IAGO

MOBILE WORKSTATION FOR PLC PROGRAMMERS & SYSTEMS INTEGRATORS

Ergonomic Modular Workstation for PLC Programmers and fytuj Systems Integrators

by

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Abstract

This thesis explores and aims to achieve a design solution which improves the accessibility, comfort, workflow, efficiency, convenience and ergonomics of a Program Logistics Controller (PLC) Programmer and Systems Integrator. Current ergonomic limitations that exist involve; physical positioning in which users interact with their equipment, transportive means of their equipment and themselves, and workspaces that consider both modularity and ergonomics. The design solution will focus on reducing the effects (such as; awkward positioning, strains, soreness, load bearing, and discomfort) that current limitations present.

This proposal will focus predominantly on user observations, interviews, and surveys from those involved and affected by the PLC programming and automation Industry. In order to evaluate and analyze ergonomics, human factors, and full-bodied design, a scaled and modelled design solution will be created. The outcome, is to help establish and propose new ergonomic and efficient solutions for current and future PLC programmers/mechatronics workers and technicians. Designing a modular workstation or device with human ergonomic considerations that could help improve and elevate existing solutions, and hopefully create and inspire new ones

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Chapter 1 : Challenge Definition

1.1 Problem Definition

In the Automation Industry, many PLC programmers and Systems integrators are continually moving. Their job is to program assembly lines or any automated manufacturing process. Systems Integrators do this as well, although their focus is more on integrating and installing this new technology as well as program it. Both of their jobs require debugging and testing these devices to ensure full productivity. They do this task with a computer that is either connected directly to the machine or the robot's network first. This "machine" or hub that they connect to is referred to as a PLC, which is a program logistics controller. This brain is what is controlling the communication between the programmer and the device being programmed. Depending on the role and the position of the programmer, they can have up to and more than twelve-hour shifts. Some of the programmer's tasks can include being on-site for many hours moving back and forth between assemblies or sitting at a work environment that may not be adaptable to their roles. Other times, they can be offsite designing schematics, doing documentation, and may provide technical support. There are varying working stations and positions. Programmers/mechatronics workers have. These programmers and technicians try to use everything around them within the factory setting to create a workstation wherever they are. The objective and purpose of this thesis are to create and design a solution that may help reduce the time or improve this demographics experience in their workflow.

1.2 Investigative Approach

In In order to gain more knowledge of the challenges that PLC programmers and Systems Integrators may have, a combination of different research methods was conducted. These methods were utilized in data and a personal understanding as are as follows:

- Literature review
- Interviews
- Surveys
- Blogs/Educational videos on daily life
- Observational studies
- Ergonomics studies
- Continuous conversation with Thesis Advisors
- Search Engines such as; Google Chrome, Humber Libraries, Yahoo.com, etc.

The most defining questions that were developed to understand the challenges and inconveniences by PLC programmers and Systems Integrators were focused and were ultimately catered and answered differently by each person's interviews and surveys. These questions had to have prior research and understanding through literature reviews, quick searches, blog videos, and consultation with my Advisors. These research methods were conducted and can be reviewed (see Chapter 8 - Appendices). Although these questions were developed primarily to answer the basic questions that would create a well-defined solution. These questions were:

1. Who is my Demographic?
2. What are their challenges and needs?
3. What is their user behaviour?

4. How long does it take them to do certain tasks within the automotive factory environment?

5. What are the challenges and limitations of current product solutions? What are their positive impacts?

6. Are there any areas that can be improved or re-designed?

7. What would PLC programmers and Systems integrators design if they were product designers, what would make a genuine difference in their workflow.

1.3 Background / History / Social Context

PLC programming and Systems integrators within the automation industry (more precisely within the automotive industry) are in charge of creating and providing solutions for those in need of establishing and controlling automation services within a factory environment. The many tasks when integrating systems include providing design schematics, programming robotic machines, HMI's (Human Machine Interface), or helpful devices that require certain programmed functions.

PLC Programming and Systems Integration were developed in order to install new technology and faster innovative systems for manufacturing. The innovation and desire to help improve and fix systems is the purpose of this job. However, these people are more than just their job. Through doing user profile research, Some identifiers concluded that:

- Programmers and technicians have a median range from 25-43,
- Have an average salary of around $66,560 CAN,
- Are dominantly male,
- Are primarily Caucasian although still have a general diversity.

Why This Demographic?

There has not been much development when it comes to the work station in the factory of these users. Many PLC programmers and systems integrators have to refer to creating their own work environment using surrounding tools. Unergonomic workstations while programming for multiple hours within a factory, awkward hand positioning, and carrying tools back and forth with them. Therefore, improving their solutions can benefit a different range of technicians by improving efficiency and relieving some unergonomic strains.

2 Research

2.1.1 User Research

This chapter is focused on detailed research of a PLC / Integrator's functions and methods. The outcomes of this research will guide the development of a hypothesis detailing possible approaches to a product that provides the best fit. Aiming to achieve a design solution which improves the accessibility, comfort, workflow, efficiency, convenience and ergonomics of a Programmable Logic Controller (PLC) Programmer and Systems Integrator. The following information was attained and organized to format this report from the appendix (Chapter 8.2).

User Profile/Persona;

User	Tittle
Primary	PLC Programmer / Systems Integrator
Secondary	Managing Supervisor

Primary:

Figure 1.1. How to Begin a Professianl Career as a Computer System Anayst. Author Unknown, Retrived October 27, 2019 from https://www.qualityeducationandjobs.com/computer-systems-analyst/

Primary User	PLC Programmer / Systems Integrator
Age	~25-43
Gender	Dominantly Male
Income	~66,560+
Hours	40+
Ethnicity	Mixed, Primarily caucassian

The Primary users within the automation industry are in charge of creating and providing solutions for companies in need of establishing and controlling automation machinery within a factory environment. The many tasks of providing design schematics and programming robotic machines may result in motions and activities which could risk ergonomic strains and load-bearing from transporting equipment and personal mobility to varying stations. The PLC Programmer is directly responsible for implementing these solutions to automated factories; this is the user that is the most at risk of exposure from factory workplace hazards, ergonomic challenges, and transport bearing. These factors may also cause a decrease in efficiency, which may impact the secondary users.

PLC Programmers have a median age that ranges from 25-43 according to google image searches and online related searches. The average salary is around $66,560 CAN, and the average user is a White male.

Secondary:

Figure 1.2. Back View of the Head of the Project Holds Laptop and Discussing Product Details with Chief Engineer while They Walk Through Modern Factory. Gorodenkoff. Retrieved October 27, 2019 from Back View of the Head of the Project Holds Laptop and Discussing Product Details with Chief Engineer while They Walk Through Modern Factory.

Secondary User	Manager/Supervisor
Age	~37-65
Gender	Dominantly Male
Income	~133,000+
Hours	40
Ethnicity	Mixed, Primarily caucassian

These users are typically the ones who are in charge of providing tasks to the Primary users or programmers/ PLC integrators. These users may include those in charge of delegating PLC programmers with their tasks, or those who are requesting these solutions and services for their companies.

User Persona

Figure 1.3 Allen Bradley / Siemens / Omron / GE / Modicon – PLC Programmers. Author Unknown. Retrieved November 27, 2019 from https://www.systemsengr.com/plc-programmers/

Name:	Nick Bola
Age	28
Gender	Dominantly Male
Job	PLC programmer/ Systems Integrator
Location	Brampton, Ontario
Income	~75,000
Hours	(Contract worker- Varies work) ~40-60 hrs
Ethnicity	Caucassian
Education	Degree in Science Technology, Diploma in Mechatronics & Robotics
Frequency	5-7 days a week (depending on contract)
Duration	8-12 hours (depending on project)
Social	Friends and Family
Other Pursuits	Flying his drone, longboarding, spending time with girlfriend

Nick Bola is a 25-year-old male who started his career as a Mechatronics and PLC programmer at the age of 20. His interests in this career included his love for taking apart RC Cars to look into systems when he was younger and creating new machines and systems off of other RC and gaming consoles. He started his post-secondary education in Mechatronics and robotics at Humber College School of Applied Technology. A few months before graduating, he was contacted by a company in the USA which provides automation solutions for larger Tier1 companies. Here he worked a few years then became an independent contractor working directly with big company's like GM, providing the PLC solutions for their robotic machines and assemblies.

2.1.2 Current user practices – User behavior summary Frequency

The behavior of a PLC programmer varies depending on the project. Some projects require being immersed in a factory setting while others can be involved in programming objects humans interact with daily- like traffic lights. Their hours also vary depending on the type of programmer, that is if they are contract workers or everyday workers. Every day workers can work a regular 40-48 hour working week as stated within their contract with a company or corporation providing plc solutions. Meanwhile, contract workers may not be given a limitation of hours, but a timeline stating when their job must be done by. This means that Contract PLC workers like any contract work may exceed the average workweek in meeting deadlines depending on a company's budget. Those mandating or in charge of the contractor or employee typically work fewer hours, complying more directly with the average workweek.

The frequency of PLC/ Integrator duties would typically be dictated by the engineering manager or the project manager that is responsible for tracking progress and project agendas.

There are some times where the PLC/Integrator will take on the role of providing the customer with services like Project management and consultation.

Duration

In general, depending on the project and timeline of the production launch, there could be a set schedule of 10-12 hours a day for 7 days, up to three weeks straight. In this time frame, the integrator is focused on commissioning equipment and getting ready for an automatic run of production.

Level of Focus

The primary tasks are to establish a work station from where the computer and other integration devices will be networked and ready to connect to the primary PLC/Computer to control the Machines being commissioned. This is usually set up near the main controller in close proximity to the cell being commissioned. The integrator must then check all peripheral connections in and around the machine to make sure that all of the hardware is to engineering specifications. This requires the integrator to be fully focused on assessing engineering blueprints and verifying software.

Social or Solitary

Figure 1.4 PLC SCADA TRAINING. Vyshakh, R. Retrieved October 27, 2019 from: https://medium.com/@vyshakhr.livewire/plc-scada-training-livewire-f5b46855b82d

Integrators will often work in teams depending on the size of the project and the scope of the work. Usually, there will be two people working together on one machine, but often there is only one integrator having to commission the equipment. The better the tools that an independent integrator has, the more efficient she/he will be in the integration process.

Motivation

Integrators have the motivation to commission machinery and robotics due to the specific skills that they bring to the table. They would enjoy the process of troubleshooting electrical connections, software and robotics. Hand in hand, the hourly compensation of the service helps motivate the integrator to complete her/his task to the best of their abilities. The focus is, the faster the integration process is done, the faster the integrator can move on to the next project.

Lifestyle

After a day's work is complete, the integrator will come home or go to the hotel if it is at a remote location, then go to the gym, eat and then go to sleep and repeat his routine. This is a draining cycle as there is not much downtime to make dinner or prepare for the next day. Time management is a critical part of an integrator's lifestyle as his work often merges hours with personal time. Many challenges faced when working with computers is eyestrain and physically tiring when the day requires a lot of physical activity, including the overload of long shifts. They would only come home to his family on certain weekends since his contracts required him to get the job done with tight timelines and at customers' sites. A PLC programmers' lifestyle could be different since they may only need to focus on the debugging and testing stage. This means that some companies may just have some trained and standby staff as well as PLC programmers who come to the factory daily to keep the assemblies in check.

Location

The most common location for this work is at an industrial factory. However, depending on the type of equipment being commissioned, it could be at a pharmaceutical company, at a food and beverage producing facility or at an automotive manufacturing plant. The in-person observation and activity mapping completed was done at an automotive manufacturing plant. The intended location is focusing in factory plants within North America.

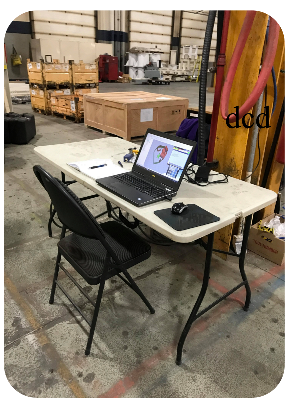
Figure 1.5. Two Born Every Minute: Inside Nissan's Sunderland Factory. Steve, Moody. Retrieved October 27, 2019 from https://www.carmagazine.co.uk/features/car-culture/two-born-every-minute-inside-nissans-sunderland-factory-car-february-2016/

2.1.3 Activity Mapping

Videos were analyzed and were used to aid with the user and activity mapping and can be found in (Chapter 8.5). The observations and analysis from these videos further clarified and confirmed the steps in addition to the user observations conducted. As indicated within the appendix (8.5), observational studies were conducted at MASSIV Automation, an automation company owned by Magna in Brampton Ontario in Canada on Friday, November 1st, 2019 under the supervision of Dave Evans, Automations Manager. Additional observation study was conducted with Santiago Moros Glaser, a PLC programmer and Systems integrator in his home. The Videos conducted in preliminary research were also used in order to understand workflow, and aided in defining these steps. All photos were retrieved were done with consent. Info graphs were created based on the analyzed observations and research conducted. Pictures were not taken of the users as the company did not want to have images of their workers for security reasons. These are the steps gathered:

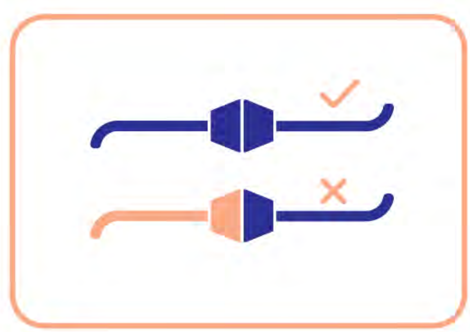
Step 1: Set up

The PLC Programmer/Systems Integrator will set up a work station with a collapsible table and chair on the factory floor by the cells so that Electrical Design binders can be laid out and studied.



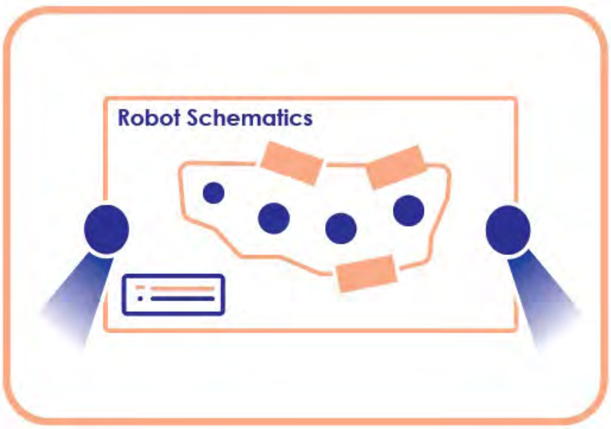
Step 2: Assessment

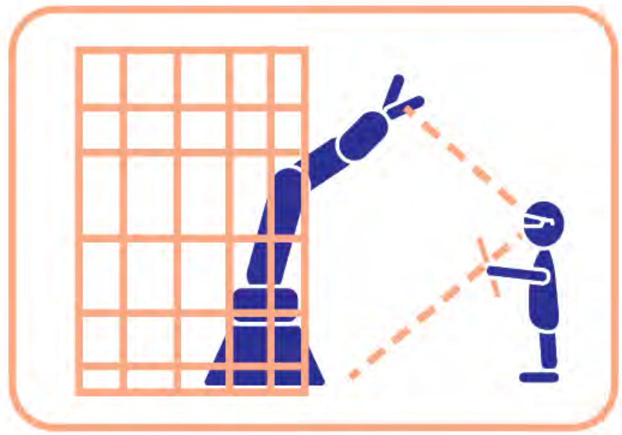
The PLC Programmer/ Systems Integrator will then assess all of the electrical connections of the installed equipment. This assessment requires looking at electrical schematics and comparing them to the physical components that are in place.



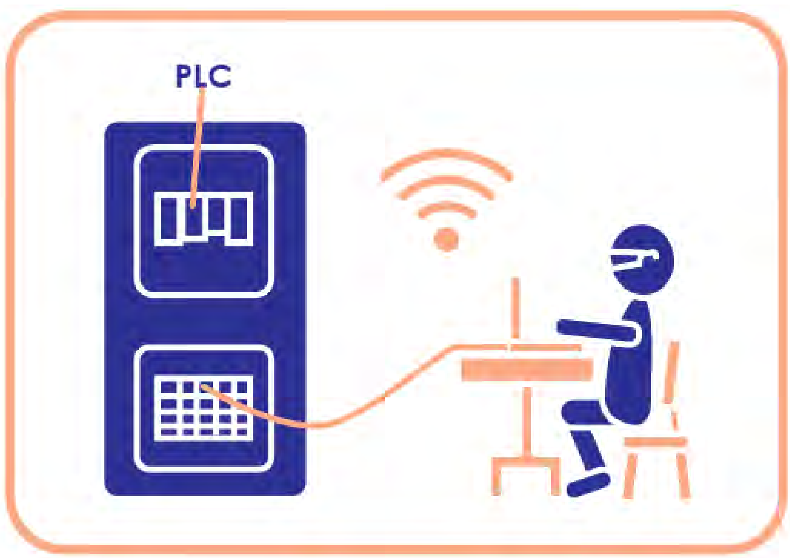
Step 3: Analysis

As the PLC Programmers/ Systems Integrators analyze schematics sketches and carry them around the cell to physically verify the cell connections and details.



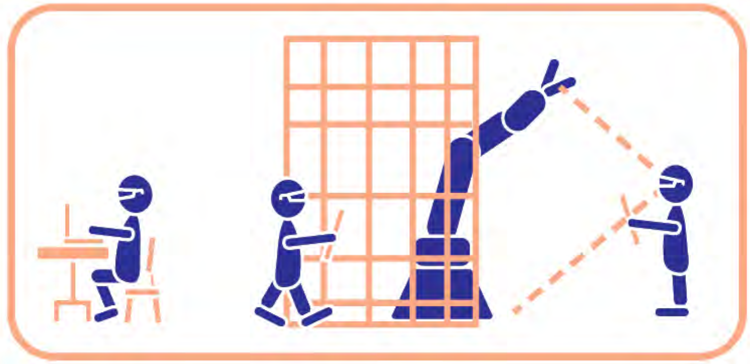


Step 4: PLC Installation



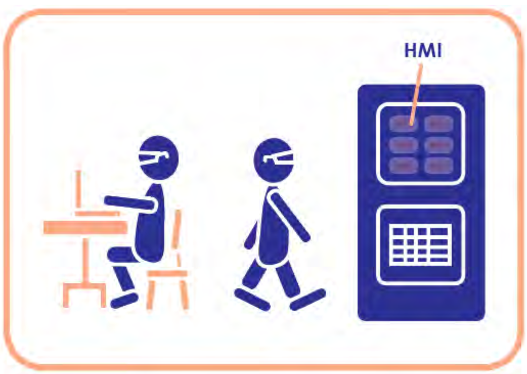
Once the connections are verified, the software and PLC network must be established. This is done close to the main PLC Processor. The work Station (table and chair) are typically moved to where the main PLC controller is and close to an HMI (Human Machine Interface). Once set up, they will connect to the PLC through a laptop. The programs are then downloaded and installed to the controllers and HMIs.

Step 5: Debugging/ Testing (A)



The Systems Integrator will then sit at the desk they set up earlier, and debug the software several times. This process involves walking back and forth between the laptop and the devices (robots, assemblies, etc.) that are being configured.

Step 5: Debugging/ Testing (B)



If there are HMI devices and remote devices inside and around the perimeter of the cell (the area in which the operation/assembly is happening) that needs special attention, the integrator must walk to the HMI to make sure they are working. This would typically involve moving around the workstation to get closer to the device.

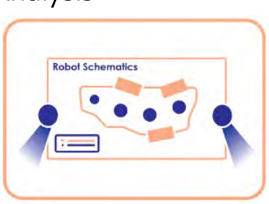
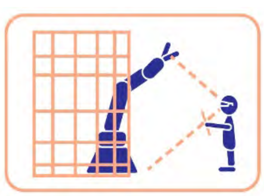
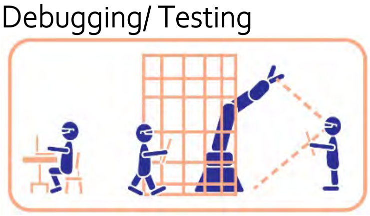
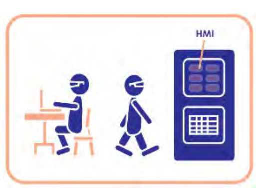
Step 6: Motion Verification

The Systems Integrator must be in front of the main control HMI. Testing with the laptop open nearby, they fix any functional issues. This process continues until all motion has been verified safe, and the main HMI works to control the cell manually and in Automatic.

Step 7: Pack-Up

Once the cell is in Automatic, the integrator should not need their laptop anymore, and the cell is now fully controllable through the HMI. The Systems Integrator packs up. she/he then focuses on assisting the production of parts through the cell.

User Observation Analysis

Task	Issues
Set up 	-PLC programmers must choose where to set up for each task if they are there for longer periods of hours - Depending on what furniture is used, it may not be the most ergonomically comfortable. -Workstations are not fully adjustable
Analysis  	-Workers must carry drawings with them -Hard to view sketches of the schematic in hand. - have to walk around the cell to see and make sure everything looks in check.
Debugging/ Testing  	-pacing back and forth between laptop and devices that are being configured. -Some of the tools that are debugging are not

Pack-Up 	-They must pack up their collapsible work station or leave it in a factory. When they go to a new project, they must move their workstation or buy a new one.

Even though these are the main points of impact, there are many other parts in which could be improved ergonomically within the workflow of a PLC Programmer and Systems Integrator. The main areas which could be improved are the set-up and taking down of a workstation and how these workers hold their schematics and laptops in hand when doing analysis. That motion of going back and forth to solve the problem with their equipment or having to run back is the main problem points.

2.1.4 Ergonomic Research

The ergonomics of a workstation are essential for the health of the worker, as well as for the efficiency of a company. The current solutions involve focusing on only collapsible chairs for ease and price. These solutions don't take into account the modularity as well as the comfort and ergonomics of a worker who may be moving or seated for multiple hours. Ergonomics was one of the main benefits that many benchmarked products (further analysis of some benchmarked items can be found in the appendix (Chapter 8.6) were advertised around. Even so, these benchmarked items have been designed to focus primarily on utility. The products which focused on a workstation touched upon the ergonomic height and structure of a standing person. These products lacked consideration of more comfortable seating, even though many are able to capture the primary positions that a person uses for workstations. The more modular solutions, for the exclusion of one, were bulkier and denser. Which for a PLC programmer, it may be an inconvenience as they prefer objects that are more compact, lighter and portable. The focus would be to stray away from a heavy product and focus on compact products. Overall, these products can be used as a base for elements such as ideal heights and positioning.

2.1.5 Safety & Health Research

The health and safety of the user is a critical part of the mechanical design and ergonomics of the final product. In this case, the product must withstand the mass of the integrator/PLC programmer sitting as well as loading it with all of the equipment she/he needs. Because the target location is an industrial setting, there are safety hazards like high power lines and sharp parts/scrap metal around. The proposed product must consider the possible location hazards and offer safety systems that isolate the user from things like sharp scrap metal or even possible slippery situations.

