

Design of Affordable Coldstorage for Horticulture Products (Urban Farming "Mom's Farm" in Sampora Village)

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Abstract. *Growing the world's population to almost 9.7 billion by 2050 will continue to address the challenges facing the food and agriculture sector. The aim of this study is to reduce food losses in Sampora Village, Cisauk – South Tangerang by creating an affordable cold-storage of Modified Atmosphere Storage (MAS) equipment with a capacity of 4.77 m³ so that it can increase the quality of food for a longer period without deterioration of the horticultural products stored. Temperature control, humidity control, air circulation, maintenance of space between containers for adequate ventilation, total capacity, dimensions, efficiency, development costs, durability, performance, and features are involved in the design. This cold storage is designed with a Design Thinking method. A qualitative research was conducted through interviews to gain insight and synthesize the needs. The selection prototype concept was chosen by the Pugh Matrix and finally this study proposed in an affordable cold-storage technology.*

Keywords: design thinking; frugal innovation; pugh; the cold-storage; urban farming

I. INTRODUCTION

As the world's population is projected to grow to almost 9.7 billion by 2050 and the demand for food and agricultural products is expected to increase by 60 percent over the same period, there is a concern about food safety and security around the world (The World Bank, 2019). Consequently, there is an urgent need for action to reduce the world hunger, achieve food security, improve nutrition, and stimulate sustainable agriculture as the second of its 17 Sustainable Development Goals (SDGs) for 2030 (FAO, 2018). To meet the second SDG (SDG 2) of

achieving zero hunger by 2030, countries are faced with a major challenge in finding a solution on how to secure food and to reduce waste. According to Food and Agriculture Organization of the United Nations (2018) roughly one-third of food produced for human consumptions is lost or wasted globally which is estimated to about 1.3 billion tons per year. Food loss and waste in the global food supply chain have a significant impact on the lost and wasted (Parfitt, et al., 2010). The food loss often occurs during the production, post-harvest, and processing phases in the food supply chain (Parfitt et al., 2010).

As part of Atma Jaya Catholic University of Indonesia Community Development program, Industrial Engineering study program, Faculty of Engineering contributes to the food security program by developing urban agriculture development in Nagrek, Sampora Village, Cisauk, South Tangerang. This program can be recognized as a joint initiative to improve food supply, local economy, social integration, and environmental sustainability together. The program also educates residents, provides training on the importance of doing urban farming, and creates applicable technology to support the community development. As a result, the residents of Nagrek Village created an urban farming program called "Mom's Farm". Urban Farming can be defined as a set of activities or practices of cultivating, processing, and

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distributing food in urban areas (Bailkey & Nasr, 2000). This urban farming may reflect various levels of economic and social development. It can thus be a part of a social movement for sustainable communities where local community form social networks based on share interests. Commonly, food security, nutrition and income generation are key motivations for the practices and in many cases access to fresh vegetables, fruit and meat products through urban farming can improve food security and safety (Bailkey & Nasr, 2000).

During the first period, the planting was carried out using mint plants (*Mentha piperita* L), but right after the first harvesting period, the types of plants to be replanted were re-assessed. To ensure the type of plant, an evaluation of the types of vegetables favored and favored by the residents of Nagrek Village was carried out. After an interview, it was found that the type of plant favored by the residents of Nagrek Village was Choy Som, Mustard Green (*Brassica chinensis*), Spinach (*Amaranthus*), Water Spinach (*Ipomoea aquatica*), and Kale (*Brassica oleracea*). The results of the subsequent planting received positive responses, namely that the residents were pleased to be able to consume their crops. This will then become the basis of urban farming with Choy Som, Mustard Green, Spinach, Water Spinach, and Kale. After harvesting, residents consume their crops for their own daily needs. To further develop the local community development program, the residents, "Mom's Farm" would like to develop the distribution parties or retailers. Consequently, it encourages an increase in production capacity, but it is not supported by the amount of land available. It is thus necessary to design an affordable storage area for the conditions of urban farming "Mom's Farm" so that it can meet the needs and desires of Nagrek Village, Sampora Village. This study uses the design thinking approach and combine with the Pugh selection method to find out a design of cold storage prototype that is in line with urban farming "Mom's Farm". Design Thinking Method was selected since this study focuses on user experience-driven method. This study will subsequently develop product concepts

that may include customer co-creation in the New Product Development (NPD) phase (Meinel, et al., 2020).

