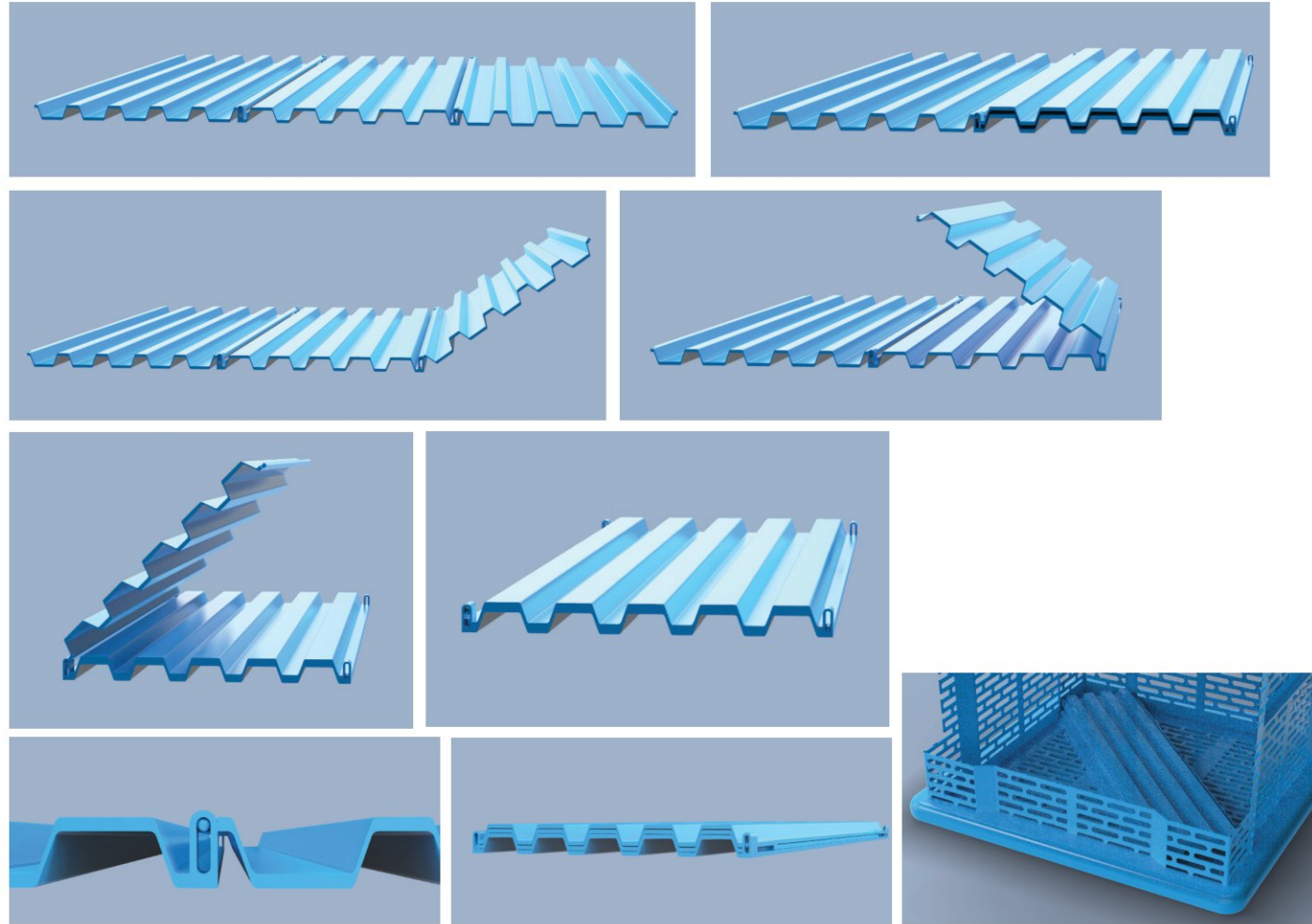
Concept Detail

The product is intended to have a structural rigidity, so that when stacked the load is transferred through the product not through the vegetables. But the maximum load capacity of the product is 80kgs, so there is a problem of vegetables at the bottom most layer getting damaged due to the self weight of 80kgs that to vegetables with low density like tomatoes easily gets damaged. So in order to avoid that 2 partitions are made.



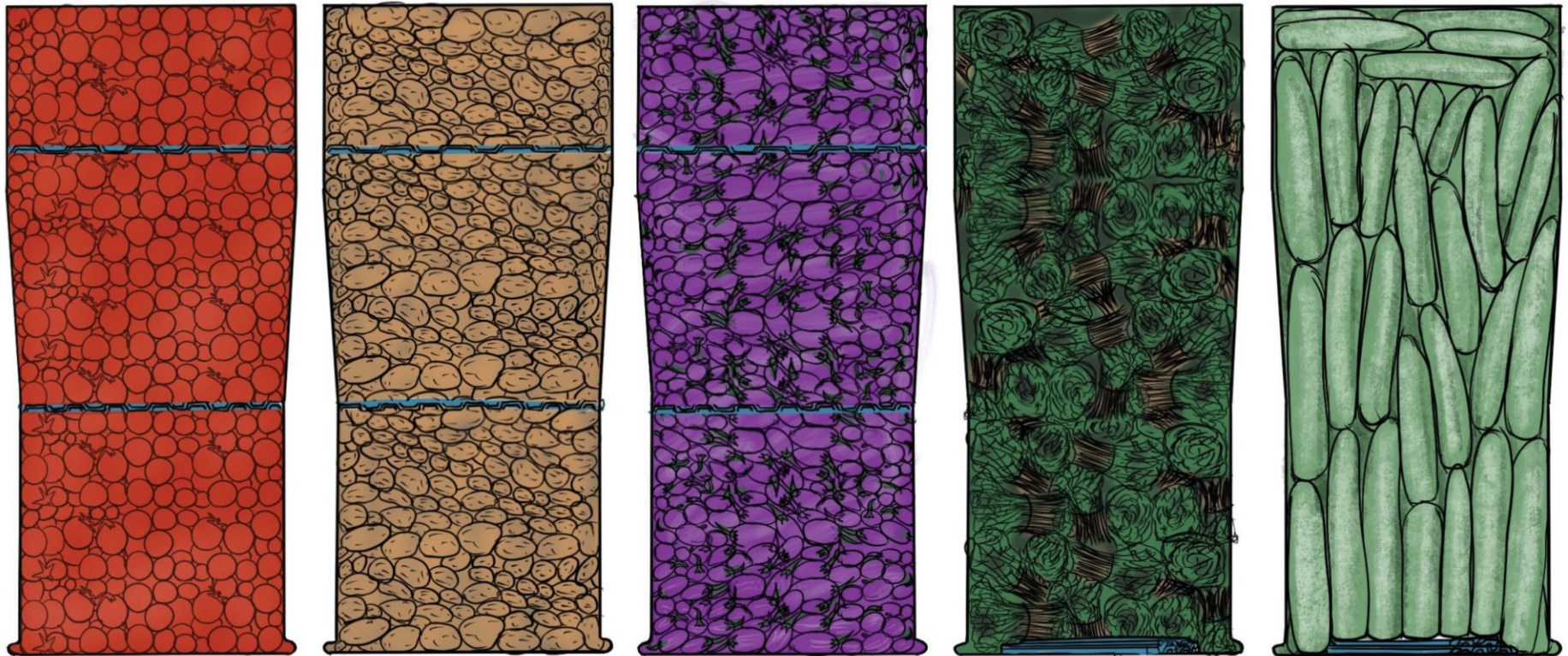
Concept Detail

The partition plate is foldable and when it is not used it can be snapped to the bottom of the product. The partition plate is designed in a wave pattern so that with 1mm thickness it can withstand the load. The hinges are designed in a way that folds and settles perfectly in a single stacked layer.



Illustration

Vegetable interaction with product illustration



Tomato

Potato

Brinjal

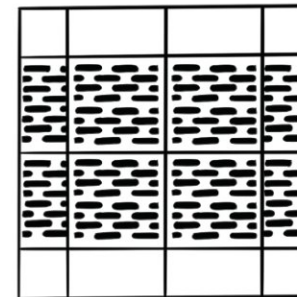
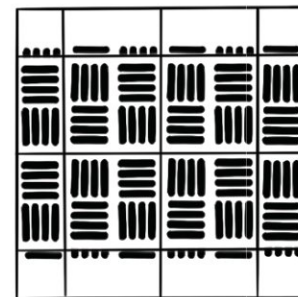
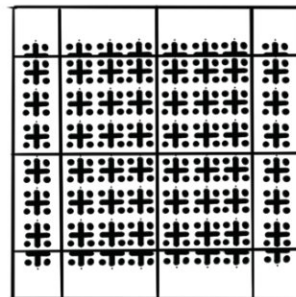
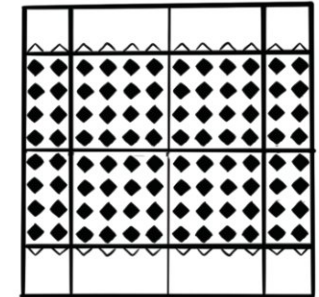
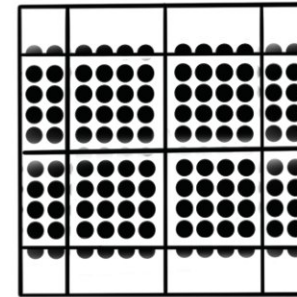
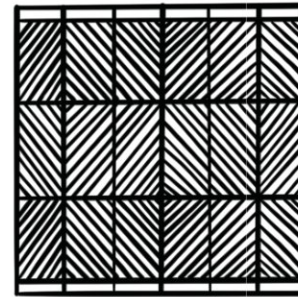
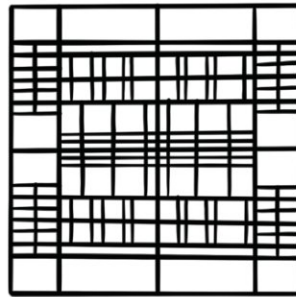
Leafy veggi