2.2 Product Research

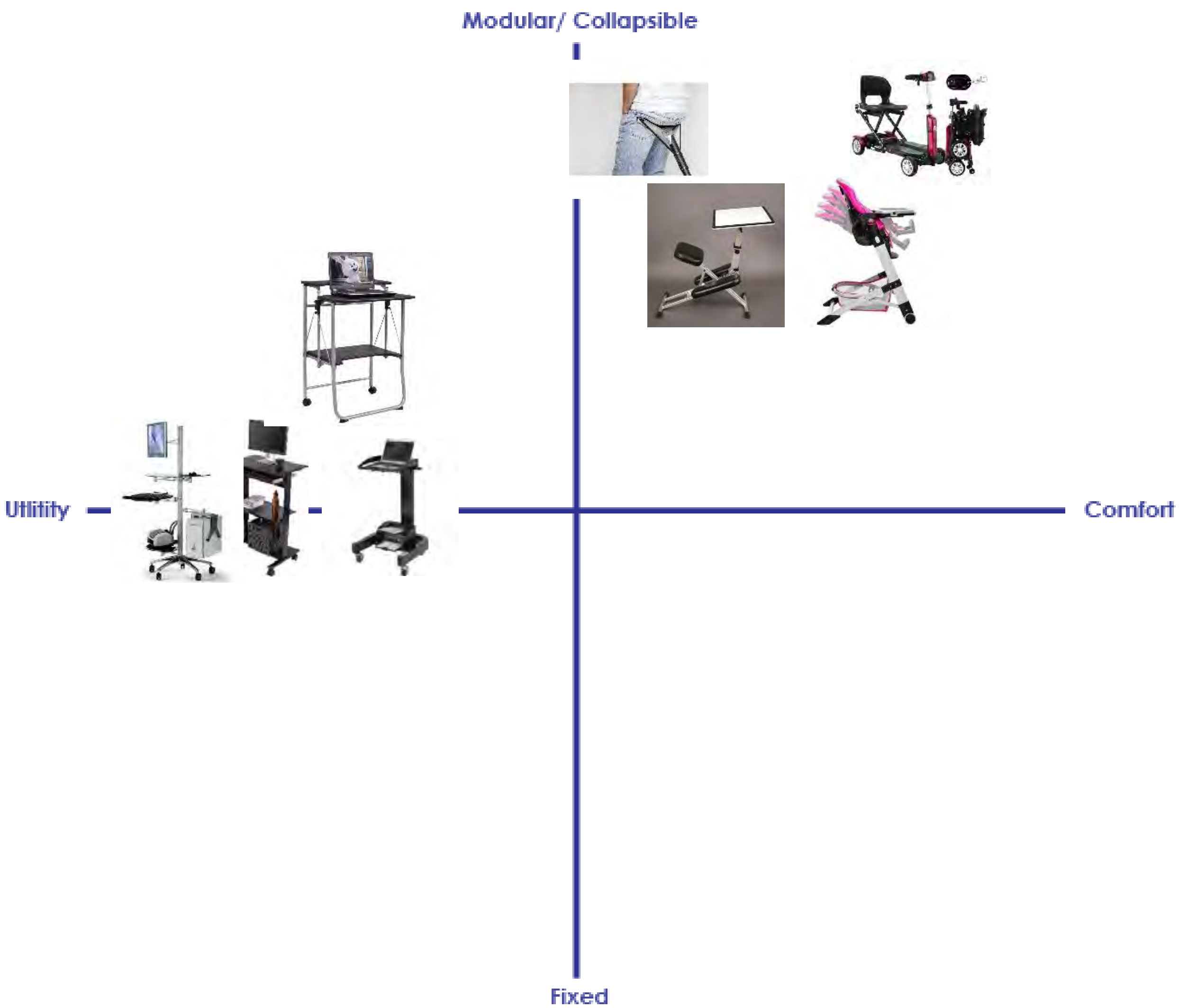
2.2.1 Benchmarking – Benefits and Features

The objective of this section is to analyze existing products that are relevant to the ergonomics and workflow of PLC Programmers/Integrators. The benchmarked tools may not be directly catered towards the same demographic but may be used by the demographic to help complete their job. By doing this process, one can then determine the features and benefits in order to understand their relevance and what could be applied to the solution in design. The products chosen were based in accordance with the primary users' needs, such as modularity, adjustability, comfort, ergonomics, collapsibility, and convenience. These products and their table analysis can be seen at the end of the report in the appendices. The products which were compared and can be found in the appendices are:

1. Ergonomic Mobile Workstation Stand AV Cart

2. Global Industrial™ Orbit Mobile Laptop Cart, Black
3. Mobile Adjustable Height Stand Up Workstation (Black & Black)
4. The Edge Desk | Ergonomic and Foldable Workstation
5. Costway Folding Computer Desk Laptop PC Table workstation Study Writing Desk w/ 2 Wheels
6. The EasyFold Scooter
7. SitPack Zen
8. KidsEmbrace DC Comics Batman Deluxe High Chair

The chart below was created in order to analyze the *feature* aspects the eight products chosen in section 1. The X-Y Graph focuses on displaying the findings in a scatter plot in order to define potential design opportunities.



2.2.2 Benchmark Functionality

This section includes a list of benchmarked mobile work station products. This exercise provides an analysis of competing products in this category. Possible design niches can be investigated and will aid in the solution design process.

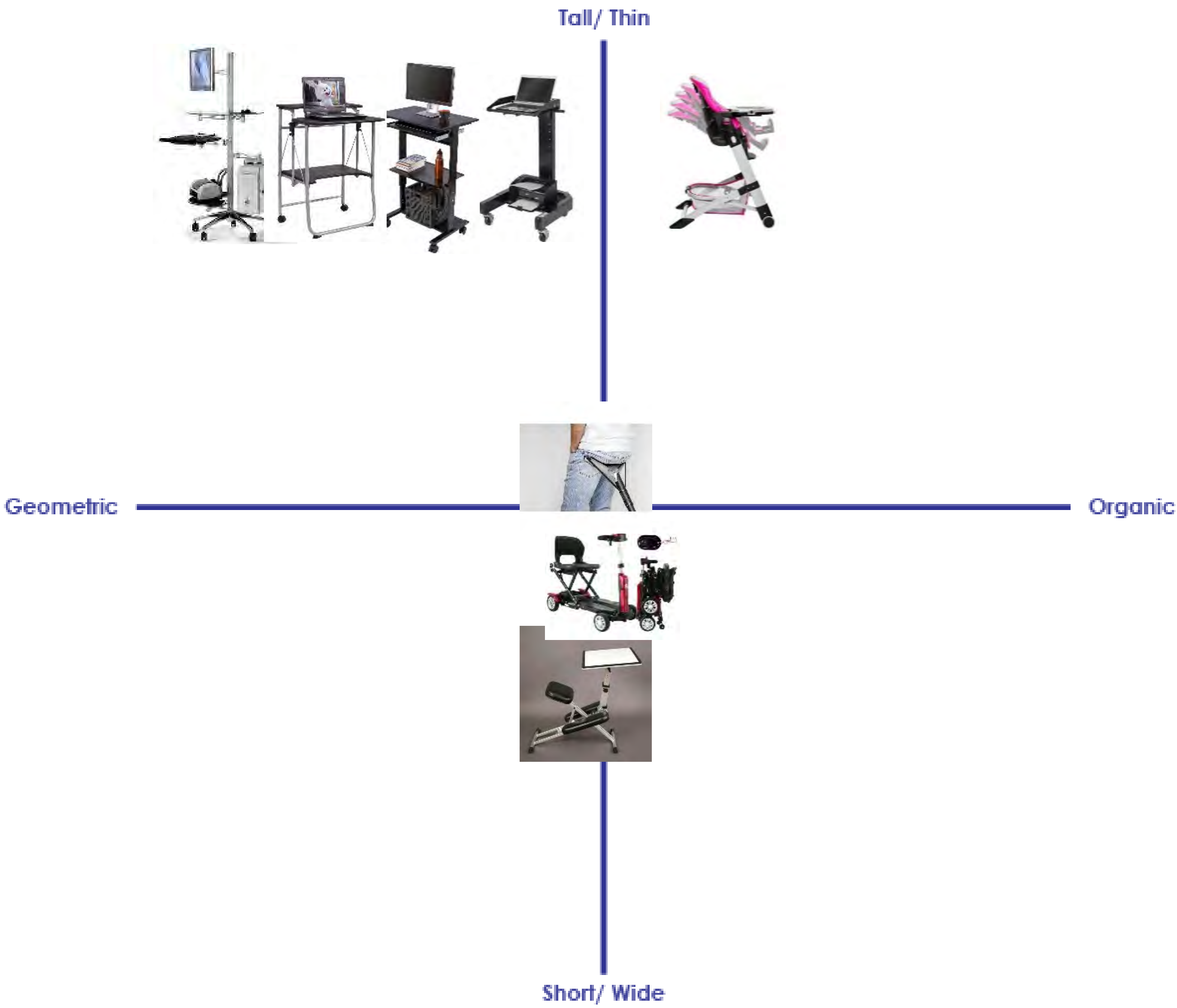
The benefits of product benchmarking are that it allows for the analysis of similar products that are catered to similar demographics or other products that can be re-designed to the intended demographic. This helps determine any similarities and differences in product design, functionality and materials. Product pros and cons can be investigated and allow for a variety of solutions with different product niches.

Based on this process, insight has been achieved, especially in the areas that need focus; mobility (moving products), adjustability (transformative products), being light in weight, and ergonomics. In design, focusing on products that are more comfortable and collapsible, balanced in utility and aesthetic, and more stable are desired. In terms of materials, the dominant materials and finishing are powder coating and aluminum. This exercise helps establish a catalogue of the best materials for this application. Even so, this will not be a limitation in exploring materials that can be better suitable for its design and function.

The focus of the product will be to create a singular, modular, and adjustable workstation or tool that improves the; accessibility, comfort, workflow, efficiency, convenience and ergonomics of a Program Logistics Controller (PLC) Programmer and Systems Integrator. While being lightweight, convenient and balanced through form and function.

2.2.3 Benchmarking Aesthetics and Semantics Profile

Focusing on the form factor or Aesthetics profile of current market products in the mobile work station sector, we can further develop and refine an aesthetics profile for the proposed product. The chart below was created in order to analyze the aesthetic aspects of the eight products chosen in section 1. The X-Y Graph focuses on displaying the findings in a scatter plot in order to define potential design opportunities.



Design language

By analyzing the form of the benchmarked items, it makes it easier for us to be able to identify the main design features and aesthetic elements that were chosen. This can then help inform the design by establishing a semantic language. In this case, the products which were tall and geometric served primarily one purpose and one position. Their design language focused on the utility of only serving those very few functions. Meanwhile, the objects which were shorter/smaller in size tended to be a bit more ergonomic and organic in shape and more user friendly. The one product (SitPack Zen) managed to encompass all of these elements in a balanced manner by having the more form-fitting seat but still being designed with the geometric semantics in mind. It was also short/small when not in use, and talk when in use. This gave the product an adjustable form. Yet the commonalities in design semantics is the focus for more geometric and functional design language. This language can be incorporated within the intended design solution, although it can definitely be re-designed aesthetically to have a more modern and balanced aesthetic while maintaining that functional design language.

Examining Features and Benefits

By examining both X-Y graphs, it can be shown that the most ergonomic and comfortable where the products were those that also offered more modular solutions, rather than the ones that were focused on utility and had less motion. The same products that focused more on the comfortable and ergonomic side were also aesthetically wider, shorter and more organic in shape than those that focused on utility and have less motion — the form of these products where focused on taller and more geometric shapes.

By examining the main demographic information of each product through its marketing. The benefits and features were examined through the frequency of text analysis in the advertisements and specifications of the eight products identified. The results and chart can be found in the appendices (x). After creating a frequency analysis chart to examine the features and benefits of the products chosen for benchmarking, the top words their synonyms within features described included mobility, adjustability, storage, powder coating, and aluminum. The Top benefits included items that were lightweight, ergonomic, and durable.

2.2.4 Benchmarking – Materials and Manufacturing

Some of the benchmarked products above do not give a complete definition of the materials that they use. For those that do, the primary material which seems to be common is aluminum or unspecified steel. It seems as though they also use a type of plastic for their outer frame, or at least for some components. A few of the benchmarked items also mention the use of having a durable powder coat finish, which is needs, especially for vehicles and tools within the factory. Even so, vehicles within factories so not go the extent of fully being created out of metal as this would be highly expensive. The best approach would be to design using durable plastic in mind for easier and less costly manufacturing. Examining other devices like mobile vehicles aided in providing a better understanding of materials. After watching " *How It's Made:* Electric Scooters", there was a list of some materials that could be used. These materials included

- Aircraft Grade Aluminum & regular Aluminum
- Aircraft Grade Stainless Steel
- High Strength Steel
- Rubber wheels

2.2.5 Benchmarking Sustainability

As designers, we are taught the importance of designing with sustainability in mind from the beginning of a project to its end. The reason for this is the more we choose plastics, which are not reusable, the more we create materials that may not be recycled, the more we endanger our world. The current benchmarked items have a focus more on the utility and durability of their products. This means that there is not much of an existing focus within the benchmarked products around sustainability or sustainable incentives. The products were not designed with sustainability in mind. Even so, some of them do use sustainable materials or materials that may be recycled or reused. Aluminum is a material that could be recycled only if it is pure. The rubber wheels used in *The Easyfold Scooter* can be recycled as many rubber tires are. Applying these incentives within the solutions design intention and continuing to research more sustainably driven products may help inform a better-designed solution.

3 Analysis

This chapter will focus on the needs of PLC Programmers and a Systems integrator by examining the existing solutions and their workflow. It will further explain what the current challenges are and why these challenges should be considered. The needs will be assessed and analyzed through functionality, usability, aesthetics, and material application.

3.1 Needs Analysis

3.1.1 Needs/ Benefits Not Met by Current Products

Within the market, there are solutions that help with certain areas when it comes to work stations. Even so, not many take into consideration the different actions users may have to undergo in their workflow. Existing designs focus on solving one problem in the way some users work. Factory stations are designed similarly. Each workstation is designed to have the fundamentals for those workers to complete that task, although they may not consider the actual habits or the limitations in their initial design. This may be since these initial layouts focus on the goal of the machine primarily, then secondarily focus on how the user can interact with that intended layout. Because of this, PLC Programmers and Systems integrators, as well as other workers, may not be considered ergonomically or their environment, comfort and aesthetics. These are important as their workers can work up to 12-hour days when on contract and can be doing the same 8-hour task, whether it be a lot of walking or looking at a computer screen. Like many, this can deteriorate the physical and mental well-being of any worker if working conditions are limited. Speaking with advisors, many may not have the luxury to have a collapsible chair and make their work station out of items they bring themselves to work or find lying around. By focusing on this, we can improve these user’s workflow so that they become more efficient in executing their job, and hopefully, limit the amount of strain that may be caused to them. Through interviews that can be found in the appendix (Chapter 8.2, 8.4) The users' needs and benefits are described below.

Needs	Benefits
Convenience	Ease of use, (doesn't give you any soreness), easy to store, speed of assembly and disassembly, portability
Comfort	Comfort for the programmer, (adjustable seat height and back angle, cushioning)
Environmental	Flexibility (has a wide range of configurations to best suit the needs of the individual programmer), Control (control and power over the movement and accessibility of the device).
Securing Resources	Value (price) – Best Solution for the best price + warranty
Safety	Durability and strength of device, load is secured and balanced, designed for the intended environment.

3.1.2 Latent Needs

Benefit	Possible Corresponding Fundamental Human Needs	Relationship Between Benefits and FHN
Comfort	Control, Security, Self-esteem	Strong
Style	Esteem, Belonging, Aesthetically Pleasing	Low
Efficiency	Accomplishment, Autonomy, Self-Esteem	Strong
Ease	Accomplishment, Autonomy, control, security, self-esteem	Strong

Fun	Leisure, Participation, Belonging	Low

Comfort

When it comes to considering the workstation of a PLC Programmer and Systems integrator, comfort is an essential consideration in the execution of a variety of tasks. When focusing on demographic research, depending on their work environment, they may be doing a lot of repetitive tasks.

Style

The chart above showcases that on a level of aesthetic and style, there is not much of an importance. Although this may be considered as a possible area that could be expanded upon. By adding more importance to the aesthetic and form it would help build more confidence and self-esteem within the user.

Efficiency

After speaking with five workers who did related work or were within the industry, many stressed that the stress and pressure of getting a job done in an efficient and timely manner were very evident. A lot of the current market does not consider much of is the ergonomic challenges that some of their users have to face as some of them can be sitting for multiple hours on end. An important consideration to make for a designed solution would be consider some of these ergonomic strains, and by doing this it may help create more efficiency within the worker. In addition, creating a solution that may help speed or regulate a task may alleviate the stresses and discomfort within that task.

Ease

When talking to advisor Santiago Moros, another consideration was the ease of use in the current products used. Some programmers and integrators use collapsible chairs and tables because of its low cost, ease in the purchase, and their modularity. Even so, creating and designing a solution that carries some of these principles which may benefit them long term would be ideal. Focusing on the ease of utility and modularity, while ensuring the solution does not end up hindering but rather improve workflow would be the goal.

Fun

When working in a factory, the latent need for fun is not really a focus as each person has to be careful in the environment as heavy-duty equipment is involved. Therefore, safety is a priority overall. Even so, designing a solution that may still give of the element of fun in its function (like buttons or design language and function) rather than a focus on recreation is what could bring a more human element.

3.1.3 Categorization of needs

This section refers to the analysis and examination of the data mentioned in section (2.1.1) the user profile, (2.1.2) user behavior, (2.2.2) features and benefits, and (2.2.3) aesthetics and semantics, and user interviews. According to this data, the intended solution must perform some advancement in the function of design, materials and overall product likability aesthetics. The categorization of needs allows us to focus the design of our final product so that it directly militates any of the current user problems, including having to place the laptop on top of cabinets to work closer to where the "action" is.

Immediate Needs

- Desktop for computer
- Sitting comfortably at the work station
- Flexibility to carry around or place in tight places
- Storage for tools

Latent Needs

- Brings a feeling of security/ Sturdiness
- Provides freedom to mover around the cell
- The product that provides mobility inside of a factory
- Modularity in the design of the product, so that it can be easily carried or rolled around.

Wants

- A device that provides a stable countertop to place Laptops and other tools
- Aesthetics in design, shape, form
- Easy to use and an excellent replacement for tables and chairs

3.1.4 Needs Analysis Diagram

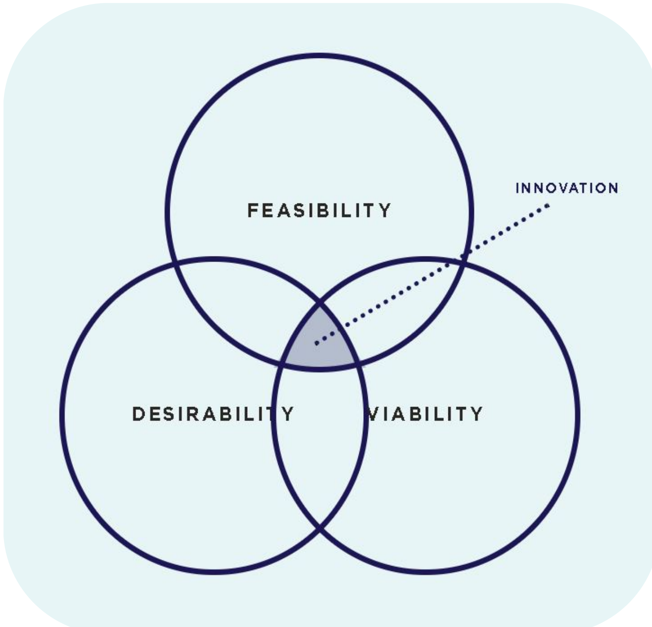


Fig 3.1 The Desirability, Feasibility and Viability (DFV) Framework by IDEO. Retrieved from: https://uxdesign.cc/give-your-idea-a-chance-to-stand-out-by-being-more-human-211dd2675bbf

IDEO has created a means to disfurnish innovation in design. Through research, they believed that this approach would merge desires and the categorization of needs alongside the logistics and reality of technology with financial viability.

Desirability

For PLC programmers and systems integrators, desirability holds itself in its function rather than form. The focus on ergonomics, comfort, and functionality are what attracts them the most to a product. The strains and limitations on desirability for products are impacted by their cost. Once these principles are then examined, the desirability for a products visual appeal and purpose in their task is what is examines. Within the market, there are not many products that are currently designed with aesthetic considerations. Therefore, this would be an area, alongside the initial desires, that would be beneficial to explore.

Viability

The current market for PLC programmers and Systems integrators has not been particularity expanded upon, more than lightly touched with similar demographic needs. Products that focus on the workflow of even programmers or workers within a factory setting have not been improved upon or have been the main focus. As these workers can be in industrial settings, the focus is primarily on getting a job done rather than how it is done. Therefore, creating products for this demographic can be economically viable, as improving harsh working conditions are needs in the market that should continuously be innovating. The scalability for the designed solution should also have to potential to be scaled as existing products, to similar demographics.

Feasibility

Technologically speaking, for plc programmers and systems integrators, there is a lot that can still be improved upon. As they still have to be within the factory for a majority of the debugging and testing component of their jobs seen in (2.1.3). The majority of solutions only focus on a few areas of their task at a time, although creating a product that can cater be adjustable according to the environment would be a challenge as not many products exist with that intended function. The only products which do can focus primarily on the transportation, or load bearing of the product while doing a function. Even so, with technologies such as the Segway, and portable workstations, conceptualizing and creating a solution with feasible and existing or new technology can definitely be expanded upon.

3.2 Functionality

In section 2.1.3, PLC programming and systems integration were observed through both in-person user observations as well as interviews in order to create a visual representation of tasks. The main area I was able to observe when doing an activity mapping was in the testing and debugging step. According to advisors Santiago Moros and John Abdallah, this is the area in which most of their time can occur in a project, and can also be a contractual job in itself. This section will discuss the analysis of the user activity and workflow mapping and experience mapping when focusing on the tasks.