Based on the characteristics of local community at Nagrek Village, this study implements a frugal innovation at the design thinking process in the context of new coldstorage development process. This is principally due to the wills to create an appropriate cold-storage with a certain condition such as inexpensive, simple, and resource-constrained innovation activities. Previous studies identified a frugal Innovation as an innovation development that aims to bring products, services, and systems within the reach of emerging middle-class consumers at the Middle and Base of the Pyramid (Bhatti, 2012) (Zeschky, et al., 2014). Frugal innovation can affect the steps in the innovation cycle, from idea to business model, marketing, and consumption (Radjou & Prabhu, 2015). Some scholars propose that frugal innovation can improve products (goods and services) and processes where organizations are seeing to minimize the use of material and financial resources in the complete value chain (development, manufacturing, distribution, consumption, and disposal). The objective of considerably decreasing the total cost of ownership and/or usage while achieving or even exceeding certain pre-defined criteria of acceptable quality standards (Radjou & Prabhu, 2015).

II. RESEARCH METHOD

This study followed the new product development phases by adopting Design Thinking, Frugal Innovation, and Pugh method as a whole design product development.

Frugal Innovation and New Product Development.

Previous study done by Prahalad (2012), Radjou & Prabhu (2015), and Viswanathan & Sridharan (2012) explained that the need to modify the current product development model for Bottom of Pyramid (BOP) markets, including the process by which innovation is planned,

introduced, distributed, and emphasized. A product development process comprises several steps or set of activities where organization begins with conceive, design, and commercialize a product for high-income markets (Ulrich, et al., 2019). Nevertheless, some scholars Radjou & Prabhu (2015), Viswanathan & Sridharan (2012) emphasizes that developing a new idea to a final scalable frugal product in the frugal context will structure around the New Product Development Phases (NPDPh). Consequently, this will motivate the focus of this study and afterwards this study may contribute to a development of NPDPh framework for frugal innovation. Some scholars highlight the necessity to adapt slightly once the NPDPh occurs for BOP markets (Radjou & Prabhu, 2015) (Prahalad, 2012) (Viswanathan & Sridharan, 2012).

Design Thinking and Pugh Methods

The design thinking is chosen as an approach to seeking an appropriate solution in the urban farming horticultural community of Nagrek Village. The design thinking refers to an iterative non-linear process used to consider users, challenge assumptions, re-define problems, create prototype, and test the prototype solutions (Brown, 2009). Five phases include empathize, define, ideate, prototype, and test phase (Plattner, 2021). First, the empathize phase was occurred. The empathy process took place through

observation and interviews with the key stakeholders of the "Mom's Farm" urban farming, using a qualitative research method. The key findings were to gain insights into the engagement and the needs of the local community in Nagrek Village. This empathic process allows for the development of an affordable solution (Plattner, 2021). All interviews were conducted in Bahasa Indonesia and the aims were to have a better understanding of the current condition in the urban farming activities at Nagrek Village. The main questions were answered by: "Who are the key stakeholder in Nagrek Village? What are the needs of the local community? What is the urban farming daily activities? What do they like? and What are the current challenges? And why do they want horticultural products to be produced?" In addition, the data collection was combined with the knowledge gained from literature studies, previous research journals, and books. In the following the research methodology scheme is illustrated in Figure 1.

