

Executive Summary

Let's Get Together's Tech4All program is a non-profit that operates within multipurpose community spaces. Within these spaces (hubs), donated technology (e.g. monitors, keyboards, laptops, RAM) is stored with a few tables for volunteers to refurbish this technology. The gap is that the current Tech4All hubs lack proper storage systems for refurbishment items. Currently, staff and volunteers at the hub face workflow inefficiency challenges. This wastes employees' time in locating equipment and increases the risk of damaging electronics. To address this, there is a need for a design that improves the workflow while also reducing equipment damage risk and enabling efficient organization and retrieval. The scope of this project is limited to a budget of \$2,000, and its physical scope is a 27'5" x 40' warehouse. This requires the system to fit within a vertically expansive yet spatially constrained environment. The design must be freestanding with no wall-mounted fixtures, quick to assemble and scalable across other hubs. It will support Tech4All's goal of refurbishing technology and positively impact many groups, including (but not limited to) receivers and donors of technology, funders of Tech4All, and third spaces (e.g., churches, libraries) where Tech4All may wish to use this design. The design will be used in the main Tech4All hub, but could be implemented in other indoor community training and refurbishment centres that feature similar workspaces with high tool density and frequent user interaction. The environment is primarily occupied by adult users, with occasional youth participants. Given this service environment, the new storage system should increase usable storage space while maintaining safe circulation and accessible reach. It should reduce storage and retrieval time through categorization and labeling to improve daily workflow. Some major constraints that were identified include safety and stability.. The solution must not block any emergency exits, and follow the Ontario Fire and Building codes. To ensure that all the components and devices are protected, the design must be stable and secure, while making sure sensitive electronic items are stored as per ANSI/ESD standards.

Using these project requirements, 231 ideas were generated using various techniques which were later refined into 72 full solutions. 68 feasible concepts were evaluated through group multivoting and graphical decision chart and based on the project objectives and ultimately producing three leading conceptual designs: The Sliding Shelf Design (SSD), 4 Zone Warehouse Layout (4ZWL) and Smart Modular Storage Rack System (SMSRS). A Pugh matrix comparison ranked SSD highest as it scored +2 compared to 0 (4ZWL) and 1 (SMSRS). Simulations were used to measure how this design compares to the current layout. Using Flexsim software it was found out that the design meets the metric for the top objective of improving workflow efficiency. The next step is to present this conceptual design to the client.

1.0 Introduction

Let's Get Together (LGT) is a non-profit committed to reducing educational inequalities by solving the problem of the digital divide. Students lacking technology access face barriers in completing schoolwork and developing essential digital literacy skills [1]. LGT's Tech4All program refurbishes donated electronic devices and distributes them to those in need [2]. This document defines project requirements and proposes a conceptual design to the client.

2.0 Problem Statement

Tech4All operates from a warehouse in Mississauga where all equipment and refurbishment materials are stored. The gap is that the current Tech4All hub lacks proper storage systems for refurbishment items resulting in inefficient use of floor space, workflow delays, a higher risk of equipment damage, and difficulty locating items, as shown in Figure 1. Poor storage organization increases search time and causes operational delay, worker frustration and item mishandling [3]. Mishandling electronic devices can increase the likelihood of battery degradation, reduce device lifespan, cause corrosion, and internal component damage [4].

This creates a need for a storage system design that supports smoother item retrieval workflows and enables safe storage of equipment. The design will store 25-30 units of major equipment such as cables, batteries, monitors, laptop adapters, hard drives, desktops, refurbishing kits, RAM, keyboards, mice, cleaning supplies, and testing kits [5]. The scope of this project is limited to a budget of \$2,000, and it must be within the warehouse's physical dimensions of 27'5" x 40' (Appendix A.1). Additionally, the design must also be freestanding and easy to replicate for other hubs [5].

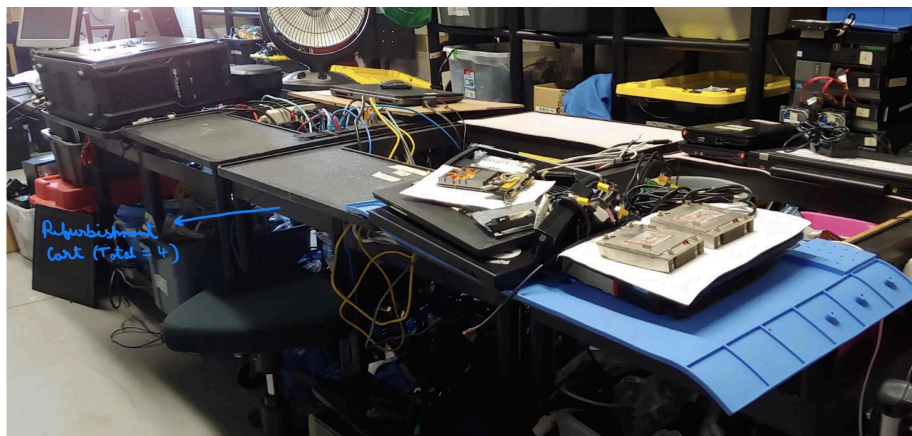


Figure 1. Current system at Tech4All's Mississauga Hub

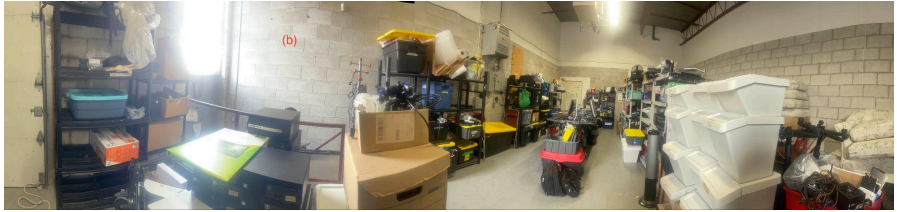
3.0 Service Environment

This storage system is intended for indoor, community-based training and refurbishment activities. This section is divided into three parts: the physical and virtual environment, and living things.

3.1 Physical Environment

The key physical characteristics of the refurbishment workspace are summarized in Table 1 and Figure 3. These characteristics influence the safety, functionality, and adaptability of the proposed modular storage system. The warehouse has one emergency exit and 2-3 users can work simultaneously.

Table 1. Physical Environment Descriptions

Factors	Descriptions
	 Figure 2. Photo of the existing refurbishment workspace
Temperature	-9 ~ 27°C [6]
Humidity	53% ~ 72%, 61% average [7]
Static Electricity Risk	Accumulation of static electricity may occur due to dry indoor air and electronic component handling.

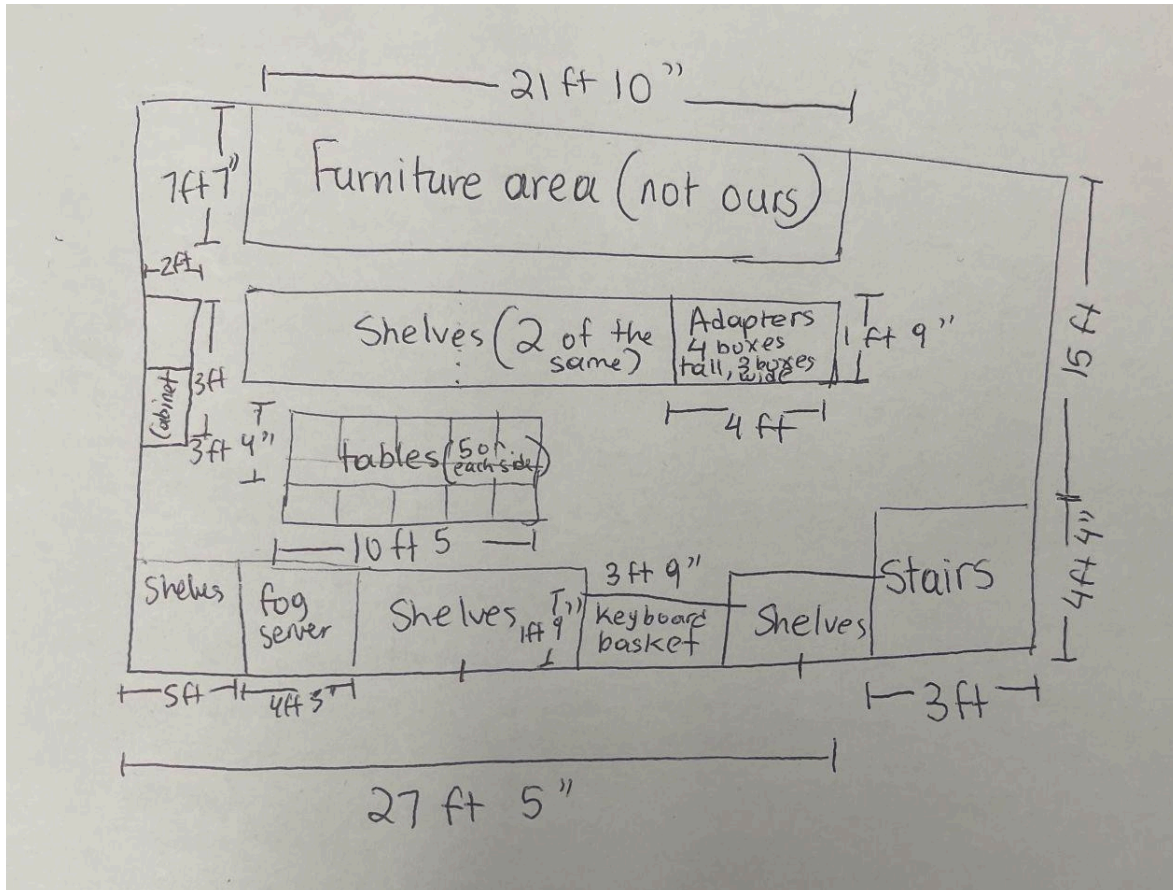


Figure 3. Layout diagram of the space.

3.2 Virtual Environment

The service environment includes wireless network infrastructure and electrical power distribution to support device testing and refurbishment activities. Reliable 120V AC power is required for charging laptops and other devices, Internet connectivity enables access to online resources, software installation, and cloud-based documentation.

3.3 Living Things

The environment primarily includes adult users engaged in refurbishment and training activities, and youth participants aged 14+.

4.0 Interest Holders

Table 2 outlines relevant people/organizations that either influence or are impacted by this design. It is ordered from high to low impact/influence, which was determined using an Impact and Influence Matrix (Figure 4). Detailed Justification can be found in appendix B.2.

Table 2. Interest Holders for the Design

	Interest Holders	Influence	Impact (+/-)	Justification
I.1	Ontario Office of the Fire Marshal	High	Low (neutral)	The design complies with critical Ontario Fire Codes, enforced by the Office of the Fire Marshal [8].
I.2	Mississauga Municipal Building Officials	High	Low (neutral)	The design complies with critical Ontario Building Codes, enforced by Mississauga Municipal Building Officials [9].
I.3	Business + Institutional Furniture Manufacturers Association (BIFMA)	High	Low (neutral)	BIFMA standards [10] are followed for objective O.2 and constraint C.6
I.4	American National Standards Institute (ANSI)	High	Low (neutral)	ANSI standards are followed for objectives O.2 and mandatory to follow in constraints C.6 and C.7. [11]
I.5	National Institute for Occupational Safety and Health (NIOSH)	Medium	Low (neutral)	The NIOSH lifting equation is utilized to define a safe load in objective O.7 [12].
I.6	Canadian Standards Association (CSA)	Medium	Low (neutral)	CSA standard CSA B651 is followed in objective O.5. CSA B651 sets metrics for reach and clearance distances [13].

I.7	GTA third spaces	Low	Medium (+)	The client plans to implement this design into churches, community centers, and other third spaces (Appendix A.3).
I.8	Refurbished technology Receivers	Low	Medium (+)	Proper storage prevents damage to components before refurbishment [14]. The quality of refurbished products will improve and positively impact the receivers, who are individuals in financial need/applicants to the Tech4All program [2].
I.9	Technology Donors	Low	Low (+)	The design will store technology that is donated by community members and corporations [5]. The technology will be positively impacted by the new design, due to better organization and storage conditions [14].
I.10	E-waste recycling organizations	Low	Low (+)	Tech4All has partnered with groups like COM2 Recycling to collect unwanted tech for safe recycling or refurbishment [15]. The design reduces device damage and boosts efficiency, enabling more devices to be refurbished instead of recycled.

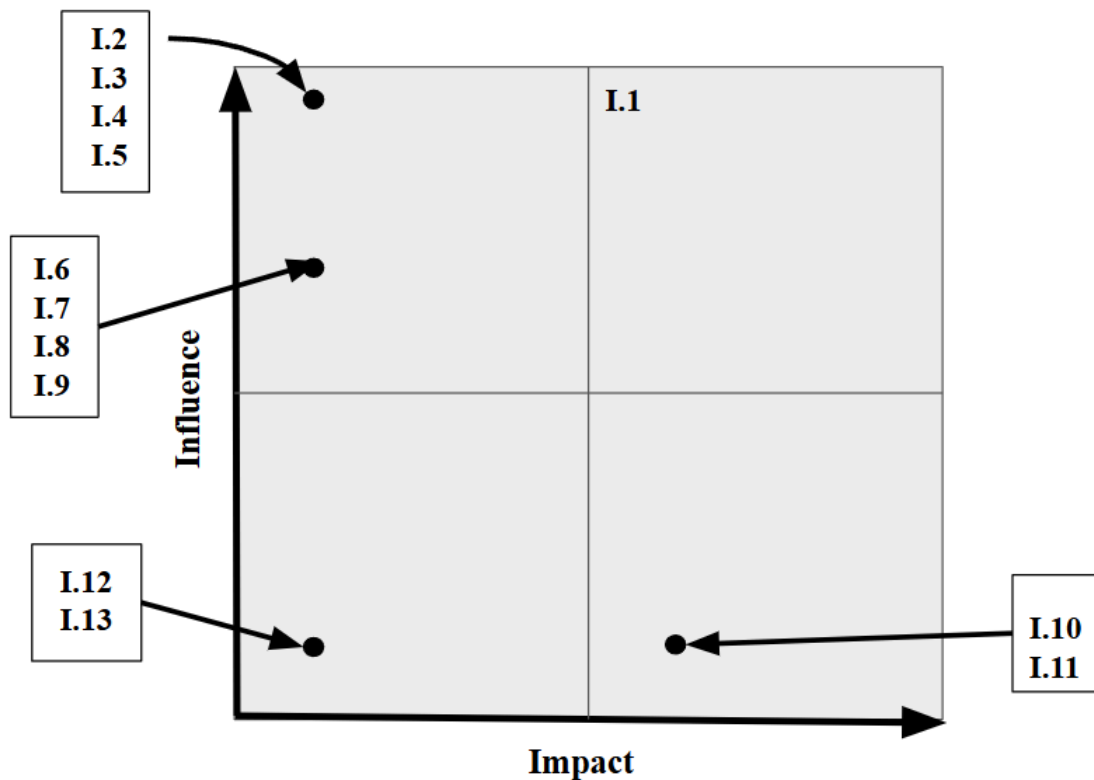


Figure 4. Matrix representing interest holder's influence on the design, and impact on them.

5.0 Detailed Requirements

This section outlines the functions, objectives, and constraints of the design.

5.1 Functions

To determine a primary function, a functional basis was used. The functional basis is "**store mass**". Functional decomposition and a how/why trees were used to determine the secondary functions (Appendix C).

Table 3. Primary and Secondary Functions

Primary Function	Store a dynamic inventory of electronic devices and refurbishing equipment
Secondary Function	S.1 Separate items within design S.2 Import and export items S.3 Support the weight of the items

5.2 Objectives

Table 4 outlines the objective goals and metrics that the design would ideally meet (Appendix D). It is sorted as per Pairwise Comparison (Appendix D).

Table 4: Objectives, their metric and their goals for the design

	Descriptor: the design should be...	Metrics	Goal	Justification
O.1	Improve workflow efficiency	Seconds/item (storage and retrieval)	≤ 45	Handling cycle time measures workflow efficiency by calculating the average storage and retrieval time [16]. A target of ≤ 45 s/item aligns with manual picking benchmarks of ~ 80 picks/hour [17].
O.2	Support high load capacity	Maximum safe load rating (kg/ storage unit)	≥ 95	Estimated total weight a unit should have with desktops and monitors, is ~ 79.6 kg; and a factor of safety of 20%, yields a goal of 95 kg (Appendix D).
O.3	Long-lasting	Expected service life (years)	~ 10	The ANSI/BIFMA X5.9 standard specifies an estimated product life of 10 years for single-shift usage [10].
O.4	Minimizing unsafe equipment handling	Maximum weight of items stored above shoulder height or below knee height (kg)	23 kg	Single-person lifts should not exceed 23 kg under ideal conditions (NIOSH load constant). Heavier items should be stored in a “safe lift zone” (between knee and shoulder height) [12].
O.5	Allocating adequate circulation space	% of floor area to circulation + operations	20–25%	Logimax has calculated the ideal warehouse space utilization to be 75-80% of the total floor area, for storage functions [18].

O.6	Ergonomically accessible	Compliance with CSA B651 reach + clearance guidance	100%	Improving workflow efficiency is a desired outcome, as mentioned by the client, and the CSA B651 standard sets an unobstructed reach of 400–1200 mm while maintaining ≥ 1000 mm of clear routes [13]. Thus reducing awkward postures and unsafe access.
O.7	Quick to assemble and reconfigure	Assembly time (hours)	≤ 5 hours	The client stated that the system should be quickly assembled, with an optimal goal of ≤ 5 hours with 4 - 5 people (Appendix A.5).

5.3 Constraints

Table 5 outlines constraints the design must meet (Appendix E).

Table 5. Constraints, metrics, and limits for the design

	Descriptor: the design must...	Metrics		Limit	Justification
C.1	Be freestanding	Number of fasteners connecting design to the building		0 [5]	The client requires the design to be freestanding and not affect the building [5].
C.2	Be within budget	Canadian Dollars		$\leq \$2000$ [5]	The design must not exceed the financial scope of the project [5].
C.3	Fit within the designated area	Area of base (ft ²)		$\leq 27'5'' \times 40'$ (Appendix A.3)	The design must fit within the maximum allowed warehouse space (Appendix A.3).
C.4	Not block emergency exits	Width of exit path (mm) [8]		≥ 1100 mm [8]	The Ontario Fire Code states that

					walkways leading to an emergency exit must have a width ≥ 1100 mm [8]
C.5	Not introduce tripping hazards	Height of protrusion from the ground (mm) [9]		≤ 13 mm [9]	The Ontario Building Code states that a barrier-free path of travel must not have protrusions > 13 mm [9].
C.6	Be stable	Horizontal force to cause tipping applied at top edge (N) [11]		≥ 44 N [11]	The ANSI-BIFMA X5.9 standard states that an object with at least 1 extendible element must withstand a horizontal force of 44 N applied to the top edge to be stable [11].
C.7	Protect sensitive electronics items from damage	Electrostatic discharge (ESD) voltage on design (V) [23]		< 100 V [23]	ANSI/ESD S20.20-202 states the design must prevent ESDs greater than 100 V to protect from damage [19].
C.8	Be modular	Propagation cost [24]		$\leq 50\%$ [24]	To be adaptable to other hubs, the design's propagation cost must be below 50% [5] (Appendix D). Propagation cost measures the percentage of changes needed on average when a change is made to a single element [20].

6.0 Generation, Selection and Alternative Designs

A broad range of ideas (Appendix H) were explored in order to get the 3 best solutions which further lead to one conceptual design. The functions were taken into account when generating solutions. During, idea selection stage objectives were used to make full solutions.

6.1 Idea Generation Process

A diverse set of techniques were used to generate ideas. Everyone on the team created morph charts (Appendix F) that allowed us to thoroughly explore the design space while also ensuring the FOCs were considered. Next, both structured and free brainstorming sessions were conducted followed by SCAMPER, analogy (Appendix G) and benchmarking. These techniques generated a total of 239 ideas (Appendix H).

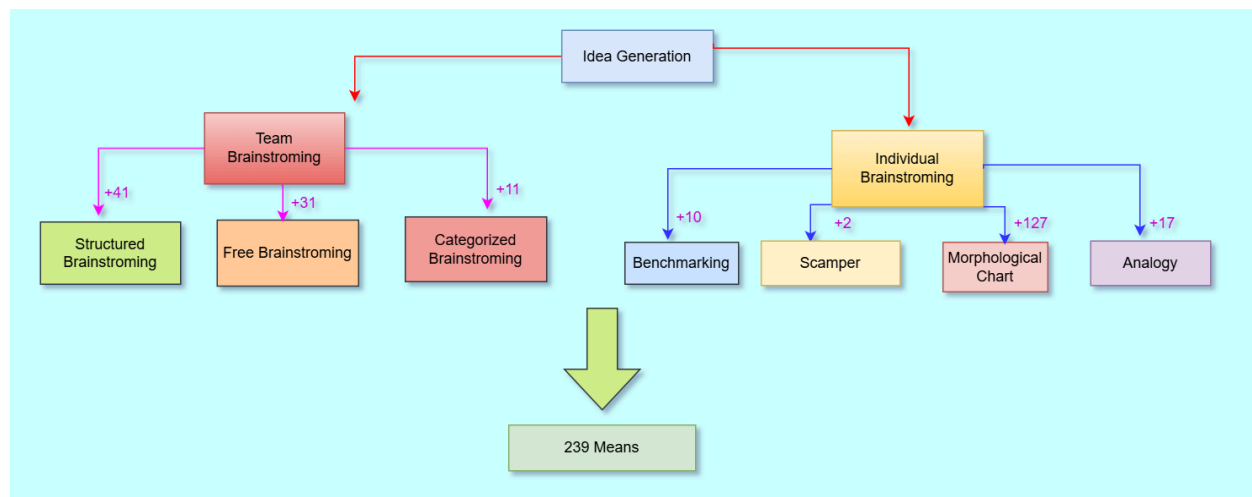


Figure 5. Idea Generation Process

One challenge during idea generation was ensuring the entire design space was systematically explored. To address this, the team organized ideas into categories to guide brainstorming. These categories included storage of items, accessibility and interaction, categorization and information display, and layout (Appendix H).

6.2 Idea Selection Process

In the selection process the team went through 5 main steps to end up with 3 alternate designs.

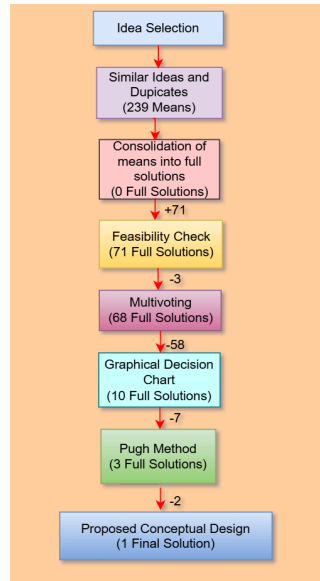


Figure 6. Idea selection Process

6.2.1 Consolidation, Feasibility Check, Multivoting

The team consolidated means into complete storage system solutions by grouping ideas based on functional categories (e.g. zoning, AI, mobility). A feasibility check was then conducted using project constraints such as safety, cost, and usability, eliminating impractical designs.

The remaining solutions were evaluated through multivoting, where team members voted for designs based on key objectives. After 3 rounds (Appendix I.4), lower-ranked concepts were removed, resulting in a refined set of competitive solutions. (Appendix I.3)

6.2.2 Graphical Decision Chart

The shortlisted solutions were further evaluated using a graphical decision chart based on workflow efficiency (O.1) and load capacity (O.2).

Solutions located in the upper-right region demonstrated strong performance in both objectives. Based on this analysis, three high-performing designs were selected as alternate designs for further development (Appendix I.5).

6.3 Alternate Designs

This section explores the three modular storage solutions chosen using the Graphical Decision Chart (Appendix I.3). Calculation /estimation processes are in Appendix J.

6.3.1 Design 1 - Sliding Shelf Design (SSD)

The SSD consists of a freestanding, reinforced steel sliding shelf unit (illustrated in figure 7) that can **support the weight of electronics**. The packing of shelves eliminates the need for aisle floor space and increases the density of storage. In Figure 9, the racks are filled with transparent bins that **separate items** by category, with commonly used items placed on the front shelves. Every bin has a scannable QR code and a color-coded LED status strip that lights up when a part is searched via the digital inventory dashboard. The colour of the LED communicates the order of which one can retrieve items. QR codes are used to update the digital inventory dashboard every time an item is taken out. Heavier items (e.g. desktops) are stored in the 'safe lift zone' and a grounded metal box at the base safely stores sensitive desktop components.

