



Airbel Impact Lab
Research & Innovation at the IRC



wazoku

DESIGN PROPOSAL



Prepared by

SAMUEL KARURU & REGINAH ONYANGO

Abstract

The approach to design was rather simplistic. We drew inspiration from existing corrugated box patterns in other packaging industries. Our innovativeness was in a folding pattern that would ensure maximum strength and rigidity without permanent joinery to facilitate unfolding and storage. The size of the box is almost exactly as it was before (60cm x 40cm x 20cm). This means that all the previous packaging plans can be maintained. Another aspect that was key in the design was making sure that the folding pattern would protect the items in the box even in rainy conditions (for example at the back of an open pick-up truck). The box itself cannot be destroyed by moisture or wet conditions due to the material selection.

Corrugated polypropylene structure hollow sheets were chosen for this design(Omnexus, 2023). Below is a list of some of the reasoning behind this choice:

- Fire retardant
- Light weight
- Excellent flexural strength, High compression resistance
- High thermal insulation
- Waterproof
- UV resistance
- Food grade (Considering that medical supplies will be transported)

This material is already being used in similar applications such as transportation of vegetables and fruits. It is therefore not a completely novel idea and was therefore highly suited for this project.

Conclusion

We have gotten in touch with the suppliers of all the materials already. The links are provided in the captions of the photos. There are also some quotations attached to the document. Overall, the cost of one box **per year** is about **USD 4.61**. This is about **68.8%** cheaper than the current solution. Of course, there are other costs involved such as material handling and logistics after shipping to the main port. In any case, we still expect that our solution will still be at least **60%** cheaper than the existing solution.

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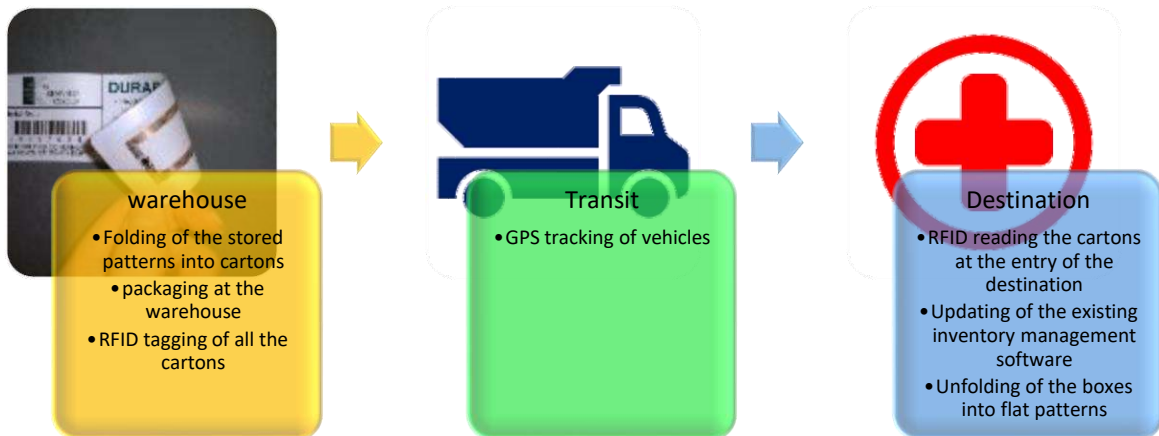
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Detailed Description



Figure 1: A render of the final product

Logistics



Trackability



RFID was chosen as the ideal method to track the items at the points of dispatch and at the destination. RFID offered many benefits with the main ones being low cost and the ability to be integrated into the existing ERP inventory system already in place. This will greatly reduce the workload during auditing. The choice of using handheld readers or fixed readers is very case specific. In this case, handheld readers are better suited due to ease-of-use, mobility and flexibility.



Figure 2: https://www.alibaba.com/product-detail/Long-range-Read-UHF-RFID-C72_1600617739500.html?spm=a2700.galleryofferlist.p_offer.d_image.4c446dcfjk3Qef&s=p

Note: Remember to match the selected reader to the right tags depending on the communication protocols.



Figure 3: https://www.alibaba.com/product-detail/Low-Cost-Warehouse-Management-UHF-Sticker_1600845074547.html?spm=a2700.7735675.0.0.4796f4DEf4DEvz&s=p

If there ever arises a need to know the exact location of the trucks or boats transporting the items, a cheap mini GPS tracker can be put in one of the boxes within each batch.