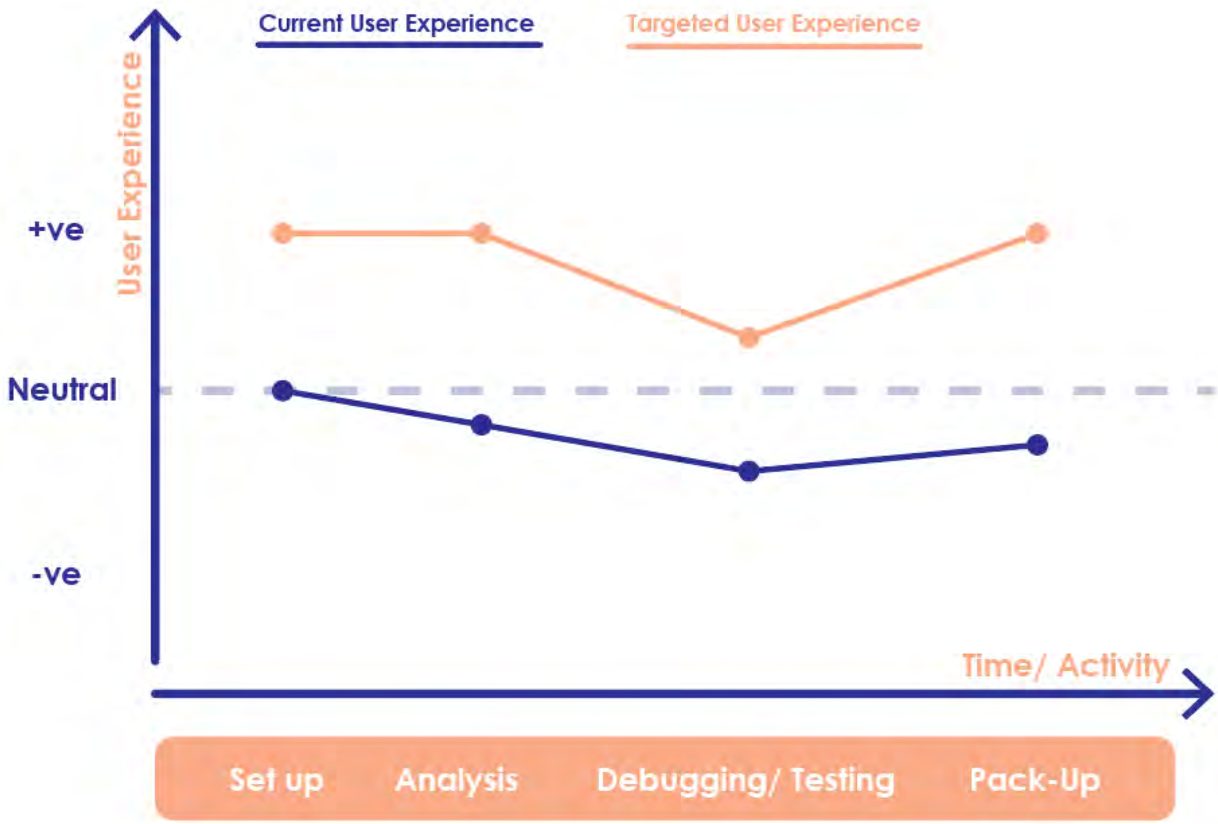
3.2.1 Activity/ Workflow Mapping

Key Activity	Steps	Base User Experience	Potential Improvements
Set-up	The PLC Programmer/Systems Integrator will set up a workstation with a collapsible table and chair so that Electrical Design binders can be laid out and studied.	-Typically, Low to medium Lifting Requirements. -Often needs continuous set up around the CELL - accessibility issues regarding lifting tables and chairs.	-Lower lifting requirements for packing mobile tables and chairs -Limiting / Facilitate the required setup process.
Analysis	As the PLC Programmers/ Systems Integrators analyze schematics sketches and carry them around the cell to physically verify the cell connections and details.	- Typically, light to moderate movement to verify connections around the CELL. -Often requires Crouching - Maneuvering through tight places & between cabinets	-A good pair of safety shoes that allows for agile movement around the cell while maintaining comfort -A bright flashlight to help when in dark places and reading Wire Tags. -a modular workstation
Debugging/Testing	-(A) The Systems Integrator will then sit at the desk they set up earlier, and debug the software several times. This process involves walking back and forth between the laptop and	- Typically, light to moderate movement around the cell to check equipment as the debug process begins. -Often need to carry laptop to different parts	- Lighter laptops or tablets could help when carrying around computing unit - A CABLE HUB would be useful when having to bring extension cords

	the devices that are being configured. -(B)If there are HMI device and remote devices inside and around the perimeter of the cell (the area in which the operation/assembly is happening) that needs special attention, the integrator must walk around and make sure they are working. This would typically involve moving around the laptop or workstation to get closer to the device.	of the cell requires moderate lifting - Network Cables must be brought with the laptop - Power Cables are sometimes required depending on laptop battery - Extension cords	and Ethernet cables around the cell. -A quick laptop stand could be of great help if it can quickly form into a desk for the laptop to rest temporarily. -a remote screen and remote AUX Wireless Cameras would help in this setup and debug process
Pack-Up	-Once the cell is ready for automation, the integrator should not need their laptop anymore and the cell is now fully controllable through the HMI. The Systems Integrators and PLC Programmers will only return for any issues that may happen but put pack up their work stations if finished.	- The movement is moderate to low, walking around the cell once in a while to check HMI details and test any custom functions in Automatic. - Maintenance work stations are now connected and working controller terminals - Camera details are verified Viewing is difficult	- A more ergonomic maintenance work station could help when programming for long hours - Packing up workstation and all components is sometimes time consuming.

3.2.2 Activity mapping experience:

Fig 3.2 Targeted User V.s. Current User Experience



Insights Gathered and Overall Analysis

Observational research must be required when developing any solution for a demographic. The helpful insights gained can be a lot more beneficial in understanding the needs and challenges a user may face. Some of these challenges can be addressed in the interview stage, although the user may not be conscious of challenges that may be limiting efficiency.

There is some user mapping that may be too difficult or long to explain in which the user may feel it not necessary to share within the interview stage. This is why observational research through observational studies in person or through videos and photography may be even more useful to help the observer gain more of a visual understanding rather than verbal.

While analyzing and observing, there was data that, in this case, was confirmed and better presented visually within user observation. This included understanding the motion in the workflow of a PLC programmer/Systems Integrator. The most tedious task that may be lost along in the process, is trying to solve problems happening with the system or improve them. This motion of walking back and forth between computers, workstations, and devices can be very repetitive and needs to be done in order to get visibility of what the actual problem with a device is.

Another Challenge that was discovered, was the set-up and take-down of their workstation. Through in-person observation and conversation, it was discovered that programmers and integrators must purchase a workstation or get one from the factory in order for them to set up. Some automotive factories may not even have this luxury, causing the users to make up a workstation out of boxes or tools lying around.

Overall, the main aspects which need to be improved include adaptability and modularity of workstations, as well as ergonomics within these workstations. This would improve workflow and in-tern improve the quality of work life.

3.3 Usability (Ergonomics Report)

Introduction

Current modular work station solutions focus on designing for an in-office setting or a stationary setting. Even so, these work stations have ergonomic considerations but may not be designed together with the rest of the possible products or furniture within a space. Currently, factory work stations lack the ability be modular and have to be moved from place to place by being taken apart then re-assembled. On many occasions, these users do not have anywhere to sit or place their computers while they work. In order to evaluate these challenges a buck was created to test these innovations that have been created through conceptualizing designs and product challenges. The results attained from the data will be used to help develop design characteristics and considerations within utility, form, and function.

Literature review:

The data that is referenced within developing this study is from The Measure of Man and Woman by Henry Dreyfuss. The literary book thoroughly analyzes the different human percentiles through different environments and products to help define standards for creating and designing. The Measure of Man and Woman (2002) by Alvin R. Tilley and Henry Dreyfuss may help develop a greater understanding of basic standards for workstation within chair and table dimensions, angles, and details. Thus, more accurate and proportionate designs to the average PLC Programmer and Systems Integrator may in-tern be achieved.

Methodology

To evaluate ergonomics and a full-bodied interaction for the intended user, the following considerations were developed:

Objectives:

-Enhance the existing workstyle of PLC programmers and Systems integrators

- To analyze the full-body interactions… which include (back, legs, bottoms, hands, posture, support, writs, arms.

- To analyze full-bodied ergonomics and human factors

Decisions to be made:

The following pinpoints were analyzed in order to define the main body areas which are impacted by the challenges of current designs to improve the experience of the users:

1. The size of the seating and table in relation to each percentile and average percentile.
2. The comfort and posture of the seated position
3. The comfort and posture of the upright position when moving or being moved by model.
4. Ease of access, and modularity.

Description of users targeted by Product

The target demographic are plc programmers and users from the ages of 25-43, with a majority of these workers being male. Within a similar field of robotics engineering, %81 of the demographic was identified as male. According to the measure of man, the 50% height for a male above the age of 20-65 is 69.1 inches, or 5 feet 9 inches tall (seen in Figure 1.0). This data will help define and analyze a more average size for defining the height and proportion of the designed solution. The location is focused within manufacturing companies (preferable automotive for their harsher working conditions), that are in constant adaptation within their job and work area. The demographic has been focused on North America which includes both Canada and the United Stated of America.

Evaluation Process

The evaluation process involved creating a 1:1 scale ergonomic buck of the estimated size(s) of a modular work station using a rollator walker for those with walking impairments, as well as rough foam core boards to help define the size of the work station (desk) and foot rest (or possible pedal if the design is established as motorized). This allowed for a critical analysis of the following:

1. Observing the first touchpoint for the user.
2. Observing how the user interacts with the walker if pushed or driven.
3. Observing how the user secures and sits down.

4. Dimensions of the product in relation to the user. As well as the dimensions that may affect how the user may interact with the product. Seat Height, desktop height, desktop size, pedal height (only if the product is motorized).

Description of User Observation Environment Used in this Study

For this study and particular thesis, a 1:1 existing walker was used a structural back-bone to establish standard height requirements, as well as foam core board to test the size and height of the location of the desk and pedals. The mock-up was created for testing in the researcher's home in Ontario.

Location and Time Frame

Date of Observation: January 2, 2020 7:00pm-9:00pm

Location of Observation: Researchers Basement.

Results:

5^{th} Percentile Female	50^{th} Percentile Male
 Figure 3.31: 5^{th} percentile female interaction with handle and possible pedal element.	 Figure 3.32: 50^{th} percentile male interaction with handle and possible pedal element.

Figure 3.33: 5th percentile female seated within the individual seating walker/theorized work station with desktop and laptop.

Figure 3.34: 50th percentile male seated within the individual seating walker/theorized work station with desktop and laptop

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Figure 3.35: front view of 5th percentile with comfortable size for desktop.

Figure 3.36: front view of 50th percentile male with comfortable size and good height for desktop.

Ergonomic Drawings

After conducting the study, average measurements of the buck model, along with measurements from Dreyfuss' The Measure of Man and Woman, helped to clarify some of the described evaluation process. Average sizing for the seat, overall dimensions of the possible product as well as how the user interacts with the product helped further define the products' potential wireframe within ergonomics. Figure 3.41 helps showcase established dimensioning for the intended design project scope. Figures 3.42 and 3.43, help showcase the different percentiles interacting with a possible framework for the design solution.

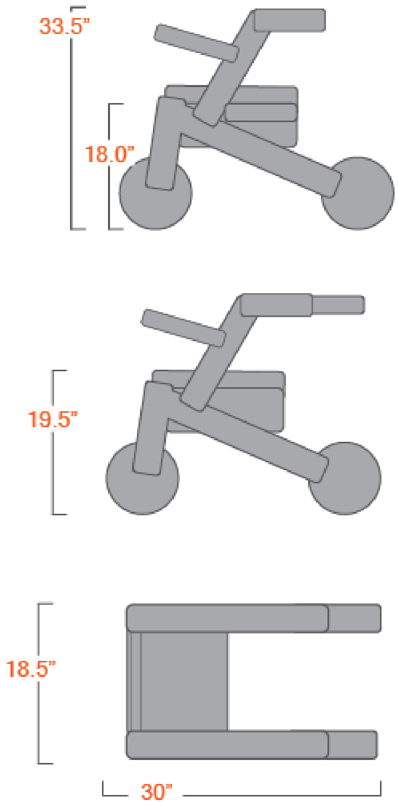


Figure 3.41 Ergonomic Drawing

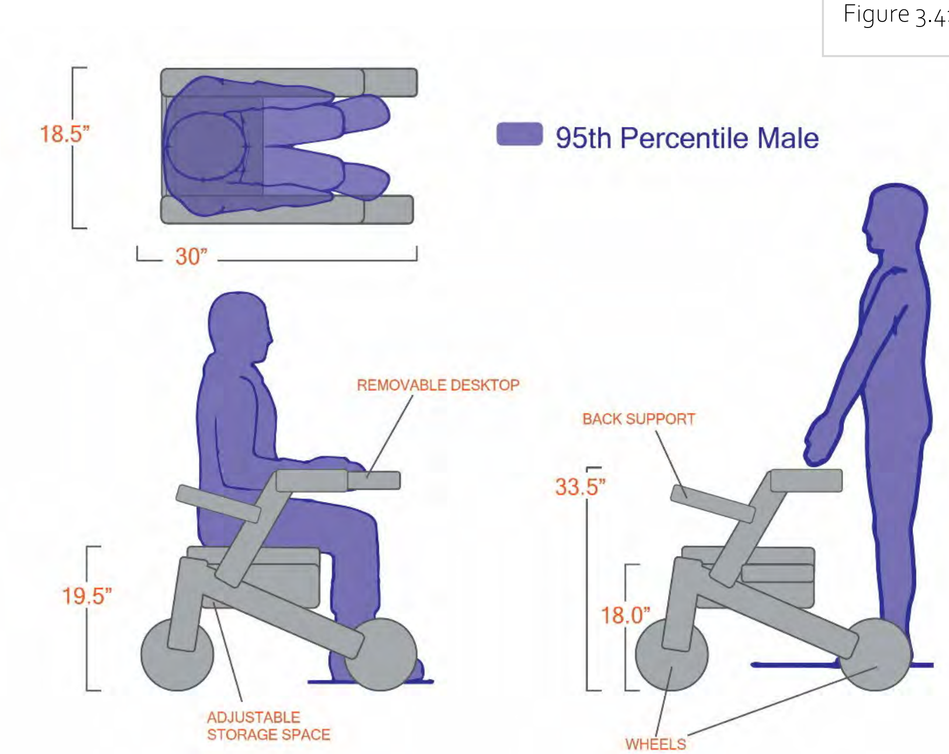
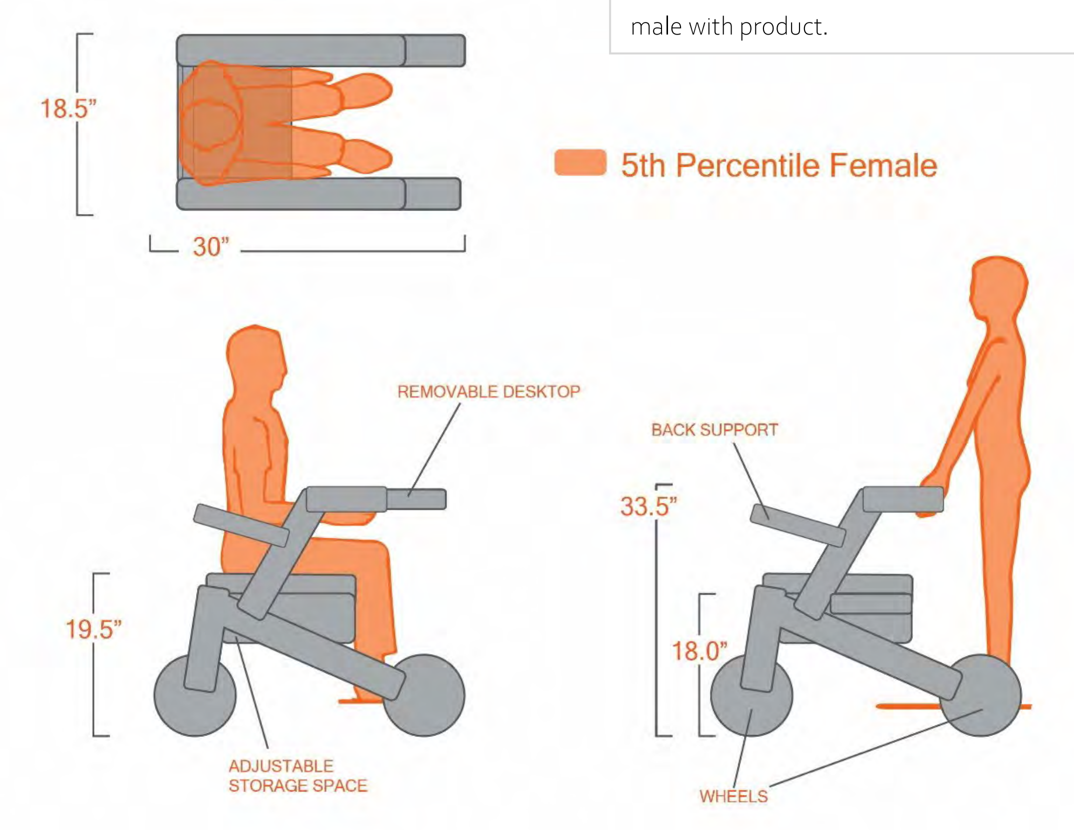


Figure 3.42: Ergonomic Drawing of 95th percentile male with product.

Figure 3.43: Ergonomic Drawing of 95th percentile male with product.



Analysis:

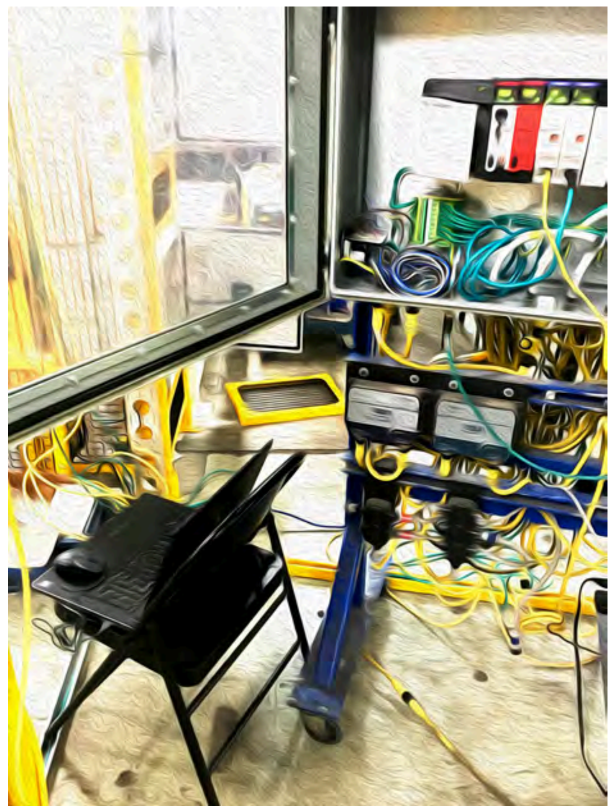
Once the ergonomic buck was finished, the main focus was on the user interaction. Depending on the type of task, users may take a longer or shorter time for some debugging and testing solutions. Carrying their laptops with them generally results in some discomfort within their wrists and arms, depending on how many houses they must do the task. It is also important to acknowledge that users are proportioned differently. This means that a design or area that may focus on aiding in the height for a 95th percentile man may not benefit another user with 5th percentile height. These considerations were the most visibly seen within the results focusing on desktop table height. What focused on being the average height for both the 50th percentile man and 5th percentile women were perfect when coming into contact with the handgrips. Although when maintaining that same height for when the users where in the seated position, the table/desktop ended up only working alongside only the 50th percentile. This height and placement were still a bit taller than the 50th percentile male would have desired, although it helped him gain better posture and focus within his screen (figure 2.6). For the 5th percentile female, the height of the desktop/table when she sat down overpowered her (figure 2.5). She expressed concern that the table may be too high for her to give her room to slouch and work more comfortably. Even with this data, we must consider that the intended demographic is Dreyfuss' proposed man with the height of 69.1 Inches. This meaning that the average height of the desktop may work for the majority, but for comfort reasons, when in seated position should be lowered. This means that the desktop should not be dependent on the height of the grips if the final design continues to have handles.

Limitations and Conclusions:

For the modular work station, it would be ideal to consider focusing on the demographics measurements more in order to get a more accurate design for the catered demographic. Even so, analyzing a 5th percentile male was helpful in order to understand the possible limitation the outliers may have when it comes to using the intended product from the buck. Creating a product that may have an adjustable range just like the walker/rollator have may be critical in helping achieve a more customizable design, although it may also challenge the designs' complexity. Users identified that even though there was only one back touchpoint on the buck, they preferred this as it helped better their posture in not relying the whole time on back support. The test subjects expressed suggestions of the improvement of the design through flexibility and compatibility as they felt this might make the workstation easier to transport. By using a walker/rollator as the buck's frame, the weight of the overall product seemed light which would make it easier to transport. Although, if the solution where to be motorized this would raise question of cost, weight, and utility. Therefore, the final design direction could focus on technologies which are very lightweight and not as costly. The areas in which the users had the most touchpoints would be the back, bottom and grips. All of these parts had padding or softer material to make it more ergonomically comfortable and friendly for the user.

3.4 Aesthetics

Fig 3.5 In-factory Image of PLC and laptop placement



Considering the existing benchmarked products, tools and workstations, functionality is at the focus as mentioned in section (3.1.4). This means that much of the current and existing aesthetics within a PLC programmer's and Systems integrator's environment include products that are very structural, rigid, or whose form only focus on the function. The image above shows the current environment and station of this demographic. Very aggressive and geometric shapes are displayed on a wide variety of products. This design language within their environment can be used and modernized within the new solution. The existing material finishes that a lot of the benchmarked items use are metal more metallic finishes (seen in 2.2.3). This may be to help create a sense of strength and durability and rigidity. The typical colours chosen for benchmarked products are more on the minimal and straightforward side, siding with many blacks and greys. Although, within the particular factory observed in the image above, the main colours that a lot of the fences and tools would have would be blue and yellow. This does not mean that every manufacturing factory has these colours as every brand is different. Different colors are important and vital in showcasing different emotions or environments. In this case, in a place that is so technical, so structured and rigid, with high stress on deadlines, creating a product that communicates confidence and efficiency while releasing some tension is crucial. That’s why a cool toned yet strong colour like a royal blue could help portray this efficiency in a better manner. Designing a solution to be more neutral, with still implementing hue considerations is the focus.

3.5 Sustainability - Safety, Health & Environment

This section will talk about the sustainability aspects of safety, health, and the demographics environment. It will discuss the effects of current benchmarked products in section (2.2) on the workflow and life of these users.

Safety & Health

Focusing on the sustainability within safety of the demographics, it is important to recognize what the fears of the users are. This could be focusing on the long term and short-term effects that these products may have on them. Muscle strains, ergonomic limitations, or potential physical or mental effects are seen. This can also include life-altering or threatening fears about working within a factory, with certain machines malfunctioning or some type of hazardous materials which may be created or used to form products. Although the main fears of users that may be considered when designing products, is the assurance that the tools that they use are not getting in their way of navigating through their job and within a factory. Therefore, creating a solution that takes into account these considerations would be the ultimate goal.

Environment

Examining sustainability within the environment of PLC programmers and systems integrators, it is helpful to understand and to note that there is not much of a strong focus on the reusability and environmental impact that products or tools they use may have on the environment. The main focus to which their sustainability focuses on is if they have quality products, then these products may last the user for a longer time then getting cheaper and inexpensive solutions. There is potential in finding a means of exploring materials that may have this longevity and durability, that still have more environmental considerations than the benchmarked items.

The Sustainability of the overall product solution should be inspired by not only the demographic, but by means of solving and finding solutions that could also be expanded upon or redesigned for the potential of other workers, and another demographic.

3.6 Commercial Viability

3.6.1 Materials and Manufacturing Selection

The design solution intends to be manufactured in mass-scale therefore the materials and processes should reflect this accordingly while still maintaining its function and form. The product will aim to have the most function with the least amount of materials for costs and manufacturing. This will mean that the materials selected will have a longer life span. The design should be curated to it the needs of the average user focusing on measurements that will create a balance between the ninety-fifth and fifth percentile. This will ensure that the product will be versatile enough and reach a majority of workers. The only space for customization is within the equipment users may want to store, other than this the product is meant to be an all-in-one solution. Even so, there is space for different colour finishes and branding.

Materials that are versatile in its function that may be applied to other parts of the design will also be considered.

3.6.2 Cost

The products' price range must be logical for its user or the company they work for. Current work stations are either nonexistent, made out of make-shift objects, or are more on the inexpensive side by using collapsible tables and chairs. The solution should stay within the low to middle tier expense so that it would be ultimately considered and implemented within a factory setting.