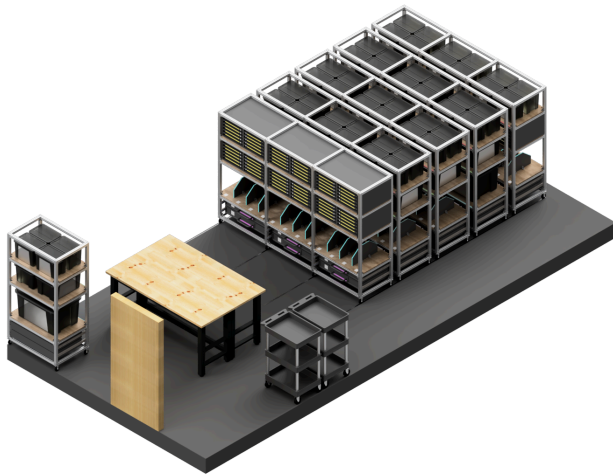


Figure 7. SSD Angled view.



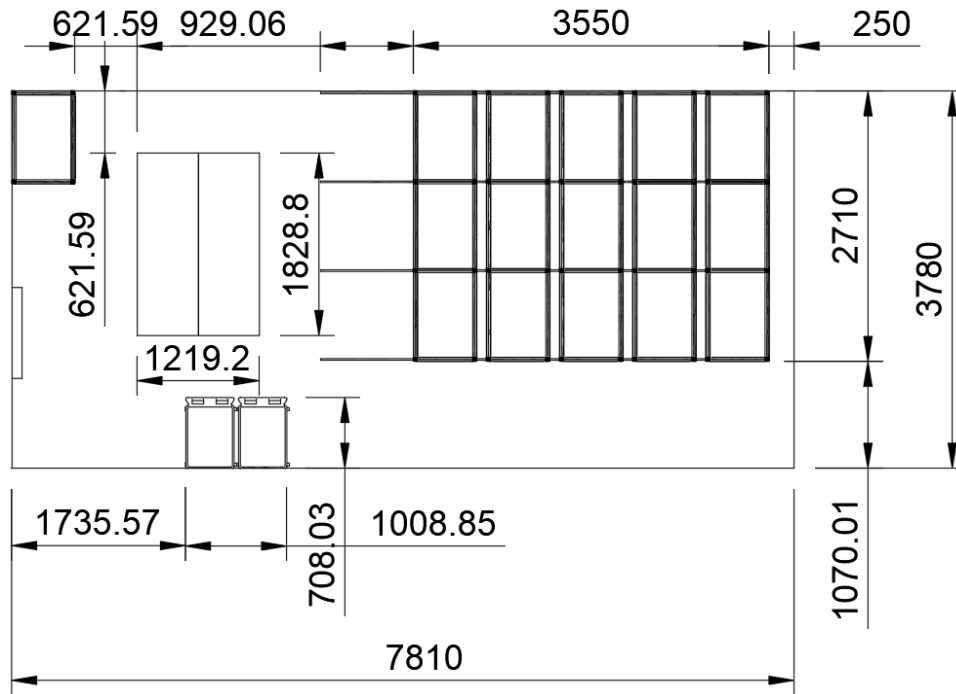


Figure 8. Bird's-eye + measurements of SSD

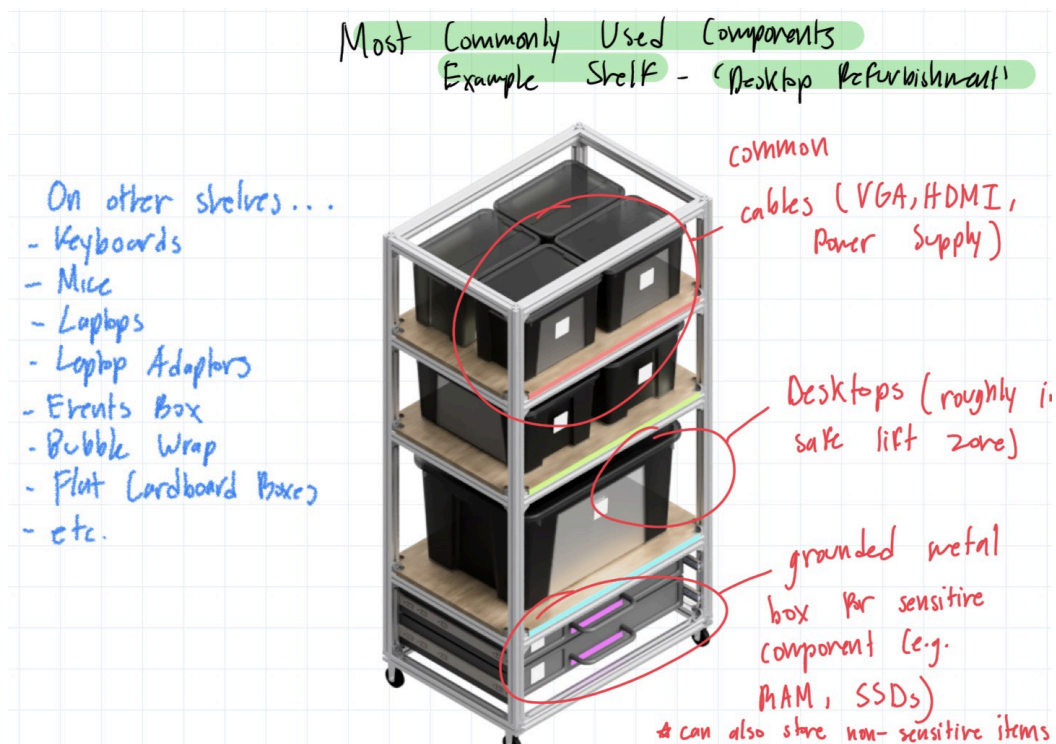


Figure 9. Exemplar SSD unit.

The SSD supports a dynamic warehouse environment. Looking at objectives, SSD succeeds in improving workflow efficiency, with an LED label system and increased circulation space. Table 6 further describes SSD's objective fulfillment.

Table 6. How SSD meets objectives.

Objective #	Fulfilled?
O.1	Yes. The LED identifier lights on each bin eliminates searching time.
O.2	Yes. Each SSD shelf is estimated to hold ~316kg (Appendix J).
O.3	Yes. Metal units are expected to last 10+ years [21].
O.4	Yes. There are no objects >23kg in the warehouse [5].
O.5	Yes. The circulation area percentage is ~ 57% (Appendix J).
O.6	Partially. Reach extends below 400mm. Depending on model, it may exceed 1200mm reach. Paths are mostly >1m wide in Figure 8.
O.7	Yes. 4-5 people can assemble the SSD in <5 hours (Appendix J).

6.3.2 Design 2 - 4 Zone Warehouse Layout

The 4 Zone Warehouse Layout (4ZWL) consists of intake, repair, storage and dispatch zones. Intake tables, dispatch shelves and laptop charging stations are located near the garage door for temporary storage and **easy import/export** out the warehouse. The repair zone contains the workstations and repair carts. There is storage underneath carts for storing WIP devices. The storage zone surrounds the repair zone for easy worker access, as shown in Figure 10. The equipment is **separated with transparent bins** and coloured non-stick tape on the floor marks each zone for visual blocking, as illustrated in figure 11. The shelves are separated by common categories as shown in figure 12, w/ heavier items (e.g. desktops) stored at the 'safe lift' zone [12].

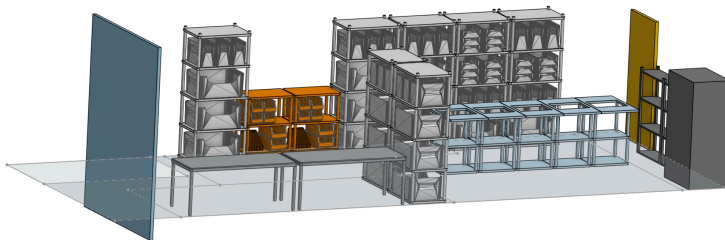


Figure 10. Angled view of 4ZWL.

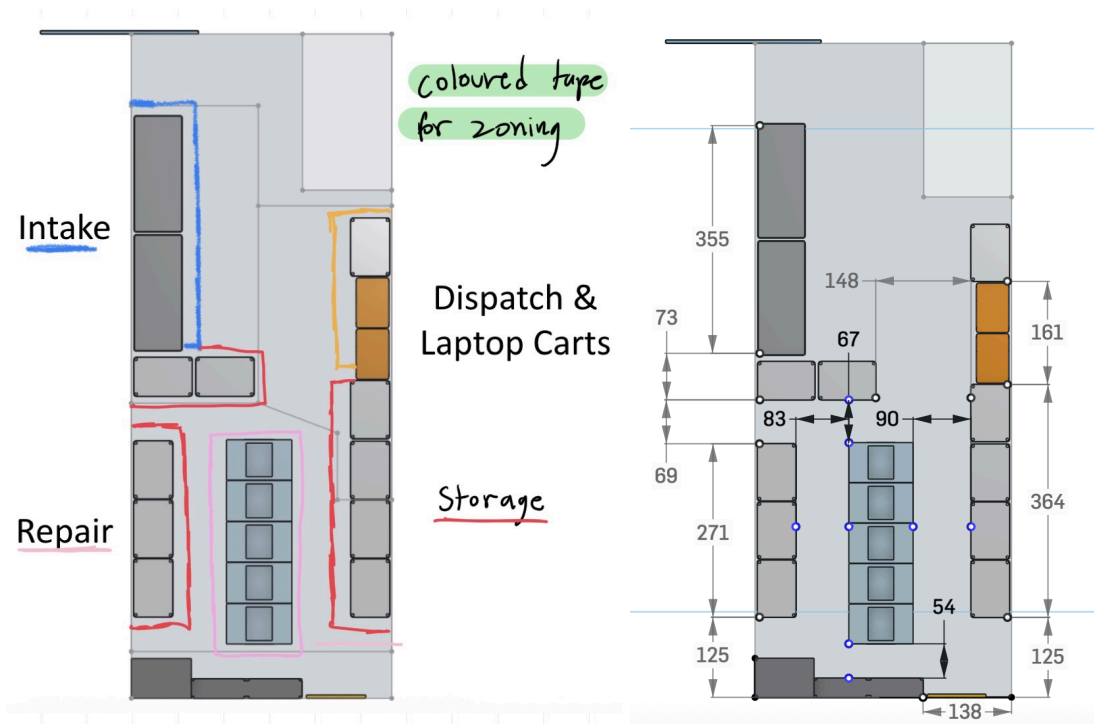


Figure 11. Bird's-eye view of 4ZWL + measurements

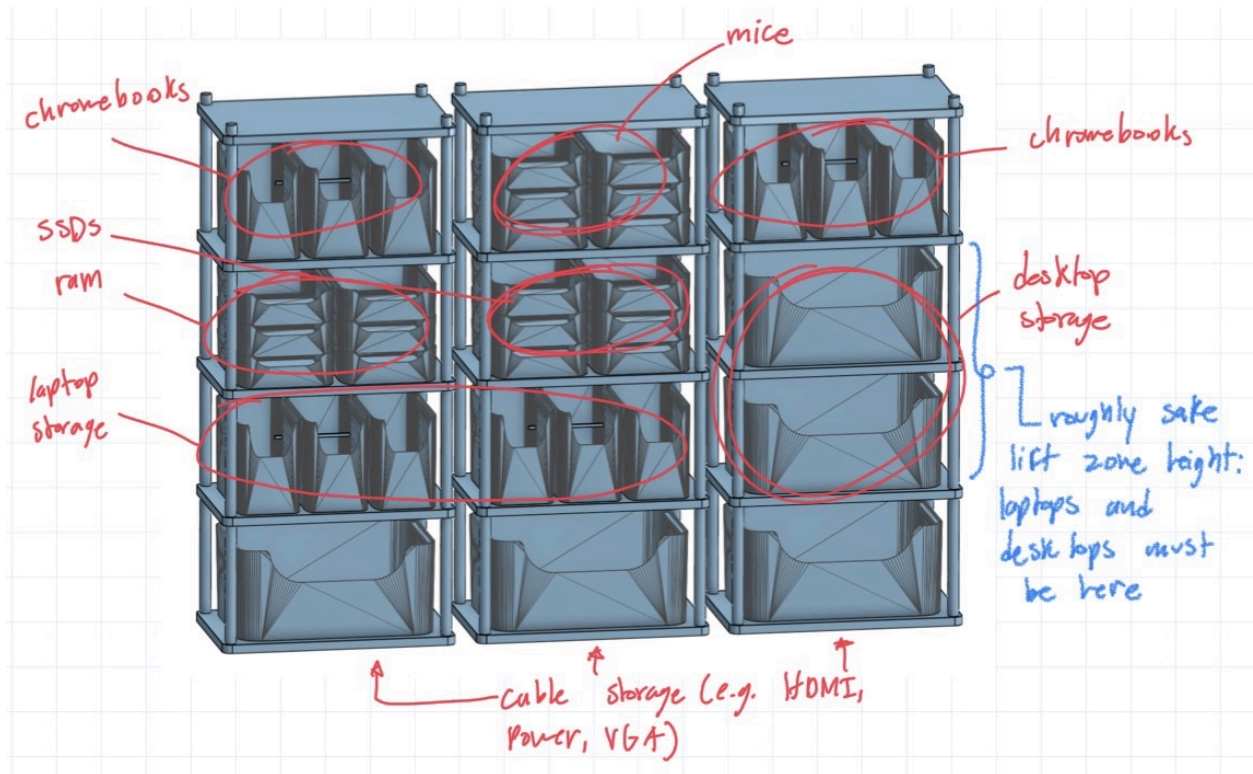


Figure 12. Exemplar Shelf Layout.

4ZWL separates the warehouse and the individual shelves in an intuitive manner. Looking at objectives, 4ZWL succeeds in being modular and adjustable to various hub layouts, but is weaker in enabling safe navigation of the main hub. This is discussed in Table 7.

Table 7. How 4ZWL meets objectives.

Objective #	Fulfilled?
O.1	Yes. Retrievability increases with intuitive storage [22].
O.2	Yes, the current shelves support desktops and monitors [5].
O.3	Yes. All furniture in 4ZWL is purchased from big-box retailers (which generally lasts 10-25 years) [23].
O.4	Yes. There are no objects >23kg in the warehouse [5].
O.5	Yes. The circulation area percentage is ~43% (Appendix J).
O.6	No. Vertical reach of shelves goes below 400mm and goes above 1200mm (Appendix J). Path width of design is not 1m, as shown in Figure 11.
O.7	Yes. 4-5 people can assemble the SSD in <5 hours (Appendix J).

6.3.3 Design 3 - Smart Modular Storage Rack System (SMSRS)

The SMSRS integrates physical storage with simple visual tracking. The system places laptop storage carts with built-in charging at the front of the workspace for ready-to-refurbish devices, with adjacent **separate shelving** for tools and frequently accessed materials to support a logical workflow. Modular shelving units **support stackable bins** that support **import/export** and are used to organize components by category/device model. Each storage compartment for WIP devices is equipped with an LED indicator and manual control button to display item status. A standardized color system is used (green = ready, red = requires repair, yellow = in progress), enabling quick identification and reducing search time.

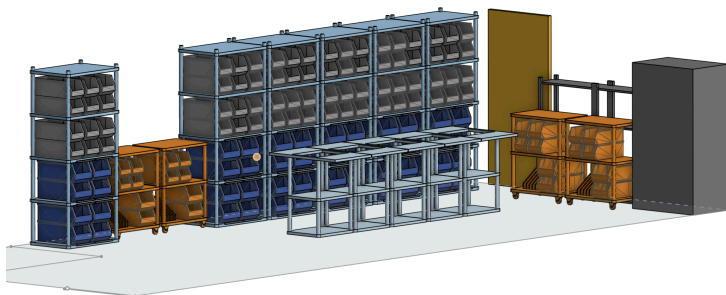


Figure 13. Side view of SMSRS

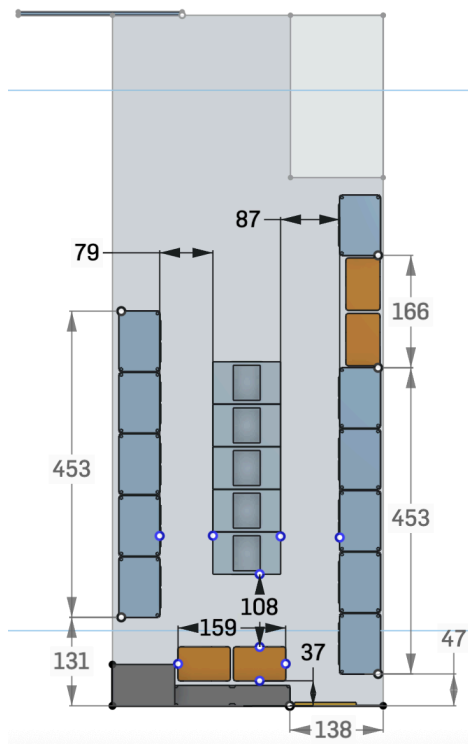


Figure 14. Bird's-eye view of SMSRS

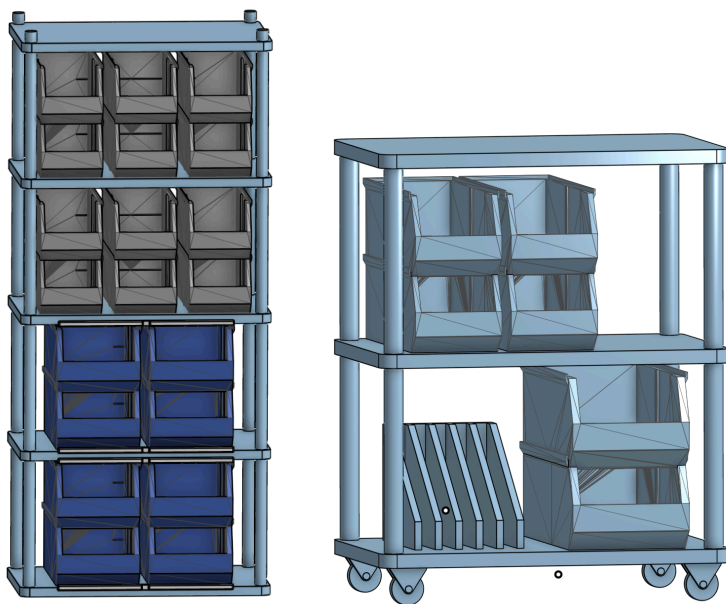


Figure 15. Layout of shelving unit and cart

Overall, the SMSRS design effectively meets most objectives by improving accessibility, durability, and workflow efficiency, while partially addressing ergonomic optimization. More information can be found in Table 8.

Table 8. How SMSRS meets objectives

Objective #	Fulfilled?
O.1	Yes. Organized bin systems reduce search time and movement, improving workflow efficiency and minimizing bottlenecks [22].
O.2	Yes. Industrial racking supports heavy loads (~100–300 kg per shelf) and maximizes capacity through multi-level configurations [24].
O.3	Yes. Metal shelving (10–20 year lifespan) and HDPE bins provide durability and chemical resistance. Modular parts allow replacement, extending system life [25].
O.4	Yes. Layout reduces unsafe handling by minimizing bending and stretching, lowering injury risk per ergonomic guidelines [26].
O.5	Partially. Frequently used items are placed within a 0.4–1.2 m reach zone, reducing bending and strain per ergonomic guidelines [26].
O.6	Yes. Perimeter shelving creates a central circulation path (~900mm), meeting accessibility guidelines for safe movement [27].
O.7	Yes. Boltless systems enable fast assembly and reconfiguration, keeping the time under 5 hours [28].

7.0 Proposed Conceptual Design (PCD)

To select the PCD, the Pugh Method was used to determine the ‘Sliding Shelves Design’ as our selection (Appendix I.4). Considering how the alternative designs fulfilled the objectives, the SSD scored 2 points over the ‘Four-Zone Warehouse Layout’ and 1 point over the SMSRS, making it the favourable design.

The proposed SSD addresses the client’s need for a design that supports smoother workflows by optimizing storage density while maintaining accessibility. By implementing sliding shelves, the design reduces the need for fixed aisles. The shelves themselves are organized in an intuitive way, with heavier items like desktops and monitors at the safe lift zone (O.7). Should the client’s needs change, the shelf bins containing all the equipment can be easily rearranged. Additionally, the digital dashboard and the LED indicator on the bins drastically reduces search time and therefore, unnecessary navigation. Overall, this design bridges the gap of an inefficient storage system and addresses the client’s needs.

8.0 Measures of Success

Using the pairwise comparison (Appendix D) and according to the client (Appendix A), the objective of improving workflow efficiency is of high priority for this project. This objective directly relates to the workflow aspect of the design, as it allows us to compare how the new layout improves the identification, retrieval, and storage of items. To determine how long a single retrieval cycle takes, we first identified the typical workflow of employees at LGT was identified (Appendix A). In Figure 16, two main tasks were observed: refurbishing laptops and desktops.

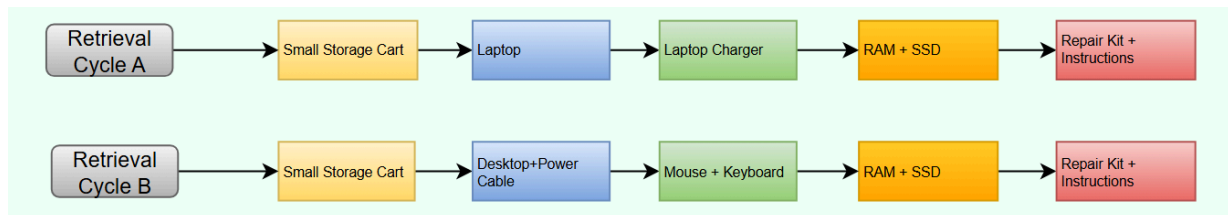


Figure 16. Process flow for both retrieval cycles

8.1 Testing Plan

To evaluate how the SSD performs on these tasks, the team considered several testing approaches. Ultimately, simulation was selected as it is the most accurate method for representing how the design would function in real-world conditions. FlexSim, a 3D simulation and modelling software with warehouse and logistics capabilities [29], was used for this purpose. To model the simulation as closely as possible to real warehouse conditions, exact dimensions were implemented in FlexSim (Appendix K.2), with all constraints and calculations detailed in Appendix K.1. Key parameters included an average walking speed of 1.2m/s, 12.4s for QR code scanning, and 5 s for digital dashboard interaction (Appendix K.1). Based on kinematics research, walking acceleration was taken as 0.84 m/s^2 , decreasing with cart load, and speed reduced to 1.05 m/s when pushing a cart.

To establish a baseline, a person unfamiliar with the current layout will conduct physical retrieval trials at the Tech4All Mississauga warehouse.