Second, the define phase was explored. At this phase, the problem facing the local community in Nagrek Village was redefined and revised. The results of this defining process provided a problem statement for the next ideation phase. A transition step from the define phase to the next phase is a brainstorming phase, that comes from the well-defined problem

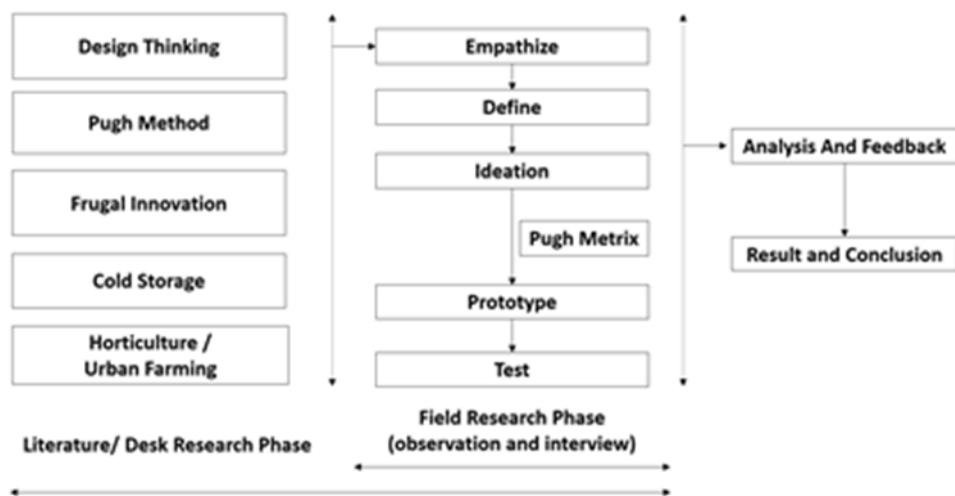


Figure 1. Research Methodology Scheme

statement. Third, the ideation phase was followed. The ideation phase is aimed for finding quantity of ideas, variety of ideas, and creation of novelty ideas. As a result, 5 (five) prototype ideas were studied that can later be used for choosing an appropriate prototype solution to the urban community in Nagrek Village.

This study uses a Pugh Method to select a prototype from alternative prototypes. This Pugh method was generally referred to as a decision matrix or Pugh concept selection (Frey, et al., 2009). The Pugh Matrix facilitates to compare alternative design candidates that lead to a prominent design meets a set of criterion or requirements. This matrix also allows the generation of hybrid candidates to compare optimization of alternative concepts. One of its benefits is addressing various requirements for decision-making. Many decisions also need to answer several interconnected variables or criteria which may lead to incoherent and unreasonable decisions.

The Pugh matrix therefore provides a modest approach to considering the multiple factors or variables while deciding. By developing people's inner ability to make peer-to-peer comparisons, subjective opinions on one alternative compared to another can be more objective (Frey, et al., 2009). The Pugh matrix helps individuals or team to analyze the robustness of a particular option, however the quality of outcome will depend upon the experience of team's expertise or individual experience (Pugh, 1991). The Pugh matrix can be described as follows: on the first run, it starts with certain ideas as seen in the ideation phase of the design thinking method. Then the following steps are taken forming the matrix, selecting and clarify all appropriate criterions for the selections against a reference concept called the datum (base concept). The datum is labeled as a finest current concept at each iteration of the matrix. After selecting the datum (base concept) the choice is continued by select one of the "best" solutions and evaluating how well the possible solutions perform in accordance with the defined criterion and score, combining the score of each alternative with the positive (+), negative (-) and

neutral (0) to summarize all the scores of each alternative.

The fourth phase of design thinking was the prototype phase. An appropriate cold-storage prototype was built based on the selected model with software A Virtual Reality (VR) device with SIM LAB VR and AutoCAD. Based on the selected model an appropriate cold-storage prototype was developed. Lastly, the testing phase was performed, the cold storage prototype was presented to the end-user as well as validated by several engineering experts in Material Engineering and Electromagnetic field From Dept. of Mechanical Engineering and Dept. of Electrical Engineering, Atma Jaya Catholic University of Indonesia to validate and to develop the cold-storage prototype to the end-user. The result of this phase will be used to improve the design of cold storage prototype in the next iteration product development process.

III. RESULT AND DISCUSSION

Empathize Phase.