3.7 Design Brief

The goal of this thesis is to improve the accessibility, comfort, workflow, efficiency, convenience and ergonomics of a Program Logistics Controller (PLC) Programmer and Systems Integrator. The design solution will focus on reducing the effects (such as; awkward positioning, strains, soreness, load-bearing, and discomfort) that current limitations present. Designing a modular workstation or device with human ergonomic considerations will be the focus of this Thesis. These possible solutions may eliminate or improve the current limitations of benchmarked items, as well as expand on their features and benefits towards their users. The following list demonstrates a list of objectives in which should be met by the deigned solutions:

- Provide modularity for users (different settings)
- Create a comfortable solution with design considerations in mind.
- Have storage for tools users use (laptop, cables, cutters)
- Challenge the market by creating a product that differs from current work stations.

- Provide different ergonomic positions for the user
- Ensure that the product helps the user and does not gets in the way
- Have factory design considerations and layout in mind.
- Create a solution that is more aesthetically pleasing and modern yet still relative to the users and their environment.
- Design a portable (and collapsible) solution for users.
- Use durable materials, while still considering costs.

4 Design Development

4.1 Ideation

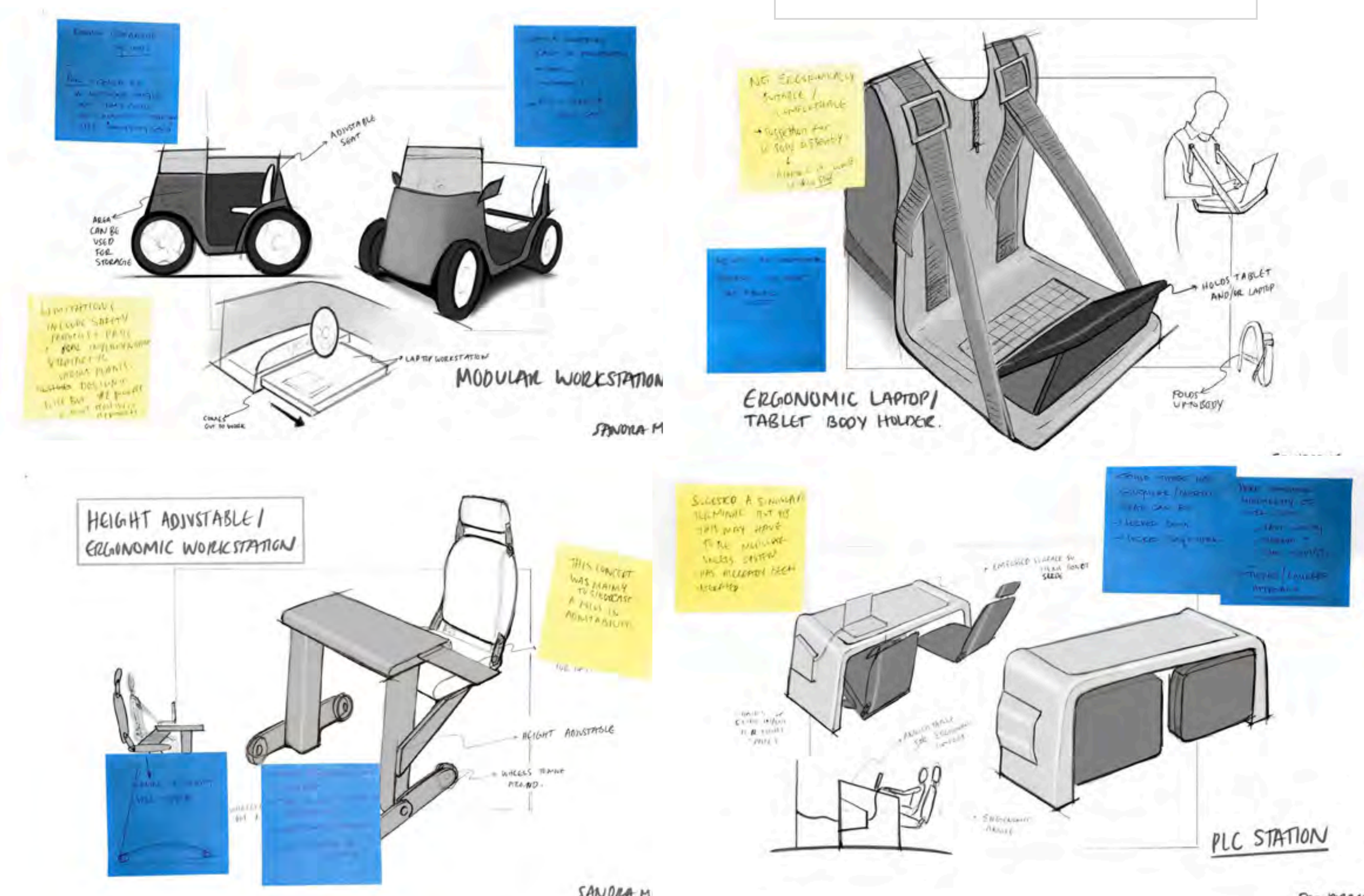
Fig 4.1 Inspiration Images

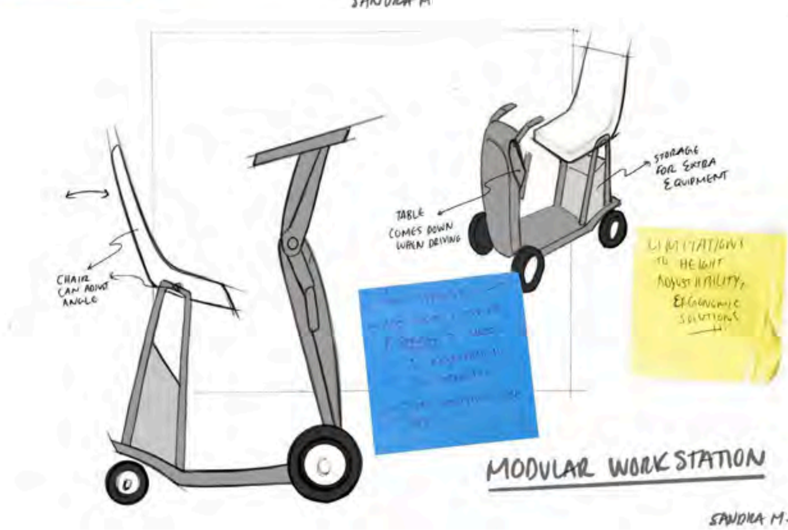
To begin the design process, the importance of exploring inspiration through form and function in order to discover which elements could be further pursued or translated into sketch ideations of the design was a critical process. In addition, a mind map was created in order to help visualize the main considerations in the initial design phase going forward. The Images above were taken from Pinterest and were gathered and assembled to create an inspiration board. The references for these images can be found in the appendix.

The initial ideations in design focused on exploring a variety of solutions, focusing on different needs separately, as well as different functions altogether. What remained the same was the desire to create a diverse solution for its user. Early ideations included large scale vehicles, to small scale solutions. Even though there may be faults within these designs, they were necessary to instigate the creative process.

Fig 4.2 Mind Map of considerations

Fig 4.3 Initial Concept Exploration

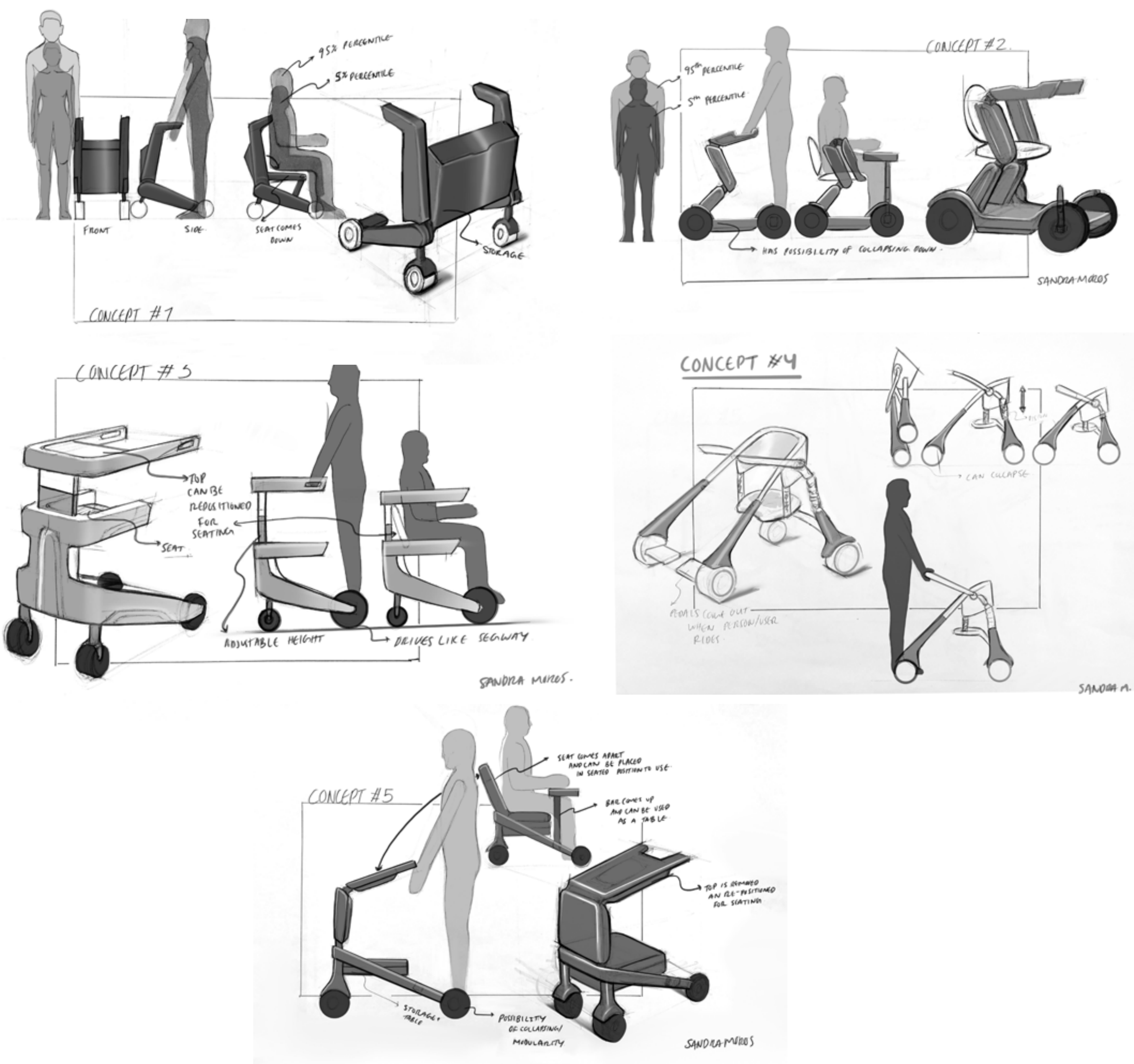




4.2 Preliminary Concept Exploration

After exploring some possibilities in the direction of design solutions for the intended user, the most successful concepts were then narrowed down to two directions. One focusing on creating a debugging station for plc programmers and system integrators, but the other more tangible concept included focusing on a portable working solution for in factory use. The concepts below (Fig 4.4) showcase the direction that was taken going further to develop the final design direction.

Fig 4.4 Preliminary refined sketches



4.3 Concept Refinement

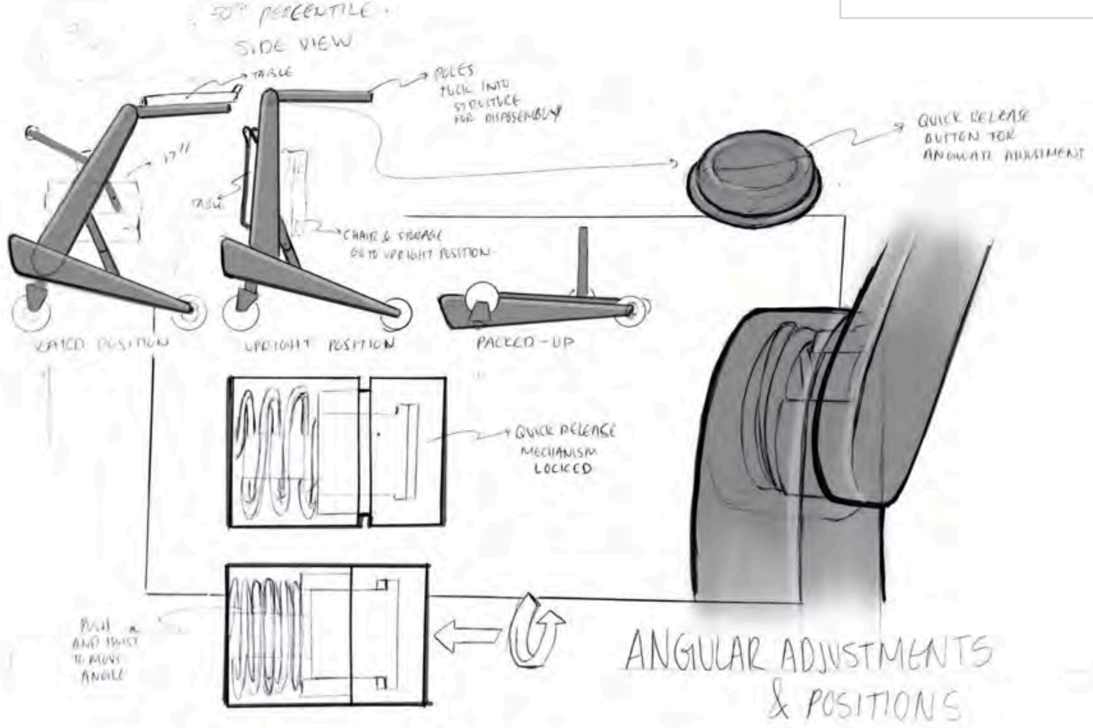
Fig 4.5 Concept Refinement Sketches

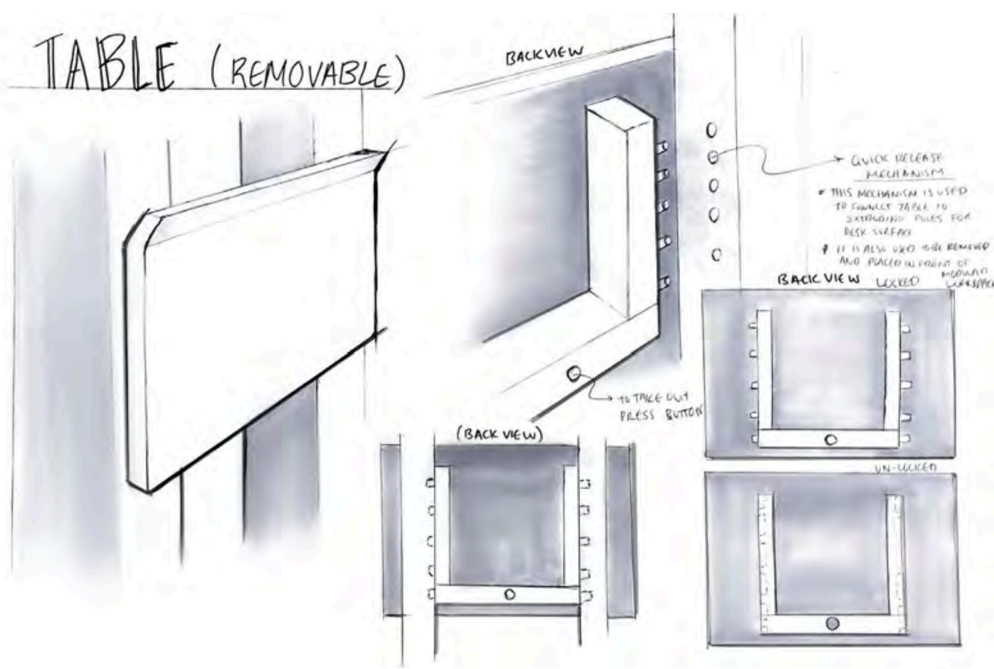
Concept Refinement focused on narrowing the design direction into its form. This meant taking the main elements that were effective from each of the preliminary sketches and identifying one solid direction in design and function. This was initially done by proposing the different configurations in design and a rough concept which merged these basic elements into one design. Next was to further refine this concept with a better understanding of the possible challenges and limitations of that design. The major components which were identified within this process included focusing on a modular solution that is collapsible, has storage, and can be used in different configurations. These major components were necessary on developing the concept further.

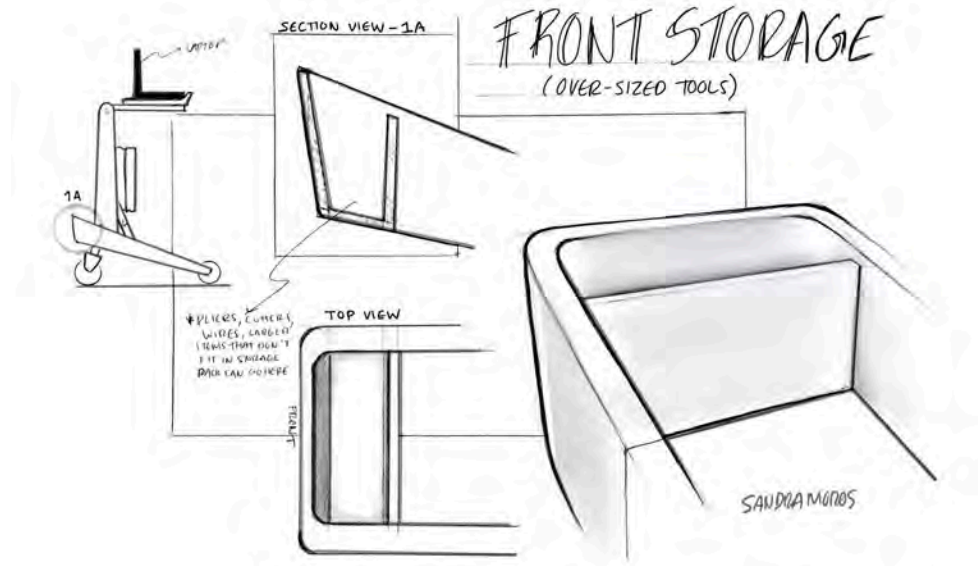
4.4 Detail Resolution

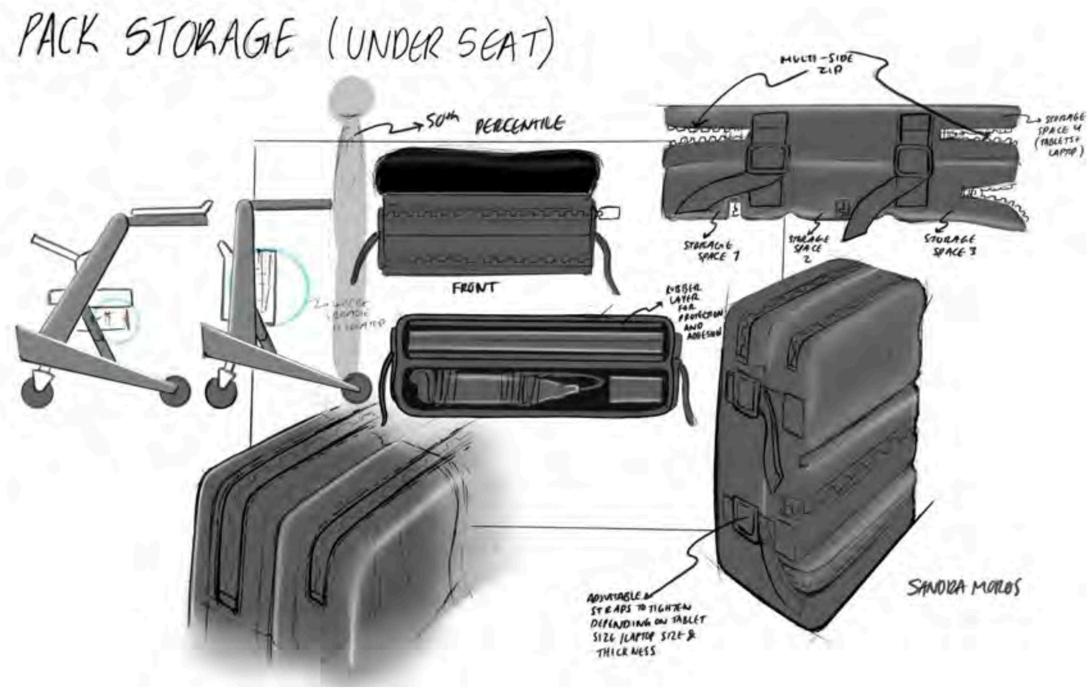
Detail Resolution consisted of focusing on how each component of the proposed design would work. Examining closer and more in to detail the different attachments, adjustments, removable components, and storage solutions.

Fig 4.6 Detail Resolution







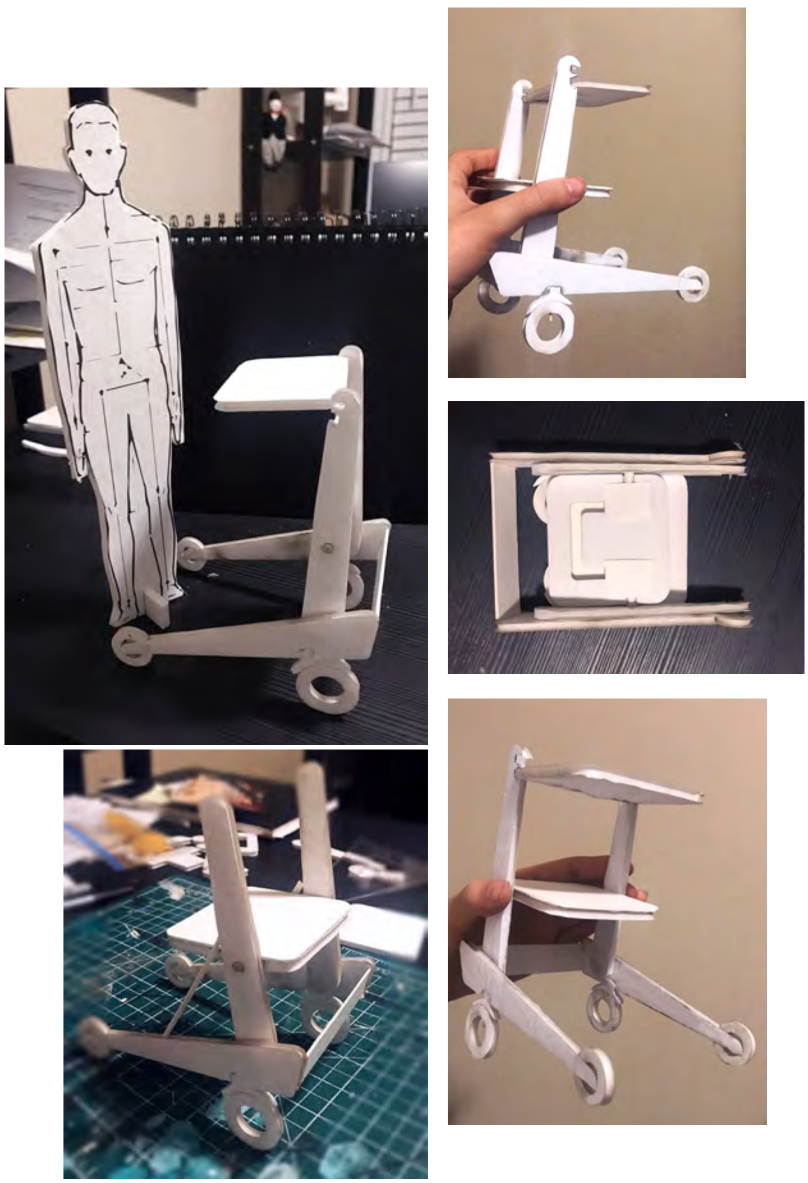


The main details of each of the components were explored further and close to being finalized. The next step would be to further adjust its design within computer aided design (CAD) to see what needed to be adjusted, added, or removed from the final design. The next steps were to create a mockup of the overall form to scale in order to see what adjustments or considerations were missing.