Tamper Proofing

We believe in a certain level of accountability for all the involved parties involved in the transportation. That is why we propose a method where we have clear evidence of tampering with the packaging. These locks are off the shelf products and come at a cheap price as you will see in the costing section. They will be attached to the polypropylene sheet by means of riveting. It is critical to select a design of the hasp and staple that will facilitate storage without damaging other sheets (i.e., smaller and without sharp edges).



Figure 4: https://www.alibaba.com/product-detail/Furniture-student-cabinet-hasp-lock-and-62550905172.html?spm=a2700.galleryofferlist.normal_offer.d_image.77abf09cRb7Qxs

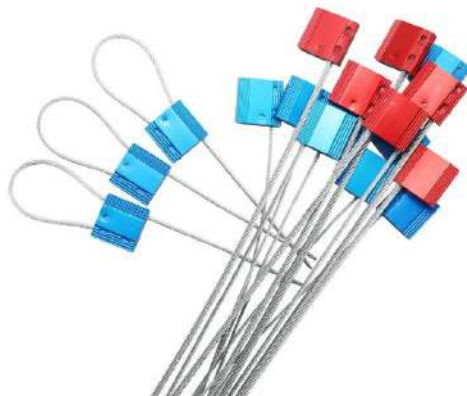


Figure 5: https://www.alibaba.com/product-detail/Cable-Seal-Rfid-Security-Tamper-Proof-60764599399.html?spm=a2700.galleryofferlist.p_offer.d_title.72cc7517hwDR6C&s=p

This is a single-use reliable lock which once put in place it cannot be unlocked unless by destroying it. It is made up of an aluminum body and a steel cable and therefore accidental destruction during transportation is next to impossible. This will be used in combination with the steel hasp and staple lock that is securely rivetted in the box. The cost of this is about \$0.15 per piece.

Temperature Monitoring and Control



The control of the temperature inside of the box is purely passive and incredibly efficient due to the selection of the material. Choosing Polypropylene sheets made with a hollow structure means that the inside of the box is shielded by a layer of air around the box due to an extremely low thermal conductivity of 37.1 mW/mK (Yang et al., 2021). This means that if the packaging is done in temperatures below 30 degrees Celsius, it is highly unlikely that the temperature of the inside of the box will ever go beyond that during transportation.

Our system uses temperature strips that record the highest temperature reached during transit. The strips are single-use and very cheap. The strips have an adhesive surface and can be put on the inside wall of the box. Ultimately, depending on the contents of the box, the team at the receiving end will determine if the products are still fit for use or not. The temperature strips come in different temperature ranges too.

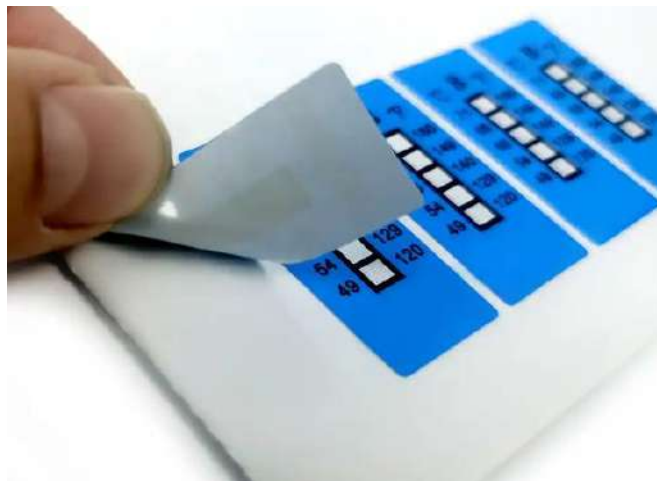


Figure 6: https://www.alibaba.com/product-detail/Color-Label-Changing-Stickers-Change-Customized_60578008313.html?spm=a2700.galleryofferlist.p_offer.d_image.21bd6d7feXx0Sy&s=p

Rigidity, Durability & Storage

Owing to the material selection and the nature of the folds, we approximate that the box can be used repeatedly for about 20 cycles. The corrugated polypropylene sheets proposed can carry up to 40kg for the 1200gsm specification. A good settle would be the 900gsm that can carry up to 30kg (based on the supplier whose quotation is attached to the costing section). This means that the boxes can be used for about 5 years (4 Cycles per year). This is a very conservative approximation based on usage of polypropylene sheet boxes in similar transportation scenarios involving vegetables.