In the early phase all relevant information was gathered in the Nagrek Village. Interviews were done directly with stakeholders who were involved in urban farming "Mom's Farm" in Nagrek Village, namely Mr. Gandi (member of Urban Farming "Mom's Farm") and Mrs. Susi (head of member of Urban Farming "Mom's Farm"). Further, the interview session was followed with Ms. Florenzia Jasin (urban farming activist) and Ms. Riana Magdalena (head of urban farming community development program from Industrial Engineering Study Program, Atma Jaya Catholic University of Indonesia). Results of this empathize phase was summarized into several user stories and subsequently prioritized to the customer needs. Figure 2 shows the personal canvas of two urban farmers in Nagrek Village.

From the empathizing process, a few expectations can be concluded including: To increase crop productivity and livestock horticulture products. To make "Mom Farms" available in both retail industry and the food distribution channel of South Tangerang Area. To match the crops, supply with the demand for

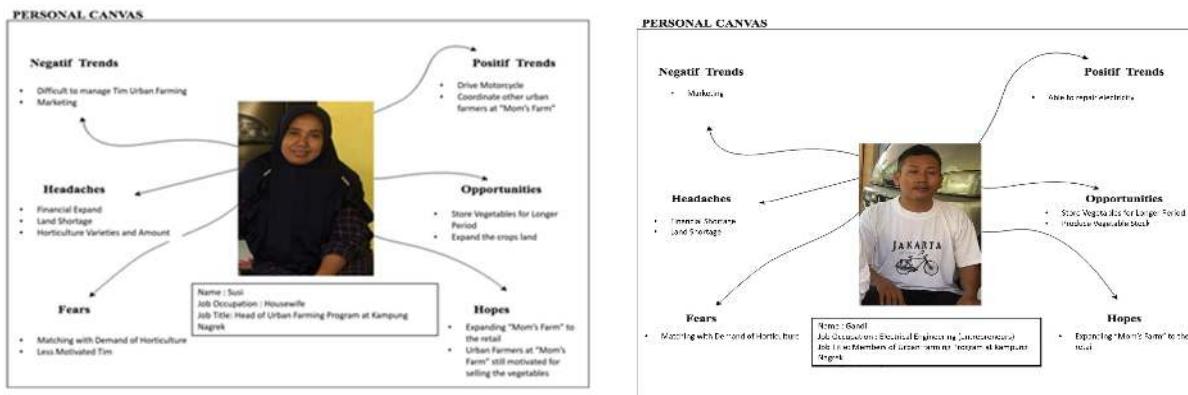


Figure 2. Persona Canvas from Two Urban Farmers in Nagrek Village.

horticulture products (Choy Som, Mustard Green, Spinach, Water Spinach, and Kale) in the surrounding area. To expand the agriculture land (arable land) in Nagrek Village. To support the development program for urban farming community in Nagrek Village. To encourage local community to continue planting urban farming activities.

Define Phase

At this define phase, the collected data were synthesized to gain a new insight resulted in a user story of local community in Nagrek Village. First, the data analysis was performed. The result of this analysis can be retrieved as follows: as an urban farmer I want to have an affordable cold storage which can prevent post-harvest waste so that the crops productivity can be increased, and the crops supply can be matched to the demand for crops in the South-Tangerang Area with less electricity consumption. Further, another user-story can be described as the following: as an urban farmer I want to distribute the crops production to the retailers so that the required range and quality of fresh vegetables can be consistently available in the supermarket or retails in the surrounding South-Tangerang Area. Finally, the last user-story can be identified as follows: as an urban farmer I want to increase crops production in the narrow land and densely populated village such as Nagrek Village so that I can have extra income to support for my family. Result of this defined phase formulates the needs