4.5 Sketch Models

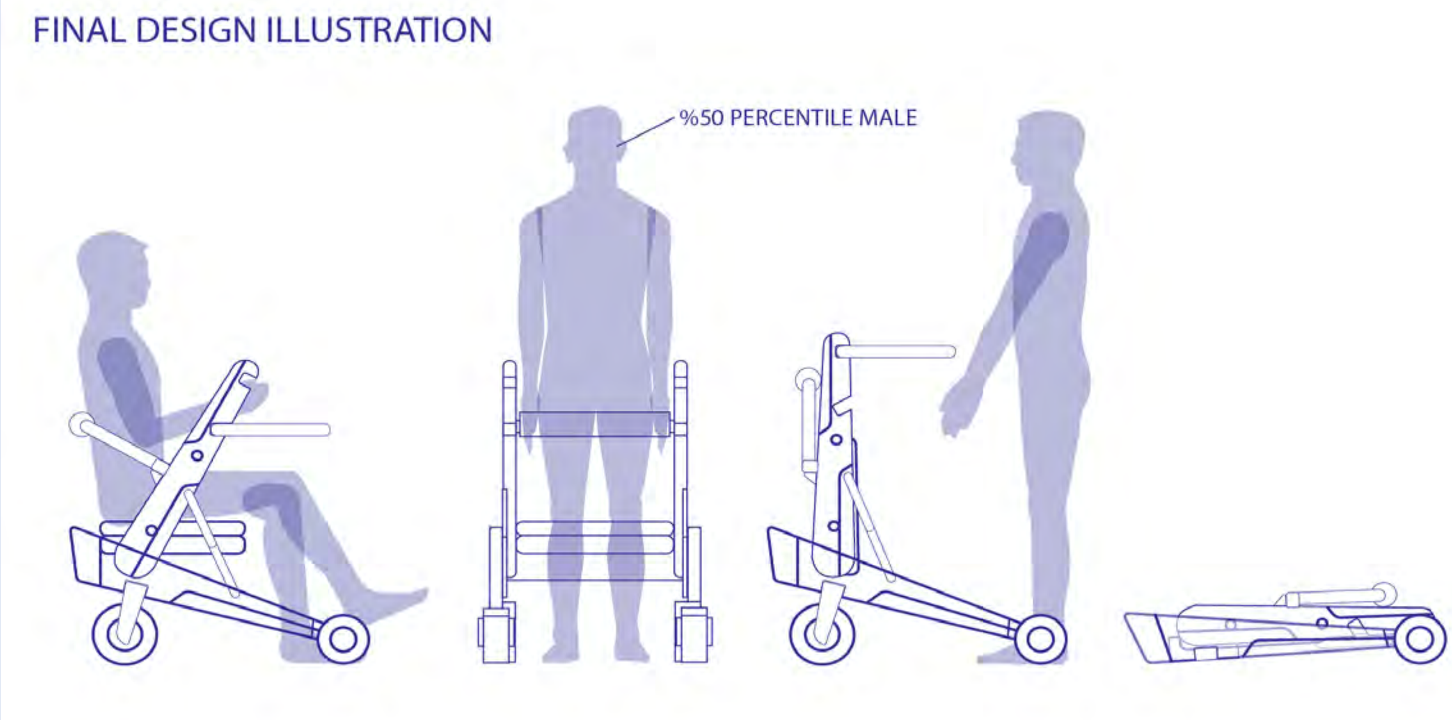
The importance of a sketch model is to understand the ergonomic proportions of the design in relation to scaled person. This process helps to visualize the correct scale for each of the design's components, as well as how they interact with its user. This model was initially created on illustrator to the $1/6^{th}$ scale and was laser cut out of foam core. The sketch model was beneficial in realizing that the scale of the model could be larger and changed to $1/5^{th}$ scale before moving to computer aided design (CAD).

Fig 4.7 Sketch Model



4.6 Final Design

Fig 4.8 Final Design

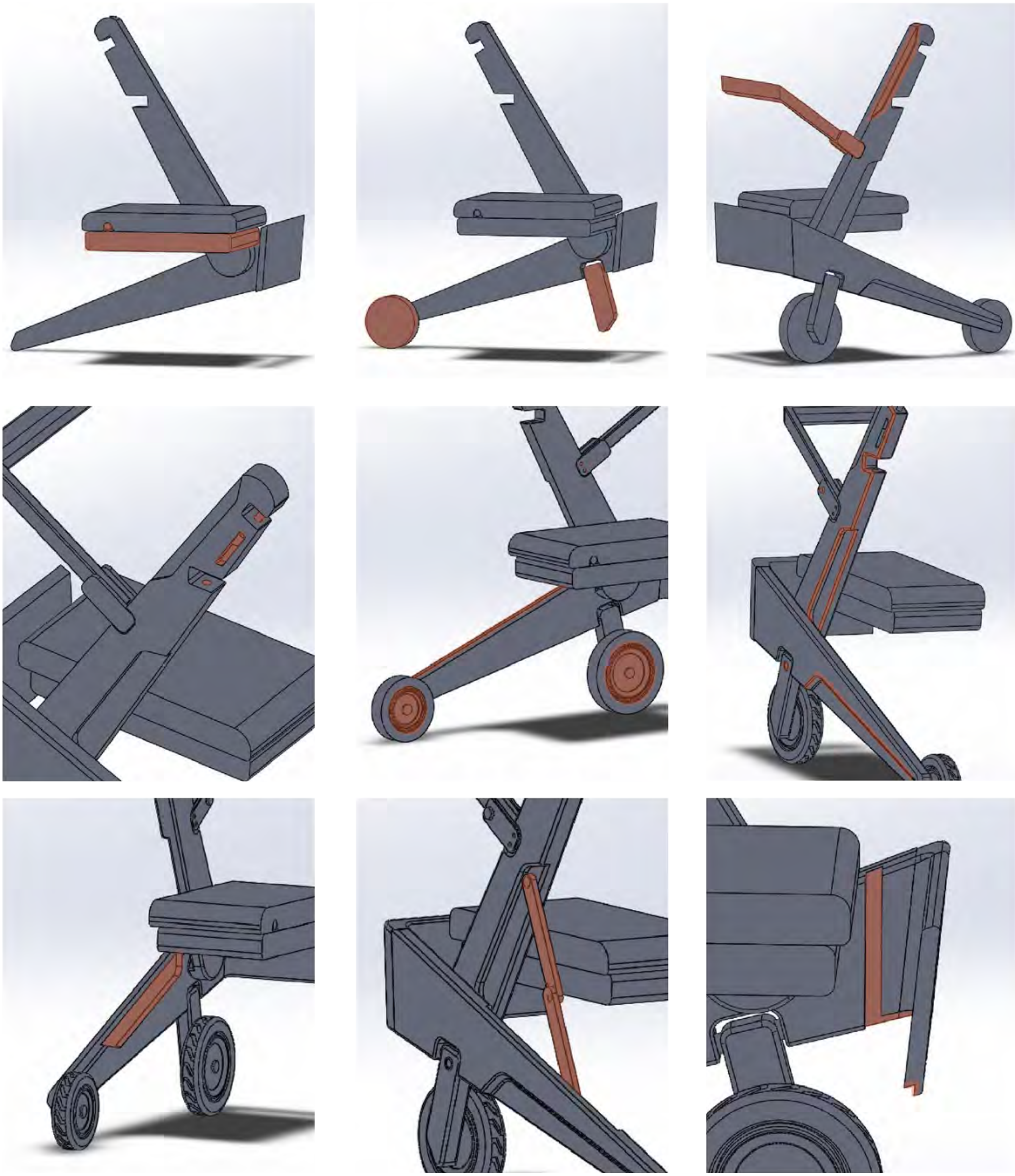


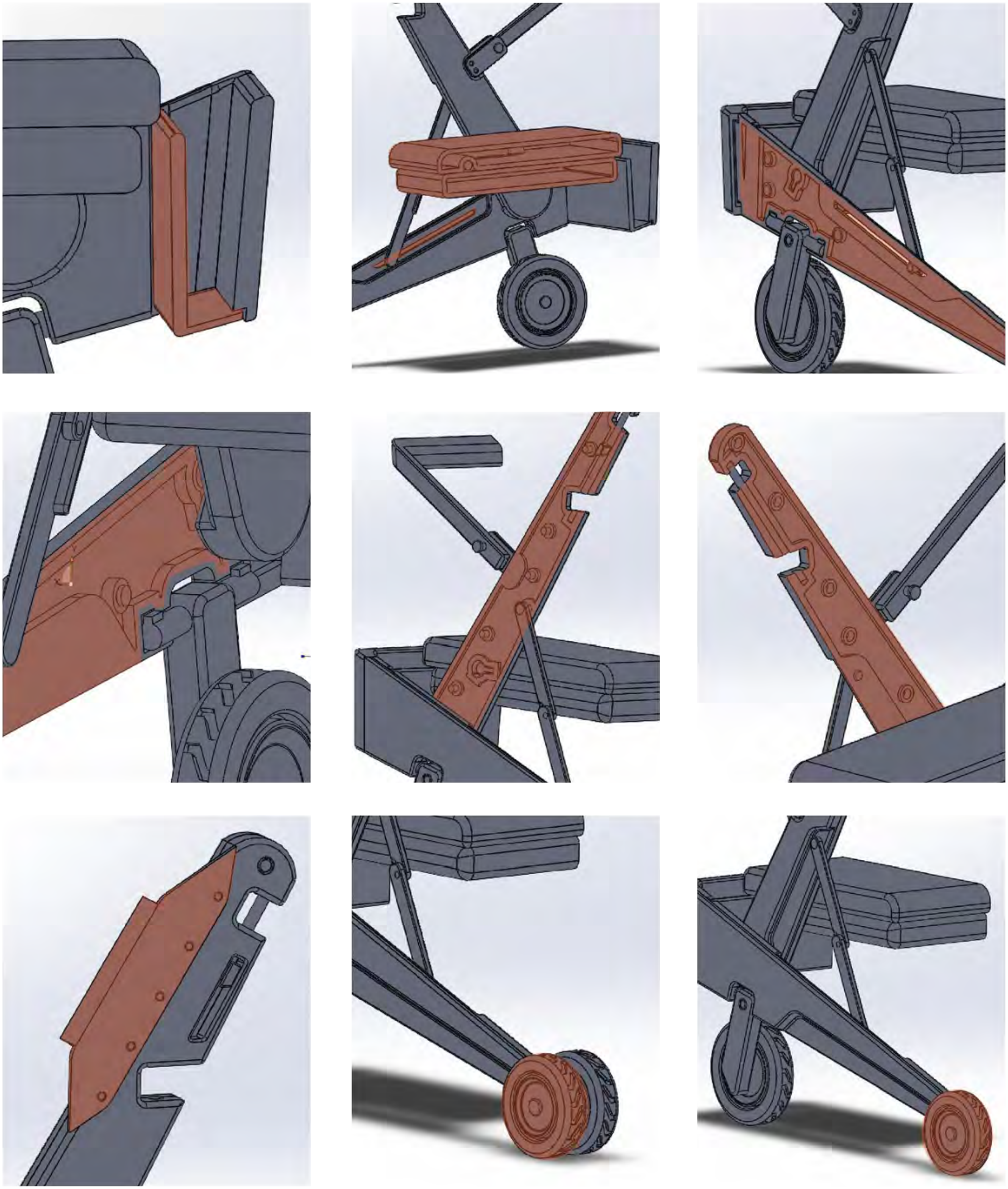
Each step previously helped clarify and define a direction towards the final product solution. The final design aims to embody a more function-driven design to provide its users with multiple configurations of use and storage. It focuses on improving accessibility by providing users with a solution to a portable and smaller workstation that is currently not regulated or designed for in factory use. The main purpose with this final design was to incorporate all the details considered into a product that adapted to the needs of the user. These needs were, or a stationary and modular workstation with multiple configurations, and when not in use, would not get in the way of its user's tasks.

4.7 CAD Model

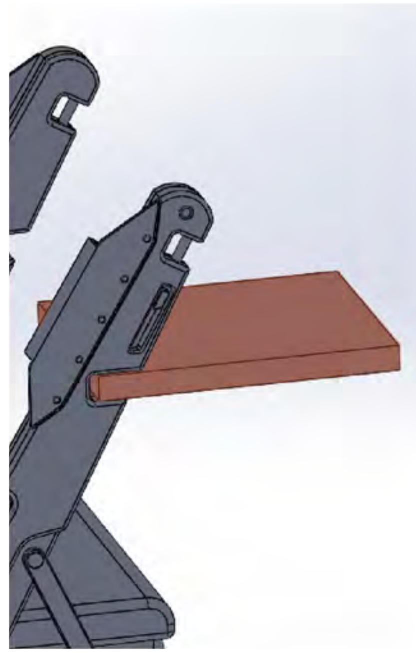
Computer-aided design is a helpful tool that can further the development of the design by giving it a tangibility through accurate size, proportions, and three-dimensional visualization for production. By doing this process, design flaws that were not considered or discovered through sketching and the sketch model are now identified by being able to see it in a three-dimensional space. This space allows for ongoing modifications from the final proposed design. The final design had to be edited accordingly in order for the concept to be feasible. The process of developing the three-dimensional model is showcased below.

Fig 4.9 Beginning of CAD Development – Orange Highlights show the next step of CAD

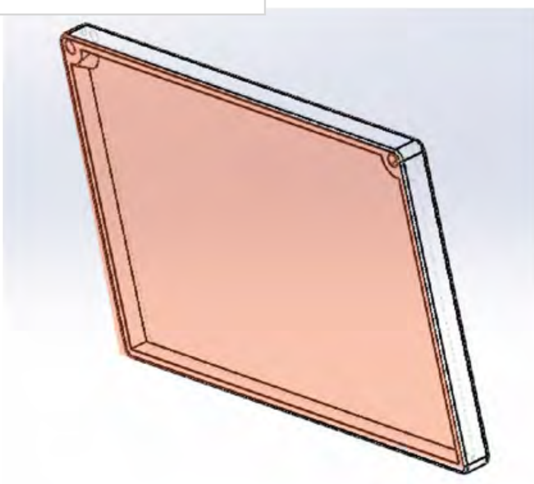


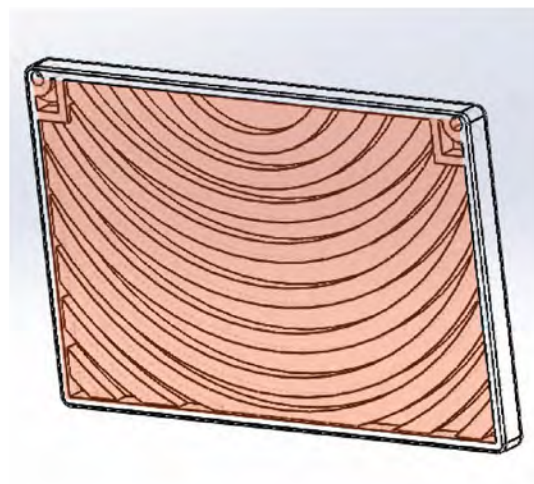


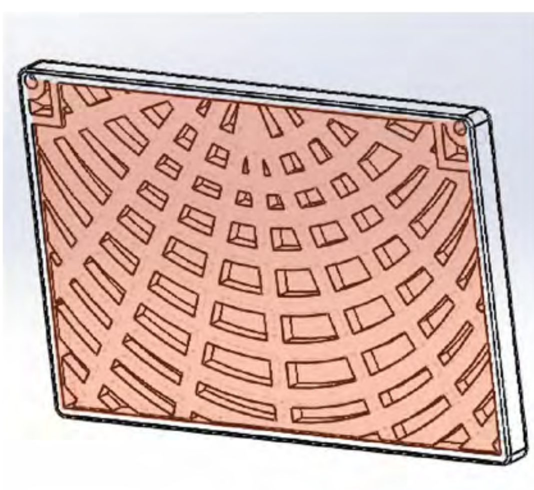
All entities/bodies were mirrored.

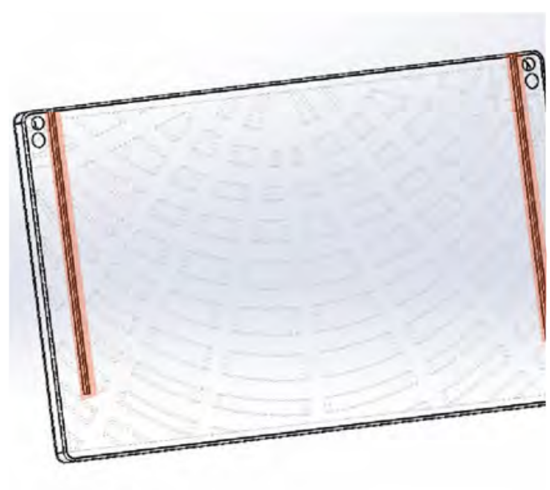


Tray Development



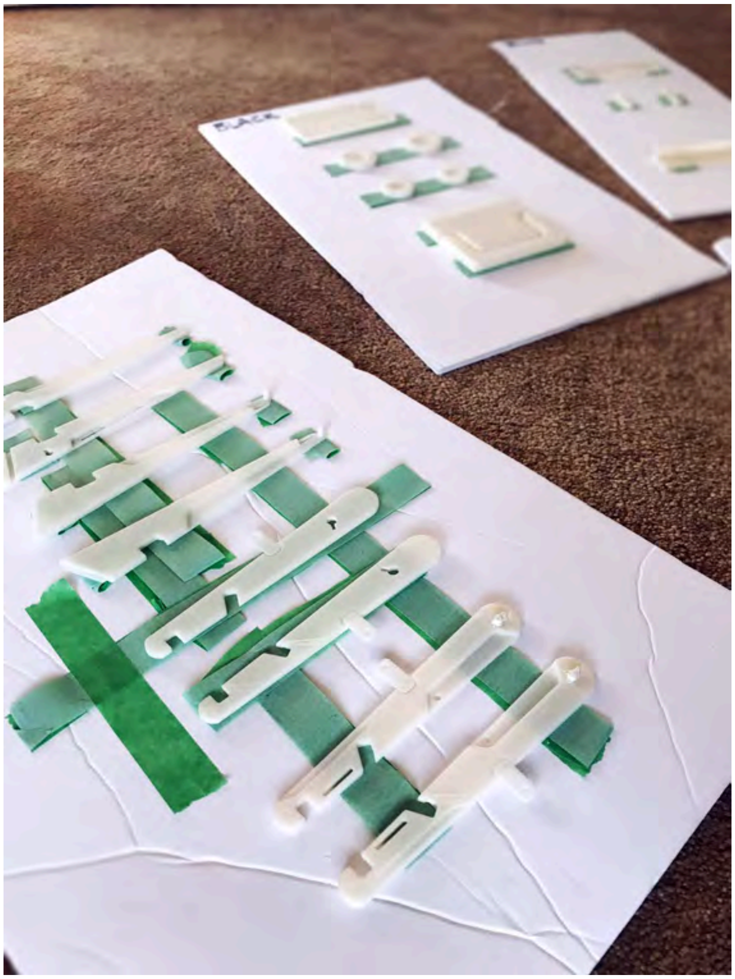


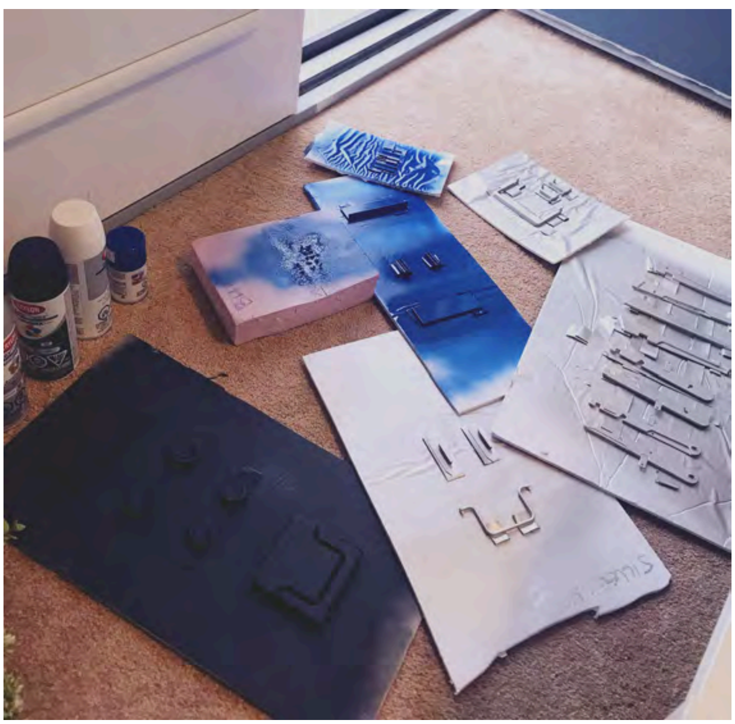




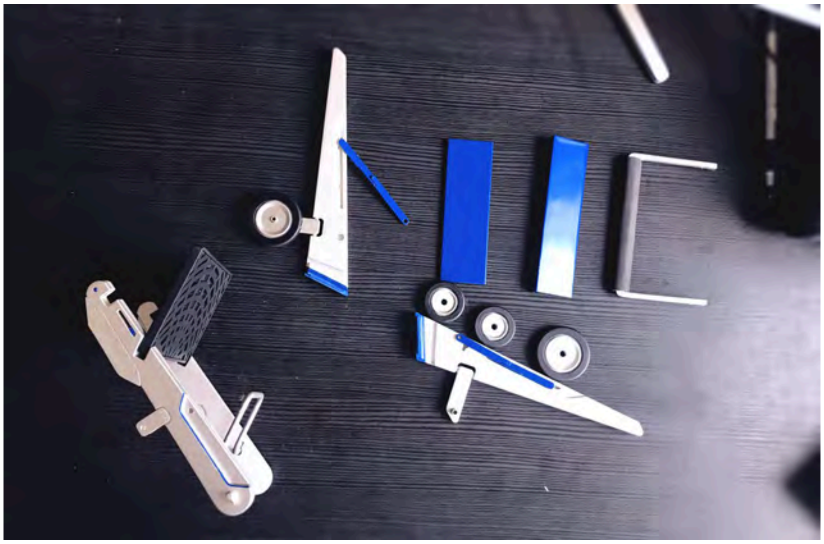
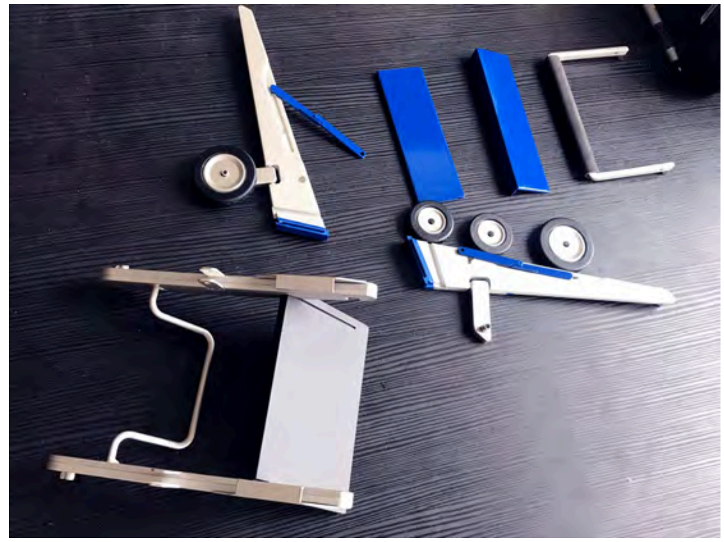
4.8 Hard Model Fabrication

The three-dimensional Solidworks CAD incorporated aligners (shown in section 4.7) in order to ensure the correct placement of each of the pieces when assembled. Once the CAD model was completed the components were sourced to *Agile Manufacturing* for three-dimensional printing. These pieces were printed in SLA using one of their resin printers. Once printed the components where then sanded going from 120 grit sand paper to 600 water sanding with paint primer.