Figure 7: <https://www.corrugatedplast.com/PP-Corrugated-Sheet-Appl/>

Storage

After every use, the boxes will be unfolded and stored in the flat-pattern form as shown in the figure below. The hasp and staple remain attached by rivets on the flat sheet.

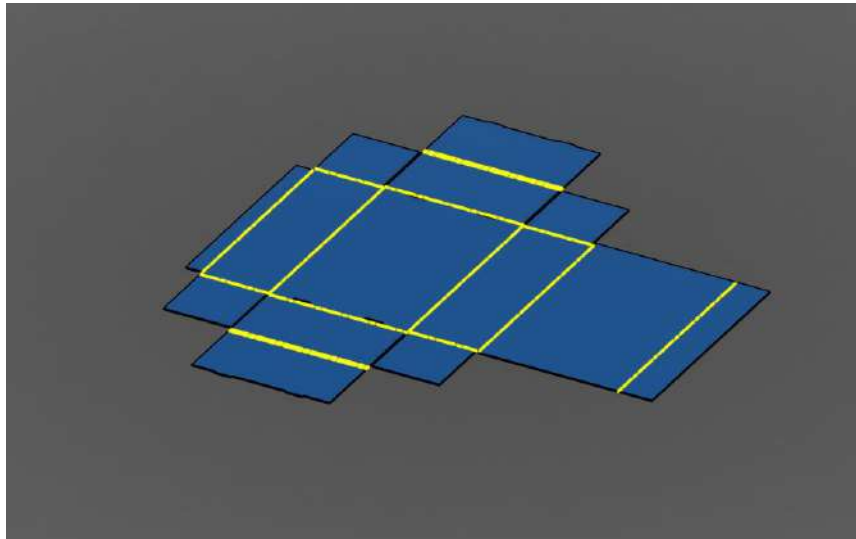


Figure 8: Flat patterns unfolded and ready for storage.