Bottle gourd

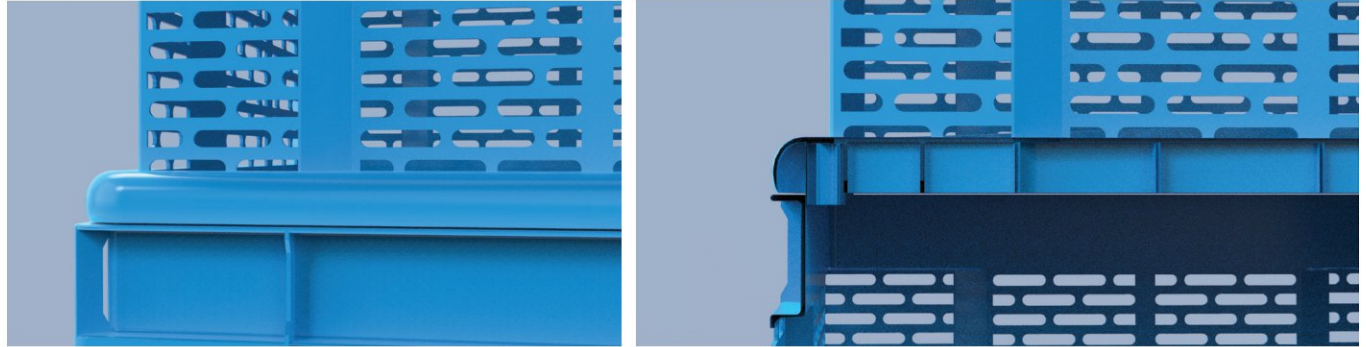
Concept Detail

Grill holes pattern designs

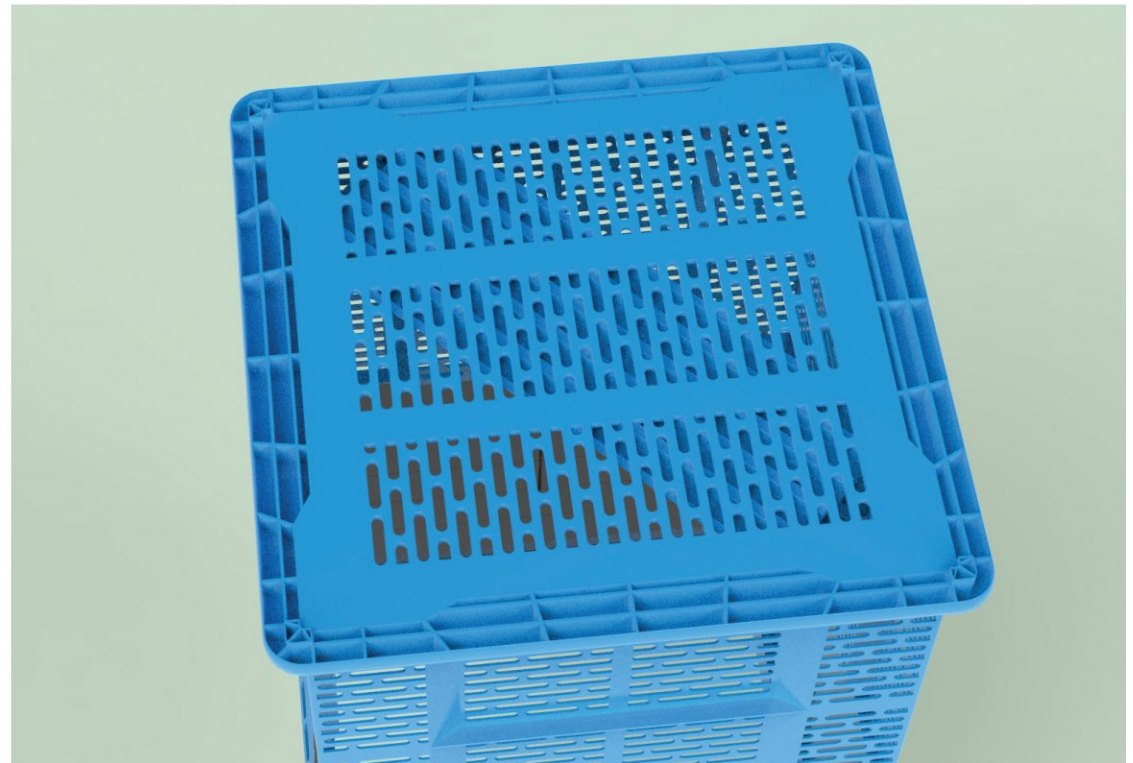
The grill holes are one of the important features of the product. It gives both cooling air to pass through and also it creates the aesthetics to the product. The desirability of the product is also dependent on it. Considering all these different patterns are drawn. While doing this, it should also be considered the structural aspect, because too many holes will make the surface more flimsy. Thickness of the holes should also be considered. If too large a hole, vegetables will get stuck and cover the holes, if too small a hole, air will pass through it efficiently. With all these taking it into account the last two designs are chosen to further develop.



Concept Detail

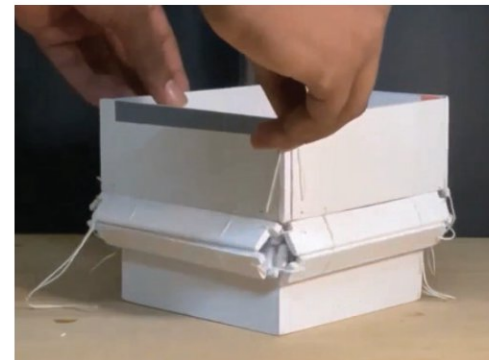
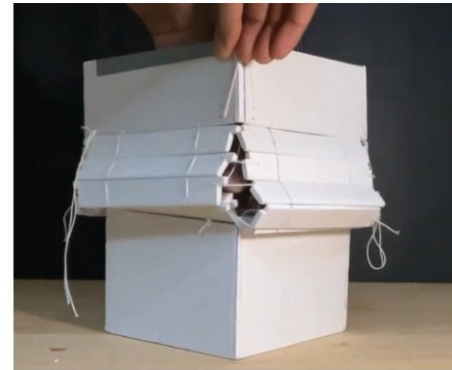


The product is intended to have a structural rigidity, so that when stacked the load is transferred through the product not through the vegetables. Since the form of the product is having a big volume on the top and small volume at the bottom. when it is stacked the small and large gets interacted. To make it perfectly fit and easily stackable. A small curved extension is given at the bottom part for stacking purpose.

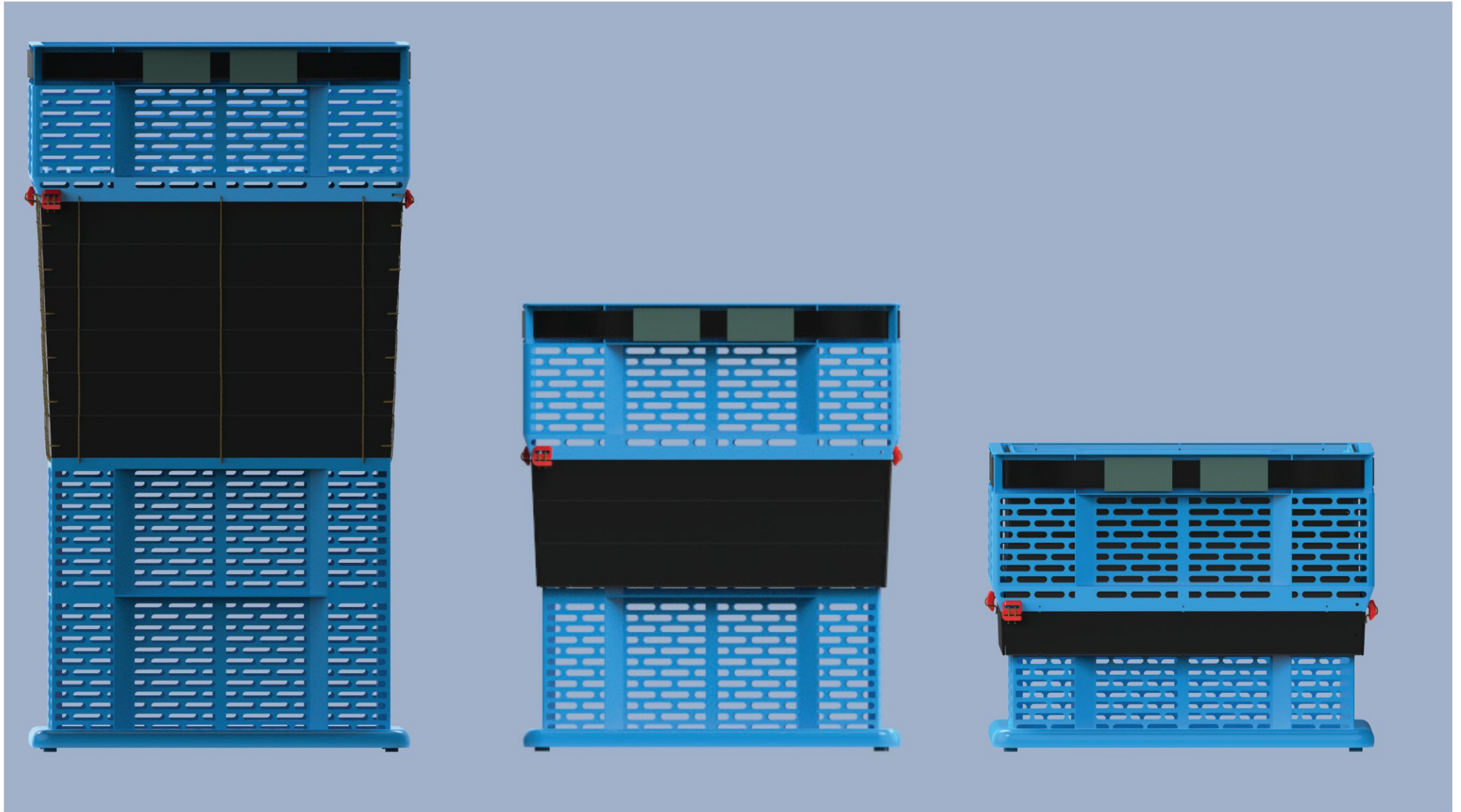


Concept Detail

The main purpose of this product is to make it flexible and structurally rigid. With the flexibility feature, the product can bring in more options to the volume adjustment. To make standard volume settings in order to avoid problems in stackability and logistics calculations. The product is made to be set only for 3 volume options. The 1st configuration has a capacity to carry 80kgs, the 2nd configuration is adjusted to carry 50kgs and the final compressed configuration can contain 30kgs.