Top Left: After sanding parts were placed on carboard as a base to spray paint
Top Right: Home Crafter spray area for parts at home.
Bottom Left: After last coat of spray paint
Bottom Right: Assembling smaller pieces first.

The images above were taken after assembling the larger pieces of the model.

After the main components of the model were assembled the only elements which were left included adhering the bag/storage compartments underneath the seat for the user's laptop/tablet. This was made from 3D printed buckles and a zipper to simulate the look of a bag. Black ribbon and aluminum teeth from aluminum wrap were also used to add these physical elements of a storage bag. The final model can be seen in section 5.4.

The cost of the 3D printed model was $325.00. Although, with primer, paint, poly-fill, glue, paint brushes, sandpaper and other minor details it came out to $400.00 total.

Conclusion

The design process in itself is one with great challenges that hopes to push our thinking and design thinking to another level. There were instances throughout its development that created both doubt and confidence. All areas until the end posed questions to challenge the solutions within the current workstation for PLC programmers and systems integrators. What really supported and ultimately helped guide every design direction was conversating back with the users and referring to research to help dictate the important elements and components for a successful design.

5 Final Design

This chapter will focus on blending all of the research from previous sections to provide an analysis of the outcome. Final aspects of the solution including renderings, hard models, technical drawings and sustainability.

5.1 Summary

IAGO is designed to be a simple and non-intrusive solution to help create a workstation for a modular worker with modular needs. It is a workstation that could ultimately improve the workflow and efficiency of a PLC programmer and systems integrator by focusing on alleviating their ergonomic discomforts and awkward positioning within the factory setting. By focusing more on the workers' work-life, this may help improve the demenour and efficiency of a worker.

Explanation

IAGO is a mobile workstation that improves the ergonomic limitation of PLC programmers and systems integrators within the factory setting (primarily automotive). IAGO helps achieve this through its different configurations for the users' needs depending on the tasks. It also provides transport and storage. The tasks at which PLC programmers engage while in the factory include working for multiple hours next to a group of machines, they are programming or integrating. Their touchpoints include interacting with Human Machine Interfaces (HMI), which are typically embedded in the design of a Machine. They use their portable laptops to connect to the machines and their systems, which is the PLC control hub. During this process, they are either carrying their laptop around with them or setting up a make-shift work station next to the areas around the machines to do their work. This creates ergonomic conflicts, such as awkward positioning with carrying their laptop as they program, uncomfortable seating and table area (depending on whether the worker is creating a make-shift workstation, or is gathering any table and chair they can find), and constant set up and pack up of their equipment.

IAGO desires to change this by providing a modular solution that has a sitting configuration for longer computer programming tasks a standing position for shorter tasks, and collapsed for the transport of both the station and any necessary equipment which can be stored within the unit itself.

5.2 Design Criteria Met

The following section focuses on each of the components and elements that pertain to IAGO's final design and how they successfully integrate. The main elements will be separated in order to go more into detail of the final design and how it tackles the user's challenges.

5.2.1 Ergonomics

Seated Position

IAGO's seated position caters its design to ensure that the seating and desk positions are optimal for a longer period of time use. Its back support, table, and seating height are designed to target the 50^{th} percentile man since the target market is primarily the average male. Even so considerations like the space between the backrest and front of the desk were also considered to suit both 50^{th} and 90^{th} percentile, while the table and chair height and seating focused more on considering the 50^{th} percentile and the 5^{th} percentile. The width of the seat as well as the product solution as a whole were catered towards the 90^{th} percentile so that there is more space while sitting. Overall, IAGO's dimensions are 34.9" x 26.8" x 37.8" allowing which ensure that it's not too big for transport, but not too small for when the seated position is desired.

Standing Position

The standing position focused on ensuring the ergonomic needs of the user when the seated position is not necessary. These situations would include when the user is programming an HMI (Human Machine Interface) or connecting to a PLC (Program Logistic Controller) Hub. This would improve their work experience by helping eliminate the need to hold the laptop in their hands while programming a machine by providing an alleviated surface for them to work. The measurements for the height of the tray when it is in the standing position is 38.05". It was designed to suit a 50th percentile male to help target a larger group of users.

Collapsed

The collapsed position is intended to make it easier for users to pack up and set up their workstation. Through user observation, when setting up a workstation within the factory, the focus of finding the fastest, simplest, and easiest solution triumphs over any other consideration. Therefore, by designing IAGO to be collapsible, they would ensure that this be the fastest solution for their current needs. By ensuring the design is not motorized, and developing the frame to be very minimal and structured, this will allow for the lightest weight possible for a modular workstation that can be grabbed and taken on the go. The lighter the weight of the frame and overall product would then allow for a majority of the weight (If desired) to come from equipment that is stored within IAGO. Since it is transported with the two back wheels like a factory trolley, this will help distribute any added weight from the added equipment. The total dimensions for the product in collapsed position are 34.9” x 26.8” x 10.0”. This was all intended and designed to be grappled and transported or the average percentile male (50th percentile).

5.2.2 Materials, Processes & Technologies

The materials selected for IAGO were chosen in order to withstand in factory use, while still maintain the least amount of weight. IAGO's materials are meant to withstand harsh factory conditions while still providing comfort and function to its user. The materials showcased below are used to create IAGO.

MakroBlend®

Considering IAGO's casing and "skin," Makroblend ® plastic technologies prove to be the best for this application for their high toughness and low temperatures. Makroblend® KU2-7912/4 may be the ideal Makroblend® plastic to use as its applications have been widely used for automotive body panels. It is a combination of Polycarbonate and Polybutylene Terephthalate and is an injection molding grade, which is beneficial for both ease of production and mass production. This material, as advertised from Covestro, is tough, durable, adaptable, stable, and specialized.

Polyurethane (PU)

For Industrial wheel applications, forklifts currently use polyurethane since it is lightweight, but also has a high resistance. Polyurethane wheels also have a longer life span than most tires do, especially rubber.

Polyurethane is a very versatile polymer as it can be used in a variety of different applications. Another application that PU can be seen to be used among is in furniture and fashion. PU can be used to create fake leathers that have the same life span as leather, as it is so similar in properties to leather. PU within textiles also tend to have a much longer lifespan. For IAGO's seat cushion, this would be the ideal material to use for comfort and longevity.

PU can also be applied in foam. Memory foams, typically used for bed applications, although it may be too soft for cushioning. The cells in regular PU foams have open cells, which makes them very comfortable, although they are not waterproof. Closed-cell foams are polyurethane foams which have been treated differently so that their pores are closed, making it easy for water to get through and not stay and gather mold which is what standard open cell memory foams do. They are stiffer than open-cell memory foams, which make them better for seating

. Silicon

To create traction within the storage bag so that a laptop or a tablet device is well protected and stable, a material that has some resistance when placed on a surface must be considered. Silicon is a more environmentally friendly application that rubber yet tends to have similar properties as resistance and traction. It is highly durable and has a much longer life cycle than other plastics.

Technologies

The technologies chosen for IAGO include automatic quick release buttons and internal brakes to help keep it stationary or released when desired for transport. These buttons help release the locking mechanism internally in order to change it to different configurations, and help release and lock the front wheel. It uses support locks in order to keep it in a seated or standing position.

Designing IAGO to be motorized was also considered, although it was eliminated because this would have added more weight to the product which would intern make it more difficult for users to make compact and transport with ease. Costs were also considered. After interviewing users, it was informed that many companies or users go for simpler workstation solutions. This could be detrimental for the company they work with would much rather invest in the least expensive solution.

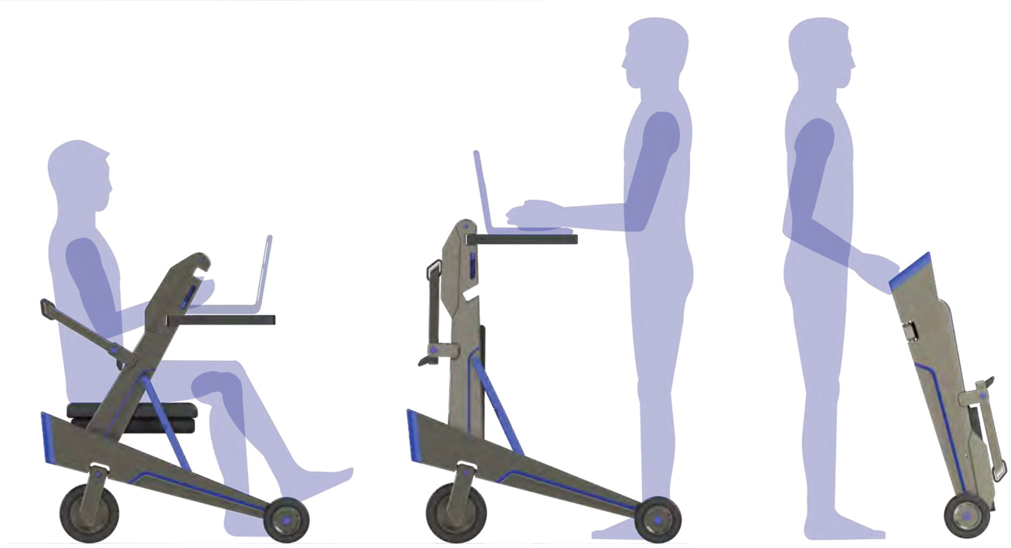
5.2.3 Manufacturing Cost Report

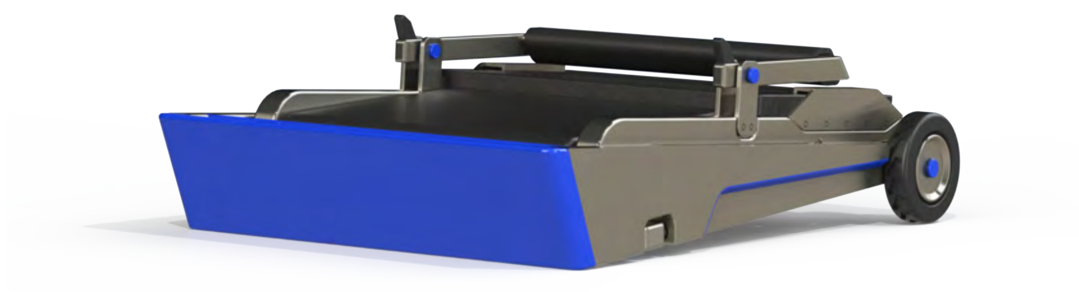
The manufacturing costs throughout the design process of IAGO have been considered throughout the design process. The final solution focuses on providing the most inexpensive solution through its utilitarian and structured design. Its exterior was intended to be a thinner casing exterior that only houses the minimal internal components. These components consist of housing its aluminum structure, and any internal mechanisms. In order to provide an approximation for the total cost of IAGO, benchmarking similar components and parts that have been applied to other products and industries will help provide more accurate data. The following table below outlines an estimate of the costs of each component based on mass manufacturing parts and quoting. Essentially, these components were compared to other parts from other products that were produced in larger quantities (1500 units +).

IAGO Parts	Materials	Manufacturing Process	QTY	Cost/Unit	Total Cost (Low)	Total Cost (High)
Exterior						
Exterior casing (1)	Makroblend®	Injection molding	2	$15-60	$30	$120
Exterior casing (2)	Makroblend®	Injection molding	2	$15-60	$30	$120
Exterior casing (3)	Makrobelend®	Injection Molding	2	$20-80	$40	$160
Exterior casing (4)	Makroblend®	Injection Molding	2	$20-80	$40	$80
Exterior casing (5) (for back component	Makroblend®	Injection molding	1	$20-80	$20	$30
Internal						
Internal chassis	Aluminum	Extrusion	1	$50-200	$50	$100
Internal mechanisms	Aluminum, ABS plastic	Extrusion, Injection molding	N/A	$50-$100	$50	$100
Other						
Back rest beam	Aluminum	Extrusion	1	$5-20	$5	$20
Back rest	Closed cell	Cut, wrapped and	1	$0.30-$5	$0.30	$5

	Polyurethane foam (PU)	glued				
Seating	Closed sell Polyurethane foam (PU) with PU leather casing	Cut, sourced, sewed	1	$20-100	$20	$100
Storage bag Exterior	Black Polyethylene terephthalate (PET fibers from recycled water bottles,	Sourced, sewed	1	$25-60	$25	$60
Storage bag Interior	(PET) fibers for lining	Sourced Sewed	1	$25-60	$25	$60
Storage bag Interior	Silicon pads	Injection molded, cut, sewed into bag	2	$1-5	$2	$10
Tires	Polyurethane foam	Cast	4	$10-30	$40	$120
Support/storage area	Aluminum	Extrusion	1	$10-30	$10	$30
Black Soft touch removable table	Polyethylene (PET) from recycled water bottles	Injection molding	1	$5-30	$5	$30
Miscellaneous (painting, nuts, bolts, finishing, etc.)	Various	Various	N/A	$5-250	$5	$250
			Grand total:		$397.30	$1,395.00

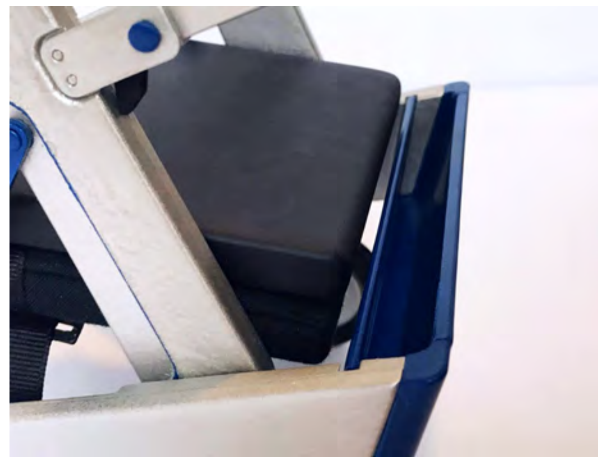
5.3 Final CAD Renderings





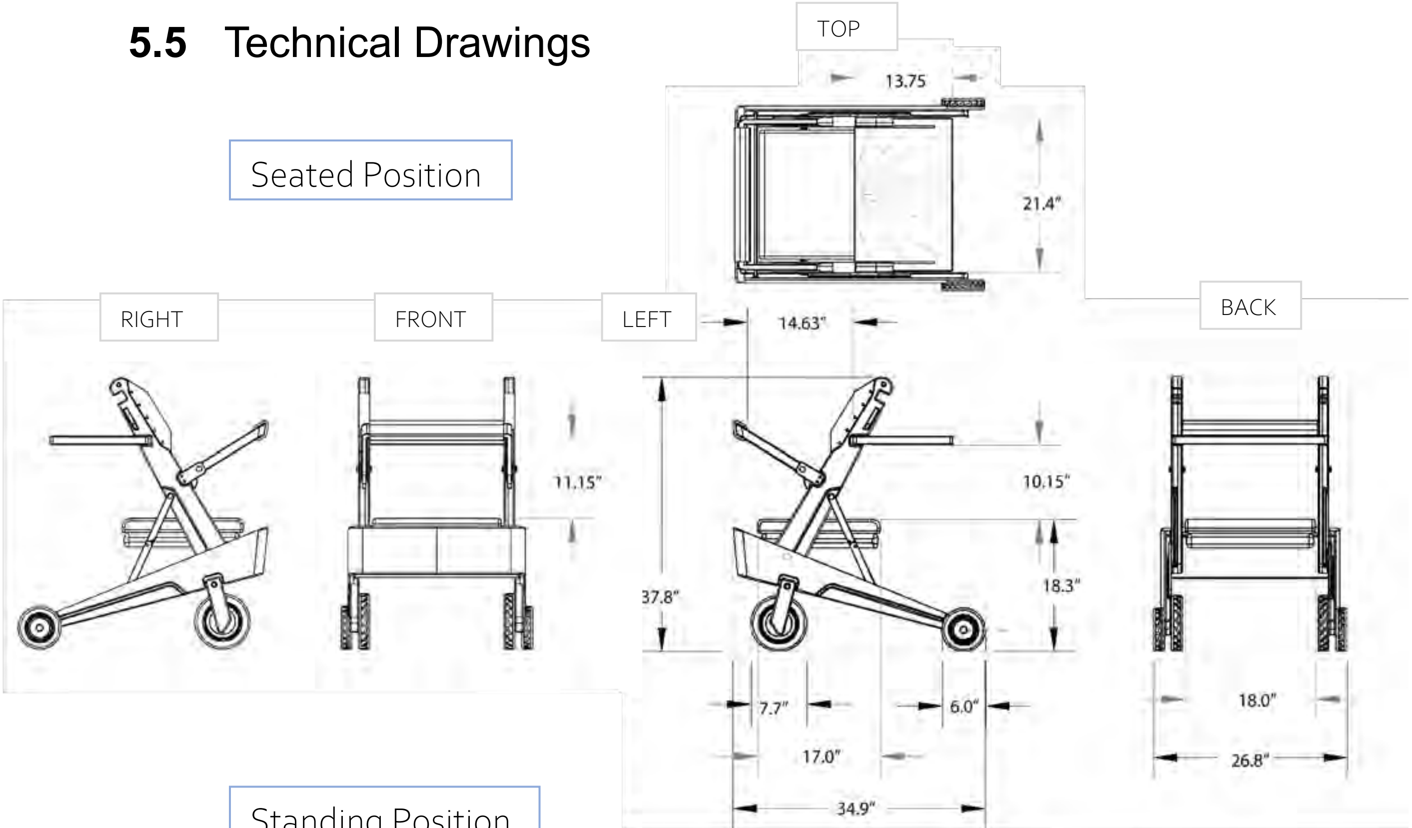
5.4 Hard Model Photographs

The photos below are of the final 1/5th scale hard model with and without a 50th percentile male.

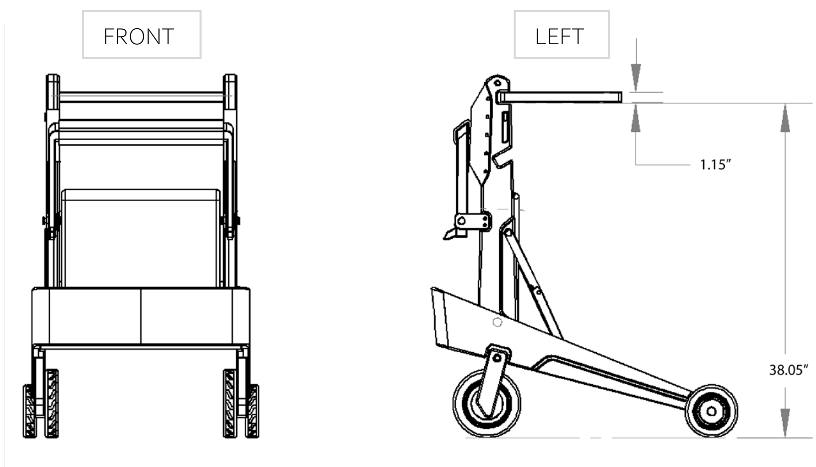


5.5 Technical Drawings

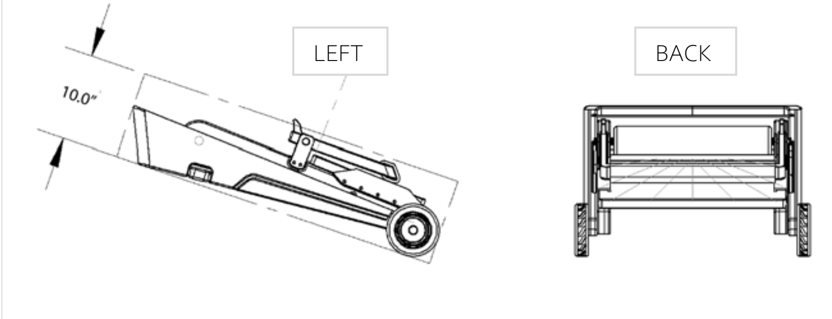
Seated Position

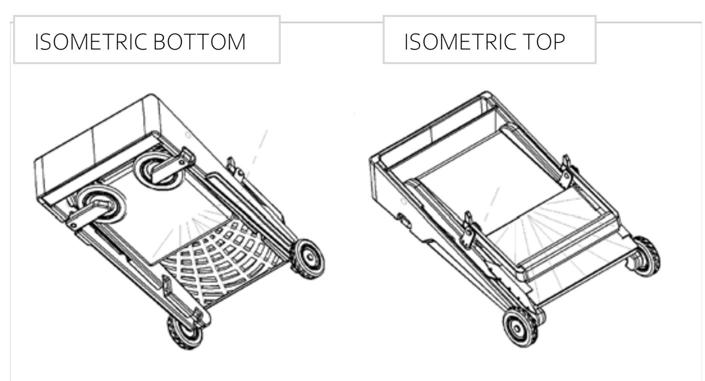


Standing Position



Collapsed Position





The technical measurements above showcase thin each of the positions and their measurements in 1:1 scale of IAGO's final design. There are three technical drawing as it is critical to showcase the ergonomic scale and measurements for each configuration.