of the users in Nagrek Village to have a cold storage for handling and safety perishable crops between production and marketing. This study also used several literature studies to complete the criteria and requirements for the design of cold storage. Several factors were considered such as: temperature control cold storage, cold storage technologies for small production such as passive/evaporative cooler, absorption refrigerator, and refrigerators, and the cold-storage management such as temperature management, storage mix, stacking, and operation and maintenance, and hygiene (GIZ-HERA, 2021). A cold storage is a widely used as one of the methods of reserving crops perishable commodities in fresh and in some states for a longer period by controlling the temperature and humidity of the storage system (Krishnakumar, 2002). Maintaining a sufficiently low temperature is critical as it would cause damage to the product without proper treatment. In addition, for most of the perishables below (or above) its harmful effect on the quality of the product, the relative humidity of the storeroom should be kept as high as 80-90 per cent (Krishnakumar, 2002). Cold-storage facilities are thus crucial for minimizing post-harvest losses; however, losses occur at every stage of the post-harvest cycle, and therefore cold storage facilities cannot be considered as independent solutions to prevent post-harvest losses but as one component that needs to be integrated in a cold chain network from the point of harvest to the point of purchase

by the end consumer (GIZ-HERA, 2021). In some cases, horticultural produce has a short period time of harvesting season and vegetable weight can be reduced to 5% after harvesting period. Consequently, at the postharvest treatments generally aimed to preserve or to enhance the quality of vegetables by controlling the physiological, mechanical, and pathological agents responsible for both postharvest losses and degradation of quality (Fellows, 2009). Horticultural commodities are thus required to be handled properly during post-harvest period so that the quality of vegetables can be maintained and reduces losses (Hardenburg, et al., 1986). The cold storage has improved a lot in recent years, leading to better maintenance of organoleptic qualities, reduce spoilage, and longer shelf lives. According to several studies shows that generally cold storage or storage include the temperature control, relative humidity control, air circulation and maintenance of space between containers for adequate ventilation and avoiding incompatible product mixes. Further, general features of cold storage include the total

capacity, number and size of rooms, refrigeration system, storage and handling equipment and access facilities. The United Nations' food and agriculture organization recommends the use of ferro cement to provide insulation for the construction of a storage structure in tropical regions with thick walls. The air composition in the storage should be manipulated by increasing and decreasing the rate of ventilation (introduction of fresh air) or by using gas absorbers such as potassium permanganate or activated charcoal. Storage can thus be described as a place consisting of different products and having its own capacity to store products that can be received from the producers or customers. This can be noticed as a distribution place for a short period of placement time (Hardenburg, et al., 1986). From the user's point of view, the set of criteria lists according to the user needs and technical requirements are shown in Table 1 and Table 2. Additional technical criterion to the design of cold storage also will be considered afterwards during the prototype phase as well as during the validation step with the experts.

Table 1. Criteria List of the User Needs

No	Criteria's	Description
1	Durability	Long lasting
2	Performance	Efficiency
		Capacity
		The capacity of the cold storage must persist for at least 1 (one) period, so that it can also support the crops from the previous harvest period. This will count to the amount of produce to be stored (5,000 – 10,000 grams)
		Energy use
		Cold storage must use less electricity and energy range of the electricity use around 2 – 10 kWh.
3	Features	Dimension
		The dimension of the cold storage should be proper maximum width = 3 meters, length = 2 meters, and height = 2 meters.
		Location
		The cold storage must be able to be located both indoor and outdoor.
		Flexibility
4	Conformance	Specification
		The cold storage must conform with the specification to store fresh vegetable for longer period and can be used for small household.
		Cost
		The development cost of this cold storage must be lower than IDR 5,000,000
		Maintenance
		Low maintenance will be priority, so that it can be used for household in Nagrek village

Table 2. Criteria List to the Technical Requirements.

No	Criteria type	Technical needs	Unit	Defined
1	Capacity	Number of crops which can be stored in the cold storage	Grams (g)	5,000 – 10,000 grams
2	Dimension	Long, wide, height	Centimeter (cm)	< 2,000 cm
3	Efficiency	Energy consumption	Kilo-Watt hour (kWh)	2 – 10 kWh
4	Development cost	Cost to develop the cold storage	Indonesian Rupiah (IDR)	+/- IDR 3,000,000