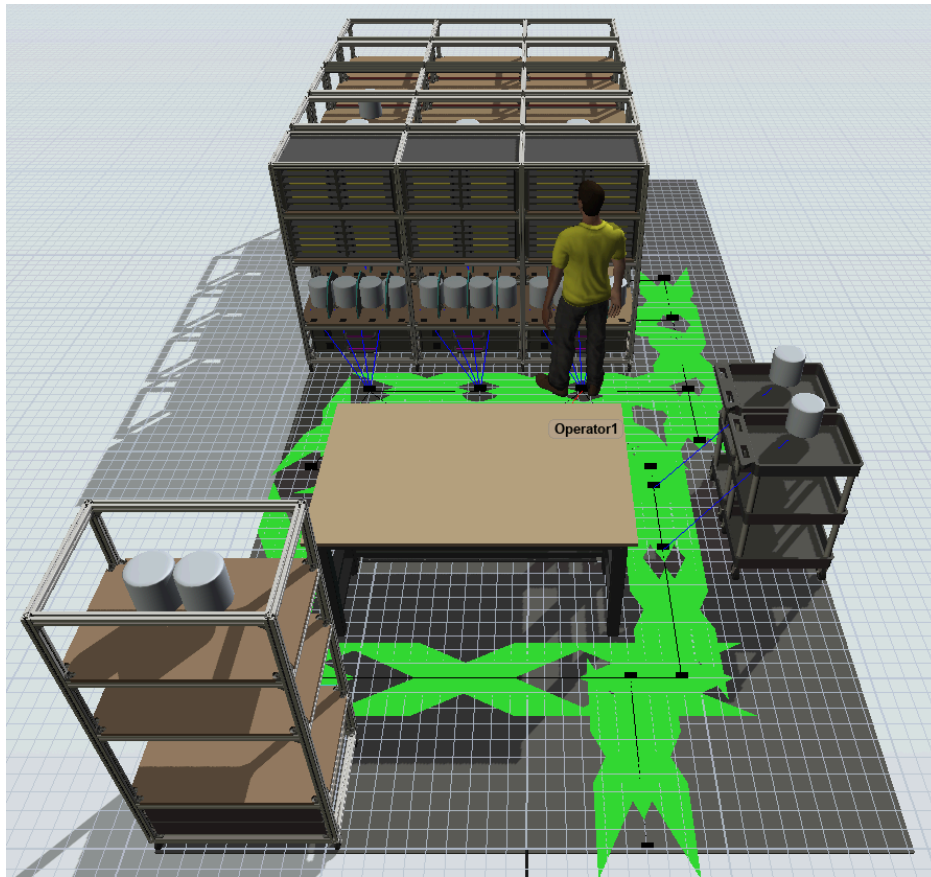


Figure 17. Layout in FlexSim.

8.2 Results and Next Steps

After setting all parameters, the simulation produced an average time of 13.67s/item for laptops and 13.17s/item for desktops (Appendix K.2) The new layout was tested with 10000 iterations for each cycle (Figure 18). These results meet the objective metric of 45s/item.

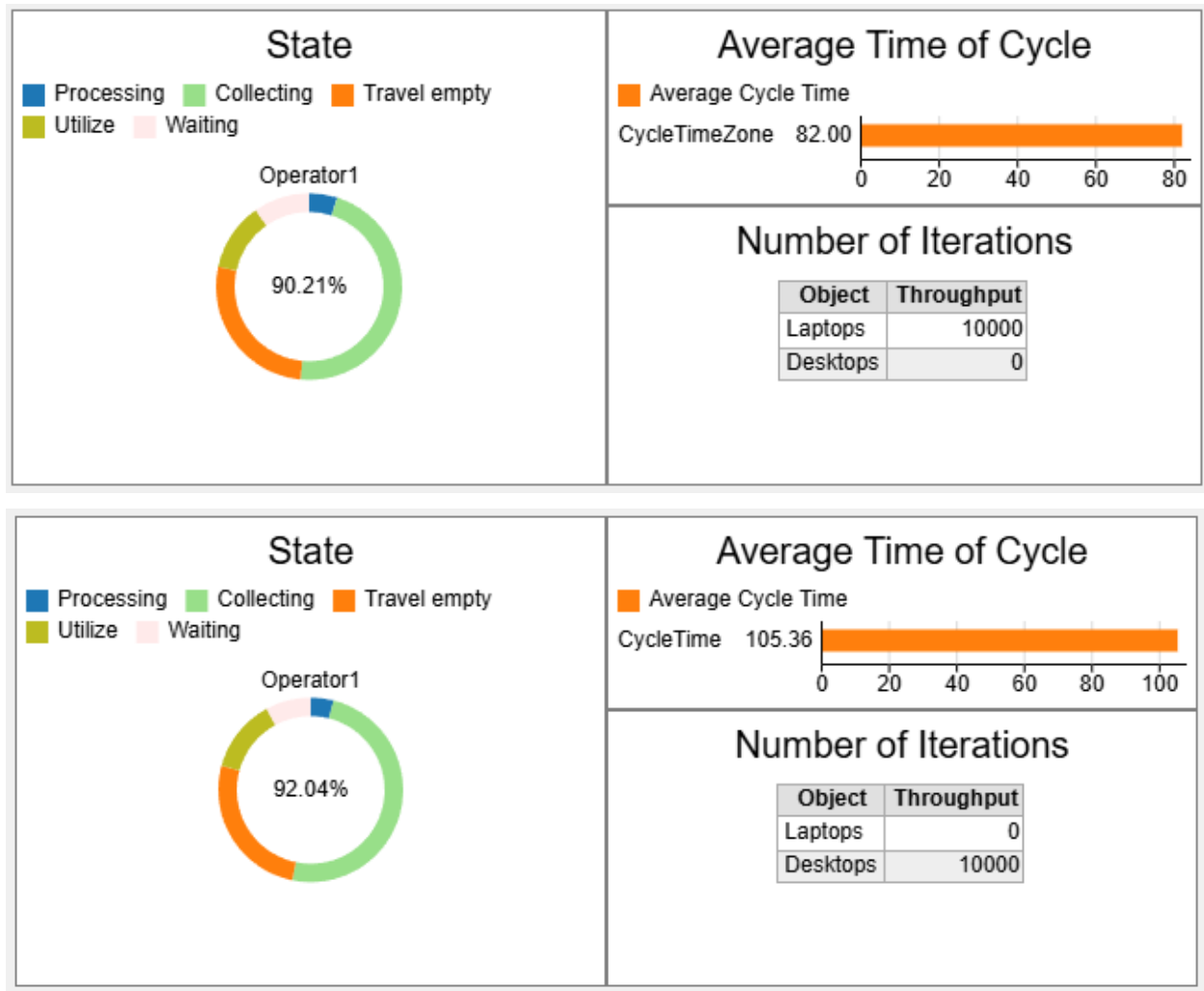


Figure 18. Statistics from Flexsim

The next phase involves visiting the site to observe how the current layout performs for the tasks described in Cycle A and Cycle B (Figure 16). This assessment will be conducted by someone who is unfamiliar with the existing warehouse arrangement and using it for the first time, which simulates conditions similar to those used in the FlexSim model.

9.0 Conclusion

This Conceptual Design Specification (CDS) presents a modular storage system for Tech4All hubs to improve organization, workflow efficiency and safe handling of electronic devices. The selected design incorporates modular components, categorized storage and visual management (e.g., LED indicators) to enable efficient item retrieval while maintaining safety and structural reliability. Overall, the design meets client requirements, with next steps including validation, implementation, and testing based on defined Measures of Success.

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Appendices

Appendix A. Client Meeting Notes

Meeting notes taken by Team 165 members during the first client meeting.

Appendix A.1. Devansh's Client Meeting Notes

Meeting notes taken by Devansh during the first client meeting that occurred on 4th February, 2026.

Date: 4th Feb, 2026

Client Meeting Notes

Client Questions

- ✓ 1. Georgia: About ease of accessibility; is there a certain height we should make the storage so that children could access the system? Would a step stool be an acceptable way of accessing the storage? Is bending, reaching or lifting acceptable?
- ✓ 2. Georgia: Are there any accessibility guidelines (based on your employee needs) that we should keep in mind? E.g. braille.
- 3. Tong: What is defined as 'basic tools' (as quoted in the client statement)?
- 4. Tong: Are there any key interest holders that we should keep in mind while making the design?
- 5. Kevin: How many years should the design last (durability, safety)?
- 6. Kevin: Usually how many people use the room at one time? It is only used for training and refurbishment purposes or are there other ways in which it is used?
- 7. Felix: What is the current solution in storing these electronics, and what are some of the main pitfalls with this current solution? Are there any dangers with disorganization?
- 8. Felix: What do you mean by 'easy to assemble'? Does that mean a certain time taken to set up, something that 1 person can easily set up by themselves, etc?
- 9. Devansh: What is inside the "cleaning supplies", "testing kits" and "refurbishing kits" mentioned in the client statement? Are there any hazards that we need to be aware of?

Q1: We wouldn't have kids there. Age of 13 years or old. It is mostly people over 20 years. No one of accessibility has worked there so far.

→ So one or two people will be working in the room. Others in the refurbishment center.
They work with a lot of student groups.

Q5

Build an inspection plan. So, and so should be inspected every month. Temperature range kids can use what durable and affordable. It can be two or more different brands.

→ The plan is expand

→ Efficiency is main goal. Close to the door or along one wall

→ Lockers and lockers are the priority.

→ She needs storage bins (Ikea)

Q: What's biggest challenge

Ans: Safety and organization (Wasting time)

3-D facility

→ Big box retailers should also have a role.

→ A team will assemble

Height? 5'-6" - 5'-7" Nothing

It is a big factor

→ 2 stories → Maybe 20 feet across (with stair cases)
4 feet deep shelves
→ 40 feet length

1



It includes the monitor storage space Team 166

→ Health and safety

↳ First aid kit, admin area

→ Legacy is important. Maintaining legacy is also

→ These are things that

→ We can learn how space for other items that are not

→ It there is a way to

→ We should recommend guidelines as to who should use it and how.

Main Goals and main problems:

1. Laptops and desktops (Main items they refurbish)
2. Having a nice organized system and to improve workflow.
3. Also, safety is a big challenge.
4. Also, a plan so that other hubs can also implement it.
5. Easy to assemble and quick to set up by 4-6 people. And instructions to assemble it.
6. Height is a big factor. Everyone is around 5-7 or 5-8
- 7.

She wants to buy from big retailers like Ikea, etc. because that gives them the opportunity of solving a bigger problem of digital divide.

Q: What are your biggest challenges? Safety

Ans: Height, and not able to find things. She needs a plan so that she can be like here's what I need first, then second and then third.

→ Accessibility is important but not as important for the right now.

Q: What is your workflow like?

Ans: Firstly people get their repair kit (in cart) then the device.

→ Device repair kit, cart, repair kit, desktop monitor

→ Rectangular, Behind this there is furniture (can't see)

→ The monitor are kept really badly. So team 166 is working on it. Work with them.

→ There is an admin area

Q: Fix its repair kit. Openable cart. Cordable. Hangers for it but not keeping it. Also tapes with cables, plug in, adapter cables

→ The goal is to set up. So a design that can be replicated to other tech hubs (other locations)

→ She wants it to be like eastern. Saint hub and Branton hub

→ Olympia cart is what she has right now.
(2 carts)

Q3: You are designing for me. But also other community centers, like library space, church, etc. should be able to replicate it.

Appendix A.2. Georgia's Client Meeting Notes

Client notes taken by Georgia during the first client meeting.

 UNIVERSITY OF TORONTO FACULTY OF APPLIED SCIENCE & ENGINEERING	DATE	Feb 4/26 ¹	PAGE
	NAME	Georgia Wu	
	COURSE NO.	COURSE NAME	2
		APS112	

CLIENT MEETING #1

200 laptops
Think pads, Dells, HP,

Goal: scale up, modular design for growth (holding new components, adding more of the same components)
COSTCO: layout is same, intuitive access to components
Portable, cost-friendly

Tong — headphones, bags
Fix-it repair kits (currently kits on Olympic carts) ^{portable for refurbishing projects in} main space
Also want safety kits.

Kevin

- inspection recommendation from us (temperature range)
- 3D printing can be used for design
- Use of 3D printing can segue into the public learning about 3D printing
- safer, more space... , efficient use of floor space that reduces searching time

Donors: Ikea, Home Depot (could be nice to use their products so that they donate the parts)

- Ikea Bins model: "Sort Term"
- More about adapters: different HP adapters !!

Felix

- Biggest problem w/ Current Design: organization, safety for sharing
- Nice-to-Have: modularity
- 3D printing is something client is willing to take on since it cld advance community outreach on 3D printing
- Team will set-up, 4-5 hrs of setup is fine.



DATE	1	PAGE
NAME		
COURSE NO.	COURSE NAME	2

- Accommodate 5'4" → 5'7" heights, heavy stuff shouldn't be stored on top.

- Warehouse height: 20ft across 4ft depth shelves } general space available
40ft wide (back door to warehouse door)
- emergency exit (check photos)

Devaugh

- cleaning supplies/kits (Health and Safety (MSDS Binders, First Aid kits), outside scope but check refurbishing stations and how they can be used
- Health and Cleanliness so easy to clean, store cleaning products
- Design should be able to store many things beyond the things in client statement.
- General Info: usually has what is on Client Statement...

General Questions

- Digital Organization is possible
- Foster Growth Mindset

Client Feedback

- don't say 'sorry' when asking questions; reflects on our confidence

Appendix A.3. Felix Client Notes

Felix's client notes during the first client meeting.

- What height?
 - No kids, come up with safety procedures
 - Adults, 13 and over, height might be a challenge for wheelchair users
 - Refurbishing currently
 - Someone broke their foot, make accommodations (clear aisles, no tripping hazards)
 - Not ideal space for everyone
- Priority of project is safety of people
 - Make sure equipment stored safely, maximize storage space
 - Efficiency of storage process
 - Make sure layout makes sense

- Cost
- Big box retailers
 - Help them solve problems relating to digital divide
- Accessibility guidelines
 - Braille not something considered yet
 - Largest barrier is **height, not organized**
- Order: repairing kit, parts, device, desktop then monitor, then cables
- Only half the warehouse space, other half is donated furniture
- White bins --> recent purchases for adapters, on rolling carts
- 200+ laptops, where to store them
- Admin area with printer
- Laptops: thinkpads, dell, hp, assortment
- Monitor storage
 - Other team is working on storage for monitors
 - Our design should accommodate for this
- Desktops: near emergency exit
 - Many desktops being refurbished
- **Design should be modular** --> scale up
 - Implemented in other locations
 - Should be like costco, similar layout for each warehouse
- **Design floor plan** to help implement in other locations
 - Template
- Basic tools?
 - Ifixit repair kits in cart
 - Collapsible, olympia cart
 - Headphones on olympia cart, cleaning kit
 - Tape for labelling
 - Extra cables
 - Vacuum
 - Battery testing kit
- 2 carts used to store parts so people don't need to go back and forth
- Interest holders
 - Design for other community spaces, church, library
 - Adapt current design for those spaces, could be temporary
- **Out of all the electronic parts and devices you guys have, which ones should we make sure our design targets?**
- How long should the design last?
 - Withstand 5-6 years
 - More permanent solution
 - **Build in an inspection**
 - **Design space and process to use and maintain**
 - Inspect parts to make sure they don't break
 - Affordable and durable material

- Maybe use existing parts, big box retailers
 - 3d printed parts to add to design
- How many people?
 - Anyone who is refurbishing will go into area
 - 2-3 people
- What work is most common?
 - Should laptops and desktop parts be near the front
- Ikea bins (??) which model of bins
 - Ikea stackable bins with lids sortera x 12
- **Design signage**
- Height
 - Make sure things don't fall on people's heads
 - 5'4 to 5'8 people working there
 - 2 stories, warehouse height
 - 20 feet across, 40 feet
 - Total warehouse space, not including monitor storage
- Hazards
 - Factor in health and safety things, like first aid kits
 - Cleanliness, disinfectants
- QR codes for sorting

Design

1. **Floor plan / layout**
2. **Storage units**
3. **Signage, visual management / sorting systems**
4. **Maintenance systems**
5. **Assembly instructions**

Appendix A.4. Tong's Client Meeting Notes

Tong's Client Meeting Notes.

The training centre is primarily used by adults (mostly age 16 and above), though some younger users such as Grade 9 students may occasionally access the space. Safety was emphasized as the highest priority due to the diversity of users, which may include individuals with disabilities or temporary injuries (e.g., users wearing medical boots). While wheelchair users can physically access the training centre, they typically do not operate the storage racks themselves.

the space is currently not ideal for everyone, and future designs should focus on improving safety while maximizing storage capacity.

Safety, Efficiency, and Storage Priorities

The client stated that human safety takes precedence over all other factors, followed closely by storage optimization and operational efficiency.

The team should aim to:

- Maximize storage space
- Improve process efficiency
- Maintain cost effectiveness

The organization already has storage infrastructure; but many units are not portable. Increasing portability while keeping costs low would therefore be beneficial.

Accessibility improvements are welcome but are not the primary design driver. Labeling systems may be implemented, but excessive labeling is unnecessary.

Equipment and Storage Observations

Several storage-related practices and needs were discussed:

- Training kits are currently used and often transported via carts.
- The client suggested reducing storage to one primary shelving unit when possible to simplify organization.
- Devices stored are typically older digital products (approximately 4–10 years old), including brands such as Dell and HP.
- Future designs should focus specifically on digital device storage, potentially incorporating monitor stands that could be standardized and replicated across other locations.
- Costco-style solutions were referenced as examples of cost-friendly, portable, and visually consistent storage systems.

Color consistency and standardized formatting are preferred to create a more organized environment.

Cart and Shelf Configuration (Q3 Discussion)

The client proposed using one to two carts alongside a shelving system.

Example contents include:

- Cleaning kits
- Fixed equipment kits
- Headphones
- Large zip plastic bags
- Safety tools (e.g., scissors)
- Extra cables
- Battery testing kits
- Overhead projectors

Each cart is expected to support structured organization while remaining easy to transport.

Potential Deployment Locations (Q4)

The solution should be adaptable to multiple temporary or shared environments such as:

- Churches
- Community centres
- Libraries

This suggests a need for modular and portable design features.

Environmental Guidelines (Q5)

The client mentioned providing environmental guidelines, including temperature considerations for equipment storage. Some locations may include advanced tools such as 3D printers, which further reinforces the need for controlled storage conditions.

Spatial Constraints and Workflow (Q6)

The storage room is approximately 40–50 feet in length.

Key workflow insights:

- Ideally, only 2–3 people should enter the storage space at once to maintain safety.
- More space is preferred, but efficiency must not be compromised.
- The retrieval process should take approximately two minutes, indicating a need for intuitive layout design.
- High-priority items such as laptops should be placed closer to the entrance.

Warranty handling procedures remain unclear and will require follow-up during the February 17 meeting.

Innovation Opportunities

The client expressed openness toward innovative solutions, including:

- QR code systems for tracking or instructions
- Visual aids such as pictures
- Digital platforms

Potential platform integrations mentioned:

- Chatbot interface
- Front-end user system
- GIS mapping system

The team is expected to focus primarily on backend development if a digital component is pursued.

Key Design Direction

Overall, the design should prioritize:

Safety

Efficiency

Cost-effectiveness

while ensuring the system remains portable and adaptable to multiple environments.

Appendix A.5. Kevin's Client Meeting Notes

Kevin's Client Meeting Notes.

Client Meeting

Feb 4 2026

Q1: no kids using it

have/design 'best practices' for design

mostly adults using it (Gr. 8/9 and up)

Client Meeting

Feb 4 2026

Q4: for T4A

Keep other various communities in mind

- ↳ plays w/ the universality

- ↳ can be deployed anywhere and everyone would roughly know how to use it

~ 1-2 workers in the area

Q5: as long as possible (5-6 years)

inspection points

- ↳ points on the design to check every [time period]

- ↳ *

temp range

fluctuates...

3D-printed parts are good!

- ↳ alongside IKEA/big box

Q6: only a few people in the room at given moment
make equipment retrieval quicker

Q7: only working personal come to the SE

SORTERA ikea bins is what the client has

- ↳ 12 bins

organization and safety pitfall

- ↳ wasted time from transitioning to different areas

- ↳ universality!

Q8: around 4-5 people to set-up the active in ~5 hours

- ↳ thinking is quick deployment

Client Meeting

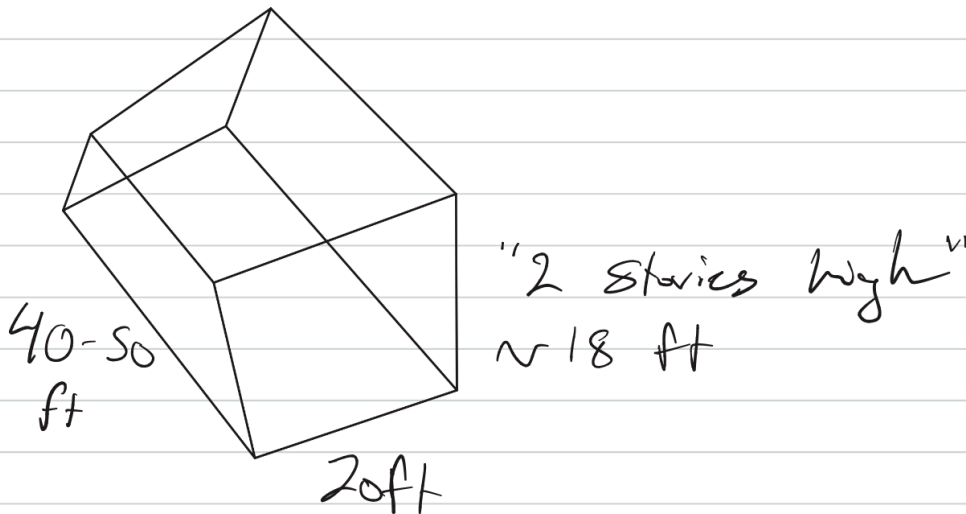
Feb 4 2026

Q9: height limitation

↳ users around are from 5'4" - 5'7" on average

↳ heavy items on the bottom

Rough-Room Sketch:



note software implementation is also good

↳ ref. to how toyota manages inventory

↳ maybe some software dashboard to see inventory

↳ SQL

↳ additionally an app to record inventory

↳ python (FastAPI) BE

↳ maybe incorporate w/ their existing site

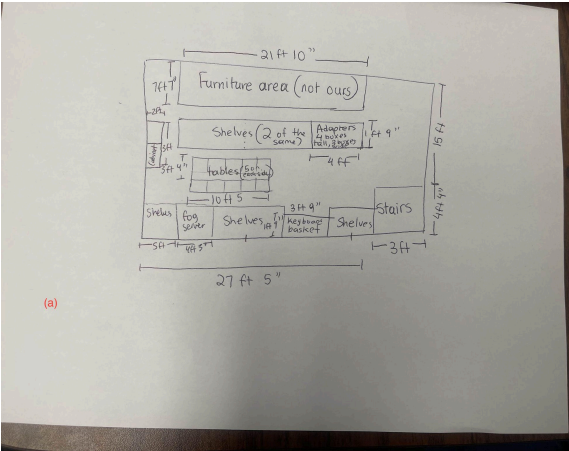
↳ js (react) FE

↳ maybe not needed
if incorporated in
existing site

↳ only for showing the client

Appendix B.1 Additional Dimensions relating to Service Environment

The operational setting is primarily indoors and consists of shared workspace environments used for refurbishment and training activities. These semi-permanent spaces support multiple users and commonly contain electrical equipment, safety materials, and cleaning supplies. The workspace should also accommodate a high volume of tools and components, resulting in dense storage conditions. The system may be deployed across multiple indoor locations, requiring it to function reliably under varying spatial constraints, usage patterns, and organizational practices. As a result, the service environment is defined by consistent indoor conditions combined with variability in layout, access, and user behavior.