5.6 Sustainability

This section will focus on the materials which can inform the sustainability of the designed work station solution. Its utility and form of the product can inform the possible materials and effects to the catered demographic, which in this case is Program Logistics Controller (PLC) Programmers and Systems Integrators. The Materials that will be discussed are:

- Recycled Aluminum
- Polyethylene Terephthalate (PET)

Recycled Aluminum

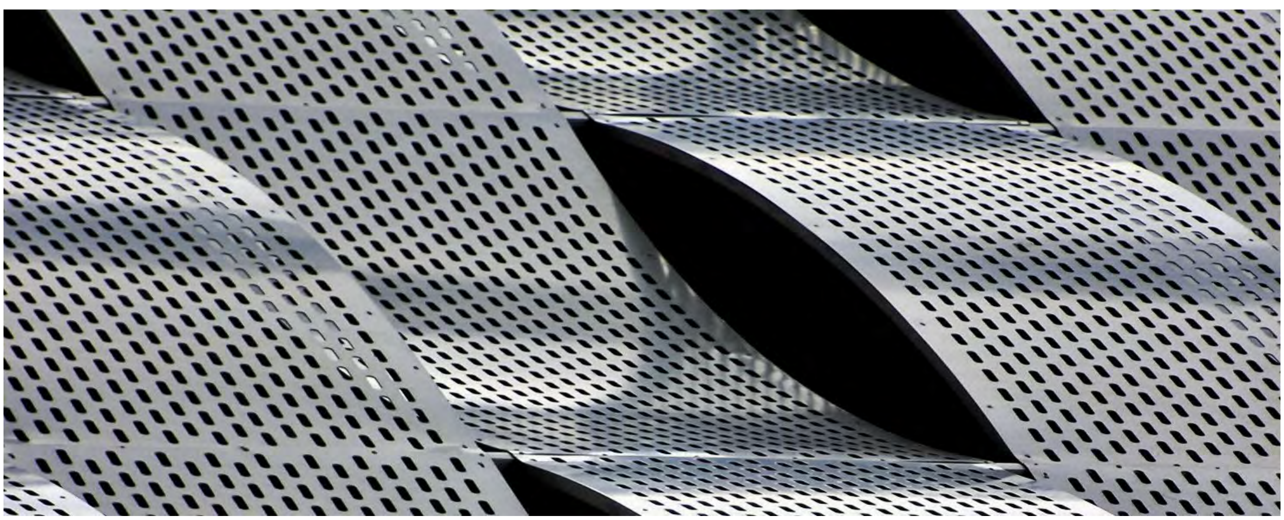


Figure (5.0) Photo by Yender Fonseca from Pexels

Aluminum is very lightweight but also proves to be very durable in an application such as the automotive industry in body chassis and supportive structures. It is also used within the U.S Military because of its crash -absorbency (Drive Aluminum). It is also used because of its low rust point, making it a resistant material. It is also a material that can be fully recycled. It will be used for the inner mechanisms of the modular workstation, as well as any structural supports and bars. The current environment of a PLC Programmer and Systems Integrator is within a very industrial area when they are within the factory. For this thesis, I will be focusing on the conditions more based around the automotive industry as they lack more focus within incorporating more modular stations for their workers, which are safe. In this case, potential in any left-over aluminum from product manufacturing could be melted down into forming the structural supports of the designed product. This ethical and sustainable product manufacturing is being considered, as well as the user's environment.

Polyethylene Terephthalate (PET)

For an extra storage compartment, fabrics and flexible materials to store accessories similar to a bag or back bag must be considered. PET has been used to create footwear, accessories and clothing threads. Many footwear companies use PET as it derives from recycled water bottles, which makes this material recyclable. It is a material that gathers water bottles from oceans and landfills to then be broken down into its thread.

PET is also a versatile material that can also be used in other applications to create solid parts. For the removable desk space, reusing the same plastic for this application through injection modelling to keep its strength would help create other reasons to use the recycled material.

6 Conclusion

IAGO improves the ergonomic limitations of PLC programmers and systems integrators by focusing on improving awkward positioning with equipment, limited workstation, and modular solutions. IAGO does this through providing a mobile solution with multiple configurations, and storage. It considers the reality of costs and possible manufacturing solutions making it highly feasible. IAGO is a mobile workstation solution that could really benefit an industry that is lacking a more modular solution to in factory workstations for PLC Programmers, Systems integrators and potentially any factory worker. The possibility of scaling to other industries within manufacturing is possible, and could be beneficial to improving the workflow and efficiency of factory workers overall.

7 References

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Humber Communiqué. (2017, March 21). Retrieved from https://humber.ca/staff/announcement/neal-mohammed-director-centre-technology-innovation-cti

Figure 1.1. How to Begin a Professianl Career as a Computer System Anayst. Author Unknown, Retrived October 27, 2019 from https://www.qualityeducationandjobs.com/computer-systems-analyst/

Figure 1.2. Back View of the Head of the Project Holds Laptop and Discussing Product Details with Chief Engineer while They Walk Through Modern Factory. Gorodenkoff. Retrieved October 27, 2019 from Back View of the Head of the Project Holds Laptop and Discussing Product Details with Chief Engineer while They Walk Through Modern Factory.

Figure 1.3 Allen Bradley / Siemens / Omron / GE / Modicon – PLC Programmers. Author Unknown. Retrieved November 27,2019 from https://www.systemsengr.com/plc-programmers/

Figure 1.4 PLC SCADA TRAINING. Vyshakh, R. Retrieved October 27, 2019 from: https://medium.com/@vyshakhr.livewire/plc-scada-training-livewire-f5b46855b82d

Figure 1.5. Two Born Every Minute: Inside Nissan's Sunderland Factory. Steve, Moody. Retrieved October 27, 2019 from https://www.carmagazine.co.uk/features/car-culture/two-born-every-minute-inside-nissans-sunderland-factory-car-february-2016/

Fig 3.1 The Desirability, Feasibility and Viability (DFV) Framework by IDEO. Retrieved from: https://uxdesign.cc/give-your-idea-a-chance-to-stand-out-by-being-more-human-211dd2675bbf

Figure 4.1 from left to right from Pinterest:
https://www.pinterest.ca/pin/689191549209734472/

http://www.tuvie.com/search/folding+bike or https://www.pinterest.ca/pin/689191549210715314/

https://furo.org/en/works/ily_a/ily_a.html

https://www.behance.net/gallery/24060225/Backpack-Electric-Scooter
https://www.yankodesign.com/2017/12/19/the-babys-day-out-suitcase/

For Sections 5.2.2 and 5.6:
Ultra-tough MakroBlend® for the Toughest Applications. Retrieved from https://solutions.covestro.com/en/brands/makroblend
Aluminum Advantages: Durability. Retrieved from https://www.drivealuminum.org/aluminum-advantages/durability/
Understanding Forklift Tires. Retrieved from https://www.drivealuminum.org/aluminum-advantages/durability/
Sustainability Since Day One. Retrieved from https://rothys.com/sustainability
An Introduction to PET. Retrieved from http://www.petresin.org/news_introtoPET.asp
Cushion Foam: Which Type Should I use for MY Boat or Home? Retrieved from https://www.youtube.com/watch?v=ZoZN8UqVE88.
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Grey-meta-frame-2610319. Photo retrieved from https://www.pexels.com/photo/grey-meta-frame-2610319/. Pexels.

For Section 5.2.3:
https://www.alibaba.com/product-detail/Custom-made-5083-alloy-8mm-thick_60845373688.html?spm=a2700.themePage.5238101000611.46.11975d283IWD1j

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https://www.alibaba.com/product-detail/China-manufacturer-aluminum-square-tube-or_62428903457.html?spm=a2700.galleryofferlist.0.0.2317d5830XWmDJ

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Salary: Engineering Manager in Toronto, ON. (Retrieved October 28, 2019). Retrieved from https://www.glassdoor.ca/Salaries/software-engineering-manager-salary-SRCH_KO0,28.htm

8 Appendices

8.1 Discovery

Objective

To obtain information from a fast, and initial search on the possible thesis topic. Either focused on the user demographic, their needs, or about innovation already happening or said to happen within their industry.

Scope: Focus for the search will include the needs met by function and form of a product or service, and the effect of that experience on the user.

Background

In the Automation Industry, Many PLC programmers/ Systems Integrators are constantly moving. Their job is to program assembly lines, or any automated manufacturing process. They do this job with a Programming licensed controller or computer that is either connected directly to the machine or to the robot's network. Depending on the role and the position of the programmer, they can have up to and more than twelve-hour shifts. Some of the programmer's tasks can include being on-site for many hours moving back and forth between assemblies or sitting at a work environment which may not be adaptable to their roles. Other times, they can be offsite designing schematics, doing documentation, and may provide technical support. There are different working stations and positions Programmers/Systems Integrators may face.

Needs Statement

How may we help PLC programmers and Systems Integrators in the automation industry with more suitable workstations?

How is this need being addressed currently? (Current products and services)

The automation Industry, and its workers are constantly trying to find the best and most ergonomic portable solutions. Although when putting both portable and ergonomic, there are not many companies that have focused on tackling these two challenges with one solution. The Edge Desk System is an example of one company who has decided to focus on the on-the-go consumer and comfort. Although, the needs of a quick mobile workspace are limited because of weight and the process by which the consumer must set up and take down.

8.1.1 Findings

Method 1

Search Engine: Humber Library

Keywords Used in Search:" review plc programmers' workspace"

APA Citation: Tsarouchi, P., Makris, S., & Chryssolouris, G. (2016). Human-robot interaction review and challenges on task planning and programming. *International Journal of Computer Integrated Manufacturing, 29*(8), 916-931. doi:10.1080/0951192X.2015.1130251

Summary Statements

1. Human-robot interaction is a very complex subject matter that is being done by a variety of researchers. The scheduling, metrics for HRI, as well as the social aspects are key in order to understand how the relationship may become more efficient in the future.

2. Task planning and systems and organization is needed in order to understand the difference in tasks between human and robot in a system related function.

3. Human and robot interaction is beneficial since it brings down costs in manufacturing and uses skills of both parties in order to execute a process or product successfully and efficiently.

4. Hybrid Cells are better than manual cells as working together with a system will make the job faster. Although manual cells work more efficiently for certain applications.

5. HRI has been used a lot in many applications, although it is not used enough in the automotive industry since they are not autonomous enough.

8.1.2 Method 2

Search Engine: Humber Library

Keywords Used in Search: "Computer Workstation Ergonomics"

APA Citation: Lin, M. Y. C., & Dennerlein, J. T. (2015). A psychophysical protocol to provide ergonomic recommendations for standing computer workstation setup. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 59*(1), 1288-1290. doi:10.1177/1541931215591209

Summary Statements

1. "Office computer workers in developed countries often suffer from work-related Musculoskeletal symptoms and disorders (MSDs) due to prolonged computer work (Smith, 1999). Evidence has emerged that modern office workers are at increased risk for adverse health outcomes, including obesity and diabetes mellitus, as a result of their sedentary work behavior."

2. "While there are recommendations for sitting workstations which states that the desk should be set at resting elbow height and the top of the monitor should be set slightly below eye level to reduce risk of MSDs and symptoms, there are currently no specific ergonomics guidelines and few recommendations on the best configurations of desk height or the location of the keyboard, mouse, and visual display for standing workstations."

1. "The preferred setup, specifically for tablet height and monitor height, was lower than what is currently recommended for sitting computer workstation that suggests table to be

set at resting elbow height and monitor top edge to be set at eye level. Sample figure for real time data collection."

2. "The current study findings show that standing computer workstation users may prefer a workstation setup that differs from a standard sitting computer workstation. In particular, users found that setting the table height lower compared to their elbow height more comfortable to work with. Additionally, they preferred lower monitor height compared to their eye level with a slightly up-tilt display angle while performing standing computer work."

3. "The protocol evaluation shows that indeed the participants' ideas of comfortable computer workstation setup do vary initially, but could gradually converge to a final preferred setup if granted enough time. The final preferred location data with respect to user's body frame is representative of their perceived comfortable setup."

8.2 – Interviews

Objective

To obtain information on the user needs, demographic, and personal connection. To better understand the user's work environment.

Scope: This process will be done by in person interviews

Findings:

8.2.1 Santiago Moros

Interviewee: Santiago Moros

Interviewer: Sandra Moros

Interview Date: October 6, 2019

Basis of Expertise: PLC Design and Systems Integrator, Contractor and Project Management.

Helped with Trainings in PLC Logistics in Plants.

Method of Record: Response was done/sent through email.

Place of Interview: Interviewers Home.

1. What are you most passionate about?

   A: I really like to help others with their electronics, mechanic's and automation ideas and development. I am passionate about traveling and enjoying food.

2. What is your Ethnicity?

   A: Colombian. Latin American

3. What is your marital status?

   A: Single, In a relationship

4. What is the size of your Family? Do you have a big family/Small? who does your immediate family consist of?

   A: Small Family. Mom dad and sister

5. What are your hobbies?

   A: Travel, help people with their designs and engineering needs. 3D printing, Automation. Product design programming.

6. What is your age group?

   A: 25-34

7. What are your aspirations personally and career wise?

   A: Aspire to be travelling all over the world. And have a career that falls in line with my hobbies.

8. If alumni or apart of Humber College: What is your background at Humber? (Educational and extracurricular)?

A: I was in Automation and Robotics at Humber for a 3-year program. And competed at the mechatronics skills competition.

9. How did you learn about PLC programming? Have you done it or worked in the Industry?

   A: I learned PLC's at Humber College. Since then I have professionally worked as a PLC programmer on multiple projects.

10. If you are/were a PLC programmer what was your work environment like? (In a factory?)

    A: Typically, a plc programmer first must design the program for the machines based on the hardware (both mechanical design and electrical blueprints). This is done in an office setting. After the equipment has been built and connected, the plc programmer is required to start debugging or fixing the program so that it works as intended with the physical hardware. This process is done at the site of where the equipment is located. Mors of the time it is at an industrial manufacturing site, but there are applications where integration can happen at a conference, office, and anywhere where there is automation.

11. what companies have you worked for and what were the roles you had?

    A:
    - Esys: Project Engineer - PLC Designer/Integrator for 3 years,
    - GM Direct Contractor PLC Designer/Integrator & Project Management.

12. What are some challenges in regards to workflow and ergonomics with plc programming that you have discovered?

    A: In terms of Challenges of the work space, I would say that the biggest bottleneck is the problem of having to go back to the laptop that is on the table to check the software, while conducting the testing and debugging of the software. In many cases, the programmer must walk the perimeter of the cell, back to the workstation to review data and debug software. In some cases, we use laptops. But this presents a new problem which is power and connectivity to the main PLC computer. A solution has been to use WIFI and get a better battery for the laptop. But the ergonomics of the laptop don't always allow for an easy mobile workstation.

13. Have you or anyone that you know of in the Industry ever had any discomfort or have interacted with in the following while you were working? If so, can you explain further?

    a) Holding your laptop while programming?

       A: As discussed, a laptop is a mission to hold and walk around with.

    b) Load bearing with equipment (carrying equipment around)?

       A: The only equipment that a PLC programmer would carry is the laptop, ENet Cables, charger for the laptop and mouse.

    c) Modular workstations (i.e. collapsing tables/chairs)?

       A: The plastic tasks and Chairs are typically Carried around the perimeter of the cell in order to set up a sitting workstation. This is done periodically to get closer to different locations that require detailed attention.

8.2.2 Neal Mohammed

Interviewee: Neal Mohammed

Interviewer: Sandra Moros

Basis of Expertise: Director of the Centre for technology and Innovation at Humber College, Educator, Program Development, trainer within automation, robotics, and mechatronics.

Date of Interview: October 8, 2019

Method of Record: In person Interview – Voice Recording.

Place of Interview: Barret Center of Technology and Innovation (Humber College School of Applied Technology)

1. What are you most passionate about?

   A: My passion, is really helping students realize their dreams. My passion is really about helping students realize what their passion is, and to help them realize what their skills are. To Guide, and help students realize their passion, and their skill set. So that they can get meaningful opportunities.

2. What is your Ethnicity?

   A: I am from Trinidad my wife and children are from Canada.

3. What is your marital status?

   A: Married.

4. What is the size of your Family? Do you have a big family/Small? who does your immediate family consist of?

   A: Medium sized family. I have a wife, and 2 kids. Most of my family is back home in Trinidad.

5. What are your hobbies?

   A: Anything to do with the outdoors, things like camping, fishing, Hiking. Reading up on technical trends. The evolution of technology and how it's causing disruption.

6. What is your age group?

   A: 45-54 years old.

7. What are your aspirations personally and career wise?

   A: From my career in education, and working really close and understanding where the industry trends are going. So really the next goal is to transform the Barrett building to align it with Industry. What that means is really to give students an experiential but meaningful learning while working on real world problems. And to see this vision come true.

8. If alumni or apart of Humber College: What is your background at Humber? (Educational and extracurricular)?

   A: So much! I am involved in teaching engineering courses. Right now, I am the director for the Barrett center so I run the day-to-day operation of this building. That means everything from training, to projects, to applied research, to community engagements like STEM.

   Off Record according to the Humber College School of Applied Technology website, "In past Humber roles he has been responsible for the design, development, and delivery of over 20 courses for customized training, certification, and diploma programs.

9. How did you learn about PLC programming? Have you done it or worked in the Industry?

   A: "It's part of the training and education engineers have to do; it is a mandatory course. In education it's not called PLC programming specifically but coding and programming. Under the Programming category you study various languages, one of those languages is PLC programming. I also learnt it from working within the Industry and from continuous learning. Workshops seminars, outreach, it's really a self-discipline too."

10. If you are/were a PLC programmer what was your work environment like? (In a factory?)

    A:

    - I worked in clean and messy environments. So, in the medical, food, packaging, automotive, and even toys. And even in the educational environment, I have worked on so many projects, research projects, skills competitions, to corporate training. Going to many industries and provided training.

- In the medical field is the clean field.
- The Automotive field which is high pace, very demanding, harsh, not always clean. Because you have different layers of companies. Smaller companies don't really have the nice and clean. So, when you go into these conditions, it can be hot, dusty, logistics can be a problem.
- Food factories have to be very clean, very nice.
- Within High speed packaging and quality control it can be very anxious because you might be costing a company a lot of money. High level of accuracy. Especially in drug packaging.

11. what companies have you worked for and what were the roles you had?

    A: I worked for a variety of companies. One for example, are medical companies such as AstraZeneca, and the role was to constantly be integrating new equipment and new technology.

    Off Record: According to the Humber College School of Applied Technology website, Neal Mohammed also "managed many custom training programs with some top companies including: Magna International, General Motors, Toyota, Husky, Collins & Aikman, Stanpac, Denso, and Polytainers, just to name a few. "

12. What are some challenges in regards to workflow and ergonomics with plc programming that you have discovered?

    A:

    - The condition you are working in. If you are a systems integrator you would have to carry your tools with you but also a laptop. But if you are just a PLC programmer then it would just be a laptop and the software and small tools.

- For when you are sitting down for longer hours it would have to be the chair and the table. For a 10 min job its fine. But When you have to spent 8 hours in a harsh condition coding, it can be very challenging. The computer, the mouse, the keyboard. There would be certain panels that were not designed with ergonomics in mind so sometimes you have to bend and get into awkward positions when accessing panels. You would have to go back and forth between machines when debugging. So, there is a lot of movement. Other challenges could be, coding while standing, eyestrain, and overworking if you are a systems integrator.

13. From your experience, what would you say the Industry like in the following:

    a) Gender - What is the most common Gender?

       A: Male. Very few females.

    b) Race - What is the most common Ethnicity?

       A: Mixed. There is no dominant ethnicity.

    c) Age – What is the most common Age?

       A: It is varied. Right from 22,23 to retirement age.

14. Would you happen to know what the typical work hours of a PLC programmer is? Or in any similar related fields?

    A: An employee can work a normal employee hour. Although when talking about a contractor or systems Integrator, depending on the contract their primary goal is to get the job done. This means they are paid a flat rate fee and have to get the job done by the required time if not in the end they are paying out of their pocket to get it done. This means that they could work however long to get the job done, which sometimes could mean long hours or one day they could win the lottery and have a simple task to do.

8.2.3 Key Points/ Take-Aways From Interviews:

The First Key point for this interview was that PLC programmers primarily deal with the coding and troubleshooting of a control system. They may design schematics, and find solutions all with just using their software and laptop. A systems integrator does all of this although in addition they are in charge of also implementing and integrating new systems within old ones which may require certain tools, plc programming roles, and training roles. This was what Neal said my brother did. Secondly, there are different automation fields to which each industry has their standards and different conditions. Thirdly, there is a lot of ergonomic discomfort an awkwardness when it comes to accessing certain panels as they were not designed thoughtfully initially. Fourthly, the PLC programming and Systems Integration field is dominantly male in demographic. Lastly, there is a lot of movement from workstation to workstation.

8.3 User Research

Objective

This section will identify and furtherly define the user demographics as well as how their persona and research can help guide the final design.

Scope:

The date gathered will showcase who the primary, and secondary users in order to validate the user persona.

Findings – User Profile Report:

Image Search Analysis:

Primary User: PLC Programmer

Image search Results using Image Search:

An image search of what a typical PLC programmer looks like was conducted.

Key Words to Find images listed below included:

- PLC programmer
- Computer Analytics Training
- Computer Systems Analyst
- PLC Programmer sitting down
- PLC Programmer working

Secondary User: Systems Engineering Manager

Image search Results using Image Search:

An image search of what a typical Systems/PLC Manager looks like was conducted.

Key Words to Find images listed above included:

- Computer Analyst boss in Factory
- Computer Information Systems Manager
- Computer technologist boss
- Programmer Manager
- IT programmer boss
- PLC Programmer working
- Chief Engineer directing

Images Gathered:

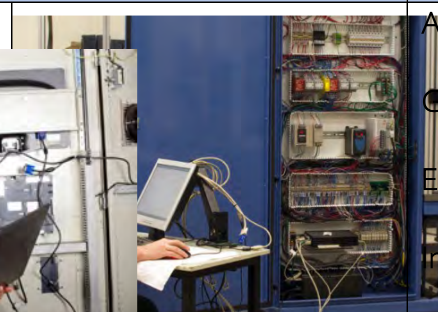
Primary User: PLC Programmer/Systems Integrator			Summary Of Image Search:
 Zhang, H. (2014, August 23). Industrial Technician checking distribution box with laptop in factory. Retrieved from: https://www.alamy.com/stock-photoiindustrial-technitian-checking-distribution-box-with-laptop-in-factory	 Talos Automation. (Date unknown). PLC Programmer – Talos Automation. Retrieved from: https://talosautomation.com/campaigns/automation-engineers/plc-programmer-20/	 Author Unknown. (2014, October 27). How to Begin a Professional Career as a Computer System Analyst. Retrieved from: https://www.qualityeducationandjobs.com/computer-systems-analyst/	**Age:** 25-50 **Gender:** Male **Ethnicity:** Mixed **Income:** Mid-High Range
Secondary User: Project Manager/ Director of Operations			User Summary of

		Image Search:
 Author Unknown. G.1. Jobs. (Date Unknown). Computer Information Systems Manager. Retrieved from: https://www.gijobs.com/hotjob2017-computer-information-system-manager/	 Gorodenkoff. (Date Unknown). Back View of the Head of the Project Holds Laptop and Discussing Product Details with Chief Engineer while They Walk Through Modern Factory. Retrieved From: https://www.shutterstock.com/image-photo/back-view-head-project-holds-laptop-782845411	Age: 28-65 Gender: Male Ethnicity: Mixed Income: High Range

Literature Search:

A Secondary search was done using literature sources to identify any additional users, focusing on data and statistics.