Detailed Drawings

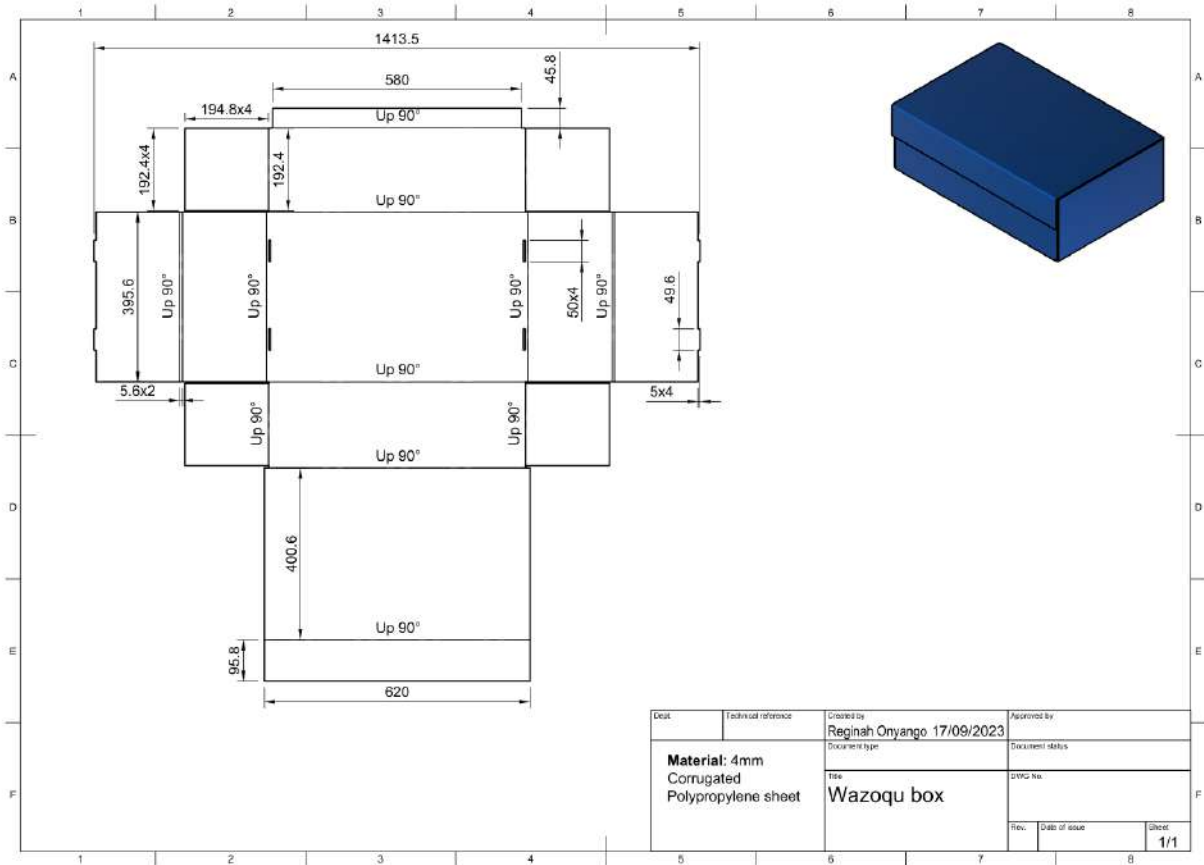
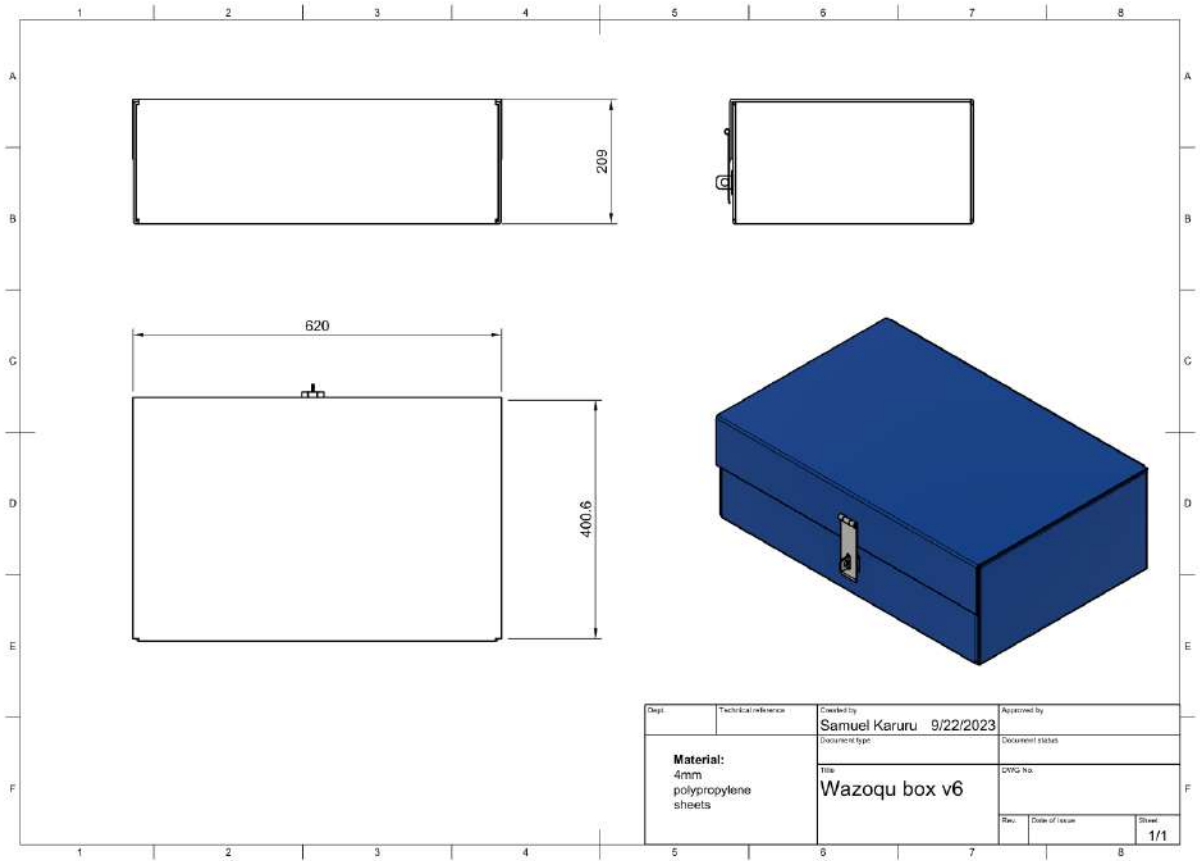


Figure 9: Annotated drawing showing all leading dimensions and bending instructions.