Object	Dimensions  (a)
Workspace: i) Ceiling Height ii) Floor Width iii) Shelf Depth iv) Working Space (Garage Door) v) Entrance to Corner Distance vi) Cabinets Length vii) Total Length of Other Side	i) ~20 ft ii) ~40 ft iii) ~4 ft iv) Width: 15 ft v) 19 ft vi) 27 ft 5 inches vii) 27 ft 5 inches

Shelf: i) Grey Shelf 1 ii) Grey Shelf 2 iii) Shelf 3	i) 6 ft 1 inch ii) 6ft iii) 5 ft 8 inches
Furniture: i) Tables (5 together) ii) Locked cabinet iii) Keyboard basket iv) Adapters v) Furniture area	i) Length: 10 ft 5 inches Width: 3 ft 4 inches Height: 3ft ii) Height: 5 ft 5.5 inches Width: 3 ft Length: 2 ft iii) Height: 1 ft 9 inches iv) Length: 4 ft 2.5 inches Width: 1 ft 9 inches Height: 5 ft 4 inches v) Length: 21 ft 10 inches Width: 7 ft 7 inches

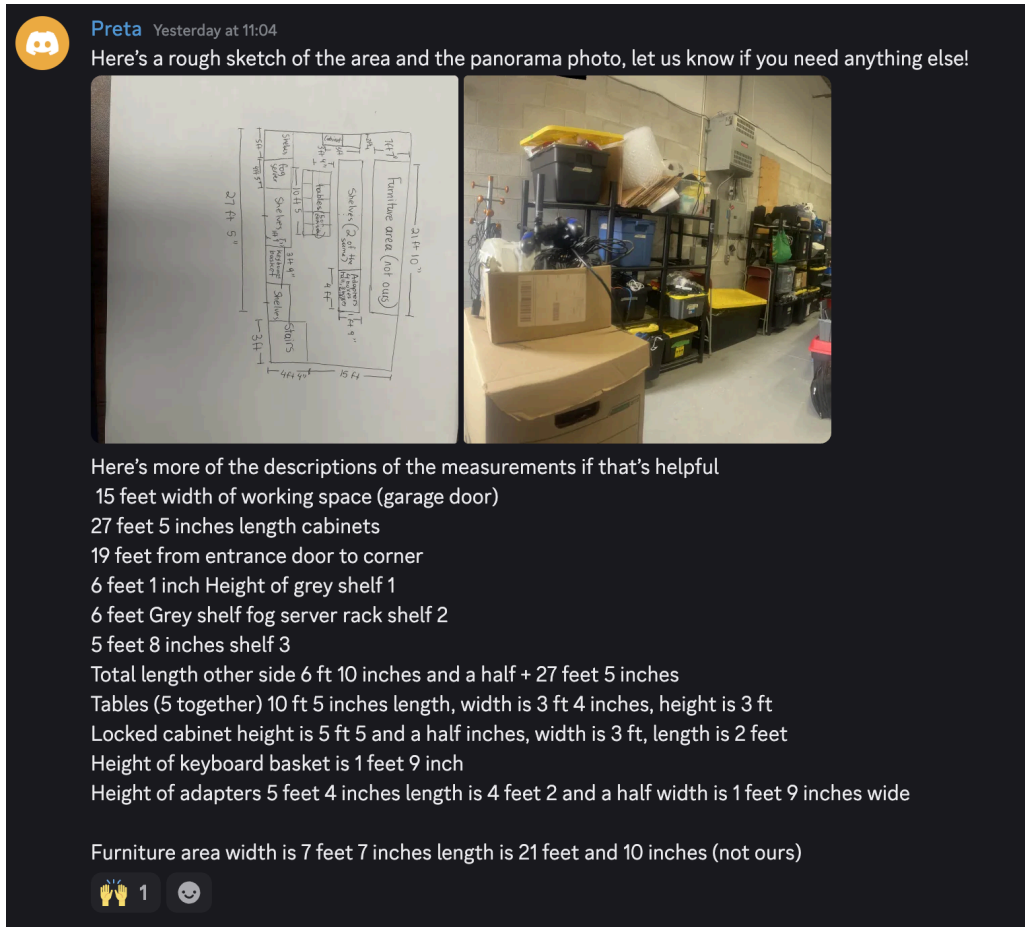


Figure B.2. Screenshot in discord showing the data and layout

Appendix B.2. Further Justification for Interest Holders.

Table B.2. Further Justification of Interest Holder Influence and Impact.

	Interest Holders	Influence	Impact (+/-)	Further Justification
I.1	Ontario Office of the Fire Marshal	High	Low (neutral)	The design is constrained to follow the Ontario Fire Code standards of emergency exit clearances of 1100m width path leading to the emergency exit. This is outlined in constraint C.4 [8].

I.2	Business + Institutional Furniture Manufacturers Association (BIFMA)	High	Low (neutral)	BIFMA standards are followed for objective O.2 and constraint C.6. O.2 targets lifespan of design [10] and C.6 constrains the design to withstand tipping force [10].
I.3	Logistics Bureau	Medium	Low (neutral)	The Logistics Bureau's warehouse design principles for circulation space are followed and listed as objective O.1 [18].
I.4	National Institute for Occupational Safety and Health (NIOSH)	Medium	Low (neutral)	The NIOSH lifting equation is utilized to determine a safe lifting load depending on the height of the object, as outlined in objective O.7 [12].
I.5	Canadian Standards Association (CSA)	Medium	Low (neutral)	CSA standard CSA B651 is followed in objective O.5. CSA B651 sets metrics for reach and clearance to ensure facilities are accessible to individuals with physical, sensory, and cognitive disabilities [13].
I.6	Third spaces in the GTA	Low	Medium (+)	The client plans to implement this design into churches, community centers, and other third spaces (Appendix A.3). This is part of Tech4All's efforts to set up hubs across the GTA and make technology more accessible [15].
I.7	Receivers of refurbished technology	Low	Medium (+)	Proper storage prevents damage to components before refurbishment [18]. The quality of refurbished products will improve and positively impact the receivers. Receivers are individuals in financial need/applicants to the Tech4All program on the LGT website [2].

I.8	Donors of technology	Low	Low (+)	The design will store technology that is donated by community members and corporations [5]. The technology will be positively impacted by the new design, due to better organization and storage conditions [14].
I.9	E-waste recycling organizations	Low	Low (+)	Tech4All has worked with groups like COM2 Recycling in the past. They collected unwanted tech to either recycle safely or refurbish [15]. The design will reduce damage to devices and increase efficiency of Tech4All hubs. This increases the number of devices that can be refurbished rather than recycled.

Appendix C. Justification of Functions

The functional basis was used to determine the primary function. “Mass” was chosen as the component since the design deals exclusively with physical objects like electronic components, devices and different kits. “Store” was chosen as the operator for the primary function since the fundamental purpose of the design is to keep the mass in a specific location. Therefore, “store mass” is the most accurate abstraction of the primary function for the design.

To get the primary function, the abstraction to get the functional basis was reversed, resulting in “Store a dynamic inventory of electronic devices and refurbishing equipment”

To determine the secondary functions, functional decomposition with a how/why tree was used.

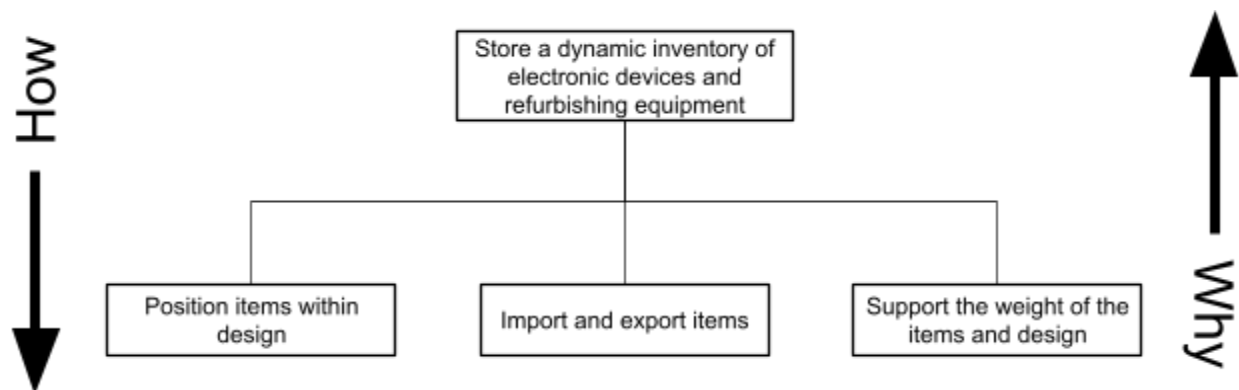


Figure C.1. How/why tree for determining secondary functions

Table C.1. Justification for Secondary Functions

Secondary Function	Justification
Support the weight of the items and design	The design should be able to counteract gravity, if it is unable to hold items up against gravity, the mass would fall through the system, causing the primary function to fail.
Enable positioning of items within design	The design should be able to keep items within a fixed position within the design. If the items move around and somehow exit the system, they are no longer being stored by the design, causing the primary function to fail.
Enable the import and export of items	To be able to store and supply items, they must be able to enter and exit the design. With no way of import and export, storage is impossible, causing the primary function to fail.

Appendix D. Justification for Objectives

	Allocating adequate circulation space	Long-lasting	Improve workflow efficiency	Support high load capacity	Ergonomically accessible	Quick to assemble and reconfigure	Minimizing unsafe equipment handling	Enabling clear categorization/identification of stored items	Score	Rank
Allocating adequate circulation space		0	0	0	1	0	1	1	3	4th
Long-lasting	1		0	1	1	0	0	1	4	3rd
Improve workflow efficiency	1	1		1	1	1	0	1	6	1st
Support high load capacity	1	0	0		1	1	1	1	5	2nd
Ergonomically accessible	0	0	0	0		1	1	1	3	4th
Quick to assemble and reconfigure	1	1	0	0	0		0	1	3	4th
Minimizing unsafe equipment handling	0	1	1	0	0	1		1	4	3rd
Enabling clear categorization/identification of stored items	0	0	0	0	0	0	0		0	5th

Figure D. Screenshot in discord showing the data and layout

This appendix provides further justification for the design's objectives.

Table D.1. Justification for Objectives

Descriptor	Justification
Should allocate adequate circulation space	The Logistics Bureau's warehouse design rules of thumb recommended having 20-25% of the warehouse floor allocated for non-storage operations. This includes receiving, dispatching, and staging. They specifically warn against compromising aisle space to avoid bottlenecks/funnels, resulting in a space that

	supports flow while still maximizing storage density [18].
Long-Lasting	The BIFMA X5.9 (storage units) sets recommended minimum performance levels “to help ensure reasonable safety and performance” and states an estimated product life of 10 years based on single-shift usage [10].
Improve workflow efficiency	Handling cycle time is a good measure for workflow efficiency, as it captures the average time required for storage and retrieval. The Legacy Supply Chain has the formula for this: put-away cycle time = total put-away time / # items put away [16]. A target of ≤ 45 seconds/item for common items corresponds with a published manual picking benchmark of ~ 80 picks per hour [17].
Weight capacity	Using a general assumption from what the client stores, the heaviest items that the client has are desktop towers and monitors. Assumptions: - Weight of desktop tower (Dell OptiPlex 7000): 9.68 kg [30] - Weight of 24” monitor (Dell UltraSharp 24): 5.38 kg [31] Calculations: If a unit of storage holds 6 desktop towers and 4 monitors, then: • 6 desktop towers: $6 \times 9.68 \text{ kg} = 58.08 \text{ kg}$ • 4 monitors: $4 \times 5.38 \text{ kg} = 21.52 \text{ kg}$ Total = $58.08 \text{ kg} + 21.52 \text{ kg} = 79.60 \text{ kg}$ Adding in a factor of safety of 20%: $79.60 \text{ kg} + 20\% = 95.52 \text{ kg}$ Thus, a goal of $\geq 95 \text{ kg}$ per storage unit is justified.
Accessibility / Ergonomics	The client mentioned that improving workflow efficiency is a desired outcome, and frequently used items should be quick to access (Appendix A.5). CSA B651 is setting measurable reach and clearance metrics, such as keeping common items within an unobstructed reach of 400–1200 mm and maintaining $\geq 1000 \text{ mm}$ of clear routes [13].
Should be easy to assemble and reconfigure	The client stated that the storage system should be easily and quickly assembled, as many other hubs may need to set it up, move it, or reconfigure it to their workflows (Appendix A.5). They stated that an optimal goal should be ≤ 5 hours with 4 - 5

	people for the entire system to be assembled.												
Minimize unsafe equipment handling	The client highlighted that workers should not lift or reach heavy items above shoulder height, as it increases the risk of injury during day-to-day storage and retrieval (Appendix A.5). The Revised NIOSH Lifting Equation guidance, summarized by CCOHS, defines a load constant of 23 kg as the maximum recommended load under ideal lifting conditions [12]. Since real tasks are often not under ideal conditions, heavier items are stored in a safer “lift zone” (between knee and shoulder height).												
Categorization and Identification	The United States Standard recommends that labels be legible at a distance of 710 mm, which corresponds to the typical “standing and looking” distance in a storage aisle. The character height at this distance is ~5 mm. The table below gives minimum character heights for other viewing distances [22]. <table> <tr> <th>Viewing Distance</th><th>Minimum Height</th></tr> <tr> <td>< 500 mm</td><td>2.3 mm</td></tr> <tr> <td>500 - 1000 mm</td><td>4.7 mm</td></tr> <tr> <td>1000 - 2000 mm</td><td>9.4 mm</td></tr> <tr> <td>2000 - 4000 mm</td><td>18 mm</td></tr> <tr> <td>4000 - 9000 mm</td><td>38 mm</td></tr> </table>	Viewing Distance	Minimum Height	< 500 mm	2.3 mm	500 - 1000 mm	4.7 mm	1000 - 2000 mm	9.4 mm	2000 - 4000 mm	18 mm	4000 - 9000 mm	38 mm
Viewing Distance	Minimum Height												
< 500 mm	2.3 mm												
500 - 1000 mm	4.7 mm												
1000 - 2000 mm	9.4 mm												
2000 - 4000 mm	18 mm												
4000 - 9000 mm	38 mm												

Appendix E. Justification for Constraints

This appendix provides further and more detailed justification for constraints.

Table E.1. Justification for constraints of the design

Descriptor	Justification
Must be freestanding	As stated by the client, the design must be freestanding and must not be secured to any part of the warehouse [5].
Must be within budget	As stated by the client, the total cost estimates of the design must not exceed \$2000 budget [5].
Must fit within designated area	The design must physically fit within the designated warehouse area (Appendix A.3).
Must not block emergency exits	Within the warehouse space, there is an emergency exit, located next to where the desktops are currently being stored (Appendix A.3). According to section 2.7.1.1.(2) of the Ontario Fire Code, an aisle leading up to an emergency exit must have a clear width greater than 1100 mm [8]. The path leading to the emergency exit can't just be a small gap; it has to be an unobstructed pathway allowing for quick exiting in case of an emergency.
Must not introduce tripping hazards	The walkways of the warehouse must avoid any tripping hazards. By following universal design and designing for the strictest accessibility requirements, the space would be safe for all users. According to section 3.8.1.3.(2) of the Ontario Building Code, a barrier-free path of travel must not have any protrusions greater than 13 mm [9]. Even if the client doesn't expect people with special accessibility to use the space, unexpected injuries could still occur, like the case of the worker who broke their foot (Appendix A.3). Finally, carrying large objects could make it difficult to see the ground, furthering the need for a clear path.
Must be stable	The solution must not tip or fall during normal usage. According to section 9.3 of the Ansi-Bifma X5.9 standard, an object with at least 1 extendible element must withstand a horizontal force of 44 N applied to the top edge to be considered stable [11]. A design that is not stable could be a hazard to workers in the warehouse and could also lead to the damage of goods.
Must protect sensitive electronics items from damage	The design must make sure that sensitive electronic components are not damaged. The main cause of damage for these components in this scenario would be electrostatic discharge (ESD) [19]. Even

	a small electric potential could cause an ESD event that could destroy a component. According to section 2.0 of ANSI/ESD S20.20-202, the design must prevent ESD's greater than 100 V [19]. If a solution was unable to do this, electronic components will be damaged and lead to a loss of goods for the client.
Must be modular	As stated in the client statement, the design must be modular to be used in all Tech4All hubs [5]. A modular solution allows for individual units to be changed without affecting the entire system. This is crucial for using and scaling the design in multiple locations, preventing the need for a completely new design for each hub. To quantify modularity, the propagation cost could be calculated with a Design Structure Matrix [20]. The propagation cost measures what percentage of the system changes on average, when a change is made to a single element [20]. Assuming 5 to 6 total design elements, a limit of $\leq 50\%$ could be chosen. For example, if a change was made to the storage solution, that change could propagate to the layout and visual elements of the design as well. Therefore a limit of 50% balances the inherent correlation between separate components of the design, while still allowing for scalability and adaptability.

Appendix F. Morph Charts of each member

Appendix F.1 Devansh Bhutani Morph Chart

Table F.1 Devansh Bhutani Morph Chart using FOCS

Morph Chart					
FOC	Means	Means	Means	Means	Means
① Long Lasting	Galvanized steel frames	Aluminium extrusion frame system	Anti Corrosion coated metal shelves	Epoxy coated metal shelving	Triangular frame bracing
② Enable positioning of items within design + Stability	Heavy duty magnets	Screw filled PVC pipes at the bottom for extra weight	Putting heavy items at the bottom	Longer shelves (in terms of width) help in prevent left or right fall	Curved cabinet on corners
③ Improve workflow efficiency	QR Code Bin Labels	Transparent Bins	Color - Coded LED Strips	Instructional posters for standard subassembly process	Shelving lanes: Made Parts → Testing Rack
④ Protect sensitive electronics items from damage (ESD)	Anti - static copper tape around the edges	Aluminium Foil lining	Disposable ESD wrist strip	Anti static bubble wrap for shelves with Roms + HDD	Humidity Controlled Cabinet

Appendix F.2 Kevin Morph Chart

Table F.2 Kevin Morph Chart using FOCS

FOC	Mean 1	Mean 2	Mean 3	Mean 4	Mean 5
Allocating adequate circulation space	Vertical wall pegboards	Slim rolling tool carts	Sliding racks	Foldable wall workbenches	Ceiling hanging racks
Quick assembly and reconfiguration	3D printed modular joints	Boltless snap together steel shelves	Interlocking stackable IKEA bins	Modular aluminum rail framing	Magnetic mount storage strips
Clear categorization and identification	Scannable smart QR codes	Color coded LED status strips	Large magnetic label plates	Transparent bin storage units	Digital inventory dashboard
Minimizing unsafe equipment	Gravity fed sliding racks	Designated safe lift zone shelves	Heavy duty rolling tower carts	Rotating Lazy Susan organizers	Tilting parts access racks

handling					
Supporting high load capacity	Reinforced industrial steel frames	Grounded metal desktop boxes	Heavy duty workbench hybrids	Vertical walnut laptop stands	Steel reinforced wooden racks

Appendix F.3 Tong Morph Chart

Table F.3 Tong Morph Chart using FOCS

FOC	Mean 1	Mean 2	Mean 3	Mean 4	Mean 5
Optimizing workspace circulation	Narrow mobile shelving units	Wall-mounted foldable tool racks	Corner rotating storage towers	Overhead rail sliding baskets	Under-bench pull-out storage drawers
Fast assembly and adaptability	Slot-fit wooden frame modules	Adjustable perforated metal rails	Clip-on modular shelf brackets	Snap-lock plastic storage frames	Tool-free adjustable rack connectors
Easy identification and sorting	Large color-coded bin labels	RFID tag tracking system	Icon-based category labels	Numbered storage zones	Transparent drawer compartments
Reducing physical strain during use	Waist-height access shelving	Pull-down overhead racks	Soft-close sliding drawers	Rotating vertical carousel storage	Lightweight aluminum rolling carts

Appendix F.4 Georgia Morph Chart

Table F.4 Georgia Morph Chart using FOCS

			Georgia				
Secondary Functions	Means	Means	Means	Means	Means	Means	Means
Separate items within design	Cardboard separators	Shelf	Rack	Individual box shelves	Ai uses computer vision to identify each item	Bags	3d printed separators
Import and Export items	Robotic arm	Conveyor belt	Easy access surface (e.g. shelf)				
Support the weight of the items	The ground	Block pallet	shelf	hammock	hooks	Jars	crates
Important Constraints	Means	Means	Means	Means	Means	Means	Means
Be freestanding	Shelves	Racks	Boxes	Sticky Hooks	drawers	Hook wall	
Be stable	Shelves	racks	Boxes	Drawer units on the ground			
Protect sensitive electronics from ESD	Antistatic bags	Cardboard separators	Bubble wrap	Storage cases with separators for small items (e.g. ram, cpu)			

Appendix F.5 Felix Morph Chart

Table F.4 Felix Morph Chart using FOCS

FOC	Mean 1	Mean 2	Mean 3	Mean 4	Mean 5
S.1 Separate items within design	Stackable bins, each bin holds separate type	Adjustable shelf dividers, slots to separate different items	Drawers with compartments, each compartment for items	Gridfinity modular compartments, modular open source grid storage system	Standing pegboard to hold items (wires) / tools
S.2 Import and export items	Sliding shelves/drawer	Rotating design to access different components	Tilt design to access components	Carts to hold components / commonly used tools, can be docked	Doors with locks to secure expensive items
O.2 Lost lasting	Aluminum extrusion frame	Heavy duty plastic materials	Treated hardwood	Carbon fiber elements	Structural supports and trusses
O.3 Improve workflow efficiency	Color coding different compartments	Shadow board, shows outline of what should be where, useful for tools	Freestanding map showing where items should go	Shelves angled toward walkways for easy visual identification	Transparent storage bins to allow users to see whats inside
O.6 Quick to assemble	Foldable frame shelf that unfolds and stands	Components from big box retailers (ikea, home depot)	Parts that interlock together for easy and toolless assembly	Magnetic connectors, connect through magnetic force for easy assembly	Design with only one type of fastener (i.e. allen key), assembled with one tool

Appendix G. Analogy used by Georgia

1. One of the current problems in the Tech4All hubs is that things like cables, adapters and RAM are all stored in 1 box. This makes for less efficient retrieval and possibility of damage due to delicate parts and electrical residue (especially with chargers).

Other people in the electrical industry also have problems with storing all of their parts. As per the video above, one person has a big box with cardboard separators that ensure a) components are easy to take out

and b) transportation of the large boxes won't rattle the components around. The functional basis of this cardboard separator is to 'separate mass'.

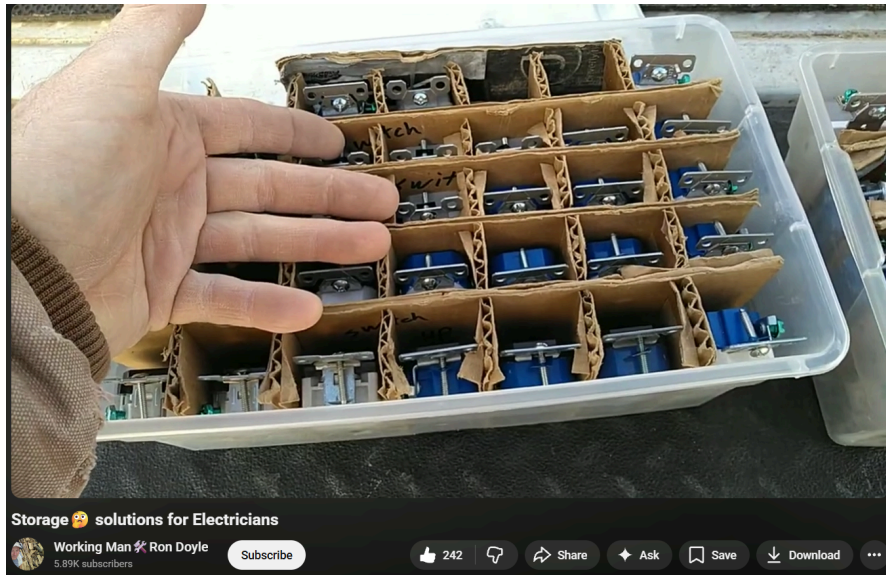


Figure G.1. Storage Solution by Ron Doyle.

Biological Analogy

2. Efficient use of space and dangerous storage of heavy objects on high shelves is another problem that Tech4All hubs have.

In nature, honeycombs in bee hives are used to store honey with a distinct hexagonal shape.

Hexagonal storage can be applied to the Tech4All hubs in terms of storing heavier items lower, since hexagonal shelves slot together and shelves are only half taller than the height of the shelf below (whereas with rectangular shelves, the next shelf is as tall as the height of the shelf below).