Table 3. Product Prototype Ideas

Product Prototype 1	Product Prototype 2	Product Prototype 3	Product Prototype 4	Product Prototype 5
One door type storage which uses a direct cooling system with total capacity of 170 Liter, 100 watt electricity, unit dimension = 524mm x 520 mm x 110 mm. Estimation cost = IDR 1,549,000	Cold storage using a normal air conditioning, 600 watt electricity, unit dimension = 1.5 m x 1.5 m x 5 m, estimation cost = IDR 10,000,000	Cold storage using a modified atmosphere storage (MAS), fan with 18 watt, unit dimension = 1.72 m x 1.72 m x 1.72 m, estimation cost = IDR 5,000,000	Cold storage using a controlled atmosphere storage, 140 watt electricity, capacity 20 kg, estimation cost = IDR 7,500,000	Cold storage using a direct control, 180 watt electricity, unit dimension = 0.54 m x 0.58 m x 1.33 m, estimation cost = IDR 2,000,000

Ideation Phase

At the ideation phase, various ideas were explored so that can be matched to answer the challenges which was defined at the previous phase. At this stage, one may focus on the quantity of novelty ideas, diversity and produce the first version of cold storage prototype. During this ideation phase, the crazy 8's template for design sprint was used as a tool to brainstorm to design the possible prototypes (Google, 2021). Using the crazy 8's brainstorming tools, this study was able to obtain 5 (five) ideas, as shown in Table 3. These 5 alternatives have advantages and disadvantages in their use.

One door type storage which uses a direct cooling system with total capacity of 170 Liter, 100-Watt Electricity, Unit dimension = 524 mm X 520 mm X 110 mm, Estimation Cost = IDR 1.549.000, - Cold Storage using a normal air conditioning, 600-watt electricity, unit dimension 1.5 m X 1.5 m X 5 m, Estimation Cost = IDR 10.000.000, -, Cold Storage using a modified atmosphere storage (MAS), fan with 18-watt, unit dimension 1720 mm x 1720 mm X 1720 mm, estimation cost = IDR 5.000.000, -, Cold storage using a controlled atmosphere storage, capacity 20 kg, electricity 140-watt, estimated cost IDR 7.500.000, -. Capacity 140 Liter, Electricity 180-Watt, Unit dimension 54 cm X 58 cm x 133 cm, using a direct cooling, estimation cost IDR 2.800.000, -.

Results of this brainstorming design prototype combined with the technical calculation, will be used to obtain an appropriate cold-storage prototype to accommodate the activities of "Mom's Farm" urban farming. Therefore, to choose the appropriate solution /

idea / alternative, calculations are made using the Pugh Matrix (Pugh, 1991). The matrix uses several reference variables that are the basis for choice of solutions, namely the consumer needs table and the technical requirements obtained from user interviews and literature. The table also includes the intended consumer needs such as capacity, efficiency, size, and costs also in the construction of the design.

In this Pugh method, there is a datum, which is given a value of null, that is used as a parameter or benchmark in conducting the selection (Pugh, 1991). This datum is adjusted to the table of technical requirements, so that each of the selection criteria contained in the selection table with the Pugh method is compared and given an assessor with a value (+), which was better than the datum criterion value (0) then a value is given. (-) is less when compared to the datum criterion value (0). The selection results are obtained by applying the criteria (+) and (-) values, so that the ranking of the criteria (+) values is carried out, so that Product Prototype 3 (three) were obtained by getting the criteria (+) of 5 and the criteria (-) of 2. As a result, Product Prototype 3 gets a value (+) higher than the 5 selections or other alternatives. Product Prototype 3 was designed using a Modified Atmosphere Storage (MAS) equipment. the MAS storeroom is made gas-tight using metal cladding and carefully sealed doorways and the breathing activity of fresh food, using oxygen, and producing CO₂ (carbon dioxide), can change the atmosphere (Krishnakumar, 2002). Individual gasses will be added from pressurized cylinders in MAS stores that are not completely gas-tight to speed up the creation of the required

Table 4. Pugh Matrix for Selecting the Prototypes.