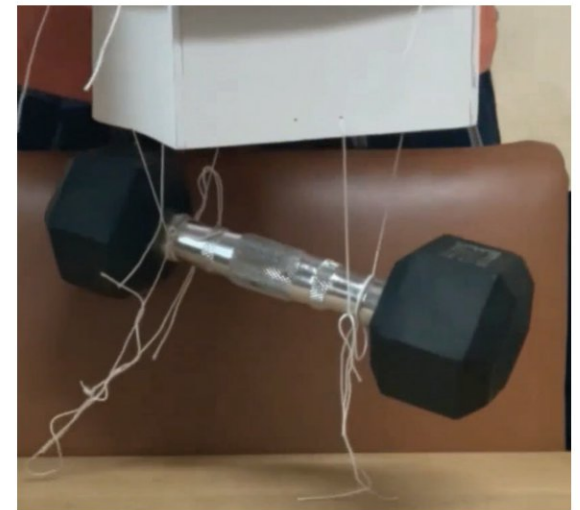
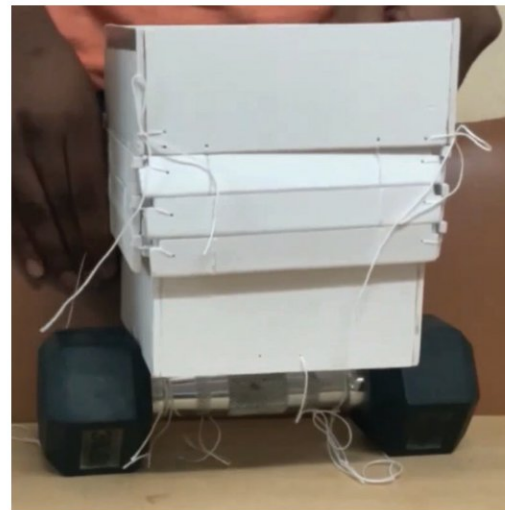
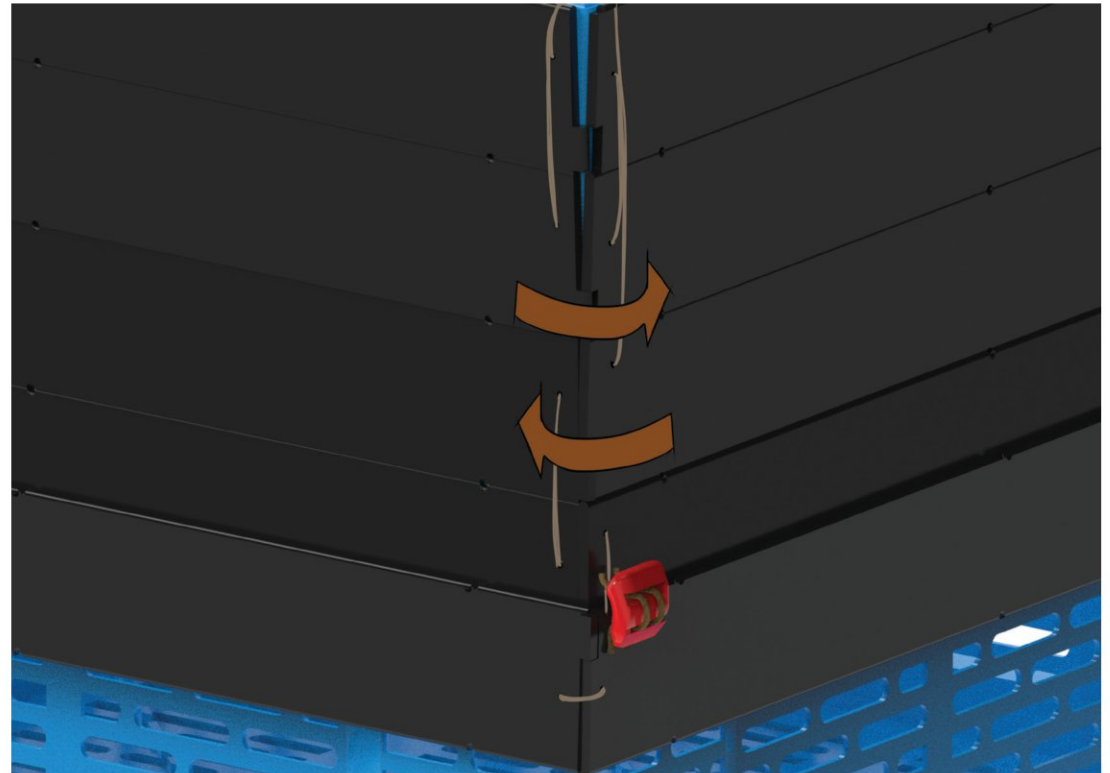


Concept Detail



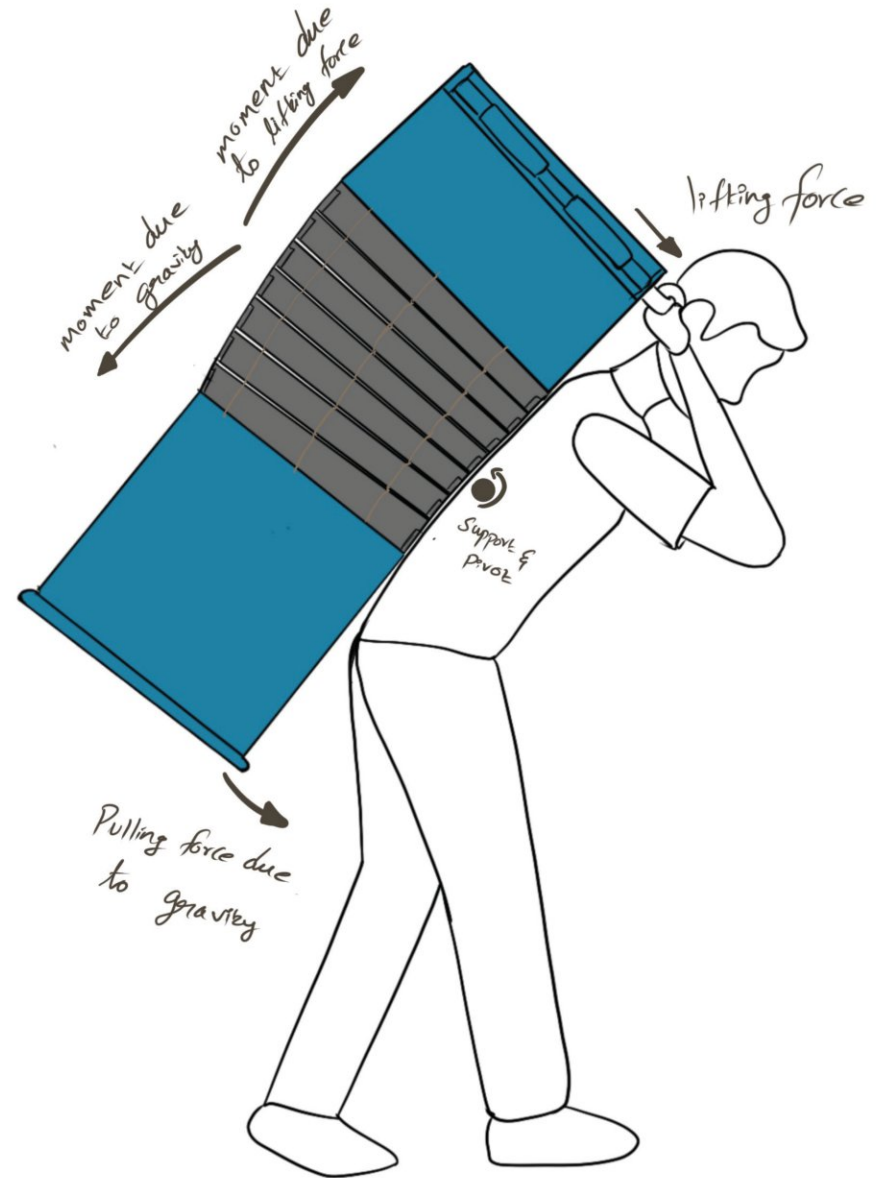
Concept Detail

The flexibility and different set of configuration is achieved but to hold the product at different configurations another locking method has to be used. But since the sliding concept of blinds is too compact including another locking mechanism is very difficult and the mechanism would become weak since the area is small. So the lace locking method is tested again for this different configurations. This locking method works efficiently and it is also tested by tying a weight at the bottom part of the mock up. The lace locking method works in the same way but in the opposite side of the blinds when it is compressed.



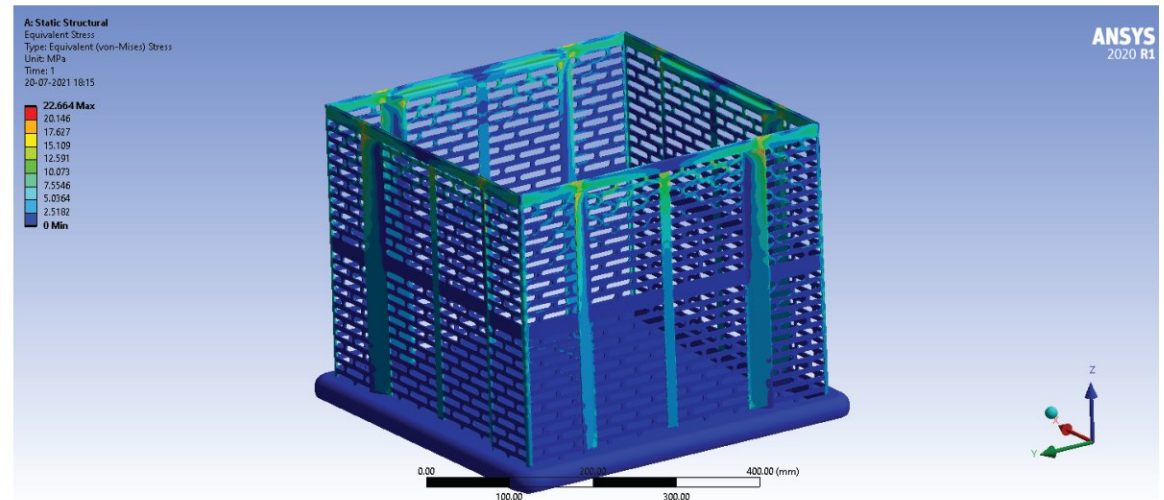
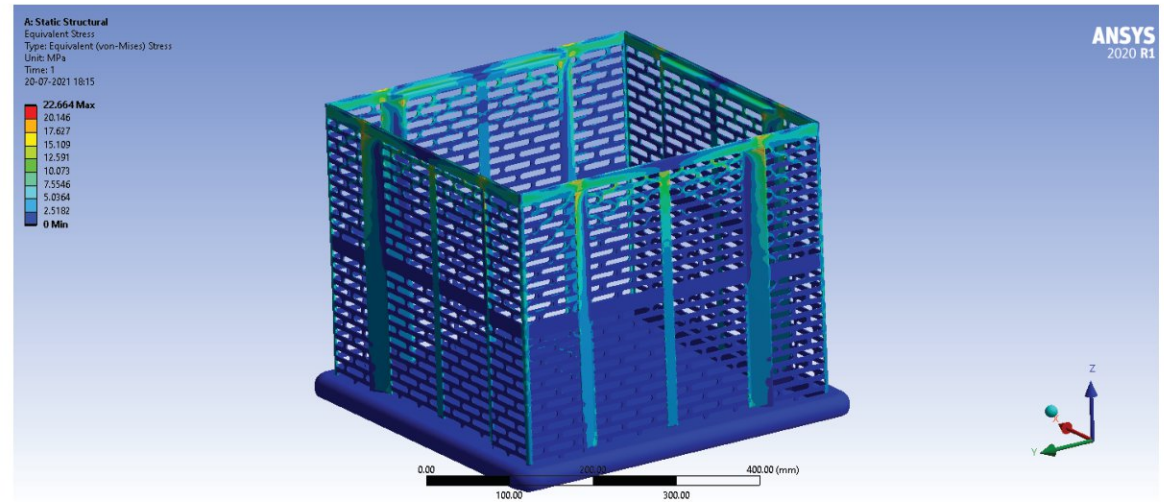
Force Illustration