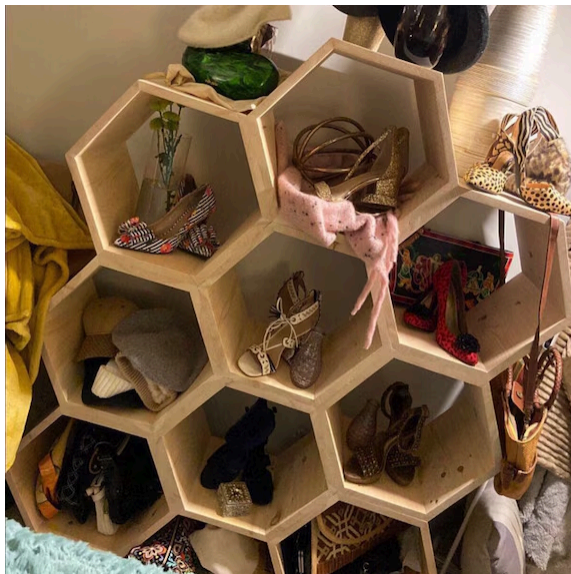


Figure G.2. Biological analogy

Appendix H. Idea Generation

Table H.1 Legend for Ideas/ Means Table

Idea Generation Technique	Highlight colour	No. of ideas/means/solutions
Structured Brainstorming		41
Free Brainstorming		31
Categorized Brainstorming		11
SCAMPER		2
Morph Chart		127
Benchmark		10
Analogy		17

Categories

1. Storage of items
2. Accessibility and interaction
3. Categorization and conveying information
4. Layout

Table H.2 Storage of items

Idea	Solution/Mean	Generation Technique	Idea	Solution/Mean	Generation Technique
1	Laptop storage carts that have a built-in charger	Structured Brainstorming	39	Wires: velcro/tape each wire and put the specific type in own bin	Categorized Brainstorming
2	Magnetic tool and cable wall	Structured Brainstorming	40	ECE lab hanging rack for wires, 3D printed	Categorized Brainstorming
3	Gravity-fed cable storage rack	Structured Brainstorming	41	3D printed cable spool	Categorized Brainstorming
4	Vertical laptop library rack	Structured Brainstorming	42	Laptop drawer	Categorized Brainstorming

5	Rotating electronics storage tower	Structured Brainstorming	43	Rolling cart for most commonly used tools/items	Categorized Brainstorming
6	Sliding monitor slot rack	Structured Brainstorming	44	Large desk with cabinets at desk to replace workbench	Categorized Brainstorming
7	Adjustable modular rail storage system	Structured Brainstorming	45	Rolling cart for desktops to be transported	Categorized Brainstorming
8	Laptop charging and storage cart	Structured Brainstorming	46	Smart storage cabinet. You would enter code and then it opens with that item	Free Brainstorming
9	Foldable monitor storage rack	Structured Brainstorming	47	Sliding file storage cabinet for paperwork	Free Brainstorming
10	Magnetic cable organizer strip	Structured Brainstorming	48	AI robotic Carts (Robot waiter)	Free Brainstorming
11	Stackable smart storage bin system	Structured Brainstorming	49	Auto-rotating smart storage tower	Free Brainstorming
12	Tilting parts access rack	Structured Brainstorming	50	Modular rail-based storage system	Free Brainstorming
13	Rolling repair tool station	Structured Brainstorming	51	Sliding box on rails for most commonly used items	Free Brainstorming
14	Under-table hidden storage drawer	Structured Brainstorming	52	Sliding high-density compact storage system	Free Brainstorming
15	Vertical cable reel rack	Structured Brainstorming	53	Hanging storage from roof	Free Brainstorming
16	Rotating lazy-susan parts organizer	Structured Brainstorming	54	Incline railway	Free Brainstorming
17	Rotating Gondola Shelving Unit With shelves and Bins	Structured Brainstorming	55	Baker's racks with slide in trays, entire tray could be pulled out, loaded, then quickly inserted back into shelf	Benchmark
18	This is a mobile device cabinet but kinda like this and it will be used to segregate and categorize cables	Analogy	56	Angled library book carts, V shaped groove to hold laptops, easily rolled around	Benchmark
19	Sliding Shelves	Analogy	57	Louvred bin panels and storage bins for small	Benchmark

				components	
20	360 degree rotating cabinet	Analogy	58	Mailroom sorting cabinets for small items or laptops, prevents stacking of laptops	Benchmark
21	Conductive stackable bins and carbon-infused divider boxes are sold specifically for electronic components and circuit boards to follow our ESD constraint.	SCAMPER	59	Hexagonal storage tubes based off of honeycombs, maximum storage capacity and structural strength	Analogy
22	Vertical laptop stands as it improves the density of storage.	Structured Brainstorming	60	Modular stackable shelving with twist locks, based off of shipping containers. Stack modules on top of each other and twist to lock modules together	Analogy
23	Curved cabinets	Structured Brainstorming	61	cardboard separators in boxes	Analogy
24	Foldable workbench	Structured Brainstorming	62	Hook wall for tools	Free Brainstorming
25	Wall-Mounted Laptop Slot Rack	Structured Brainstorming	63	jars for small items	Free Brainstorming
26	Modular Cube Electronics Storage System	Structured Brainstorming	64	antistatic bags	Free Brainstorming
27	Cable Hanging Track System	Structured Brainstorming	65	bubble wrap	Free Brainstorming
28	Mobile Modular Storage Tower	Structured Brainstorming	66	honeycomb storage solution (hexagonal shelves are shorter compared to rectangular shelves)	Analogy
29	Sliding Laptop Tray Storage System	Structured Brainstorming	67	Library style vertical slots for the laptops to fit as many as possible into the warehouse footprint.	Benchmark

30	Adjustable Height Equipment Rack	Structured Brainstorming	68	Grocery store style gravity racks where cables or parts always slide to the front for an easy ergonomic reach.	Benchmark
31	Rotating Cable Spool Storage Rack	Structured Brainstorming	69	Retail pharmacy style locked cabinets to keep the expensive testing tools and refurbishing kits secure.	Benchmark
32	Hybrid workbench storage rack	Structured Brainstorming	70	IKEA Sortera stackable bins to keep all the loose parts like RAM and adapters from turning into a giant mess.	Benchmark
33	Fixed vertical equipment rack with adjustable shelves	Structured Brainstorming	71	Automotive garage style pegboards for hanging cables and tools so the floor stays clear of tripping hazards.	Analogy
34	Pull-Out Deep Bin Storage System	Structured Brainstorming	72	Server room style air gaps between desktops to keep them cool and stop batteries from dying during storage.	Analogy
35	Wall-Mounted Foldable Workbench Storage	Structured Brainstorming	73	File cabinet style sliding trays for the laptops so they are protected and easy to audit at a glance.	Analogy
36	ESD bags for desktop components	Structured Brainstorming	74	velcro fasteners to separate cables	Free Brainstorming
37	ESD wrap/tape to cover components	Structured Brainstorming	75	cable hooks	Free Brainstorming
38	Grounded metal box for desktops	Categorized Brainstorming			

Table H.3 Accessibility and interaction

Idea	Solution/Mean	Generation Technique	Idea	Solution/Mean	Generation Technique
------	---------------	----------------------	------	---------------	----------------------

1	Computer Vision Software that directs users to the presented object's storage	SCAMPER	5	crank that brings items to 'safe lift zone'	Free Brainstorming
2	Wearable pouch based off of kangaroos to carry tools and commonly used items instead of a cart	Analogy	6	Tool box style portable cleaning kits so volunteers can grab all their supplies and move to any station.	Analogy
3	Gravity powered dispenser based off of vending machines, could be used to dispense heavy duty items like cables	Analogy	7	Sushi restaurant style conveyor belt to bring refurbishing kits right to the worker to minimize walking around.	Analogy
4	trolley for safe transportation of heavy items	Free Brainstorming	8	Kitchen pantry style Lazy Susan rotating bins to get 360 degree access to all the tiny RAM and hard drive parts.	Analogy

Table H.4 Categorization and conveying information

Idea	Solution/Mean	Generation Technique	Idea	Solution/Mean	Generation Technique
1	Placing most commonly used items at the front	Free Brainstorming	15	AR goggles with computer vision showing where the item you are holding is supposed to go	Categorized Brainstorming
2	Information kiosk	Analogy	16	Map for conveying info	Free Brainstorming
3	Color-Coded LED Strips: Low-cost battery LEDs (Green = Ready, Red = Needs Parts) for instant visual status.	Free Brainstorming	17	Color coded bins	Free Brainstorming
4	Each storage shelving would have a barcode/QR code so that you can track the import and export of items	Structured Brainstorming	18	Color coded tapes for wires	Free Brainstorming

5	Smart QR-Code Inventory Storage System	Structured Brainstorming	19	AI-assisted object recognition storage	Free Brainstorming
6	LED lights on the shelf when something is searched up, like at Canadian Tire	Analogy	20	Conveyor belt that automatically sorts	Free Brainstorming
7	Color-Coded Cable Storage System	Structured Brainstorming	21	Projector that shows inventory	Free Brainstorming
8	Transparent Storage	Structured Brainstorming	22	Robotic arm to take things in and out of storage	Free Brainstorming
9	Magnetic Labels	Structured Brainstorming	23	RFID tag on each item	Free Brainstorming
10	Smart Digital Inventory	Structured Brainstorming	24	Voice-assisted storage retrieval system	Free Brainstorming
11	OpenCV recognition	Structured Brainstorming	25	Weight sensor for identifying the item	Free Brainstorming
12	Transparent Drawer Electronics Organizer	Structured Brainstorming	26	Storage system where everything is linked to alexa and you can just name which item you wanna store. The alexa would light up and then you can go to that cabinet.	Free Brainstorming
13	Smart LED Location Indicator Shelf	Categorized Brainstorming	27	Conveyor belt sushi restaurant system, except you can request the item you want and it comes to you	Free Brainstorming
14	RFID Tag Device Tracking Storage System	Categorized Brainstorming	28	Amazon style barcode labels on every shelf so finding any of the 200 plus laptops takes under two minutes.	Benchmark

Table H.5 Layout

Idea	Solution/Mean	Generation Technique
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1	Costco style layout using wide aisles and bright floor markings to keep paths clear for two or three people walking around.	Benchmark
2	Most commonly used items placed near entrance	Free Brainstorming
3	Heaviest items are in the safe lifting zone	Categorized Brainstorming

Appendix I: Overview of Idea Selection Process

Appendix I.1. Consolidated Full Solutions List

Table I.1 Consolidated Full Solutions List

#	Full Solution
Theme: AI / Tech Solutions	
1.	Transparent bins will be used to store cables, and adaptors. Laptops will be store in verticle racks by model. Desktops will be stored in heavy metal storage with 5 shelves to store based on model. Smart digital inventory scanner will be put on each storage to track different items.
2.	Smart Digital Inventory system that will be implemented with the help of scanners and QR codes. This will enable efficient store and inventory count. This is be added on top of each storage shelf. Galvanized steel frame structures will be used to store heavy items like desktops which will prevent ESD discharge. Anti static copper tapes will be put around at the edges of storage strutures. Storage design will have 3 lanes one of refurbishment parts, and the other two for dispaching and testing items.
3.	Canadian tire - esque led lights, where you type the item you want into a computer and lights will start flashing, showing you where the item type is on the shelf. Additionally, label all shelves and sort electronics on the shelves by equipment type and by weight (heaviest on the bottom). Use racks for laptops, antistatic bags for delicate electronics
4.	Storage system where everything is linked to alexa and you can just name which item you wanna store. The alexa would light up and then you can go to that cabinet. There will be metal epoxy coated shelving on the left to store laptops, desktops, keyboards, and mice. On the right the design will store ready-to-go refurbished items, adminstrative documents, cables, and miscellaneous items.
5.	A high-density smart bin system uses sliding racks mounted on reinforced industrial steel frames to maximize the four-foot shelf depth. The racks are filled with interlocking stackable bins that are transparent, to identify internal parts like RAM and hard drives. Every bin has a scannable smart QR code and a color-coded LED status strip that lights up when a specific part is requested via the digital inventory dashboard. Additionally, designated safe lift zones where the heaviest bins are stored at waist height, and a grounded metal box is integrated at the base to store sensitive desktop components safely. Laptops will be

	stored in vertical racks on the right side, desktops will be placed on reinforced shelving along the back wall, and cables and adapters will be stored in transparent bins along the left wall. The center of the room will contain repair tables and rolling carts for refurbishment tasks.
6.	We will implement a smart storage system where a digital map near the entrance will show the location of every storage item. When an item is searched in the system, LED strips on the corresponding shelf will illuminate to guide LGT employee to the correct location. The laptops will be stored in vertical racks and desktops will have a separate shelving. RAM, and adapters for laptops will be stored in transparent bins mounted on modular shelving.
7.	The warehouse will use a conveyor belt layout to organize refurbishment items. Near the entrance there will be an intake station where devices are tagged and scanned. From there equipment will move through three zones: testing, refurbishment, and completed storage. Desktops waiting for testing will be stored on shelving along the left wall. Laptops under repair will be kept on rolling carts near the refurbishment tables in the center of the room. Once devices are repaired they will be moved to finished inventory racks on the right wall where accessories such as chargers, keyboards, and mice are kept. Small parts such as RAM and SSDs will be stored in compact drawer organizers near the repair area.
8.	A sushi-conveyor sorting hub automates the intake of donated electronics near the garage door. As items like keyboards, mice, and adapters are placed on a conveyor belt, an AI-assisted object recognition system identifies the hardware and directs it into specific interlocking stackable IKEA bins. The bins then travel to a central storage area where they are placed into gravity-fed sliding racks.
9.	The AR-guided retrieval grid uses augmented reality goggles to simplify the management of inventory. The warehouse is mapped digitally, when an item is needed, a computer-vision overlay highlights the exact shelf or bin needed for a specific project. This system works with RFID tag device tracking to monitor the movement of high-value items throughout the room. The physical storage consists of reinforced industrial steel frames and sliding racks that only move apart when the AR system confirms the correct aisle is being accessed.
10.	An RFID-tracked locker wall utilizes mailroom sorting cabinets to provide secure, individual storage for volunteers' tools and high-value components like specialized testing kits. Each locker is equipped with an RFID tag tracking system that logs whenever a door is opened and which item is removed. The exterior of the lockers features large magnetic label plates and a color-coded map showing where different categories of tools are stored across the entire warehouse. The main storage is grounded metal desktop boxes and pull-out deep bin storage systems lined with ESD wrap and tape. The bins are stored on reinforced industrial steel frames that are connected to a common grounding point, with LEDs for component identification.
11.	A transparent bin "Search-to-Light" system uses boltless snap-together steel shelves filled with transparent drawer electronics organizers. Each drawer is assigned to a specific item type, such as "HP Laptop Keyboards" or "Wireless Mice." When an item is searched on the central computer, the smart LED location indicator shelf pulses behind the transparent bin, making it glow from the inside. The system is designed to be tool-free and quick to assemble.
12.	A high-visibility storage system uses transparent stackable bins combined with large magnetic labels mounted on reinforced steel shelves. Color-coded sections divide the warehouse into categories such as laptops, accessories, cables, and replacement components. LED shelf indicators illuminate when a specific

	item is searched in the inventory system, guiding volunteers directly to the correct location and reducing retrieval time.
13.	A smart inventory warehouse integrates QR-code labeling with a digital dashboard accessible at a central kiosk. Shelves store laptops, accessories, and repair components in clearly labeled transparent bins. Volunteers scan items when storing or retrieving them, automatically updating the inventory system. Workstations in the center of the warehouse allow volunteers to repair devices while maintaining easy access to storage areas.
Theme: Zoning	
1.	In the middle 4 carts will be placed with under the table storage for refurbishment tools to enable 4 people to work in the room. A storage structure similar to a mobile device cabinet will be used to store all the cables, RAMs, SSDs and other small electronic accessories based on model and other specs. A 360 rotating cabinet will be placed in the middle which will have laptops and desktops that are ready for refurbishment. Mice and keyboards will be placed on the left next to the current position of the FOG station to help with efficiency during the task of retrieval of refurbishment items.
2.	Cable storage ONLY drawer unit. Cables are stored with velcro, and laptop adapters are stored in antistatic bags. At the left wall upon entering. An esd drawer system on top that holds RAM, SSDs, Mini PCs if there's room. The admin stuff gets its own shelf, rest of the equipment is stored with racks (e.g. laptops, pcs)
3.	Doorbin unit: placed on left wall of the entrance to warehouse. Desktops and laptops stored on shelves w/ racks. cables stored in bins, ram sticks/ ssds/ cpus/ stored in bins BUT with smaller partitions (e.g. existing small drawer system for ram). This is so that the smaller components won't rattle in the bins if the unit moves. What is on the left wall already would be relocated to the shelf space freed up by the doorbin unit being the new home for desktops, laptops, ram, cables, etc. Magnetic labels on each bin would ensure easy identification of the contents of each bin AND make relabelling easier.
4.	Reorganize everything on the shelves and label everything. Add additional storage racks to keep things off the ground, antistatic bags for sensitive electronics (e.g. ram, ssd), velcro for cables as needed. Throw away waste. Colour code bins and create a map. Add wheels to all the shelves. Put all the heavy things in the lifting safe zone. To save space, use a hook system on the back of the door to store bags, uncommonly used items like the events box. This will free up shelf space so that items like laptops aren't stored underneath the FOG station anymore.
5.	Workbench to replace one of the carts and shelves. This workbench with drawers will have everything needed for refurbishment, like ram, a desktop, a keyboard, a mouse, a ssd, tools necessary for repair and laptops. It will go against the wall with the electric panels. The shelf and cart will be adjusted to face the workbench unit rather than line the walls. This will make for easier access to electronics when the refurbisher is collecting needed items.

6.	Vending machines for cables to replace all cables currently in bins (no need for money). Will be put in place of the white laptop adaptors storage unit, since all those cables will now be in the machines. Cables that needed to be sorted into the machines are stored on top, and can be accessed via a stepstool. Everything else is organized by zones (laptops in one zone, desktops in a nother zone, ssds in another).
7.	The warehouse will be divided into 5 zones. Zone A will contain laptops and adapters based on models. Zone B will have desktops. Zone C will be for small components and parts such as RAMs, SSDs, etc. Zone D for tools, cleaning supplies, fork station and test kits. Zone E: Refurbished Items and those that are read to go.
8.	All major storage will be placed along the perimeter/boudary walls using freestanding metal shelving and lockable cabinets, leaving the center open for refurbishment activity. The front-left wall will hold intake items and laptop carts. The front-right wall will hold administrative supplies, and documentation. The back-left wall will hold desktop towers on reinforced shelving. The back-right wall will hold small components, batteries, and sensitive accessories in lockable drawer cabinets. In the center we will have mobile worktables that will create a flexible workspace.
9.	An ESD-secure grounded vault is a dedicated section for sensitive electronics like internal RAM and CPU components. This system uses grounded metal desktop boxes and pull-out deep bin storage systems lined with ESD wrap and tape. The bins are stored on reinforced industrial steel frames that are connected to a common grounding point. To access a part, there is a digital inventory dashboard to unlock the specific drawer, and a smart LED location indicator light guide ensures the correct component is pulled.
10.	A warehouse-style zoning layout organizes the space into clearly defined areas for intake, repair preparation, storage, and dispatch. Near the garage door, a sorting table allows incoming electronics to be categorized before storage. Laptop storage carts with built-in charging stations are positioned near the refurbishment area. Transparent modular bins on nearby shelving store accessories such as adapters and cables. Color-coded floor markings guide volunteers through wide aisles, ensuring that up to four people can move safely while maintaining efficient workflow.
11.	A centralized workstation layout places four rolling refurbishment carts in the center of the warehouse to allow up to four volunteers to work simultaneously. Each cart includes under-table storage drawers for tools and repair kits. Surrounding the workspace are modular shelving units storing parts in labeled bins organized by category. A rotating 360-degree cabinet near the workstations stores frequently accessed items so volunteers can quickly retrieve components without walking across the room.
12.	Drawer Unit that replaces one of the current shelves and has commonly used items. It is a tall drawer that holds RAM, SSDs, (wrapped in antistatic bags) most commonly used CABLES *wrapped with velcro*. There are Labels that describe what's in each shelf. Stored under the electric panel. The freed up shelf can be a shelf that holds new arrivals. As well, the keyboards box previously under the electric panel can go underneath one of the freed up spaces underneath the workstations.
13.	This layout will use garage style freestanding pegboards along the left wall to hang cables, tools, adapters, and repair kits so they are visible and off the floor. Below the pegboards we will have transparent bin storage units that will hold spare parts sorted by type. The right wall will contain aluminum rail shelving that stores laptops vertically and desktops horizontally based on model. Near the entrance we will assign a dedicated table that will allow volunteers to sort new devices before placing them into storage. The center of the room will include rolling tool carts and repair tables for refurbishment tasks.

14.	The warehouse will use a cube storage layout made of interlocking frames. Each cube will be assigned a specific device category such as laptops, desktops, adapters, or keyboards. Everything will be transparent which will allow LGT employees to see contents quickly. Small components will be stored in labeled drawers inside certain cubes. The center of the room will contain two large repair tables and a mobile tool station. Color-coded labels and LED indicators on cubes will show device status such as ready, testing, or needs parts.
15.	A color-coded warehouse layout assigns a unique color to each equipment category such as laptops, cables, repair tools, and replacement parts. Shelves, bins, and labels share the same color scheme to allow volunteers to visually identify storage zones quickly. Rolling carts allow parts to be transported to refurbishment workstations without unnecessary walking.
16.	A warehouse workflow layout prioritizes movement efficiency by placing intake and sorting near the garage door. After sorting, items move to categorized storage shelves along the walls. Refurbishment carts in the center allow volunteers to repair devices while maintaining easy access to parts and accessories.
17.	A high-visibility warehouse design uses large magnetic labels on shelving units so volunteers can quickly identify storage categories from a distance. Transparent bins store accessories while vertical racks store laptops by model. Rolling carts allow volunteers to transport equipment between storage and refurbishment areas.
18.	A dual-corridor warehouse layout divides the space into two long storage corridors with a central work zone between them. One corridor stores laptops organized by device category, while the second corridor stores accessories and repair components in labeled bins. Wide pathways allow volunteers to move carts between corridors safely. A central digital tracking system records the location of every stored item.
19.	A perimeter storage layout installs shelving units along every wall of the warehouse while leaving the center completely open for refurbishment activities. Laptop carts and repair stations are positioned in the middle to allow multiple volunteers to work simultaneously. Storage bins for accessories are mounted along the walls and labeled with clear identification tags. Frequently used items are placed closer to the refurbishment area to reduce walking distance.
20.	A cross-aisle warehouse design uses intersecting aisles that divide the storage area into smaller blocks. Each block contains modular shelving units storing accessories and repair parts. Laptop storage racks are placed along the longest wall while repair carts occupy the central intersection where volunteers work.
21.	A cluster storage warehouse layout groups similar inventory types into dedicated clusters across the warehouse. Each cluster contains shelving, bins, and labeled storage areas for specific device categories such as laptops or accessories. A central movement corridor connects all clusters to the refurbishment area, ensuring volunteers can retrieve components quickly.
Theme: Mobility	
1.	Deep bin storage that have a lot of depth but are thin. used to store cables (that are velcroed), ssds, ram, desktops. a movable shelf that is stored near the entrance that can be moved into and out of the main lobby as needed.
2.	2 modular shelves on wheel that can be loaded up with the necessary materials needed for refurbishing. there will be space for a desktop, monitor, section with necessary cables, drawers for ram + ssds. a user

	would hypothetically pick out the items they need and then bring it to their workstation. this would reduce constant circulation around the warehouse.
3.	Mobile workstation that stores everything needed for refurbishment. User can load it and then work in the lobby, which allows others to continue using the warehouse freely. Label everything in the warehouse and also, center the shelves around the mobile workstation unit(s?) so that user can pick out the materials they need.
4.	The V-groove laptop mobile fleet utilizes angled library book carts designed with V-shaped slots to hold the laptops. Each cart has Amazon style barcode labels on the exterior and a slim rolling tool cart is docked at the end of the row to hold testing kits and cleaning supplies. The system is managed by a digital inventory dashboard that tracks which cart holds which brand of laptop, so that a volunteer can locate any specific machine in under two minutes while maintaining wide, Costco-style aisles for movement.
5.	Two charging carts will be used for laptops in intake and ready to deliver status. Four rolling shelving carts will be used for active refurbishment items, one for laptops, one for desktops, and one for tools. Around the room perimeter, freestanding shelving will store bulk stock in bins. All cables and adapters will be kept in transparent labeled containers so they can be quickly pulled onto a cart when needed.
6.	The storage system will be built using IKEA shelving, freestanding shelving and utility carts so it can be built using basic tools. KALLAX-style shelving unit with bins will be used for cables, mice, keyboards, and parts. BROR or similar heavy-duty shelving will be used for desktops and laptops. A lockable cabinet will be placed at the back for high-value devices, batteries, and sensitive parts. Rolling utility carts will be used for tools and in-progress devices.
7.	The rolling tower and shadow board workshop is designed for high-intensity refurbishment. Heavy-duty rolling tower carts (Olympia carts, but stacked) will be mobile workstations, each designated tool storage. These carts hold everything needed for a full day of work, including a small inventory of RAM and hard drives stored in interlocking IKEA bins. The carts will also have magnetic mount storage strips on the cart walls to ensure that no tools are lost or misplaced. The main storage will be sliding racks mounted on reinforced industrial steel frames to maximize the four-foot shelf depth. The racks are filled with interlocking stackable IKEA bins that are transparent, with LEDs for component identification.
8.	A 3D-printed modular spool hub organizes the massive variety of power cables, HDMI cords, and adapters found in the Tech4All hub. The system uses a rotating cable spool storage rack built with 3D-printed modular joints that allow for the addition of more spools as needed. Each spool is color-coded with tape to match the type of device it supports. The hub is mounted on a heavy-duty rolling tower cart, making it easy to move the entire cable inventory to the testing station. The main storage is grounded metal desktop boxes and pull-out deep bin storage systems lined with ESD wrap and tape. The bins are stored on reinforced industrial steel frames that are connected to a common grounding point, with LEDs for component identification.
9.	The slim tool cart and QR library handles the movement of cleaning kits and battery testing tools. Several slim rolling tool carts are parked in a central aisle, each labeled with a scannable smart QR code that leads to a video tutorial on how to use the equipment inside. The carts are outfitted with transparent bin storage units so volunteers can see if the cleaning supplies are running low. IKEA bins are stored on reinforced industrial steel frames that are connected to a common grounding point. To access a part, there is a digital inventory dashboard to unlock the specific drawer, and a smart LED location indicator light guide ensures the correct component is pulled.