Selection criterion	Product concept / ideas					Datum
	Product 1	Product 2	Product 3	Product 4	Product 5	
Low energy consumption	0	-	+	0	0	0
Outdoor place	-	+	+	-	-	0
Storage capacity during harvest and post harvest	-	+	+	-	-	0
Product dimension (product specification), small size	+	-	0	+	+	0
Flexibility	0	-	-	-	+	0
Low development cost	+	-	-	-	+	0
Easy maintenance and assembling	+	-	0	0	+	0
Ease of use by customer	+	0	0	-	+	0
Durability	-	+	+	+	-	0
Total (+)	4	3	5	2	5	0
Total (-)	3	5	2	5	3	0
Total (0)	2	2	3	2	1	0
Total (+) - (-)	1	-2	3	-3	2	0
Ranks	3	4	1	5	2	0

atmosphere, rather than relying solely on respiratory activity. The gas composition is controlled automatically by microprocessors to keep a predetermined atmosphere by means of information from the sensors to control air vents and gas scrubbers. The adjustment of the atmospheric structured by solid or liquid CO₂ is utilized to increase the concentration of gas. Controlled air circulation is used to acknowledge oxygen or scrubbers can be used to remove CO₂. Scrubbers attract CO₂ either by passing the air out of the store over hydrated calcium hydroxide (lime) bags, under sodium hydroxide sprays or over activated carbon. Atmospheric CO₂ element can be monitored using sensors to measure differences in thermal conductivity between CO₂ (0.015 W m⁻¹ K⁻¹), N₂ (0.024 W m⁻¹ K⁻¹) and O₂ (0.025 W m⁻¹ K⁻¹) or differences in infrared absorption. The gas composition is controlled automatically by microprocessors to keep a prearranged atmosphere by means of information from the sensors to control air vents and gas scrubbers. Hence, MAS is useful for crops that grow after harvest, or deteriorate quickly, even at optimum storage temperatures (Hardenburg, et al., 1986). The Pugh matrix is shown in Table 4.

Prototype Phase

The product prototype stage is the stage of realizing the design results or solutions that exist at the ideation stage in the form of two-

dimensional and three-dimensional images (Ulrich, Eppinger, & Yang, 2019) (Brown, 2009). At this stage it is useful to know the appropriate size for the stakeholders. This research uses AutoCAD software using a scale of 1: 1000. This depiction makes it easy to simulate virtual reality which will be carried out at a later stage. The following is the design result of the storage area design for urban farming "Mom's Farm". In this part of the prototype, this study carried out 3 stages, namely the initial stage of depiction, the stage of adding innovation from stakeholders and the stage of adding innovation from researchers and experts. The initial stage of depiction can be seen in Figure 3.



Figure 3. Design Drawings using the modified MAS equipment.

Then a discussion with urban farming stakeholders "Mom's Farm" was held, resulted in

the addition of wheels and a framework to protect gas cylinders were added to the design prototype. So that the transfer or mobility of cold storage can be easy. The stage of adding innovation from stakeholders can be seen in Figure 4.

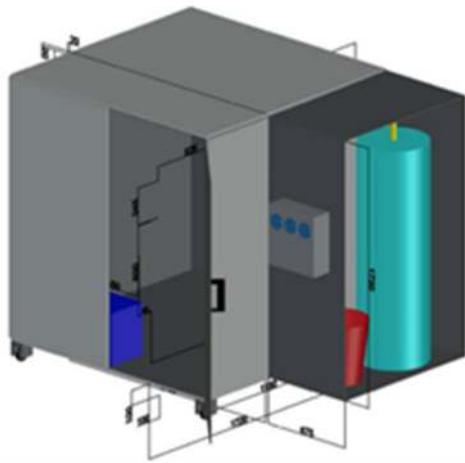


Figure 4. Design Drawings of Stakeholder Innovation

Furthermore, additional shelves were design into the cold storage, the purpose of adding these racks is to streamline the layout, so that in storing horticultural products it can be stored, arranged, and arranged neatly. In the calculation, this shelf was adjusted to the size of the stakeholder's height and the members of the urban farming "Mom's Farm" who will use it in their daily lives. Then besides that it was adjusted to the size of the plastic box which will be used as a container for storing vegetables. The stage of adding innovation from researchers and experts can be seen in Figure 5.