When the product is lifted by using the handle and being supported at the back, two forces act which leads to formation of two moments with a single pivot. The back acts as the pivot, the handle provides a lifting force and at the bottom another force is formed due to self weight and gravity. These two create two moments in two different directions. These moment forces are withstood mostly by ropes and partially by blinds.



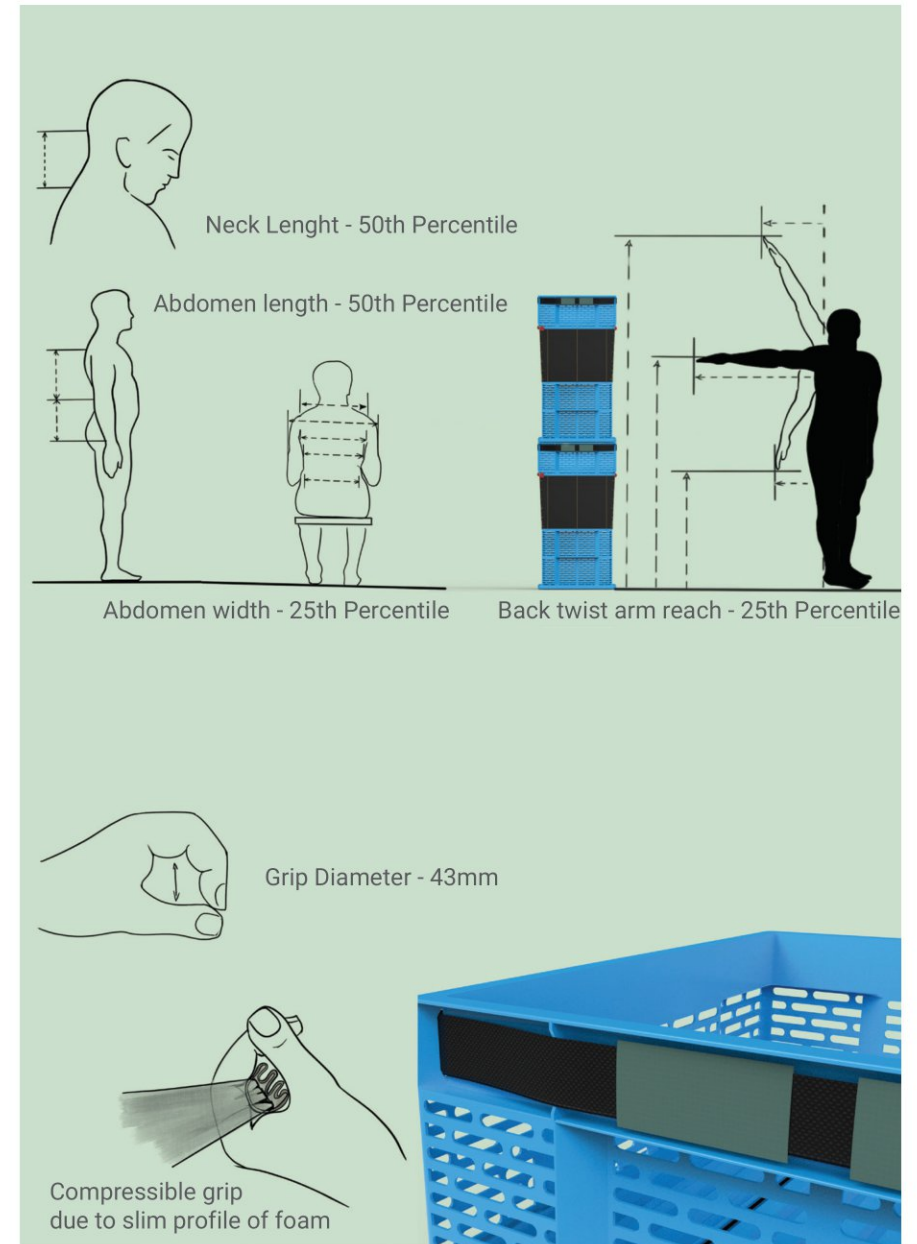
Load Analysis

The product is load test using ansys structural analysis by applying three times the products maximum load carrying capacity (i.e 80kgs x 3 = 240Kgs). The maximum stress formed is within the maximum tensile strength of the material. There was no buckling been observed in the analysis.

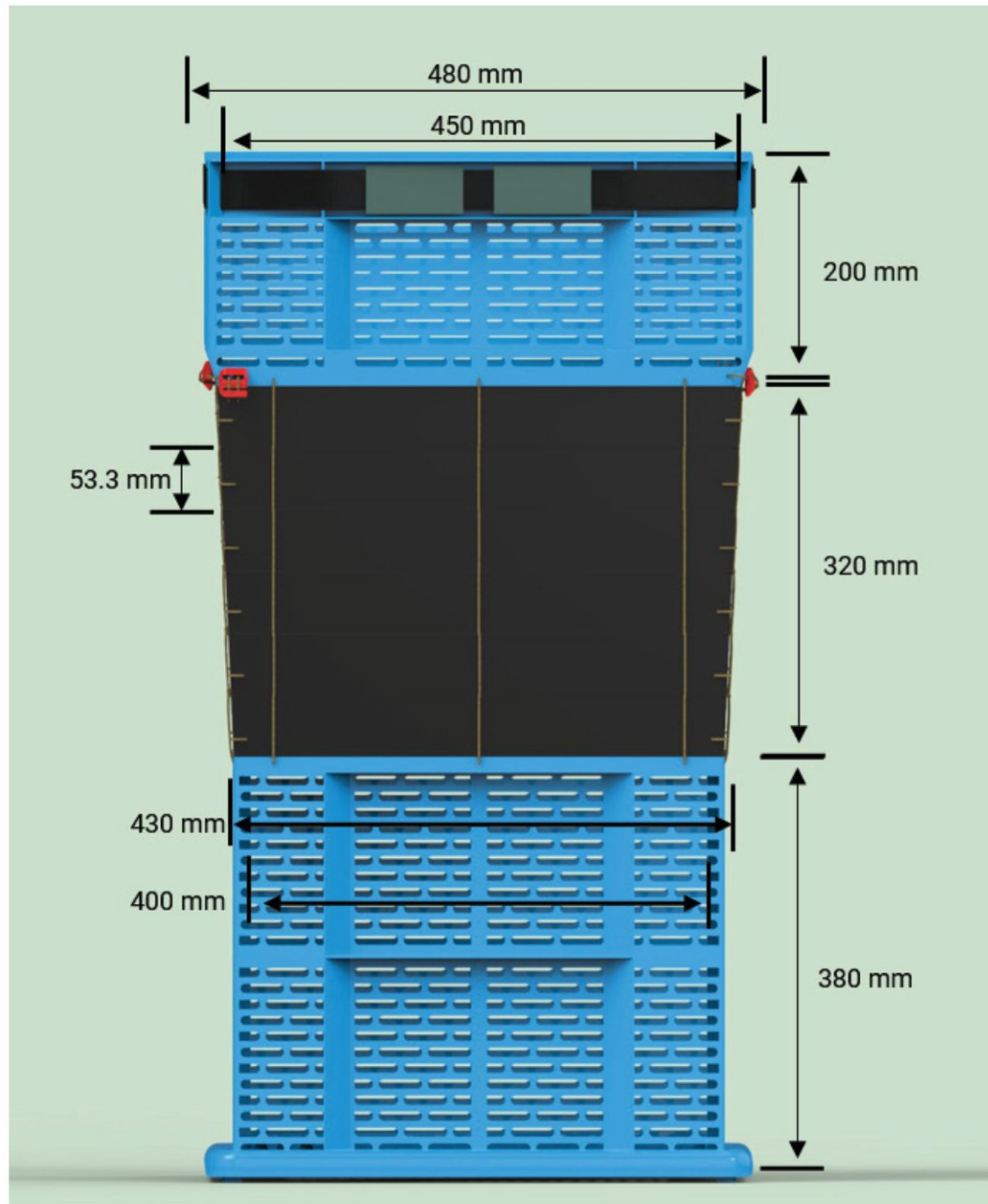


Anthropometry

The Length, width and height of the products are determined by carefully considering the need and usage aspects and based on the percentile is determined and according to that the relevant anthropometric dimensions are used in defining the dimensions of the product.