10.	A mobile storage warehouse system uses rolling tool carts equipped with modular stackable bins for accessories and repair supplies. Laptops are stored in vertical racks along the wall, while desktop towers are stored on reinforced shelving in designated safe lift zones. Volunteers move carts to refurbishment stations rather than carrying equipment across the warehouse. QR-code labels on bins and shelves connect to the digital inventory dashboard for efficient tracking.
11.	The warehouse will be organized using a tray/sliding storage system where laptops and smaller electronics are placed on removable sliding trays. Along the right wall, steel racks will store desktops with spacing between units to prevent overheating. On the left wall, vertical cable racks will store longer cables such as power cords, HDMI cables, and Ethernet cables while smaller adapters will be stored in transparent labeled bins below. Near the center of the room, four repair workstations will be placed in a square configuration.
12.	360 degree rotating cabinet w/ 2 shelves that holds the current drawer system for RAM, the hard drives (maybe stored in 3d printed slots) and boxes that hold: VGA cables, power supply cables, DVI cables, VGA cables. These cables are the cables that used to be stored underneath the workstation row of trolleys, but now they are here for easier access. They are secured together with velcro and placed in its respective bin. There is also opportunity to store mini PCs, stored the same method as the SSDs. The cables for using the miniPCs are stored in the same unit anyway. On the unit, there is a map showing which side of the shelves has what. Larger PCs are stored on a rack on the existing shelf next to the cabinet. This is Paired with laptop Stands along the FOG station shelf and the other shelves where there is laptops
13.	A pegboard wall warehouse layout dedicates one wall to tool organization using pegboards and shadow outlines. Adjacent shelving stores laptops in vertical racks and accessories in modular bins. The center of the warehouse contains rolling refurbishment carts that provide flexible workstations for volunteers. A digital inventory system tracks component locations while magnetic labels help volunteers identify storage categories.
14.	A rotating storage warehouse layout installs circular rotating cabinets for frequently used accessories such as adapters, chargers, and cables. These rotating storage units are placed near refurbishment tables so volunteers can access parts from any direction. Larger items such as laptops and desktops are stored on surrounding shelving units organized by model.
15.	A sliding rack warehouse layout uses pull-out storage shelves that allow volunteers to access items stored deeper within the shelving units. Laptops are stored in vertical racks while accessories are stored in labeled bins on sliding shelves. This system maximizes storage density while maintaining accessibility.
16.	A layered storage warehouse layout organizes items by usage frequency. Frequently used components are stored in bins near the refurbishment workstations, while rarely used components are stored on distant shelves. Laptop storage racks are positioned between these zones so volunteers can quickly retrieve devices during repairs.
17.	A storage system that entirely uses carts to store different items. There are different carts for wires, adapters, laptops, desktop components and other commonly used equipment. It will use the open source gridfinity system to generate different cutouts, grids, and components to contain different parts, all of which are 3D printable. The main carts will be made of heavy duty aluminum extrusion, to ensure they last a long time. The bins and compartments on the carts will be colour coded for easy visual identification, with a legend somewhere in the warehouse as a poster. The design will be assembled with

8.	Because desktops and laptops consume more floor space, the back wall will use extra heavy-duty shelving to maximize dense storage of these larger items. Desktops will be placed on lower shelves by model and size, while laptops will be placed vertically on upper/middle shelves with foam separators and labeled slots. The center of the room will remain open except for four mobile worktables.
9.	A honeycomb-style storage structure will be installed along one back wall using hexagonal compartments to maximize storage density for laptops and smaller devices. Each compartment will contain foam or cardboard separators to prevent damage between devices. The left wall will contain steel shelving for desktops. Small accessories will be stored in transparent bins near the repair tables. The center of the room will contain repair workstations.
10.	The modular rail and sliding box system is built for high-frequency items like cables and adapters. It has aluminum rails attached to the front of fixed vertical equipment racks, where sliding boxes on rails can be moved in and out of. These sliding boxes are filled with interlocking IKEA bins and use color-coded tapes for wires to distinguish between power cords and data cables. Additionally, scannable QR codes on the boxes ensure that the stock levels are updated in real-time on the main computer.
11.	A gravity-fed component wall uses slanted, fixed vertical equipment racks to store boxed desktops. The weight of the items keeps them moving toward the front of the shelf, so that workers don't have to reach 4 feet into the storage system. Each lane is labeled with large magnetic label plates and color-coded bins to separate repair units from finished units. At the base of the racks, grounded metal desktop boxes provide a secure place for expensive motherboards, while the top of the rack is used for lightweight items like bubble wrap and empty anti-static bags.
12.	The multi-tier Lazy Susan station for storing small hardware like screws, laptop feet, and brackets. Centered on the furniture area tables, several rotating Lazy Susan organizers are stacked vertically on a central modular aluminum rail. Each tier holds transparent drawer electronics organizers that allow multiple workers to access parts simultaneously by spinning the tower. The base of the station includes magnetic mount storage strips for the small screwdrivers and tweezers used most frequently with these parts. The main storage will be sliding racks mounted on reinforced industrial steel frames to maximize the four-foot shelf depth. The racks are filled with interlocking stackable IKEA bins that are transparent, with LEDs for component identification.
13.	A vertical storage wall uses 3D printed modular joints to create hexagonal storage tubes based on biological structures. This honeycomb design provides high structural strength for storing heavy desktop towers at the base while transitioning to lighter items like keyboards and mice in the higher slots. Every hexagonal cell is fitted with a color-coded LED status strip that indicates if the device inside is a new donation or a refurbished unit. The layout follows a "most commonly used items at the front" logic, where the center of the honeycomb holds current projects at eye level, ensuring the 4-foot shelf depth is fully utilized without stacking equipment directly on top of sensitive screens.
14.	A square grid made of aluminum rails to build a freestanding grid of self-contained storage cells. Instead of long open shelves, this system uses interlocking snap-together connectors to create individual compartments of different sizes for specific hardware types. Small cells at eye level hold transparent drawers for RAM and hard drives, while the larger cells at the bottom are sized specifically for grounded metal desktop boxes. Each cell has color coded LEDs status strips to show whether the item inside is waiting for repair or ready to be donated, and the modular design allows the whole grid to be expanded or moved as the hub requirements change.

15.	A library-style laptop storage wall uses vertical V-slot racks that allow laptops to be stored upright by model category. Each slot is labeled with a barcode that links to the digital inventory dashboard. Slim rolling carts are docked at the end of each aisle to transport laptops to refurbishment tables. Adjacent shelves contain transparent bins for accessories such as RAM, chargers, and SSDs, ensuring that all components needed for repairs remain nearby and easy to locate.
16.	A gravity-fed storage warehouse layout uses angled shelving for cables and accessories so items naturally slide forward when one is removed. Laptops are stored in labeled vertical racks along the opposite wall, while modular bins store small electronic components. A wide central aisle allows volunteers to move carts safely between storage and refurbishment stations, and color-coded labels help volunteers quickly identify different equipment categories.
17.	A vertical storage warehouse system maximizes space by installing tall shelving units along the warehouse walls. Upper shelves store lightweight accessories in transparent bins, while mid-level shelves store laptops for ergonomic access. The central floor area remains open for refurbishment workstations and movement. Inventory labels and QR codes ensure that volunteers can quickly locate parts without searching through multiple containers.
18.	A transparent storage warehouse system uses clear stackable bins and drawers to store all accessories and repair parts. Laptops are organized by model on vertical shelving units, while desktop towers are stored on reinforced racks in designated safe lift zones. A wide central aisle ensures safe movement of volunteers and carts during refurbishment activities.
19.	A stackable bin warehouse system installs reinforced shelving filled with interlocking plastic bins to store small components such as RAM, adapters, and cables. Each bin includes a barcode label connected to the inventory system. Laptop storage racks and refurbishment carts are placed nearby to ensure efficient repair workflows.
20.	Adjustable shelf system with dividers and slots that could be resized for different components. The entire shelf could slide out for easy access, and slide back in to take up less space. The shelves will be made of thin metal, but will still be stable due to structural supports and trusses. This would allow the shelves to be semi see through, and since the shelves and slots are transparent too, users will be able to see what is stored inside. The shelf will be interlocking/use parts that snap together, allowing for easy assembly. The layout of the design will be follow the client's workflow, with tools in the front, then components, then

Duplicates	
1.	The warehouse is organized around Baker's racks with slide-in trays where each tray represents a complete project kit. A tray contains one laptop, its specific adapters, and a small transparent bin storage unit for RAM or hard drive upgrades. These trays are stored in steel-reinforced wooden racks and can be pulled out and inserted directly into a heavy-duty workbench hybrid. This kit-based storage reduces the time spent searching for individual parts across different bins. Every tray slot is marked with scannable smart QR codes, allowing for a rapid audit of how many projects are currently in progress versus those ready for donation.

2.	The color-coded zone logistics flow organizes the entire warehouse into distinct colored areas based on the stage of the refurbishment process. The "Incoming" zone uses bright red floor markings and heavy-duty rolling tower carts, the "Testing" zone uses blue markings and adjustable height equipment racks, and the "Ready to Donate" zone uses green markings and Baker's racks. Each zone has its own digital inventory dashboard and scannable QR code system. By matching the color of the bins and LED status strips to the floor zone, volunteers can understand the warehouse flow instantly, even if they have never visited the hub before.
3.	Sliding racks mounted on reinforced industrial steel frames to maximize the four-foot shelf depth. The racks are filled with interlocking stackable IKEA bins that are transparent, with LEDs for component identification. Within a fixed vertical equipment rack, the shelves are adjusted so the back row of items sits several inches higher than the front row. Tilting parts access racks are added to each tier to angle the hardware toward the walkway, and scannable smart QR codes are placed on the front edge of each tier so the digital inventory dashboard can be updated without the volunteer needing to reach into the deep rack.
4.	A modular high-density storage system uses reinforced steel shelving with sliding racks to maximize vertical storage capacity. Interlocking stackable IKEA bins store cables, adapters, RAM, and SSD components. Each bin is transparent for quick identification and labeled with scannable QR codes connected to a digital inventory system. Color-coded LED strips on each shelf indicate item status such as "Ready for Refurbishment" or "Needs Parts." Frequently used items are placed near the entrance while heavier desktop towers are stored in designated safe lift zones at waist height to reduce strain on volunteers.
5.	A radial warehouse layout places a circular central refurbishment hub in the middle of the space where four volunteers can work simultaneously. Storage shelves are arranged in a semi-circle around the hub, allowing workers to quickly access parts without walking across the warehouse. Laptop devices are stored vertically in labeled slots organized by brand and model, while accessories such as cables, RAM, and adapters are stored in transparent bins mounted on modular shelving. A digital inventory system with barcode scanning ensures all parts are tracked and quickly located.

Appendix I.2. Feasibility Check

Table I.2 Feasibility Check

Feasibility Check 			
Theme: AI	Theme: Zoning	Theme: Mobility	Theme: Stacking

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[illegible]

Appendix I.3. Feasible Solutions List

Table I.3 Feasible Solutions List

1.	Transparent bins will be used to store cables, and adaptors. Laptops will be stored in vertical racks by model. Desktops will be stored in heavy metal storage with 5 shelves to store based on model. Smart digital inventory scanners will be put on each storage to track different items.
2.	Smart Digital Inventory system that will be implemented with the help of scanners and QR codes. This will enable efficient store and inventory count. This is be added on top of each storage shelf. Galvanized steel frame structures will be used to store heavy items like desktops which will prevent ESD discharge. Anti static copper tapes will be put around at the edges of storage structures. Storage design will have 3 lanes one of refurbishment parts, and the other two for dispatching and testing items.
3.	Canadian tire - esque led lights, where you type the item you want into a computer and lights will start flashing, showing you where the item type is on the shelf. Additionally, label all shelves and sort electronics on the shelves by equipment type and by weight (heaviest on the bottom). Use racks for laptops, antistatic bags for delicate electronics
4.	Storage system where everything is linked to alexa and you can just name which item you wanna store. The alexa would light up and then you can go to that cabinet. There will be metal epoxy coated shelving on the left to store laptops, desktops, keyboards, and mice. On the right the design will store ready-to-go refurbished items, administrative documents, cables, and miscellaneous items.
5.	A high-density smart bin system uses sliding racks mounted on reinforced industrial steel frames to maximize the four-foot shelf depth. The racks are filled with interlocking stackable bins that are transparent, to identify internal parts like RAM and hard drives. Every bin has a scannable smart QR code and a color-coded LED status strip that lights up when a specific part is requested via the digital inventory dashboard. Additionally, designated safe lift zones where the heaviest bins are stored at waist height, and a grounded metal box is integrated at the base to store sensitive desktop components safely.
6.	We will implement a smart storage system where a digital map near the entrance will show the location of every storage item. When an item is searched in the system, LED strips on the corresponding shelf will illuminate to guide LGT employee to the correct location. The laptops will be stored in vertical racks and desktops will have a separate shelving. RAM, and adapters for laptops will be stored in transparent bins mounted on modular shelving.
7.	The warehouse will use a conveyor belt layout to organize refurbishment items. Near the entrance there will be an intake station where devices are tagged and scanned. From there equipment will move through three zones: testing, refurbishment, and completed storage. Desktops waiting for testing will be stored on shelving along the left wall. Laptops under repair will be kept on rolling carts near the refurbishment tables in the center of the room. Once devices are repaired they will be moved to finished inventory racks on the right wall where accessories such as chargers, keyboards, and mice are kept. Small parts such as RAM and SSDs will be stored in compact drawer organizers near the repair area.
8.	The AR-guided retrieval grid uses augmented reality goggles to simplify the management of inventory. The warehouse is mapped digitally, when an item is needed, a computer-vision overlay highlights the exact shelf or bin needed for a specific project. This system works with RFID tag device tracking to monitor the movement of high-value items throughout the room. The physical storage consists of

	reinforced industrial steel frames and sliding racks that only move apart when the AR system confirms the correct aisle is being accessed.
9.	An RFID-tracked locker wall utilizes mailroom sorting cabinets to provide secure, individual storage for volunteers' tools and high-value components like specialized testing kits. Each locker is equipped with an RFID tag tracking system that logs whenever a door is opened and which item is removed. The exterior of the lockers features large magnetic label plates and a color-coded map showing where different categories of tools are stored across the entire warehouse. The main storage is grounded metal desktop boxes and pull-out deep bin storage systems lined with ESD wrap and tape. The bins are stored on reinforced industrial steel frames that are connected to a common grounding point, with LEDs for component identification.
10.	A transparent bin "Search-to-Light" system uses boltless snap-together steel shelves filled with transparent drawer electronics organizers. Each drawer is assigned to a specific item type, such as "HP Laptop Keyboards" or "Wireless Mice." When an item is searched on the central computer, the smart LED location indicator shelf pulses behind the transparent bin, making it glow from the inside. The system is designed to be tool-free and quick to assemble.
11.	A high-visibility storage system uses transparent stackable bins combined with large magnetic labels mounted on reinforced steel shelves. Color-coded sections divide the warehouse into categories such as laptops, accessories, cables, and replacement components. LED shelf indicators illuminate when a specific item is searched in the inventory system, guiding volunteers directly to the correct location and reducing retrieval time.
12.	A smart inventory warehouse integrates QR-code labeling with a digital dashboard accessible at a central kiosk. Shelves store laptops, accessories, and repair components in clearly labeled transparent bins. Volunteers scan items when storing or retrieving them, automatically updating the inventory system. Workstations in the center of the warehouse allow volunteers to repair devices while maintaining easy access to storage areas.
13.	In the middle 4 carts will be placed with under the table storage for refurbishment tools to enable 4 people to work in the room. A storage structure similar to a mobile device cabinet will be used to store all the cables, RAMs, SSDs and other small electronic accessories based on model and other specs. A 360 rotating cabinet will be placed in the middle which will have laptops and desktops that are ready for refurbishment. Mice and keyboards will be placed on the left next to the current position of the FOG station to help with efficiency during the task of retrieval of refurbishment items.
14.	Cable storage ONLY drawer unit. Cables are stored with velcro, and laptop adapters are stored in antistatic bags. At the left wall upon entering. An esd drawer system on top that holds RAM, SSDs, Mini PCs if there's room. The admin stuff gets its own shelves, rest of the equipment is stored with racks (e.g. laptops, pcs)
15.	Doorbin unit: placed on left wall of the entrance to warehouse. Desktops and laptops stored on shelves w/ racks. cables stored in bins, ram sticks/ ssds/ cpus/ stored in bins BUT with smaller partitions (e.g. existing small drawer system for ram). This is so that the smaller components won't rattle in the bins if the unit moves. What is on the left wall already would be relocated to the shelf space freed up by the doorbin unit being the new home for desktops, laptops, ram, cables, etc.

	Magnetic labels on each bin would ensure easy identification of the contents of each bin AND make relabelling easier.
16.	Reorganize everything on the shelves and label everything. Add additional storage racks to keep things off the ground, antistatic bags for sensitive electronics (e.g. ram, ssd), velcro for cables as needed. Throw away waste. Colour code bins and create a map. Add wheels to all the shelves. Put all the heavy things in the lifting safe zone. To save space, use a hook system on the back of the door to store bags, uncommonly used items like the events box. This will free up shelf space so that items like laptops arent stored underneath the FOG station anymore.
17.	Workbench to replace one of the carts and shelves. This workbench with drawers will have everything needed for refurbishment, like ram, a desktop, a keyboard, a mouse, a ssd, tools necessary for repair and laptops. It will go against the wall with the electric panels. The shelf and cart will be adjusted to face the workbench unit rather than line the walls. This will make for easier access to electronics when the refurbisher is collecting needed items.
18.	Vending machines for cables to replace all cables currently in bins (no need for money). Will be put in place of the white laptop adaptors storage unit, since all those cables will now be in the machines. Cables that needed to be sorted into the machines are stored on top, and can be accessed via a stepstool. Everything else is organized by zones (laptops in one zone, desktops in another zone, ssds in another).
19.	The warehouse will be divided into 5 zones. Zone A will contain laptops and adapters based on models. Zone B will have desktops. Zone C will be for small components and parts such as RAMs, SSDs, etc. Zone D for tools, cleaning supplies, fork station and test kits. Zone E: Refurbished Items and those that are read to go.
20.	All major storage will be placed along the perimeter/boundary walls using freestanding metal shelving and lockable cabinets, leaving the center open for refurbishment activity. The front-left wall will hold intake items and laptop carts. The front-right wall will hold administrative supplies, and documentation. The back-left wall will hold desktop towers on reinforced shelving. The back-right wall will hold small components, batteries, and sensitive accessories in lockable drawer cabinets. In the center we will have mobile worktables that will create a flexible workspace.
21.	An ESD-secure grounded vault is a dedicated section for sensitive electronics like internal RAM and CPU components. This system uses grounded metal desktop boxes and pull-out deep bin storage systems lined with ESD wrap and tape. The bins are stored on reinforced industrial steel frames that are connected to a common grounding point. To access a part, there is a digital inventory dashboard to unlock the specific drawer, and a smart LED location indicator light guide ensures the correct component is pulled.
22.	A warehouse-style zoning layout organizes the space into clearly defined areas for intake, repair preparation, storage, and dispatch. Near the garage door, a sorting table allows incoming electronics to be categorized before storage. Laptop storage carts with built-in charging stations are positioned near the refurbishment area. Transparent modular bins on nearby shelving store accessories such as adapters and cables. Color-coded floor markings guide volunteers through wide aisles, ensuring that up to four people can move safely while maintaining efficient workflow.
23.	A centralized workstation layout places four rolling refurbishment carts in the center of the warehouse to allow up to four volunteers to work simultaneously. Each cart includes under-table storage drawers for

	tools and repair kits. Surrounding the workspace are modular shelving units storing parts in labeled bins organized by category. A rotating 360-degree cabinet near the workstations stores frequently accessed items so volunteers can quickly retrieve components without walking across the room.
24.	Drawer Unit that replaces one of the current shelves and has commonly used items. It is a tall drawer that holds RAM, SSDs, (wrapped in antistatic bags) most commonly used CABLES *wrapped with velcro*. There are Labels that describe what's in each shelf. Stored under the electric panel. The freed up shelf can be a shelf that holds new arrivals. As well, the keyboards box previously under the electric panel can go underneath one of the freed up spaces underneath the workstations.
25.	This layout will use garage style freestanding pegboards along the left wall to hang cables, tools, adapters, and repair kits so they are visible and off the floor. Below the pegboards we will have transparent bin storage units that will hold spare parts sorted by type. The right wall will contain aluminum rail shelving that stores laptops vertically and desktops horizontally based on model. Near the entrance we will assign a dedicated table that will allow volunteers to sort new devices before placing them into storage. The center of the room will include rolling tool carts and repair tables for refurbishment tasks.
26.	The warehouse will use a cube storage layout made of interlocking frames. Each cube will be assigned a specific device category such as laptops, desktops, adapters, or keyboards. Everything will be transparent which will allow LGT employees to see contents quickly. Small components will be stored in labeled drawers inside certain cubes. The center of the room will contain two large repair tables and a mobile tool station. Color-coded labels and LED indicators on cubes will show device status such as ready, testing, or needs parts.
27.	A color-coded warehouse layout assigns a unique color to each equipment category such as laptops, cables, repair tools, and replacement parts. Shelves, bins, and labels share the same color scheme to allow volunteers to visually identify storage zones quickly. Rolling carts allow parts to be transported to refurbishment workstations without unnecessary walking.
28.	A warehouse workflow layout prioritizes movement efficiency by placing intake and sorting near the garage door. After sorting, items move to categorized storage shelves along the walls. Refurbishment carts in the center allow volunteers to repair devices while maintaining easy access to parts and accessories.
29.	A high-visibility warehouse design uses large magnetic labels on shelving units so volunteers can quickly identify storage categories from a distance. Transparent bins store accessories while vertical racks store laptops by model. Rolling carts allow volunteers to transport equipment between storage and refurbishment areas.
30.	A dual-corridor warehouse layout divides the space into two long storage corridors with a central work zone between them. One corridor stores laptops organized by device category, while the second corridor stores accessories and repair components in labeled bins. Wide pathways allow volunteers to move carts between corridors safely. A central digital tracking system records the location of every stored item.
31.	A perimeter storage layout installs shelving units along every wall of the warehouse while leaving the center completely open for refurbishment activities. Laptop carts and repair stations are positioned in the middle to allow multiple volunteers to work simultaneously. Storage bins for accessories are mounted along the walls and labeled with clear identification tags. Frequently used items are placed closer to the refurbishment area to reduce walking distance.