For CNC cutting purposes, please find the DXF file in this google drive link:

<https://drive.google.com/file/d/1GPxHOPmZVI2Kh7-z66C3QwmPTgQGKKgf/view?usp=sharing>


The diagrams above are sufficient for prototyping. Attached the link below is a video simulating the bending of the folds of the flat pattern:

https://drive.google.com/file/d/1eLzXdQlWrVmm0_CzalAfwTJpp0tputj4C/view?usp=sharing

Overall costing




Please note that there is a division of some of the prices in the costing table by **5**. This is to account for the fact that our product will be in use for approximately 5 years given the conservative approximation of **20** cycles. Also take notice of how the one-time use parts such as the aluminum cable lock and RDIF tags are multiplied by **4** in the quantity per year. The number of RFID readers chosen was **10**. This is of course very biased as this number should reflect on the convenience in terms of time saved during tracking.

 Quotation Sheet						
Date:6th Sep.2023						
Supplier	HEADYPHOON(SHANDONG) NEW MATERIAL TECHNOLOGY CO., LTD Address:West Courtyard,1500 meters south of the intersection of Shanquan Road and Zihe Avenue,Fujia Town,Zibo Economic Development Zone, Zibo City,Shandong Province P.R China Contact: Karen Tel:+86 15953307617 Email : sales2@headypphoon.com					
Product Name	Size	Thickness	gsm	Quantity (pcs)	FOBQingdao/PC	Total
pp corflute sheet	1220*2440mm-4*8ft	4mm	900	1000	\$4.720	\$4,720.00
pp corflute sheet	1220*2440mm-4*8ft	4mm	1200	1000	\$6.0900	\$6,090.00

1.packing: PE film with pallet;
 2.Port:Qingdao ,China;
 3.price valid: 7 days since today ;
 4.Delivery time:partial shipment7-15days after receive 30% deposit;
 5.payment:T/T,L/C

Figure 10: Cost of buying 8x4 sheets.

 Quotation Sheet						
Date:7th Sep.2023						
Supplier	HEADYPHOON(SHANDONG) NEW MATERIAL TECHNOLOGY CO., LTD Address:West Courtyard,1500 meters south of the intersection of Shanquan Road and Zihe Avenue,Fujia Town,Zibo Economic Development Zone, Zibo City,Shandong Province P.R China Contact: Karen Tel:+86 15953307617 Email : sales2@headypphoon.com					
Product Name	Size	Thickness	gsm	Quantity (pcs)	FOBQingdao/PC	Total
pp corflute sheet	1600*1400mm	4mm	900	1000	\$3.630	\$3,630.00
pp corflute sheet	☺ as your design	4mm	900	1000	\$3.8600	\$3,860.00

1.packing: PE film with pallet;
 2.Port:Qingdao ,China;
 3.price valid: 7 days since today ;
 4.Delivery time:partial shipment7-15days after receive 30% deposit;
 5.payment:T/T,L/C

Figure 11: Cost of getting the sheets already die-cut in China.

Material	Description	Quantity	Unit Price in USD	unit per cycle (divide by 5 for some)
Polypropylene sheet	Custom Size and die cut	1	3.860	0.772
Hasp and staple lock		1	0.600	0.120
rivets	As per hasp and staple holes	8	0.001	0.002
Tamper proof cable lock		4	0.150	0.600
Rfid Sticker		4	0.060	0.240
Approximate shipping price per box (One off)		1	4.928	0.986
Temperature sticker	Indicated maximum temperature in transit	4	0.300	1.200
Material Cost	Price shared by total number of boxes			3.919
RFID readers	At departure and arrival points	10	490.000	0.131
Labor Cost	Number of hours x Cost per hour	0.117	4.770	0.557
Total Cost	USD			4.607

Process of prototyping

We propose the building of a 1:1 scaled prototype that will give a true picture of the final product. If this is not possible due to time constraints (i.e., importing the 1.4m x 1.4m sheet), you can scale the provided DXF <https://drive.google.com/file/d/1GPxHOPmZVI2Kh7-z66C3QwmPTgQGKkgf/view?usp=sharing> drawing based on the available material size.