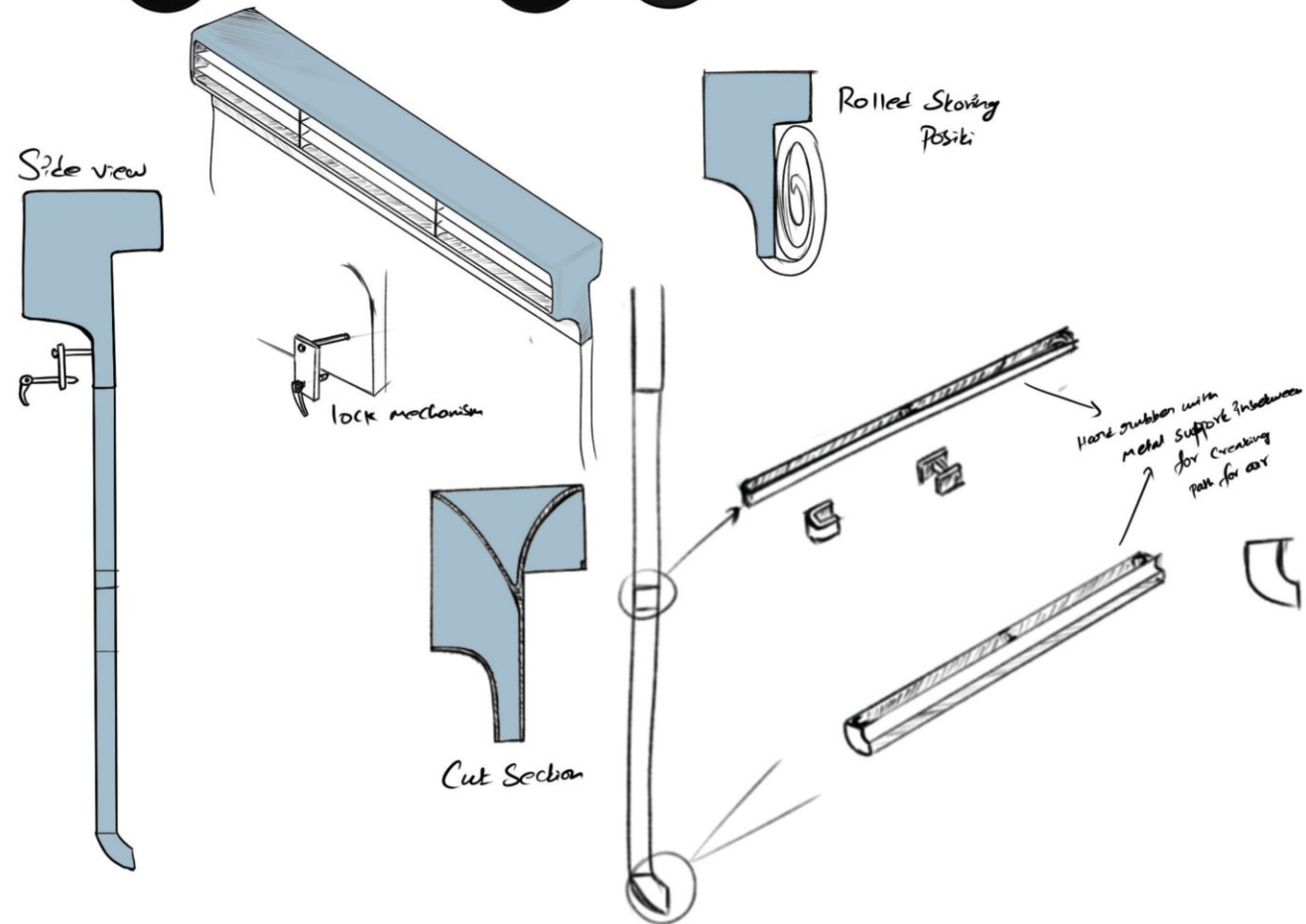
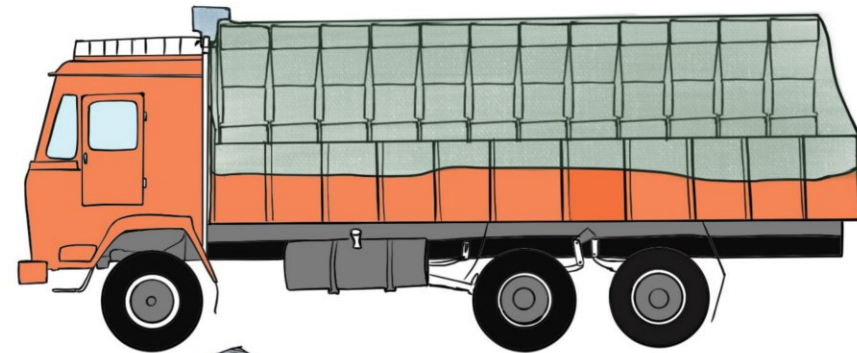


Dimensions

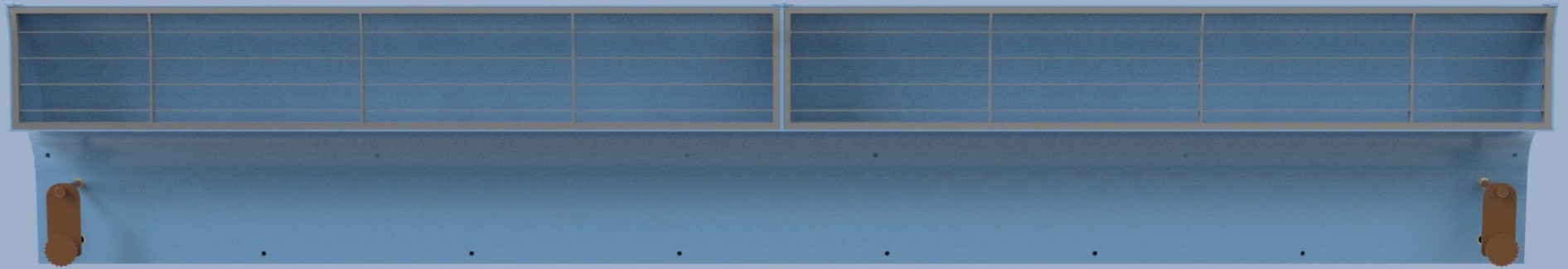


Cooler Design

Cooling is also part of the requirement and also a main component of the design brief. It was highly not practical to incorporate cooling in the product itself, because when it is stacked they are tightly packed with only ample space for air flow. So a separate product for cooling is designed which forms as a system with the proposed product. As mentioned in the ideation this cooler uses the wind catcher concept. The cooler is attached to the payload area's front face.

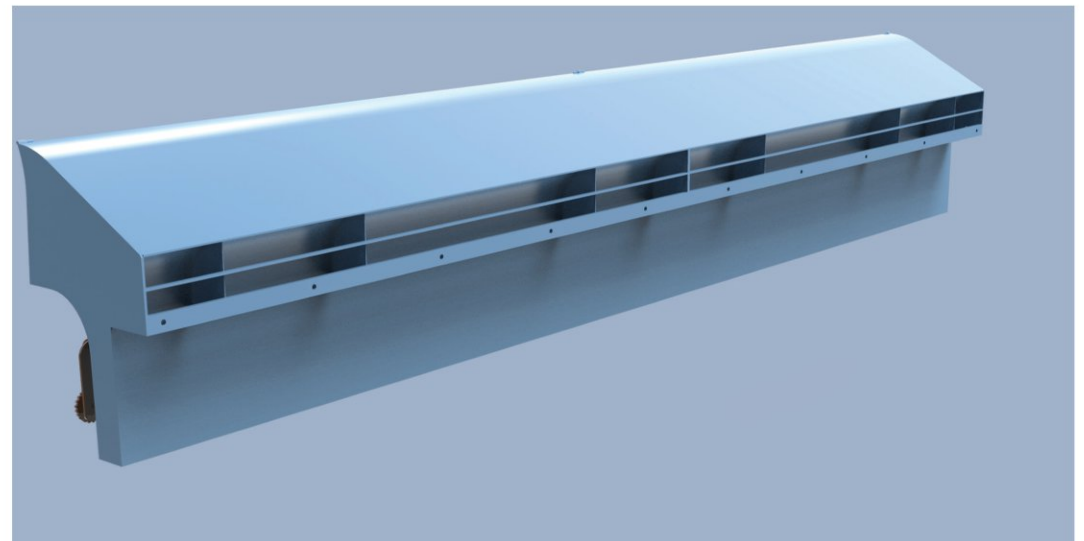
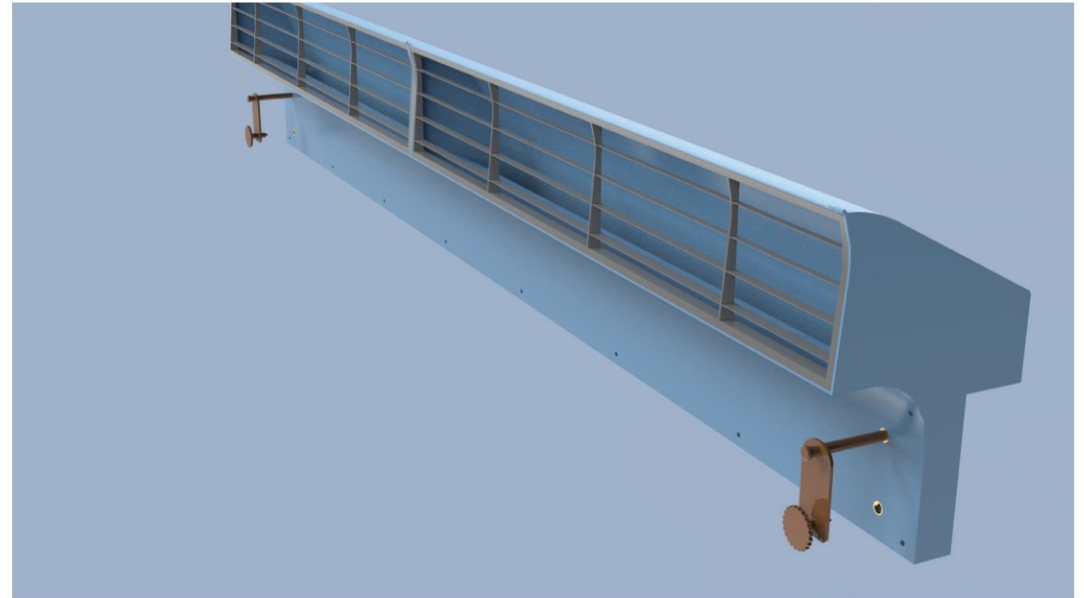


Cooler Design



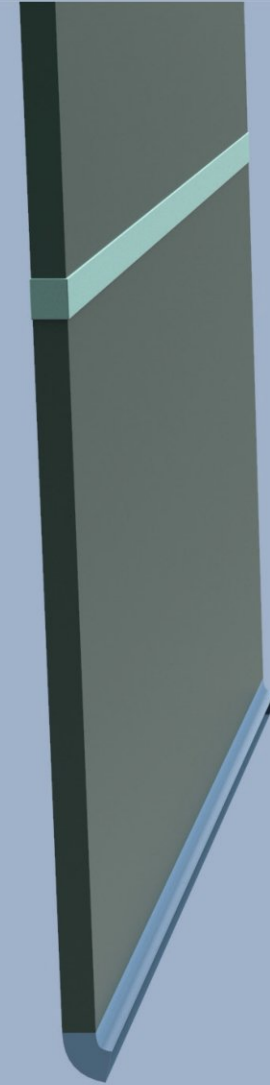
Cooler Design

The grills and ribs of the cooler are given for structural rigidity and as well as to avoid trapping of living things such as birds and other small animals. The inlet is made big because to achieve the funneling effect and the outlet is kept small for giving more space for collecting the hot air and stacking product space.