32.	A cross-aisle warehouse design uses intersecting aisles that divide the storage area into smaller blocks. Each block contains modular shelving units storing accessories and repair parts. Laptop storage racks are placed along the longest wall while repair carts occupy the central intersection where volunteers work.
33.	A cluster storage warehouse layout groups similar inventory types into dedicated clusters across the warehouse. Each cluster contains shelving, bins, and labeled storage areas for specific device categories such as laptops or accessories. A central movement corridor connects all clusters to the refurbishment area, ensuring volunteers can retrieve components quickly.
34.	Deep bin storage that have a lot of depth but are thin. used to store cables (that are velcroed), ssds, ram, desktops. a movable shelf that is stored near the entrance that can be moved into and out of the main lobby as needed.
35.	2 modular shelves on wheel that can be loaded up with the necessary materials needed for refurbishing. there will be space for a desktop, monitor, section with necessary cables, drawers for ram + ssds. a user would hypothetically pick out the items they need and then bring it to their workstation. this would reduce constant circulation around the warehouse.
36.	Mobile workstation that stores everything needed for refurbishment. User can load it and then work in the lobby, which allows others to continue using the warehouse freely. Label everything in the warehouse and also, center the shelves around the mobile workstation unit(s?) so that user can pick out the materials they need.
37.	The V-groove laptop mobile fleet utilizes angled library book carts designed with V-shaped slots to hold the laptops. Each cart has Amazon style barcode labels on the exterior and a slim rolling tool cart is docked at the end of the row to hold testing kits and cleaning supplies. The system is managed by a digital inventory dashboard that tracks which cart holds which brand of laptop, so that a volunteer can locate any specific machine in under two minutes while maintaining wide, Costco-style aisles for movement.
38.	Two charging carts will be used for laptops in intake and ready to deliver status. Four rolling shelving carts will be used for active refurbishment items, one for laptops, one for desktops, and one for tools. Around the room perimeter, freestanding shelving will store bulk stock in bins. All cables and adapters will be kept in transparent labeled containers so they can be quickly pulled onto a cart when needed.
39.	The storage system will be built using IKEA shelving, freestanding shelving and utility carts so it can be built using basic tools. KALLAX-style shelving unit with bins will be used for cables, mice, keyboards, and parts. BROR or similar heavy-duty shelving will be used for desktops and laptops. A lockable cabinet will be placed at the back for high-value devices, batteries, and sensitive parts. Rolling utility carts will be used for tools and in-progress devices.
40.	The rolling tower and shadow board workshop is designed for high-intensity refurbishment. Heavy-duty rolling tower carts (Olympia carts, but stacked) will be mobile workstations, each designated tool storage. These carts hold everything needed for a full day of work, including a small inventory of RAM and hard drives stored in interlocking IKEA bins. The carts will also have magnetic mount storage strips on the cart walls to ensure that no tools are lost or misplaced. The main storage will be sliding racks mounted on reinforced industrial steel frames to maximize the four-foot shelf depth. The racks are filled with interlocking stackable IKEA bins that are transparent, with LEDs for component identification.

41.	A 3D-printed modular spool hub organizes the massive variety of power cables, HDMI cords, and adapters found in the Tech4All hub. The system uses a rotating cable spool storage rack built with 3D-printed modular joints that allow for the addition of more spools as needed. Each spool is color-coded with tape to match the type of device it supports. The hub is mounted on a heavy-duty rolling tower cart, making it easy to move the entire cable inventory to the testing station. The main storage is grounded metal desktop boxes and pull-out deep bin storage systems lined with ESD wrap and tape. The bins are stored on reinforced industrial steel frames that are connected to a common grounding point, with LEDs for component identification.
42.	The slim tool cart and QR library handles the movement of cleaning kits and battery testing tools. Several slim rolling tool carts are parked in a central aisle, each labeled with a scannable smart QR code that leads to a video tutorial on how to use the equipment inside. The carts are outfitted with transparent bin storage units so volunteers can see if the cleaning supplies are running low. IKEA bins are stored on reinforced industrial steel frames that are connected to a common grounding point. To access a part, there is a digital inventory dashboard to unlock the specific drawer, and a smart LED location indicator light guide ensures the correct component is pulled.
43.	A mobile storage warehouse system uses rolling tool carts equipped with modular stackable bins for accessories and repair supplies. Laptops are stored in vertical racks along the wall, while desktop towers are stored on reinforced shelving in designated safe lift zones. Volunteers move carts to refurbishment stations rather than carrying equipment across the warehouse. QR-code labels on bins and shelves connect to the digital inventory dashboard for efficient tracking.
44.	The warehouse will be organized using a tray/sliding storage system where laptops and smaller electronics are placed on removable sliding trays. Along the right wall, steel racks will store desktops with spacing between units to prevent overheating. On the left wall, vertical cable racks will store longer cables such as power cords, HDMI cables, and Ethernet cables while smaller adapters will be stored in transparent labeled bins below. Near the center of the room, four repair workstations will be placed in a square configuration.
45.	360 degree rotating cabinet w/ 2 shelves that holds the current drawer system for RAM, the hard drives (maybe stored in 3d printed slots) and boxes that hold: VGA cables, power supply cables, DVI cables, VGA cables. These cables are the cables that used to be stored underneath the workstation row of trolleys, but now they are here for easier access. They are secured together with velcro and placed in its respective bin. There is also opportunity to store mini PCs, stored the same method as the SSDs. The cables for using the miniPCs are stored in the same unit anyway. On the unit, there is a map showing which side of the shelves has what. LArger PCs are stored on a rack on the existing shelf next to the cabinet. This is Paired with laptop Stands along the FOG station shelf and the other shelves where there is laptops
46.	A pegboard wall warehouse layout dedicates one wall to tool organization using pegboards and shadow outlines. Adjacent shelving stores laptops in vertical racks and accessories in modular bins. The center of the warehouse contains rolling refurbishment carts that provide flexible workstations for volunteers. A digital inventory system tracks component locations while magnetic labels help volunteers identify storage categories.
47.	A rotating storage warehouse layout installs circular rotating cabinets for frequently used accessories such as adapters, chargers, and cables. These rotating storage units are placed near refurbishment tables so

	volunteers can access parts from any direction. Larger items such as laptops and desktops are stored on surrounding shelving units organized by model.
48.	A sliding rack warehouse layout uses pull-out storage shelves that allow volunteers to access items stored deeper within the shelving units. Laptops are stored in vertical racks while accessories are stored in labeled bins on sliding shelves. This system maximizes storage density while maintaining accessibility.
49.	A layered storage warehouse layout organizes items by usage frequency. Frequently used components are stored in bins near the refurbishment workstations, while rarely used components are stored on distant shelves. Laptop storage racks are positioned between these zones so volunteers can quickly retrieve devices during repairs.
50.	A storage system that entirely uses carts to store different items. There are different carts for wires, adapters, laptops, desktop components and other commonly used equipment. It will use the open source gridfinity system to generate different cutouts, grids, and components to contain different parts, all of which are 3D printable. The main carts will be made of heavy duty aluminum extrusion, to ensure they last a long time. The bins and compartments on the carts will be colour coded for easy visual identification, with a legend somewhere in the warehouse as a poster. The design will be assembled with only one tool, allowing for easy assembly. The sides of the warehouse will be a docking station for all the carts, and the carts can be moved around and organized to however the client wants it, allowing for easy reorganization of the warehouse according to the client's workflow. The layout of the design will follow similarly to what the client has right now, but due to all the carts being the same they could be reorganized by the client.
51.	Laptop storage carts that have a built-in charger will be kept at the front for ready to refurbish laptops. There will be shelving next to it which will have administration stuff. This will be right of the door as we are facing towards the north side of the room. Furthermore, Stackable smart storage bins will be used which will also to keep track of inventory. All the cables/laptop adapters will be placed by model in the left shelves. Similarly, all other items will be arranged based on their model in the left or right shelves. Color-coded LED strips will be used to indicate status of inventory. Ex: Green = Ready, Red = Needs Parts, etc.
52.	Laptop storage shelf that holds laptops in antistatic bags on racks. Each rack can be sorted by model. Laptops that used to be on top of the fog station are now on this shelf, so you can put items not commonly used like Events box and Apple box on the fog table now. Extra laptops can populate the shelf next to the laptop storage shelf.
53.	shelves that have many slots for new racks near entrance (place most commonly used big items here e.g laptops, desktops, mini pcs) these racks can be moved as needed to accomodate smaller or bigger items. as well, there are removable racks on the shelves intended to store laptops
54.	Freestanding Foldable Workbench Storage. This unit is placed on a wall. The pegboard has holders/cups that have the ability to hold ram, a desktop, a keyboard, a mouse, a ssd, tools necessary for repair and laptops. This way, one could gather all the materials they need from the current storage solution and then work at the workbench. For loading things into the storage, the workbench could be lifted up when not in use for easier navigation.
55.	Slanted bins storage solution that stores desktops, laptops and cables, keyboards, mice. REplace all shelves in the warehouse with this, except for one that has a small drawer system for ram (perhaps this can be under the electric panel). On top, can store boxes with cleaning supplies, event stuff, apple box, e.g.

	Can access the bins/top with a step stool. Magnetic labels for dynamic organization. There is a possibility of wheels to be added for extra mobility.
56.	Sliding shelves, a computer where u input the item you want and it will tell you 'row 3, shelf 2'. These sliding shelves eliminate the need for extra walking space, and can also store more than the current storage. Items no longer need to be stored underneath and around the workstations and FOG station. Organize Most important items in the front shelves (e.g. desktops, laptops, ram, ssds) and less commonly used in the back shelf (or shelves) (e.g. events box, boxes and bubble wrap for mailing refurbished tech).
57.	Because desktops and laptops consume more floor space, the back wall will use extra heavy-duty shelving to maximize dense storage of these larger items. Desktops will be placed on lower shelves by model and size, while laptops will be placed vertically on upper/middle shelves with foam separators and labeled slots. The center of the room will remain open except for four mobile worktables.
58.	A honeycomb-style storage structure will be installed along one back wall using hexagonal compartments to maximize storage density for laptops and smaller devices. Each compartment will contain foam or cardboard separators to prevent damage between devices. The left wall will contain steel shelving for desktops. Small accessories will be stored in transparent bins near the repair tables. The center of the room will contain repair workstations.
59.	The modular rail and sliding box system is built for high-frequency items like cables and adapters. It has aluminum rails attached to the front of fixed vertical equipment racks, where sliding boxes on rails can be moved in and out of. These sliding boxes are filled with interlocking IKEA bins and use color-coded tapes for wires to distinguish between power cords and data cables. Additionally, scannable QR codes on the boxes ensure that the stock levels are updated in real-time on the main computer.
60.	The multi-tier Lazy Susan station for storing small hardware like screws, laptop feet, and brackets. Centered on the furniture area tables, several rotating Lazy Susan organizers are stacked vertically on a central modular aluminum rail. Each tier holds transparent drawer electronics organizers that allow multiple workers to access parts simultaneously by spinning the tower. The base of the station includes magnetic mount storage strips for the small screwdrivers and tweezers used most frequently with these parts. The main storage will be sliding racks mounted on reinforced industrial steel frames to maximize the four-foot shelf depth. The racks are filled with interlocking stackable IKEA bins that are transparent, with LEDs for component identification.
61.	A vertical storage wall uses 3D printed modular joints to create hexagonal storage tubes based on biological structures. This honeycomb design provides high structural strength for storing heavy desktop towers at the base while transitioning to lighter items like keyboards and mice in the higher slots. Every hexagonal cell is fitted with a color-coded LED status strip that indicates if the device inside is a new donation or a refurbished unit. The layout follows a "most commonly used items at the front" logic, where the center of the honeycomb holds current projects at eye level, ensuring the 4-foot shelf depth is fully utilized without stacking equipment directly on top of sensitive screens.
62.	A square grid made of aluminum rails to build a freestanding grid of self-contained storage cells. Instead of long open shelves, this system uses interlocking snap-together connectors to create individual compartments of different sizes for specific hardware types. Small cells at eye level hold transparent drawers for RAM and hard drives, while the larger cells at the bottom are sized specifically for grounded metal desktop boxes. Each cell has color coded LEDs status strips to show whether the item inside is

	waiting for repair or ready to be donated, and the modular design allows the whole grid to be expanded or moved as the hub requirements change.
63.	A library-style laptop storage wall uses vertical V-slot racks that allow laptops to be stored upright by model category. Each slot is labeled with a barcode that links to the digital inventory dashboard. Slim rolling carts are docked at the end of each aisle to transport laptops to refurbishment tables. Adjacent shelves contain transparent bins for accessories such as RAM, chargers, and SSDs, ensuring that all components needed for repairs remain nearby and easy to locate.
64.	A gravity-fed storage warehouse layout uses angled shelving for cables and accessories so items naturally slide forward when one is removed. Laptops are stored in labeled vertical racks along the opposite wall, while modular bins store small electronic components. A wide central aisle allows volunteers to move carts safely between storage and refurbishment stations, and color-coded labels help volunteers quickly identify different equipment categories.
65.	A vertical storage warehouse system maximizes space by installing tall shelving units along the warehouse walls. Upper shelves store lightweight accessories in transparent bins, while mid-level shelves store laptops for ergonomic access. The central floor area remains open for refurbishment workstations and movement. Inventory labels and QR codes ensure that volunteers can quickly locate parts without searching through multiple containers.
66.	A transparent storage warehouse system uses clear stackable bins and drawers to store all accessories and repair parts. Laptops are organized by model on vertical shelving units, while desktop towers are stored on reinforced racks in designated safe lift zones. A wide central aisle ensures safe movement of volunteers and carts during refurbishment activities.
67.	A stackable bin warehouse system installs reinforced shelving filled with interlocking plastic bins to store small components such as RAM, adapters, and cables. Each bin includes a barcode label connected to the inventory system. Laptop storage racks and refurbishment carts are placed nearby to ensure efficient repair workflows.
68.	Adjustable shelf system with dividers and slots that could be resized for different components. The entire shelf could slide out for easy access, and slide back in to take up less space. The shelves will be made of thin metal, but will still be stable due to structural supports and trusses. This would allow the shelves to be semi see through, and since the shelves and slots are transparent too, users will be able to see what is stored inside. The shelf will be interlocking/use parts that snap together, allowing for easy assembly. The layout of the design will be follow the client's refurbishment workflow.

Appendix I.4. Multi Voting

Table I.4 Multi Voting

Solution Number	Round 1 (10 votes each) Ideas voted for in Round 1 are yellow	Round 2 Ideas voted for in Round 2 are orange (6 votes)	Round 3 Ideas voted for in Round 3 are Red (4 votes)	Total Score
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1.				2
2.	Devansh	Devansh		8
3.	Felix			
4.				
5.	Kavin, Felix, Devansh	Devansh, Kavin, Felix	Kavin, Felix	
6.	Georgia, Kavin, Devansh	Georgia, Kavin	Devansh	
7.				
8.	Kavin, Felix	Felix		
9.				
10.				
11.				
12.				
13.	Devansh	Devansh		
14.				
15.				
16.				
17.				
18.	Georgia, Felix	Felix		
19.	Devansh	Devansh, Georgia,		
20.	Devansh			
21.				

22.	Tong, Georgia, Felix	Kavin, Devansh	Devansh, Felix, Tong	
23.				
24.				
25.	Devansh, Felix	Devansh	Devansh, Kavin	
26.	Georgia, Tong	Georgia, Tong	Georgia, Felix, Tong	
27.	Kavin, Felix	Felix		
28.	Tong	Tong		
29.				
30.				
31.				
32.				
33.				
34.				
35.				
36.				
37.	Felix			
38.	Georgia,			
39.				
40	Kavin			
41.	Tong, Devansh	Tong, Felix	Tong	
42.	Tong			
43.	Georgia, Kavin	Georgia, Kavin		

44.	Devansh			
45.	Kavin,			
46.				
47.	Georgia,			
48.				
49.				
50.	Georgia, Kavin, Felix	Georgia, Kavin, Felix	Felix, Kavin, Georgia,	
51.	Georgia, Devansh, Kavin	Georgia, Kavin, Devansh	Devansh, Kavin, Georgia,	
52.	Tong	Tong		
53.				
54.	Tong			
55.	Tong			
56.				
57.				
58.				
59.				
60.				
61.				
62.				
63.				
64.	Felix			

65.	Tong, Kevin	Tong	Tong	
66.	Tong	Tong	Georgia,	
67.				
68.	Georgia,			

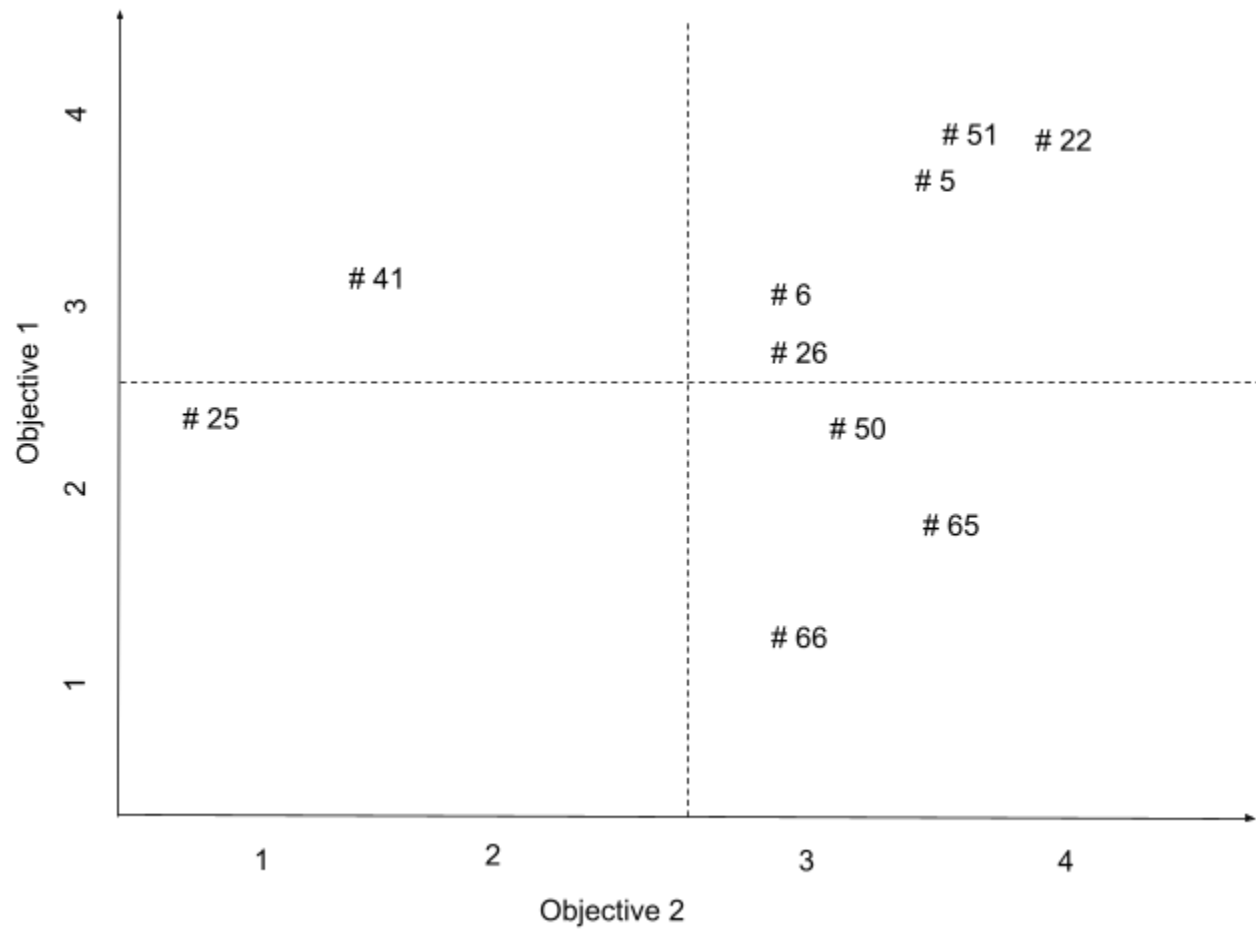
Table I.5 List of 10 Solutions

Solution Number	Solution
5	A high-density smart bin system uses sliding racks mounted on reinforced industrial steel frames to maximize the four-foot shelf depth. The racks are filled with interlocking stackable bins that are transparent, to identify internal parts like RAM and hard drives. Every bin has a scannable smart QR code and a color-coded LED status strip that lights up when a specific part is requested via the digital inventory dashboard. Additionally, designated safe lift zones where the heaviest bins are stored at waist height, and a grounded metal box is integrated at the base to store sensitive desktop components safely. Laptops will be stored in vertical racks on the right side, desktops will be placed on reinforced shelving along the back wall, and cables and adapters will be stored in transparent bins along the left wall. The center of the room will contain repair tables and rolling carts for refurbishment tasks.
6	We will implement a smart storage system where a digital map near the entrance will show the location of every storage item. When an item is searched in the system, LED strips on the corresponding shelf will illuminate to guide LGT employees to the correct location. The laptops will be stored in vertical racks and desktops will have a separate shelving. RAM, and adapters for laptops will be stored in transparent bins mounted on modular shelving.
22	A warehouse-style zoning layout organizes the space into clearly defined areas for intake, repair preparation, storage, and dispatch. Near the garage door, a sorting table allows incoming electronics to be categorized before storage. Laptop storage carts with built-in charging stations are positioned near the refurbishment area. Transparent modular bins on nearby shelving store accessories such as adapters and cables. Color-coded floor markings guide volunteers through wide aisles, ensuring that up to four people can move safely while maintaining efficient workflow.
25	This layout will use garage style freestanding pegboards along the left wall to hang cables, tools, adapters, and repair kits so they are visible and off the floor. Below the pegboards we will have transparent bin storage units that will hold spare parts sorted by type. The right wall will contain aluminum rail shelving that stores laptops vertically and desktops horizontally based on model. Near the entrance we will assign

	a dedicated table that will allow volunteers to sort new devices before placing them into storage. The center of the room will include rolling tool carts and repair tables for refurbishment tasks.
26	The warehouse will use a cube storage layout made of interlocking frames. Each cube will be assigned a specific device category such as laptops, desktops, adapters, or keyboards. Everything will be transparent which will allow LGT employees to see contents quickly. Small components will be stored in labeled drawers inside certain cubes. The center of the room will contain two large repair tables and a mobile tool station. Color-coded labels and LED indicators on cubes will show device status such as ready, testing, or needs parts.
41	A 3D-printed modular spool hub organizes the massive variety of power cables, HDMI cords, and adapters found in the Tech4All hub. The system uses a rotating cable spool storage rack built with 3D-printed modular joints that allow for the addition of more spools as needed. Each spool is color-coded with tape to match the type of device it supports. The hub is mounted on a heavy-duty rolling tower cart, making it easy to move the entire cable inventory to the testing station. The main storage is grounded metal desktop boxes and pull-out deep bin storage systems lined with ESD wrap and tape. The bins are stored on reinforced industrial steel frames that are connected to a common grounding point, with LEDs for component identification.
50	A storage system that entirely uses carts to store different items. There are different carts for wires, adapters, laptops, desktop components and other commonly used equipment. It will use the open source gridfinity system to generate different cutouts, grids, and components to contain different parts, all of which are 3D printable. The main carts will be made of heavy duty aluminum extrusion, to ensure they last a long time. The bins and compartments on the carts will be colour coded for easy visual identification, with a legend somewhere in the warehouse as a poster. The design will be assembled with only one tool, allowing for easy assembly. The sides of the warehouse will be a docking station for all the carts, and the carts can be moved around and organized to however the client wants it, allowing for easy reorganization of the warehouse according to the client's workflow. The layout of the design will follow similarly to what the client has right now, but due to all the carts being the same they could be reorganized by the client
51	Laptop storage carts that have a built-in charger will be kept at the front for ready to refurbish laptops. There will be shelving next to it which will have administration stuff. This will be right of the door as we are facing towards the north side of the room. Furthermore, Stackable smart storage bins will be used which will also to keep track of inventory. All the cables/laptop adaptors will be placed by model in the left shelves. Similarly, all other items will be arranged based on their model in the left or right shelves. Color-coded LED strips will be used to indicate status of inventory. Ex: Green = Ready, Red = Needs Parts, etc.
65	A vertical storage warehouse system maximizes space by installing tall shelving units along the warehouse walls. Upper shelves store lightweight accessories in transparent

	bins, while mid-level shelves store laptops for ergonomic access. The central floor area remains open for refurbishment workstations and movement. Inventory labels and QR codes ensure that volunteers can quickly locate parts without searching through multiple containers.
66	A transparent storage warehouse system uses clear stackable bins and drawers to store all accessories and repair parts. Laptops are organized by model on vertical shelving units, while desktop towers are stored on reinforced racks in designated safe lift zones. A wide central aisle ensures safe movement of volunteers and carts during refurbishment activities.