Materials

- Corrugated polypropylene sheet: A sample can be ordered from Alibaba and the price should be below \$4 excluding shipping. Please find attached the contact of one of the suppliers in the quotation in the costing section.
- Hasp and staple lock: Here you have a choice of whatever is already available in Sierra Leone, but we also propose ([click here](#)) which is slim, resistant to rusting over our proposed period of 5 years.
- Cutting equipment: Ideally, get in touch with any branding company in Sierra Leone that owns a drag knife CNC or a CNC wood router. Otherwise, you can get away with constructing the geometry manually according to the DXF attached in this document. If you decide to go this very manual way, you will need a utility knife.



- You will need a blunt chisel to create the bending lines on the sample after cutting. We will give a detailed description of how this can be done in a mass production setup later.
- Pop rivet gun and rivets.



Procedure

- Cut the polypropylene sheet using a CNC-drag-knife machine/construct the flat pattern on the polypropylene sheet and cut the profile with a utility knife. Make sure to use a straight edge to follow the lines (If you are using the utility knife method).
- Using a straight edge and a blunt chisel (other blunt object may suffice), create the indentations where the pattern will be bent.
- Fold the pattern following the numbers as instructed in the DXF. Additionally, you can check this video here:
https://drive.google.com/file/d/1eLzXdQIWrvmm0_CzalAfwTJpp0tppuj4C/view?usp=sharing
- Use a marker to mark the positions of the holes for the hasp and staple lock. You can use a center punch or a cordless drill to make the holes in these marked points.
- Rivet the hasp and staple lock onto the box using a riveting gun and voila!

Mass Production



- **Die cutting in China.**
- **CNC drag knife cutting locally.**
- **Die cutting setup locally.**

All the above were viable options for mass production of the boxes. Generally, die-cutting in China proved to be the cheapest option. Getting a local CNC or die cutting setup are both very easy solutions but additional overheads such as training, power and salaries to operators will simply make the box more expensive.

However, if you are interested in this option, our team has a lot of experience in building and operation of CNC machines. We would be in a good position to guide.

Circularity



To ensure that our solution falls within the sustainability goals. We felt that it would be important to see how all the waste from the box can be recycled (reused in some cases).

- The locks can be removed and donated for use in school furniture such as wooden lockers.
- The damaged locks can be recycled through local steel scrap companies.
- The used polypropylene sheets can be recycled into items such as paving blocks in order that they are not just disposed in landfills. Additionally, there are other more interesting projects using recycled polypropylene such as outdoor furniture. If you are interested in collaborating within such domains, it is a conversation we can have.

Future Collaboration

Reginah Onyango has a background in Mechanical Engineering and is currently working in one of the largest electric bikes manufacturing companies both in design and in production management. She is certified by Autodesk as a CAD engineer and is highly skilled in CNC technologies.

<https://www.linkedin.com/in/reginah-onyango-47482aa3/>

Samuel Karuru is a passionate engineer currently pursuing a masters in Mechatronics Engineering under the prestigious double degree program of ETH Zurich and Ashesi University. He is an expert in using computational methods for design. www.linkedin.com/in/samuel-kamunyu

This team is passionate about human centered design and making a positive impact in society. We are therefore open to working with you in future as consultants and even actively in designing and building ingenious solutions, especially in marginalized societies where these kinds of impacts are desperately needed.

References

Omnexus. (2023). Polypropylene (PP) - Types, Properties, Uses & Structure. In *Omnexus: The material selection platform*. <https://omnexus.specialchem.com/selection-guide/polypropylene-pp-plastic>

Yang, C., Zhang, Q., Zhang, W., Xia, M., Yan, K., Lu, J., & Wu, G. (2021). High thermal insulation and compressive strength polypropylene microcellular foams with honeycomb structure. *Polymer Degradation and Stability*, 183, 109406. <https://doi.org/10.1016/j.polymdegradstab.2020.109406>