Cooler Design

The main cooler part is made of plastic and the inlet passage is made of tarpaulin which has 2 supports made of rubber reinforced with metal pieces. It is kept so that while stacking, users should not block the inlet passage by pushing the container against it and compressing it.

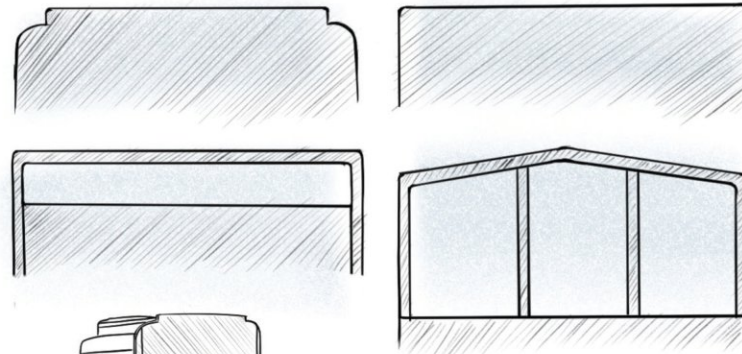


Cooler Design

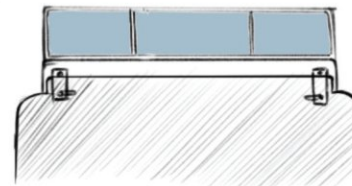
The users use different companies' lorries and trucks. All the trucks and lorries are analysed and it is found it has these four common shapes of payload front surface. Half of them are fully solid and half of them are hollow made of metal frames. A locking mechanism should be designed to lock both hollow and solid shapes with minimal changes to the mechanism. This is solved by having a sliding plate and two different length bolts. In the case of a solid section the bolt will tighten against the solid section and lock it. In Case of the hollow section, a long screw will pass through the section and get screwed on the cooler part so the sliding plate is tight against the frame and completely locks it.

Locking concept detail

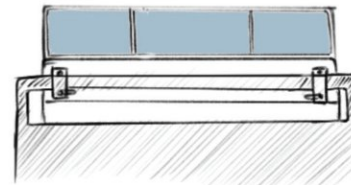
Different Shapes of Payload front side.



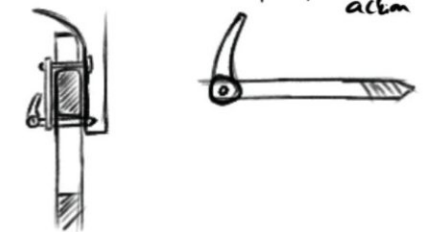
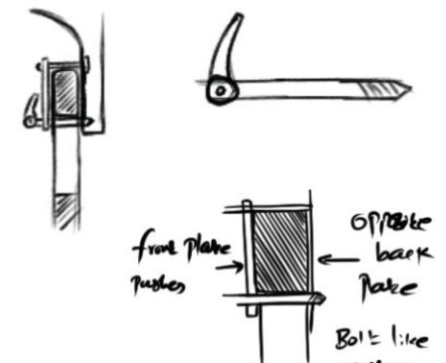
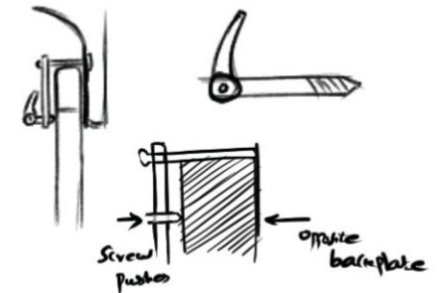
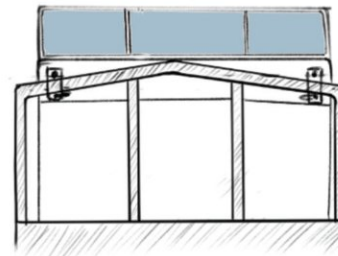
mechanism for Solid Section



mechanism for hollow section

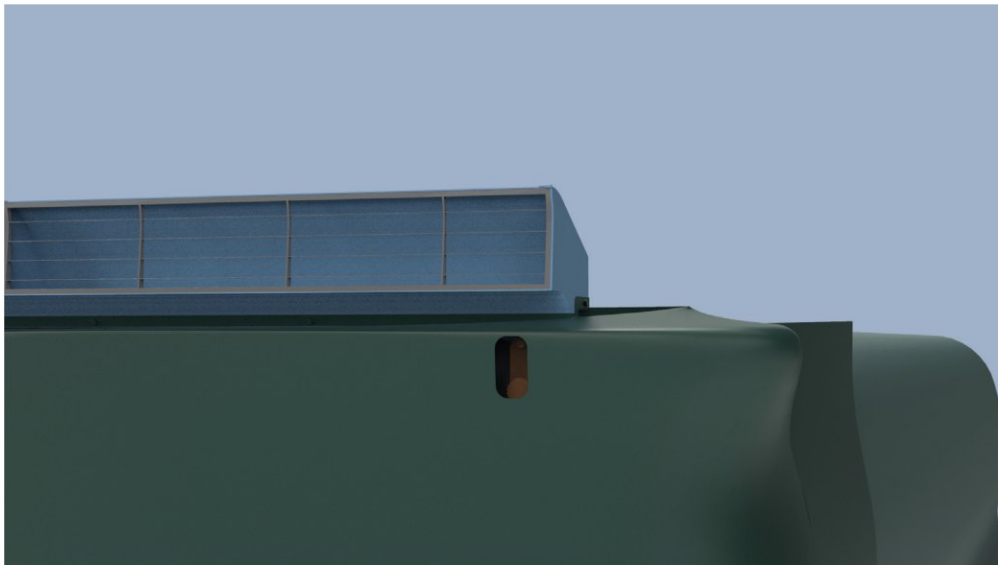
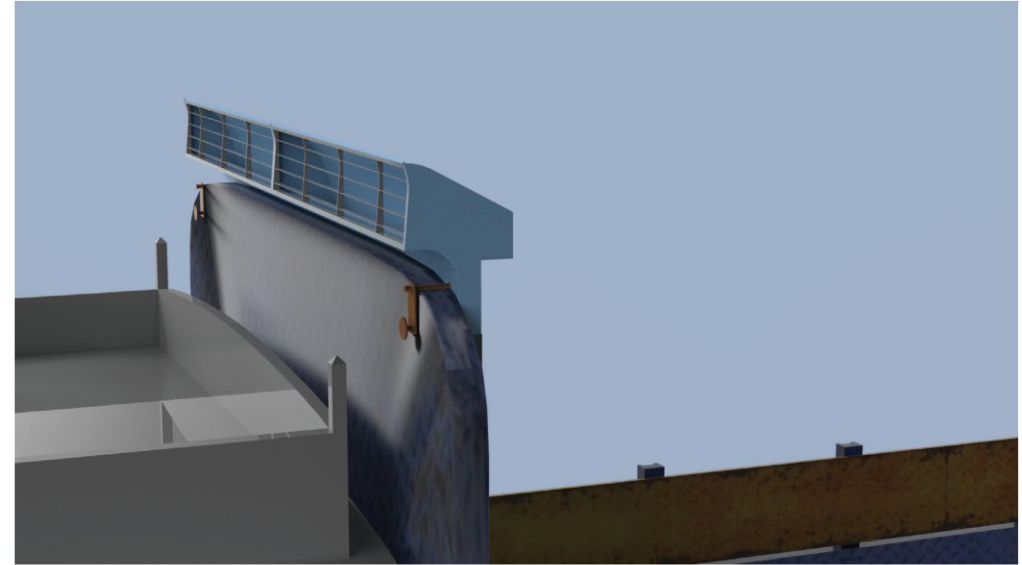


mechanism for tapered hollow section



Cooler Design

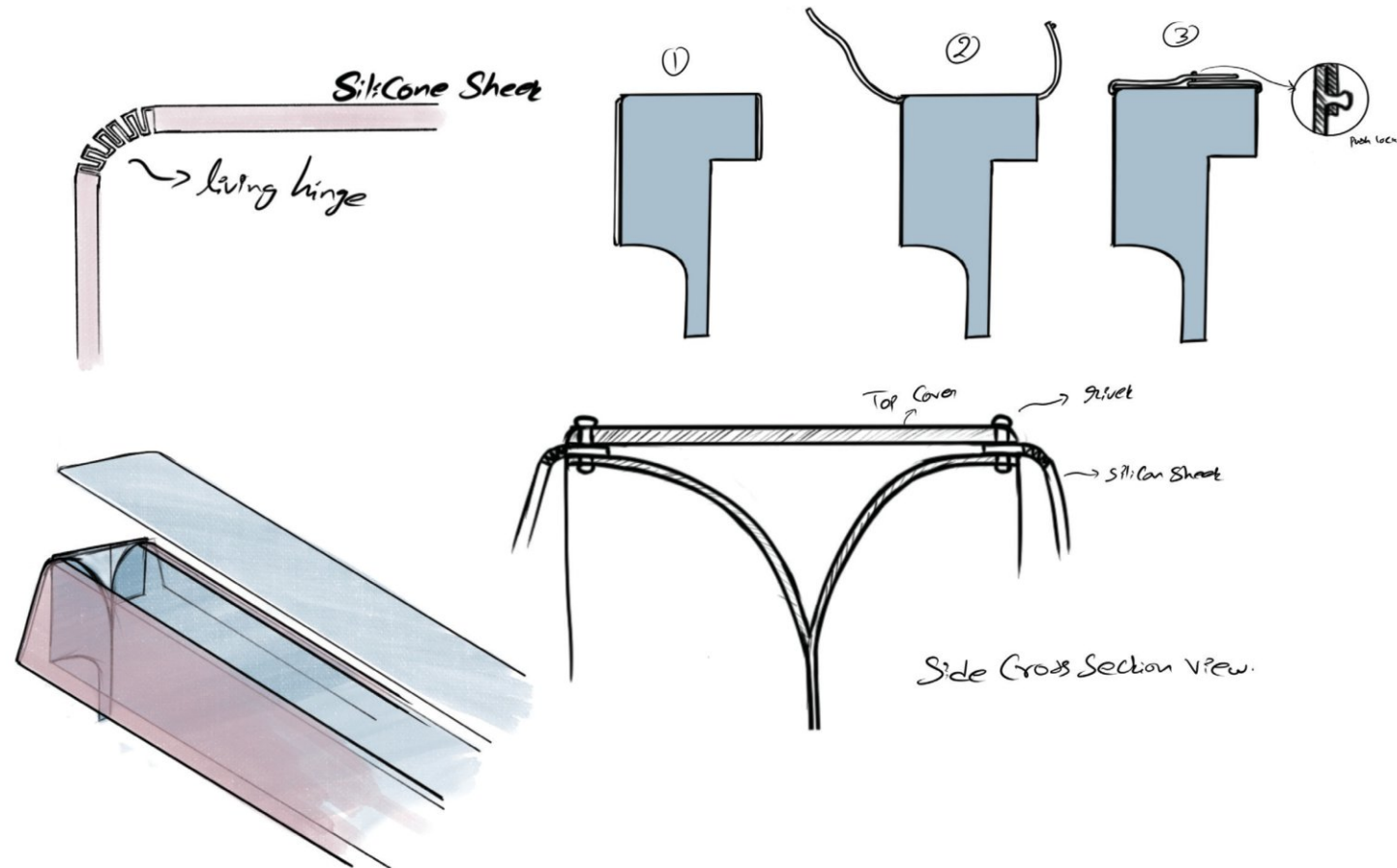
The images shows the locking mechanism rendered images and how the lock can be reached if it is covered with tarpaulin.