Appendix I.5. Graphical Decision Chart



Final 3 conceptual designs:

5. A high-density smart bin system uses sliding racks mounted on reinforced industrial steel frames to maximize the four-foot shelf depth. The racks are filled with interlocking stackable bins that are transparent, to identify internal parts like RAM and hard drives. Every bin has a scannable smart QR code and a color-coded LED status strip that lights up when a specific part is requested via the digital inventory dashboard. Additionally, designated safe lift zones where the heaviest bins are stored at waist height, and a grounded metal box is integrated at the base to store sensitive desktop components safely. Laptops will be stored in vertical racks on the right side, desktops will be placed on reinforced shelving along the back wall, and cables and adapters will be stored in transparent bins along the left wall. The center of the room will contain repair tables and rolling carts for refurbishment tasks.

51: Laptop storage carts that have a built-in charger will be kept at the front for ready to refurbish laptops. There will be shelving next to it which will have administration stuff. This will be right of the door as we are facing towards the north side of the room. Furthermore, Stackable smart storage bins will be used which will also keep track of inventory. All the cables/laptop adaptors will be placed by model in the left shelves. Similarly, all other items will be arranged based on their model in the left or right shelves. Color-coded LED strips will be used to indicate status of inventory. Ex: Green = Ready, Red = Needs Parts, etc.

22: A warehouse-style zoning layout organizes the space into clearly defined areas for intake, repair preparation, storage, and dispatch. Near the garage door, a sorting table allows incoming electronics to be categorized before storage. Laptop storage carts with built-in charging stations are positioned near the refurbishment area. Transparent modular bins on nearby shelving store accessories such as adapters and cables. Color-coded floor markings guide volunteers through wide aisles, ensuring that up to four people can move safely while maintaining efficient workflow.

Appendix I.6. Pugh Method

The team decided on using

Table I.6 Pugh chart comparing Design 5 and Design 51 against the datum (Design 22).

Objective	Design 22	Design 5	Design 51
Allocating adequate circulation space	0	-	0

Long-lasting	0	+	0
Improve workflow efficiency	0	+	+
Support high load capacity	0	+	0
Ergonomically accessible	0	-	0
Quick to assemble and reconfigure	0	-	-
Minimizing unsafe equipment handling	0	+	0
Total Score	0	+1	0

Table I.7 Justification for scoring of the designs against the datum

Objective	Justification for Design 5	Justification for Design 51
Allocating adequate circulation space	The high density sliding shelving needs to be pulled out, which can restrict operation area. Design 22 guarantees wide aisles that allow for circulation of up to 4 people.	The layout of this design puts storage at the perimeter. This is similar to Design 22, around the same amount of floor area for operation will be reserved.
Long-lasting	The reinforced industrial steel frames for the shelving are highly resistant compared to traditional storage units in Design 22. These will resist warehouse usage much longer than Design 22.	This design uses standard stackable bins and shelving, similar to Design 22, offering a similar lifespan.
Improve workflow efficiency	The system lights up the specific area the user is looking for, significantly reducing the time it takes for users to search for items. Compared to Design 22, users will still need to identify which colour corresponds to the item they are searching for.	The LED strip guiding system quickly guides users to the correct parts they need for the refurbishment process. This is much faster compared to Design 22, as users will still need to identify and search for the correct colour corresponding to the part needed.

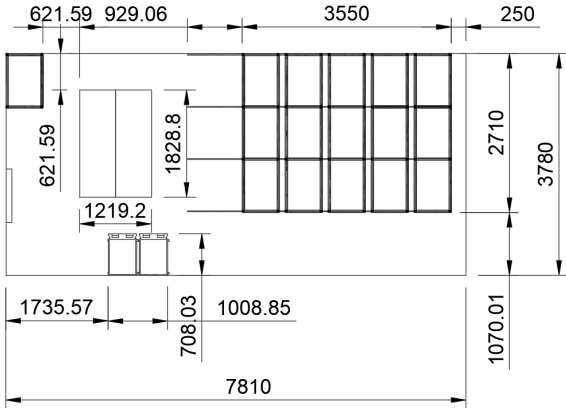
Support high load capacity	Uses reinforced industrial steel frames to hold interlocking bins, which is able to support weight much better than the more standard storage in Design 22.	Does not specifically specify any reinforcements, making the weight capacity similar to the Design 22.
Ergonomically accessible	Due to the high density sliding shelving, the clearance could be obstructed based on how far the shelves are slid out, which could cause awkward posturing. Design 22 always maintains wide and clear routes.	Both Design 51 and Design 22 both utilize standard shelving, neither of them introduce obstructions in reaching.
Quick to assemble and reconfigure	Design 5 requires many more steps to configure, like install tracks, wiring grounded ESD boxes, and setting up the LED system. Design 22 only requires the assembly of shelves, carts and laying down tape.	Design 51 and Design 22 use similar steps for setting up the actual storage. However, the LED strip categorization for Design 51 takes much longer to set up than the colour tape zones in Design 22.
Minimizing unsafe equipment handling	The system specifically stores the heaviest bins at waist height, allowing for the safest handling of heavy equipment. Design 22 categorized items into zones, but doesn't specifically indicate where heavy and light items are placed.	Both Design 51 and Design 22 categorize different items into specific zones. They also don't explicitly implement vertical safe lift zones.
Enabling clear categorization/identification of stored items	Design 5 uses scannable QR codes and LED lights mapped to a digital map, making part identification much clearer compared to the simple colour coding of Design 22.	Design 51's smart stackable bins with LED strips provide information on inventory and the workflow the user should follow, allowing for much easier identification of items compared to Design 22.

Therefore, our final proposed conceptual design is Design 5.

Appendix J. Alternate Designs: Objectives Estimates and Calculations

This appendix contains the calculations and estimations processes to reach results as shown in each alternate design objective table.

Table J. Estimations and Calculations

Result	Estimation/Calculation
Table 6, Circulation Area Percentage	 Figure J.1 Measurements of SSD Total Area of the warehouse: 3.78m x 8.563m = 32.36 m² Area used by storage units: $3.80 \times 2.71 \text{ m} + 22 \times 1.83 \text{ m} + 1.22 \times 0.71 \text{ m} + 0.62 \times 0.62 \text{ m}$ $\approx 13.78 \text{ m}^2$ Rough Percentage of free floorspace: $100\% - 13.78/32.37 \times 100$ $\approx 57\% \text{ free floorspace.}$
Table 6, high load capacity = 316kg	Estimating a range based on 3 different metal shelves with dimensions roughly correlating to 48 x 24 x 72". ULINE: 362kg [26] Wayfair: 362 kg [33] Phoenix Foods: 226.8 kg [34] Average: $950.8/3$ =316kg/unit

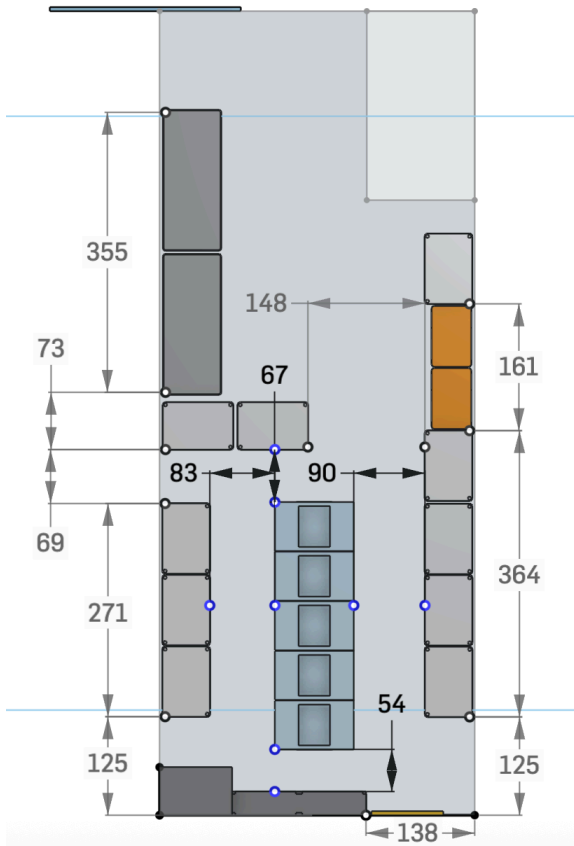
	This surpasses the original goal of 92kg/unit.
Table 6, Assembly Time	Yes. Because of the bins, shelf items are easily taken off. As well, plastic shelves are generally assembled with no tools (only a slide lock mechanism) and with 4-5 people, it is estimated that the 4ZWL can be assembled in under 5 hours
Table 7, Circulation Area Percentage	 Figure J.2. Measurements of 4ZWL Total Area of the warehouse: 3.78m x 8.563m = 32.36 m² Area used by storage units: $0.60 \times 7.04\text{m}^2 + 0.60 \times 7.04.2 \text{ m}^2 + 3.64 \times 1.55.3 \text{ m}^2 + 1.0 \times 2.72.7 \text{ m}^2$ $\approx 17.1 \text{ m}^2$ Rough Percentage of free floorspace: $100\% - 17.1/32.36\text{m} \times 100$ $\approx 43\% \text{ free floorspace.}$

Table 7, Ergonomics	Vertical reach for the current shelving goes below 400mm and goes above 1200mm in the current storage system  Figure J.3 Warehouse shelf w/ shelves lower than .4m and height estimated to be higher than 1.2m
Table 7, Assembly Time	Most Sliding Shelf designs are from ULINE. These designs are wire frame and do NOT require tools to assemble [24]. As well, bins hold every component which makes it easy to take off and on the shelf. With 4-5 people working to assemble, it is estimated that the design can be assembled in under 5 hours.

Appendix K. Measures of Success

Appendix K.1. MOS Calculations

1. Avg walking speed:

According to two sources it is found out that avg walking speed is 1.2 m/s [35], [36]

2 . Time scan to read a QR code:

According to Zenventory, barcodes take about 2 seconds to find and scan with a traditional handheld barcode scanner [37]. A very standard laser based barcode scanner (DC 101) can scan up to 300 scans/sec. So 1 scan is around 1/300, or 3.33 ms.

According to a study on infrared tags, it took on average 14 ms to decode a 21x21 QR code [38].

From this data, we can calculate the time it takes on average to find and scan a QR code.

$$\begin{aligned}
 t_{QR} &= t_{barcode} - t_{barcode\ scan} + t_{QR\ scan} \\
 t_{QR} &= 2000 - 3.33 + 14 \\
 t_{QR} &= 2010.67\ ms
 \end{aligned}$$

Therefore, it takes about 2.01 seconds on average to scan a QR code.

3. Digital Inventory Display

Time taken to read the digital inventory display and click on the task(eg. Refurbishment, stock replenishment, etc.): 5 seconds [39]

4. LED lights

To figure out how much time LED lights will save we compare Pick-to-Light vs. Manual Picking Time.

These are industry terms used to describe the difference between the visual search time (scanning shelves without a cue) versus directed retrieval time (LED tells you exactly where to go) .

For a manual picking system, average task time for a 10-item, 29-unit order was 159 seconds, while a digital light-assisted picking system reduced this to 87 seconds on average [40]. That's a 45% reduction in total task time from adding LED-directed picking.

5. Average Retrieval Time

The task time at each bin location is approximately 6.8-7.4 seconds. This covers reaching into the bin, pulling the item, and placing it. For lifting and lowering items from a height of approximately 0.9 metres, the average retrieval time is 6.8 seconds [41]. This is for items lifted from an optimal ergonomic height which is exactly what waist-height safe lift zone achieves for heavy items. In the old layout where heavy items are stored at floor or high-shelf level, retrieval takes longer and is ergonomically unsafe. In the new layout, placing them at the ergonomic zone brings retrieval time down to 6.8 seconds and also eliminates injury risk.

6. Acceleration when Pushing a Cart

To model a the worker pushing a cart in the simulation, a worker exerts an average force when pushing a cart, using this and Newton's Second Law, the acceleration could be found:

$$a = \frac{F_{push}}{m_{worker} + m_{cart} + m}$$

According to a study on acceleration in human walking, an average person accelerates at around 0.84 m/s² [42]. According to Statistics Canada, the average weight of an average Canadian is 73.0 kg [43].

$$a = \frac{73.0 \times 0.84}{73.0 + 9.07185 + m}$$

The final acceleration of a worker pushing a cart is:

$$a = \frac{61.32}{82.0718 + m} \text{ [m/s}^2\text{]}$$

Finally, a study found that the mean of a worker pushing a cart was 1.05 m/s [44].

7. Weight of items

Table K.1 Weight of items

Item	Mass (kg)
Laptop	1.6
Laptop charger	0.37
Laptop RAM (SO-DIMM x 10)	0.148
SSD (M.2 x 10)	0.09
Desktop	9.68
Desktop power cable	0.18
Desktop RAM (DIMM x 10)	0.3
Mouse	0.1
Keyboard	0.976
iFixit kit	0.853
Instructions (printer paper x 20)	0.091

1. Laptops: An average laptop weighs around 1.6 kg [45]
2. Desktops: An average desktop weighs around 9.68 kg [25]
3. Charger: An average laptop charger with the adapter weighs around 370 g, or 0.37 kg [46].
4. Desktop power cable: An average power cable weighs around 180 g [47].
5. Laptop RAM: The average weight of one SO-DIMM stick is 14.76 g. [48]. Assuming multiple sticks are stored together, and a maximum of 10 sticks are taken at a time, the mass is 147.6 g.
6. Desktop RAM: The average weight of one DIMM stick is 30 g [49]. Assuming multiple sticks are stored together, and a maximum of 10 sticks are taken at a time, the mass is 300 g.
7. SSD: The average weight of one M.2 SSD is 9 g [50]. Assuming multiple SSDs are stored together, and a maximum of 10 sticks are taken at a time, the mass is 90 g.
8. Mouse: An average office mouse weighs around 80-100 g, the higher estimate could be taken to assume a mouse weighs around 100 g [51].
9. Keyboard: An average plastic keyboard can weigh up to 976 g [52].
10. Repair kit: An iFixit pro kit weighs 1.88 lbs, which is 0.853 kg [53].
11. Instructions: Average printer paper weighs 4.54 g per sheet [54]. Assuming the instructions booklet is made up of up to 20 sheets of letter paper, the maximum weight of an instructions booklet is 20×4.54 , which is 90.8 g.

All the refurbishment items will be kept in one mostly linear path. The digital dashboard and LED lights will indicate the order of item retrieval. Currently, the employee needs to do these two tasks for retrieval:

1. Refurbish laptop: laptop → laptop charger → RAM → SSD → instructions → repair kit.

2. Refurbish desktop: desktop → power cable → mouse → keyboard → RAM → SSD → instructions → repair kit.

Note: The user will first walk to an empty cart, then load up the cart with the correct items before exiting the warehouse.

Appendix K.2 Testing using Flexsim

This appendix will have details about how the simulation was set up and its different components.



Figure K.2.1. Process flowchart that was used for both workflows in the Flexsim Simulation

Table K.2 Warehouse dimensions used in the simulation to get exact results

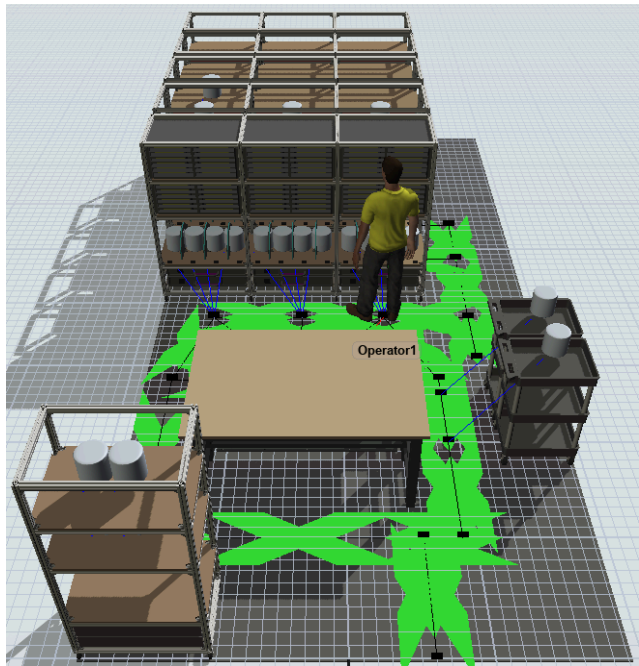
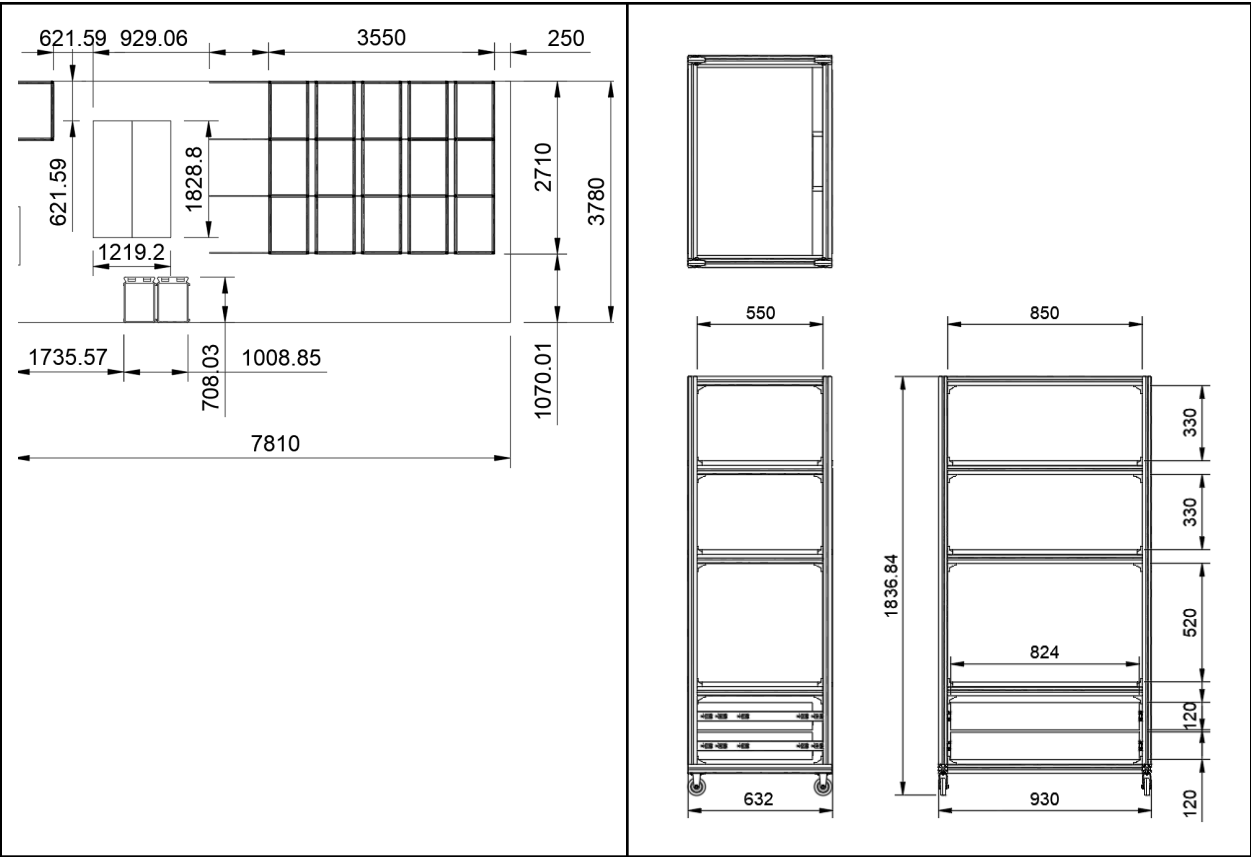


Figure K.2.2 The actual 3D model in Flexsim, with objects connected to nodes representing the actual objects the workers are going to pick up.

Calculations for seconds to retrieve one item:

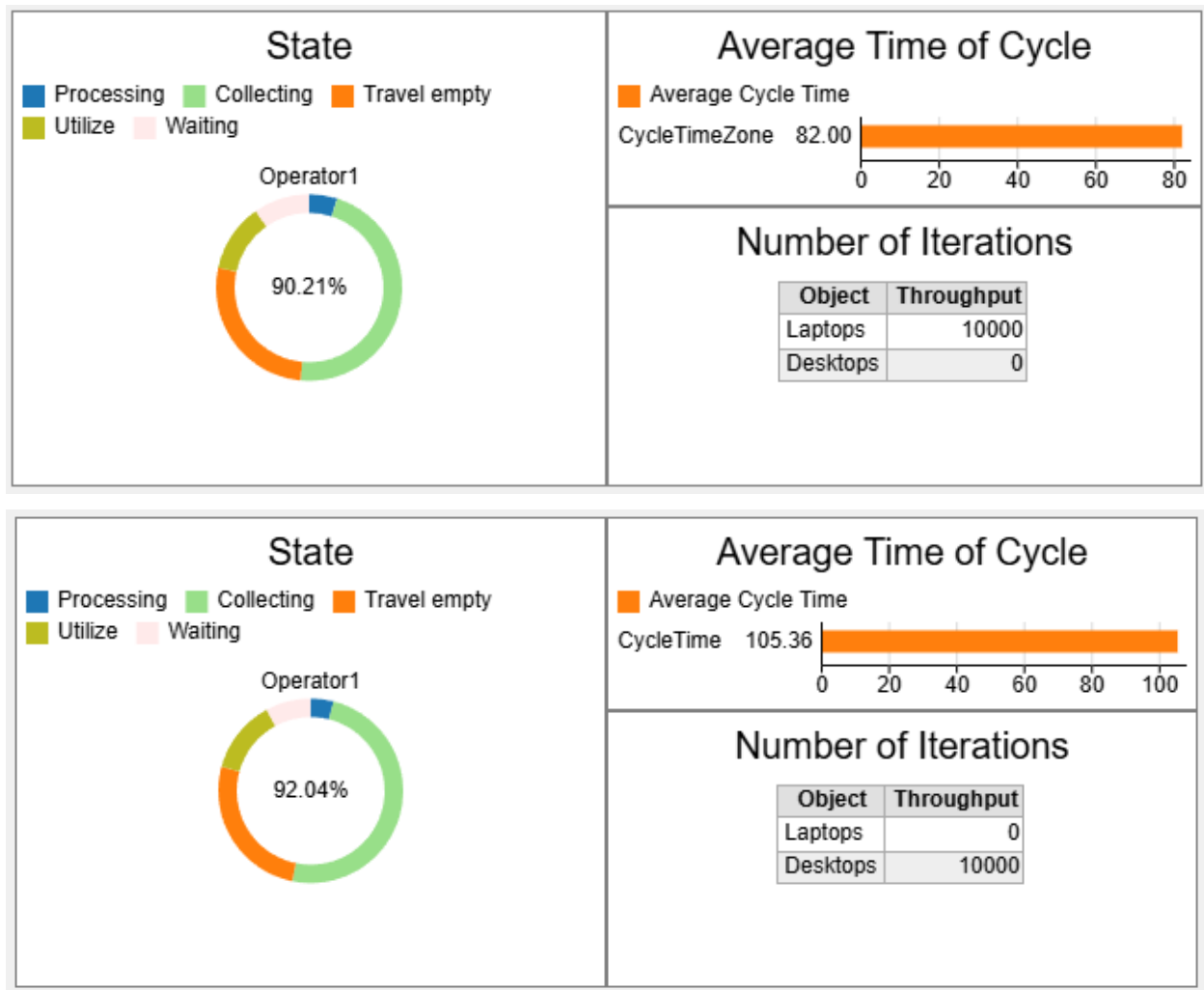


Figure K.2.3. Statistics for 10000 iterations for laptop and desktop cycle

Laptops: 82.00 seconds / 6 steps = 13.67 seconds/item, passing the objective goal

Desktops: 13.17 seconds / 8 steps = 13.17 seconds/item, passing the objective goal.