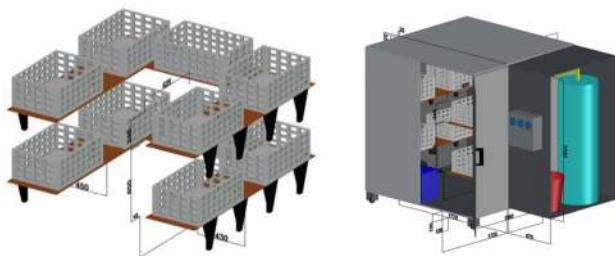


Figure 5. Design Drawings of Innovation Prototype 3

Testing

The testing stage is the final stage in the design thinking method. At this stage, the results of the design at the prototype stage will be simulated with the help of the SIMLAB VR viewer software. In this simulation, stakeholders will directly assess the results of the final design from the combined results of innovations from both stakeholders and researchers. However, because this study was conducted during a pandemic, researchers were only able to carry out the testing stages only in digital form because of the difficulty in building the design results directly. At this testing phase, visualization of product prototype 3 was directly demonstrated with the help of SIMLAB software. When carrying out this stage, stakeholders can feel firsthand about the results of the design that have been described, as shown in Figure 6.

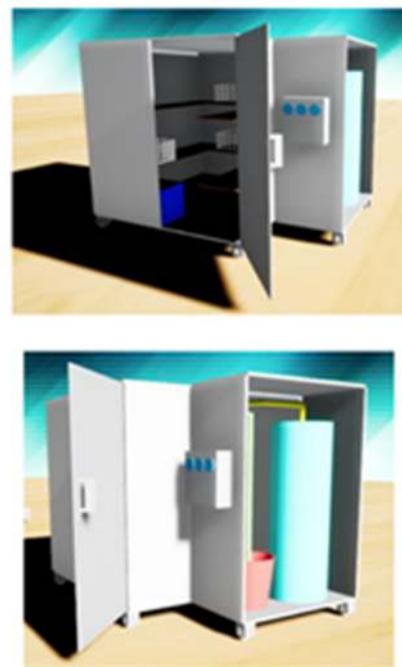


Figure 6. The Final Design Result of Visualization With SIMBLAB.

IV. CONCLUSION

This study proposes an affordable cold storage design for urban farming "Mom's Farm" to follow the design process of New Product

Development (NPD) phases by adopting design thinking, frugal innovation, and pugh method as a whole design product development. The prototype design has led to the development of an affordable cold storage with a modified atmosphere storage (MAS) equipment of 4.77 m³ and this affordable cold-storage design was to be built in Nagrek Village Urban Farming Community to enable the local community to store harvested vegetables after harvesting. This study combines frugal innovation, design thinking, and pugh method for the entire design product development phase of the New Product Development (NPD) phases. From a theoretical point of view, it is possible to use design thinking to create a conceptual creativity in the early phase of product development process in combination with the pugh method in the selection process of alternatives cold-storage design prototypes. During the product development phase, the design thinking method enables the development of an affordable cold storage prototype using empathic user observation, understanding, and improving user experience, and rapid feedback through iterative prototyping to produce a design concept. This process seems to be important as the production of an affordable cold store requires a direct interaction with the local community of Nagrek Village. Once the alternatives cold-storage prototypes are produced, then the pugh matrix is used to determine which of the potential cold-storage design alternatives can be better than the others by capturing the customer's voice. This Pugh Matrix has a set of criteria or requirements for both consolidated user and technical assessment scores. As a result, an affordable cold storage with a MAS of 4.77 m³ as illustrated in design prototype figure 6 becomes the chosen prototype. Nevertheless, this study has several limitations, including the technical specification of cold storage, which need to be further explored and some anthropometric calculations need to be further calculated. Therefore, this study suggests examining the technical assessment for the next iteration of the design of cold storage design in the new product development process. Next, it is also recommended that the next cold-storage

design should focus on the energy consumption of the cold storage which is a key element of Frugal Innovation. Typically, in some remote areas most likely classified as the Bottom of Pyramid Market, there is a shortage of electrical power and there may be difficulties in obtaining electricity.

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