Cooler Design

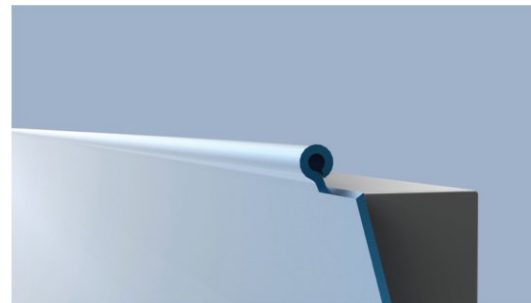
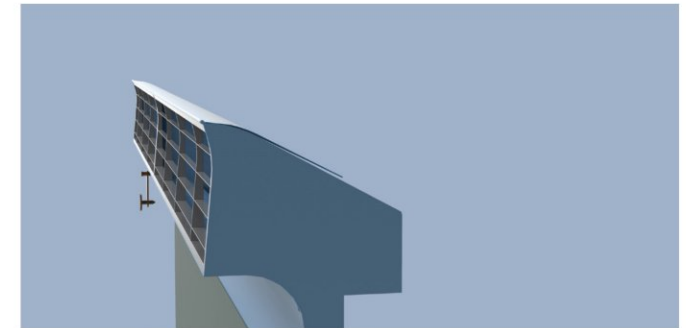
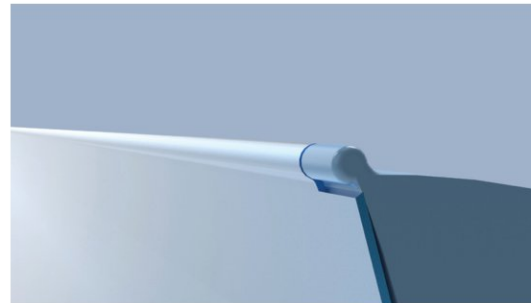
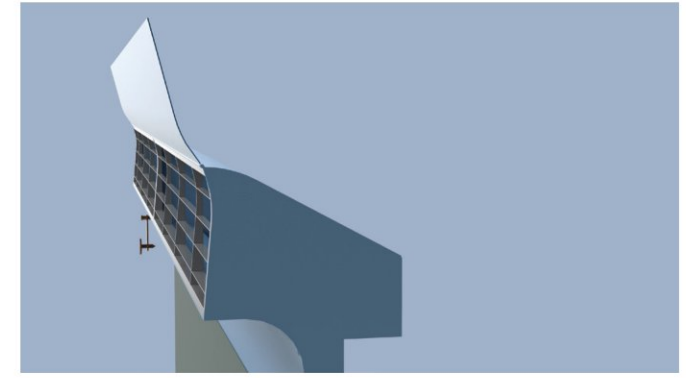
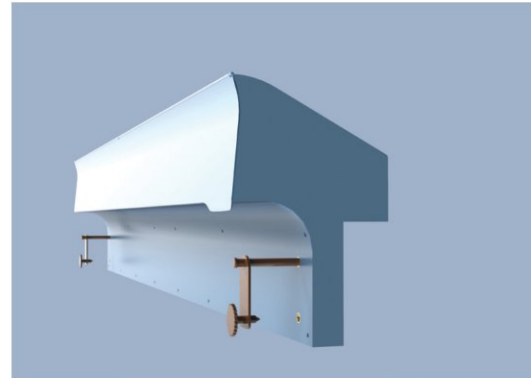
The cooler concept works well normal on and sunny days. During winter days cooling mostly is not required and to avoid rainwater to enter into the payload area, the inlet and outlet areas should have to have a flap covering them. Since the cooler is a longish product, having a long hinge is problematic in many ways. So Silicone/ rubber is chosen to act as flaps since it is denser than plastic it will close the inlet and outlet areas with self weight without locking mechanisms. The hinge is made by a laser cut living hinge. and the sheet is simply riveted on top of the product.

Cooler cover concept detail



Cooler Design

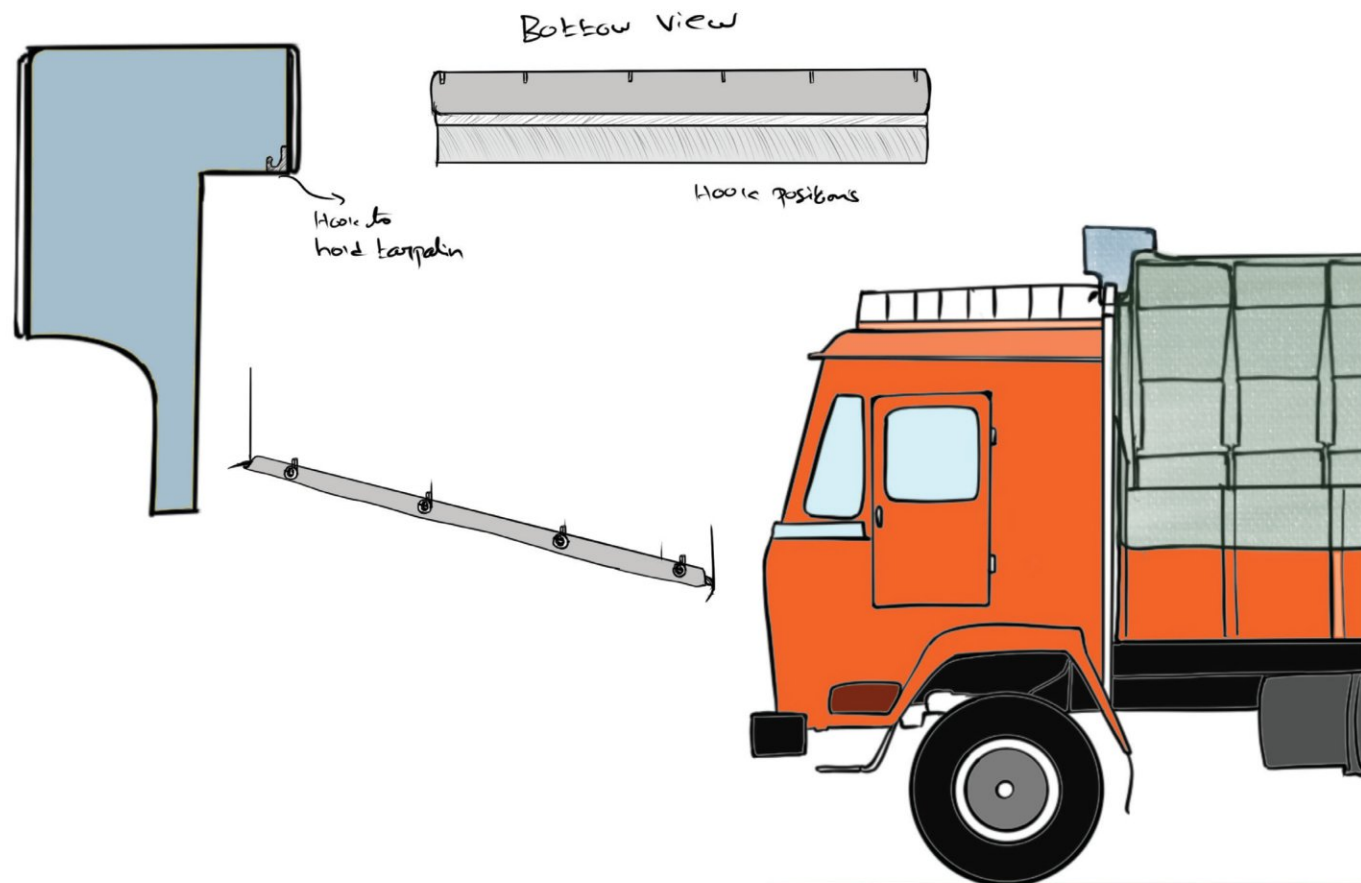
The live hinge design is prone to failure when it is used repeatedly for large structures. so the standard hinge design is used. The cover profile is made such that it perfectly takes the profile of inlet and as well as the top surface when it is opened. This cover profile doesnt a lock to keep it in place because the profile keeps in position when air flows against it either in opened or closed position. The cover is made of stainless steel considering the harsh environmental usage and aesthetics of the truck.



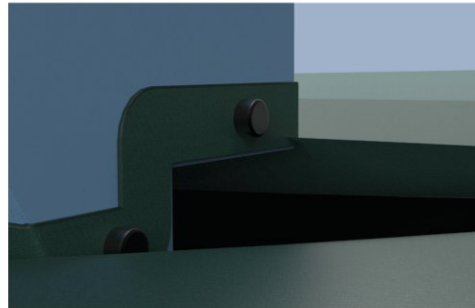
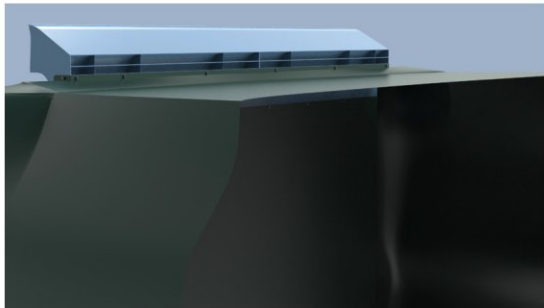
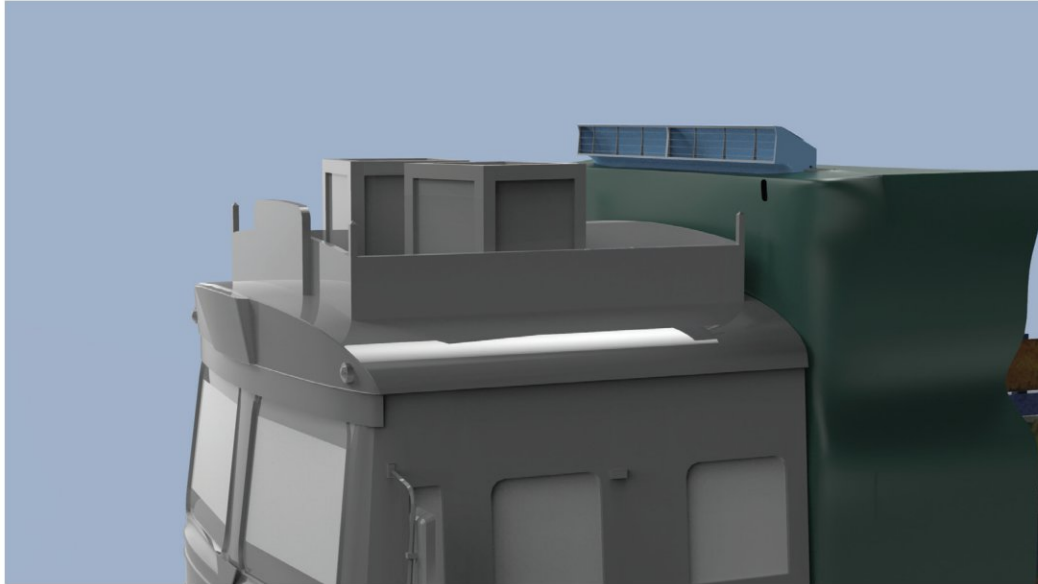
Cooler Design

The Tarpaulin which covers the storage container is connected to the cooler on the outlet area. There are hooks in the cooler and holes on the tarpaulin it is simply hanged on the hooks and tied around the cooler and the storage just like the users actually do. So, that it will form closed system.

Cooler-Tarpaulin connection detail

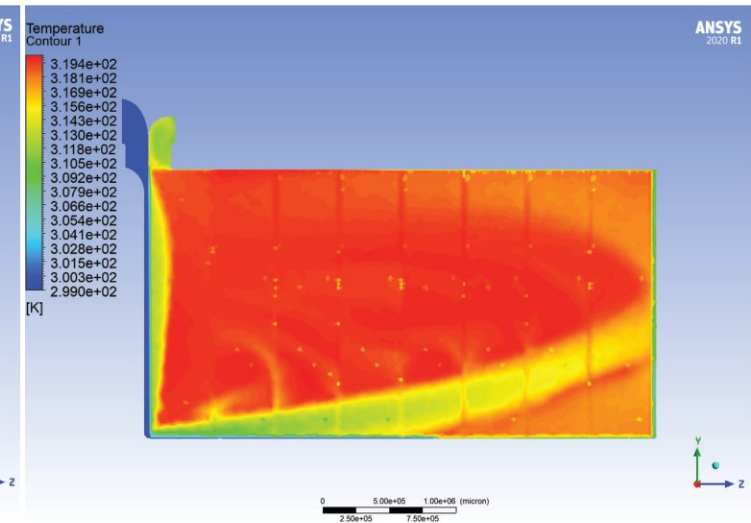
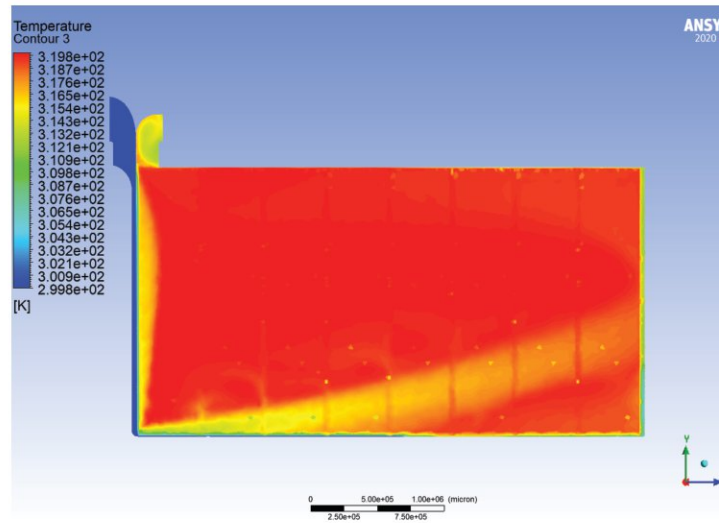
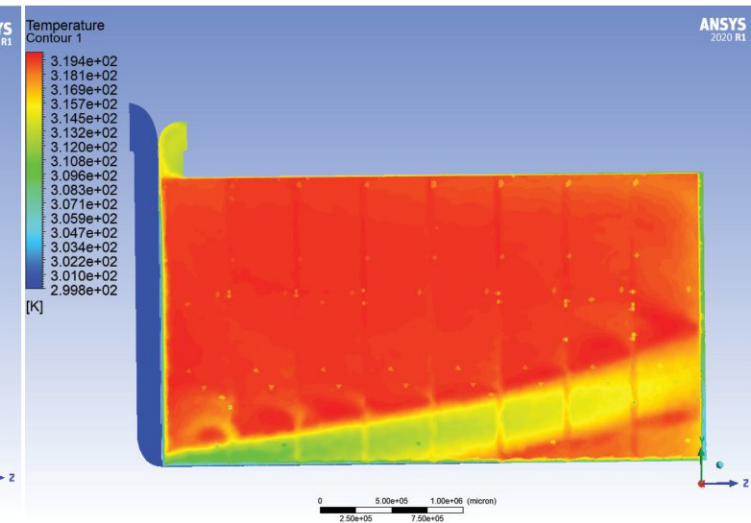
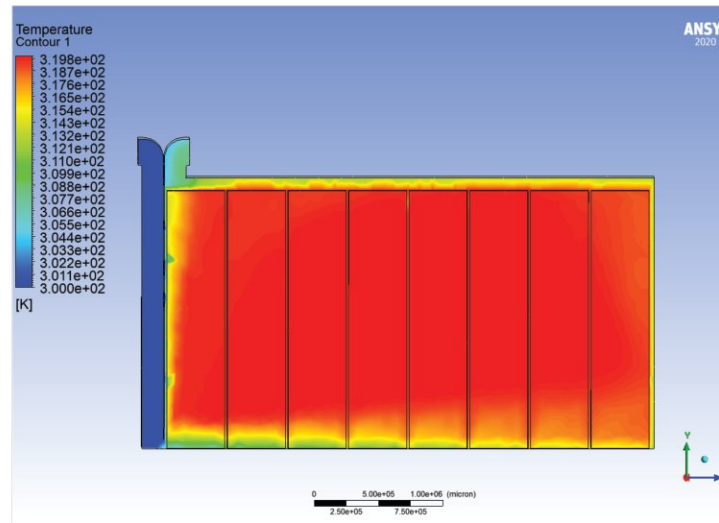


Cooler Design

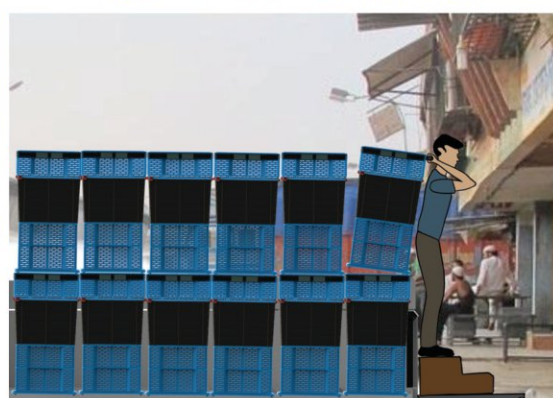


Cooler Analysis

The efficiency of the cooler is analysed using Flow analysis in Ansys fluent by making a simplified version of the stacked storage containers with inlet and outlet passage resembling the cooler setup. The first image has both inlet and outlet of same size and bottom of the storage containers are completely sealed only 10mm gap is left in between them which results in a poor air flow, The top second shows the result of increased inlet size and bottom of the inlet passage is funneled leading to force the air to the end and giving a gap of 5mm at the bottom of storage containers leads to taking the hot air out. The bottom two images are modelled as close as possible to the exact setup. The first image shows the air flow when the inlet receives 5 kmph of air and the second image shows the result of 20kmph. These results clearly show that the cooler is highly efficient, considering the electricityless design.



System Illustration



Materials

Considering the harsh environmental usage such hot sunny days, heavy rainy days, exposure to air pollution, etc and it shouldn't react in those conditions and as well as it should be food grade and high strength requirements, polyethylene is suitable plastic for both container and cooler. The material for the rope is chosen as nylon since it has high tensile strength and can handle harsh situations. The stainless steel sheets are chosen for cooler cover and the rest is covered with tarpaulin.



Conclusion

This project tries to provide a solution to reduce the loss due to damage of vegetables without causing additional difficulties to the stakeholders. People assume the loss happens is necessary for profit. This project tends to change that mindset by showing how much amount of vegetables can be saved. This objective is achieved by this design of a system with a container and cooler. The container has some probable weak points which have to be determined whether it is utterly weak or it just only poses as weak through experimenting in real usage scenarios which become impossible due to covid situations. So, the concept is limited to the mockup part only.

The reflections of the project is, the focus should have to be more on the stakeholders involved, how and who will procure and circulate the containers. The future scope of this project lies in the complete system level deployment of the proposed product and finding the pain points in the system due to the proposed product and changing the design according to it.

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