Methods used: Google Search

Key words used:

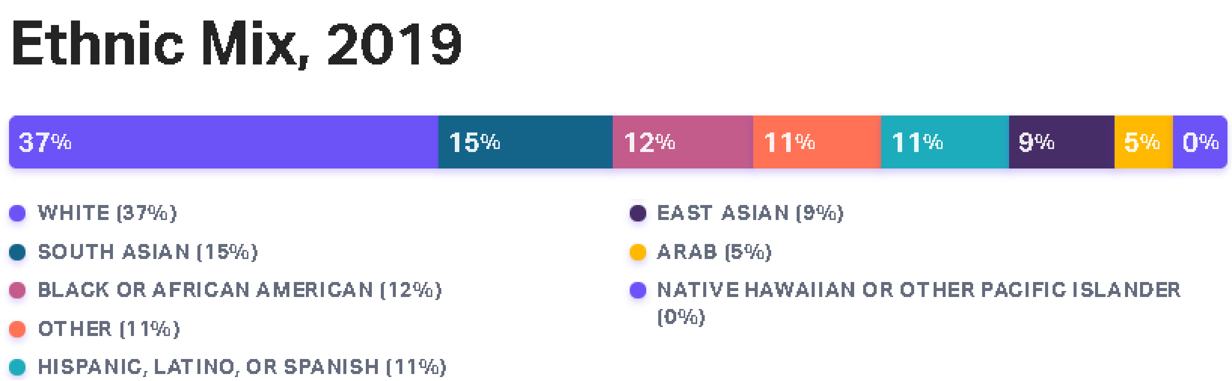
- Robotics engineer programmer's user demographics
- Engineering Manager Salary
- Average PLC Programmers pay
- User demographics of programmers

Findings:

Source 1:

CareerExplorer, F. robotics engineers on. (Retrieved October 28, 2019). Careers. Retrieved from:

https://www.careerexplorer.com/careers/robotics-engineer/demographics/



In this article by CareerExplorer.com, It is established and can be found that Robotics Engineers specifically in the USA have a complete Ethnic mix, even so the ethnicity with the largest percentage is %37 which belongs to the White male.

Within this article, it also states that "19% of robotics engineers are female and 81% are male." It is important to analyze this information as little data is available for the statistics of PLC programmers, although looking at similar fields can help create an image or idea of the user within an industry.

Looking at other sources such as:

Robotics & Automation Engineering. (Retrieved October 28, 2019) Retrieved from https://datausa.io/profile/cip/robotics-automation-engineering

Average PLC Programmer Hourly Pay in Canada. (Retrieved October 28,2019). Retrieved from https://www.payscale.com/research/CA/Job=PLC_Programmer/Hourly_Rate

Salary: Engineering Manager in Toronto, ON. (Retrieved October 28, 2019). Retrieved from https://www.glassdoor.ca/Salaries/software-engineering-manager-salary-SRCH_KO0,28.htm

The following Was concluded:

PLC Programmers have a median age that ranges from 25-43 according to google image searches and online related searches. The average salary is around $66,560 CAN, and the average user is a Caucasian male.

User Behavior

The behavior of a PLC programmer varies depending on the project. Some projects require being immersed in a factory setting while others can be involved in programming objects humans interact with daily- like traffic lights. Their hours also vary depending on the type of programmer, that is if they are contract workers or every day workers. Every day workers can work a regular 40-60 hour working week as stated within their contract with a company or corporation providing plc solutions. Meanwhile, contract workers may not be given a limitation of hours, but a timeline stating when their job must be done by. This means that Contract PLC workers like any contract work, may exceed the average work week to meet deadlines depending on a company's budget. Those mandating or in charge of the contractor or employee typically work less hours, complying more directly with the average work week.

It can be assumed that programmers or users within the related field work a variety of different jobs programming in different environments. Although, for this particular thesis proposal, the PLC programmers in the factory setting will be analyzed.

8.4 User Observations

Introduction – Description

The purpose of this research report is to attain better knowledge and identify additional ergonomic challenges for PLC Programmers and Systems Integrators. It will bring attention to the positive and negative impacts of current solutions in order to alleviate the stresses and improve comfort. These challenges may include awkward body positioning, eye and muscle strains, and any additional discomfort in their work-flow.

Research Objectives:

- Gain knowledge and understanding on the actions the user takes to complete key tasks and activities.
- Create cohesive documentation in which unifies information observed.
- Analyze documentation to gain key elements which will influence thesis purpose.
- Develop visual data with information attained with the user experience map.

Key Activities:

- Current in-factory work-station solutions.
- Using and programming with PLC controllers
- Interacting with HMI (Human Machine Interaction, either computer or HMI device)
- Programming, running tests, Debugging.

Target Users:

- Primary User: PLC Programmer/ Systems Integrator
- Support PLC Programmer/ Systems Integrator
- Head of Automation/ Manager of PLC Programmer/Systems Integrator.

Video Analysis:

Preliminary Video Scoping

Video 1

URL: https://www.youtube.com/watch?v=3B3N3LkU-3Q

Title: A Day in Life of Esco PLC Engineer

Length: 7min 39 sec

Brief Description:

This video is done in a daily vlog style showcasing the life of Mark Lance, a Filipino PLC engineer. It showcases his daily routine even before work and during. At work, mark recording himself using and operating systems software to later than programming and integrating this software to devices at his workstation. The video showcases him then later debugging and testing the device and running software analysis.

Relevance to Thesis Topic:

Even though this video does not have any subtitles or an actual explanation of what is happening, it is done in a vlog and time-lapse format which showcases how and what this particular PLC engineer/programmer does in his job. It is relevant as I am studying the workflow of PLC programmers and systems integrators primarily within a factory setting as well as at certain workstations. The main difference with the workflow of this particular programming engineer is that he stays at his workstation for most of the time, while the programmers and systems integrators which have previously been researched, tend to be interactive with their environment.

Video 2

URL: https://www.youtube.com/watch?v=q13bck7Prpo

Title: A Day in the Life…Automation Technician

Length: 3min 12 sec

Brief Description:

This video showcases Cory Gunderson, an Automation Controls Technician. The video introduces Cory's tasks and workflow while he talks about his experience and how he became aware of his field. You see him initially interacting with his laptop and his control system. You see him them bringing his laptop with him to other control systems and working while standing. The video also showcases the many tools he uses to connect to the control panels and create that communication between his laptop and the controller. Throughout the rest of the video Cory interacts with a variety of different control systems placed around a factory setting, later then discussing and showcasing his family.

Relevance to Thesis Topic:

This video is relevant as it showcases the tasks a plc programmer and systems integrator undergo. There is no difference in the tasks as they are the same job, just different titles depending on each company. This video clearly showcases any ergonomic challenges within Cory's work environment.

Video 3

URL: https://www.youtube.com/watch?v=HWTUTOOwyVY

Title: A Day in the Life of an Instrumentation Control System Specialist

Length: 1min 49sec

Brief Description:

This video explores/and is narrated by Tan Ee Sin, a Chief specialist in Instrument Control Systems and a Senior Principal Engineer. Sin explains the job roles as the video goes to showcase examples of those tasks. He does Systems and spot checks to ensure that the systems in the factory he works in are running well. He does round-the-clock checks to ensure the safety of his company. As the video states: "Instrument and automation systems play a vital role in round-the-clock monitoring and operations of Singapore's reservoirs and pumping stations. At the heart of these hardware are engineers like Ee Sin, who helps to ensure that PUB's reservoir operations can run efficiently and provide water for all – for now and the future."

Relevance to Thesis Topic:

This video is relevant to my thesis topic as interaction with both PLC controllers and desktops/computer software is the required job of a systems integrator/plc programmer. The only difference between Mr. Sin and a Systems Integrator/PLC programmer is that Sin is an in-house employee focusing on the maintenance and check of his systems, using his software to debug, and is not within the automation industry. PLC programmers do this, although Systems integrators in addition can be asked to integrate new systems into a factory also. This would mean that if Sin's company needed to integrate new software, they would either ask him because of his position within the company, or they would hire a systems integrator to integrate this new system and help with the training of its new updates and functions.

Video Observation

All three videos examine the workflow of technicians within a factory. The first video showcased a glimpse of the interactions a PLC Programmer and Systems Integrator may have when interacting with their surroundings such as; interacting with the PLC, Laptop, HMI (Human Machine Interface), their workstations and areas. Some of the videos may be useful to understand the workflow of the primary user, although not all can fully identify or showcase all the challenges that they may face.

User Environment:

For this study, multiple video's examining the day in the life of a PLC programmer and systems integrator were used as well as in person observation at MASSIV Automation, a Magna owned plant in Brampton Ontario under the watch of Dave Evans, Automation Manager.

Considering the key lists above of the activities, users, and environment, this observational research was conducted. The information and insights gathered from this research will furtherly be assessed within the conclusion. The Data below is organized in order of work-flow observed and interviewed from a Systems Integrator once all of the equipment has been installed and wired by millwrights and electricians. The images used are sketched in infographic style and pulled from video references within preliminary video observation to illustrate each step as clearly as possible.

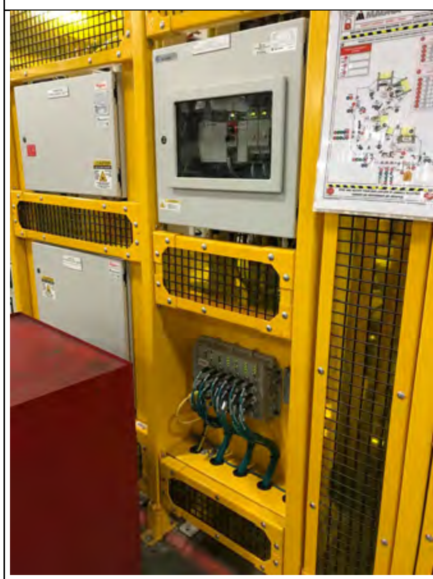
This can be found in section (2.1.3) of this thesis report. Images were also gathered in order to understand the users current work environment. The reference images to create the info graphs are listed below:

Reference images for Activity Mapping Section (2.1.3)		
 Work Station	 Work Station	 Work Station

Robot Schematics

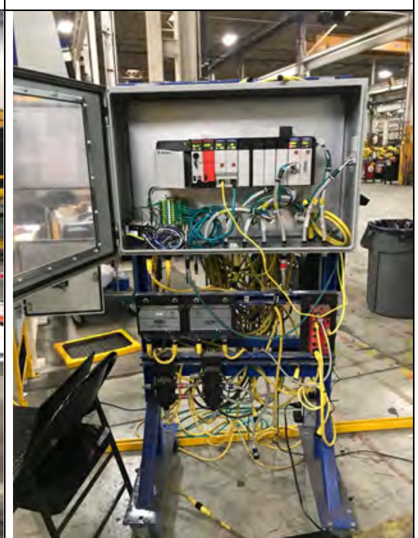
HMI (Human Machine Interface)

Close up of HMI



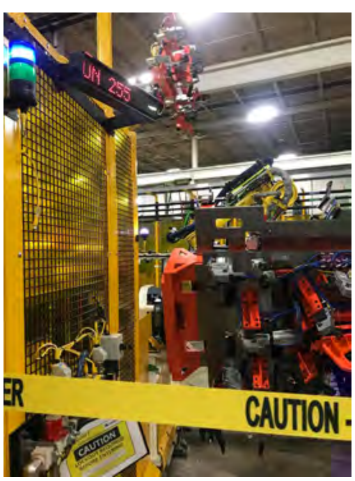
Example of PLC Control & Placement

Example #2 of a PLC control



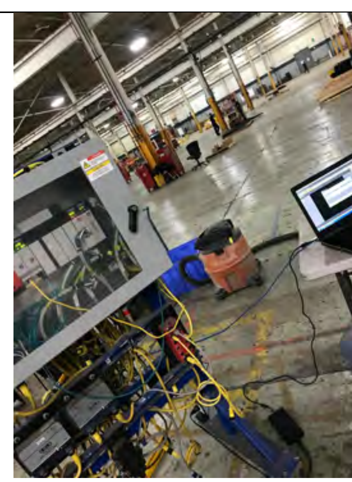
Example #3 of a PLC control

(mobile)



Example of robotic cell #1

Example of Robotic Cell #2



Example of Work Environment

The conclusions for this user observation were and insights that were gathered can be seen in section (3.2.2) of this report.

8.5 Benchmarking

Benchmarking 1

The objective of this report is to analyze existing products that are relevant to the ergonomics, and workflow of PLC Programmers and technicians. The benchmarked tools may not be directly catered towards the same demographic, but may be used by the demographic to help complete their job. By doing this process, one can then determine the features and benefits in order to understand their relevance and what could be applied to the solution in design. The products chosen were based in accordance with the primary users' needs such as modularity, adjustability, comfort, ergonomics, collapsibility, and convenience. These products are displayed below:

	1. Ergonomic Mobile Workstation Stand AV Cart Description: Cotytech Mobile Computer Workstation - Adjustable, Modular, Ergonomic is a modular system of components that when combined create a versatile range of mobile or static environment. The mobile work stand includes the dual-arm LCD mount bracket, a tempered glass mouse/desktop shelve, an ergonomic keyboard arm and tray, a secured all-size CPU or UPS holder and a printer or paper stand. The computer pole stand has 68.9” (175cm) overall height and it is fully mobile with 2 locking and 3 non-locking casters. The LCD monitor mount is VESA compatible 75x75 to 100x100 with weight capacity of 22lbs (10kgs). The mobile workstation is constructed of lightweight yet durable aluminum and steel materials. It's ergonomic, portable, space saving attributes and high-tech look make it an attractive choice in all types of businesses, office, trade-shows, mall kiosks, retail stores, factories, band, schools, hospital, internet cage and even at home. All parts are 100% height adjustable. Please note that monitor, keyboard, mouse, printer and CPU are not included.

Specifications (Features):

- Sleek design provides extra work space; moves to accommodate multiple users, sitting or standing; pole length: 68.9 inch (175cm)
- Package includes: 1 pole; 1 monitor mount; 1 glass platform for work space and mouse; 1 glass platform for large size keyboard (103 keys); 1 glass platform for printer; 1 compute holder; 5 roller wheels
- Solid aluminum alloy construction; sturdy mobile base with five casters, two lockable
- Approx. 32 inch wheel diameter, convenient to move through doors
- All modules are 100% height adjustable

https://www.amazon.ca/Ergonomic-Mobile-Workstation-Stand-Cart/dp/B0037ULB44

2. Global Industrial™ Orbit Mobile Laptop Cart, Black

Description:

Complete workstation includes a center post with mobile base and a locking laptop tray. The super strong 2" x 5" steel center post with cable management moves easily on a stable caster base that measures 24"W x 24-1/2"D and includes a 10"D shelf. Base includes four 4" rubber casters, 2 locking. Made of heavy-duty steel, the laptop tray includes a locking bar for security. The tray measures 18"W x 14"D and fits most 17" diagonal-screen laptops and Chromebooks. Mounts to post at 40"H. Overall height of 41 inches. Powder coat finish. Easy assembly.

Specifications:

- Brand: Global Industrial™
- Manufactures Part #: 239141BK
- Width (IN): 24 (60.96 cm)
- Depth (IN): 24-1/2 (62.23 cm)
- Height (IN): 40 (101.6 cm)
- Description: Orbit Mobile Laptop Cart
- Colour Finish: Black
- Construction: Steel
- Top Construction: Steel
- Weight: 80 lbs. (36.36 kg)
- Type: Mobile Cart

	• Number of Outlets: No • Mount Type: Mobile • Casters: 4" Rubber (2 Locking) • Assembly: Unassembled • Limited Warranty: 1Year https://www.globalindustrial.ca/p/office/computer-furniture/orbit-workstations/orbit-mobile-laptop-unit-black?infoParam.campaignId=T9F&gclid=Cj0KCQiAk7TuBRDQARIsAMRrfUZnBPXEOECdYdpxOzpEbjUHWNw2Cf6g3lV6xOoIrKSMEbQ1QibjoFwaAgxBEALw_wcB
	3. Mobile Adjustable Height Stand Up Workstation (Black & Black) Description: Mobile Stand Up Adjustable Height Computer Workstation is ideal for use as a stand-up desk, computer desk, or podium. Compact and lightweight, the unit measures 75 cm W x 51 cm D with sit to stand height adjustable in 2.5 cm increments from 87.5 cm - 115.5 cm. Features a durable powder coat paint finish and 7.5 cm furniture casters, two with locking brakes, for optimal mobility and secure stability. This product meets the minimum requirements of ANSI/BIFMA standards. Specifications (Features): • Compact mobile stand up computer workstation, ideal for use as a stand-up desk computer workstation and can also be used as a speaker's podium. • Standing workstation adjust in 2.5 cm increments from 87.5 cm - 115.5 cm high. • Lower shelf and keyboard shelf offer additional space and flexibility for a variety of uses. • Heavy duty powder coat paint finish delivers durability and an attractive look. • Four 7.5 cm furniture casters, two with locking brakes, provide fluid mobility as well as stability. This product meets the minimum requirements of ANSI/BIFMA standards. • Product Dimensions: 50.8 x 74.9 x 115.6 cm; 27 Kg • Shipping Weight: 27.2 Kg • Item model number: SUDWS30 • ASIN: B019EME04G

<table>
<tr>
<td></td>
<td>https://www.amazon.ca/Mobile-Adjustable-Stand-Up-Workstation/dp/B019EME04G/ref=sr_1_7?crid=1M20H5O0QCLVZ&keywords=mobile+workstation&qid=1573762882&sprefix=mobile+work%2Caps%2C174&sr=8-7</td>
</tr>
<tr>
<td></td>
<td>4. The Edge Desk | Ergonomic and Foldable Workstation
• Collapsible workstation
• Ergonomics and seating considered
• Portable
• Adjustable height for desk stand

Description:

All-in-one desk solution for modern life and work. Be more productive and maximize space with their comfortable, ergonomic, desk/chair/easel combo that folds flat and sets up in seconds.

Specifications:

-Work surface: 20”x30” (50.8cm x 76.2cm)

-Weight: Apprx 25 Lbs (~11kg)

-Folds down to 6”

https://www.indiegogo.com/projects/the-edge-desk-the-ultimate-desk-for-productivity#/

https://www.kickstarter.com/projects/78859337/the-edge-all-in-one-desk-solution-for-modern-life</td>
</tr>
</table>

5. Costway Folding Computer Desk Laptop PC Table workstation Study Writing Desk w/ 2 Wheels

- Collapsible workstation
- Modular
- Not Height Adjustable

Description:

The overall structure of this foldable computer desk is divided into three shelves. The upper shelf on the Mainstays writing desk is designed for placing photos, books, collectibles, supplies as well as computer display. You can place a keyboard or work on the second-high shelf. It also features lower shelf for the CPU, papers and even a few books storage. Sturdy powder-coated metal frame offers you a safety work time and is durable for long time use. The two casters make it easily move after you fold the desk up

Specifications (Features):

- High quality
- New Modern Style, Beautiful Generous and Strong Practicability
- Foldable for space-saving and easy storage
- 3-tier structure helps you keep your articles organized.
- Two casters to for easily move
- Sturdy bottom shelf to place the host and other equipment's
- Easy to clean
- Color: Black
- Overall Size:22.5" X 18.1" X 30.9" (L X W X H)
- Weight limit of the top:22 lbs; Weight limit of the table:66 lbs
- Weight limit of the bottom:22 lbs
- Package includes:1 X Computer Desk
- Brand: Costway
- Manufacturer: Costway
- MPN: HW52909
- Base SKU: HW52808
- EAN: 6952938397155

https://www.rakuten.com/shop/costway/product/HW52808/

6. The EasyFold Scooter

- Not an adjustable workstation
- Modular and mobile
- Collapsible
- Single person use
- Comfortable

Description:

The Ultimate Compact, Travel Scooter That Folds with A Push of a Button.

Features:

- Fully electronic folding and unfolding in 10 seconds or less with a wireless key fob
- Innovative and light-weight design
- Adjustable tiller height and angle
- 3 modes: Scooter / Folded / Suitcase
- Remote control for automatic folding
- Ideal travel companion, perfect for Aircraft & Cruise Ships
- Bright, stylish LED lighting
- Comes standard with Airline safe lithium battery
- 275 lbs. weight capacity
- Anti-tip wheels for additional safety
- Perfect for cruises, vacations, family gatherings, and more!

Specifications:

- Top Speed: 3.7mph
- Estimated Travel range: 20km for single charging
- Turning radius: 47inches (1200mm)
- Unfold Size: 38.5″ × 19.3″ × 31.5″ (L 980 W 490 H 800 mm)
- Fold size: 15.3″ × 19.2″ × 28.3″ (L 390 W 490 H 720 mm)
- Battery Charger: 24V 2 A
- Motor: 24V 120W
- Braking System: Intelligent, Regenerative and Electromagnetic
- Drive System: S-Drive 45 A, PG
- Gradient: 0`12 degrees
- Weight: with battery 66 lbs, without battery 61 lbs.
- Max. Load Capacity: 275 lbs
- Seat Width: 17 inches
- Seat Height: 22 inches
- Front tires: two 6.5 inches and two 2 inches
- Rear tires: two 7.5 inches and two 2.15 inches
- Warranty: 3 Years

	https://easyfold.ca/product/the-easyfold-scooter/?gclid=CjoKCQiAk7TuBRDQARIsAMRrfUbnz3-mH2sZCBszn5H_Z8sNK-1CDMQbFsTDjUh366Uhvp8oqJwECE8aAoXLEALw_wcB
	7. SitPack Zen • Not a modular workstation • Modular and portable seating • Compact • Single person use Description The new Sitpack ZEN is the world's most compact, and functional one-legged chair. It's designed to improve your posture, and lets you relax when you need it, whether you're indoors or outdoors. Made with either carbon or aluminum tubes, and a ballistic nylon seat, it's the toughest, most advanced and lightest portable seat on the market. Specifications: -Weight: 555g / 1.21lbs | Weight capacity: 130Kg/300lbs -Materials: carbon fiber, aerospace grade aluminum, tactical mesh, ballistic fiber and Kevlar webbing. Features: - Stronger, lighter, more adjustable, and much, more comfortable. - Designed for perfect posture. - Built with finest Materials https://sitpack.com/products/sitpack-zen

8. KidsEmbrace DC Comics Batman Deluxe High Chair

Description:

Mealtime will be your child's favorite time of day when they are seated in the Batman Deluxe Convertible High Chair! The High Chair is one of a kind, having been diligently designed to provide maximum comfort and security as your child grows. With six seat height positions, five reclining backrest positions and a footrest with three height options and three angled position options, you will have the ability to customize and create the perfect seat arrangement for your little superhero! The cushioned seat contains a five-point harness to added security and as every Super Parent wants to know, the Batman Deluxe Convertible High Chair has tested to exceed the highest Government Safety Standards. The metal frame is both lightweight and comes equipped with large front wheels for easy transportation, and when meal-time is over, it can be quickly folded and collapsed for compact storage. Your young crime-fighter will be able to fully enjoy meal time with the large plastic tray which can be quickly removed for easy cleaning and the fabric can simply be wiped down. If they want to stay and play longer, there is an extra storage basket below for added snack, toy and crime-fighting tool keeping. The Batman Deluxe Convertible High Chair is the one both parents and children will delight in!

Specifications:

- Car Seat Weight (lbs): 25.99
- Maximum Child Weight (lbs): 40
- Minimum Child Weight (lbs) 5
- Model #: 1BTGCAN
- Product Type: Other
- Brand: KidsEmbrace

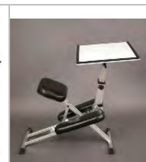
Features:

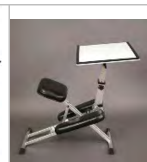
• 6 seat height positions for adjusting to the perfect position to feed your child
• 5 position reclining backrest to allow your child to be comfortable while eating
• 3 footrest adjustments and 3 foot adjust heights
https://www.walmart.ca/en/ip/kidsembrace-dc-comics-batman-deluxe-high-chair-blackyellow/6000198694843

Method:

The Chart below was created in order to compare the benchmarked items chosen to find solutions:

Features Comparison Table

								
Power	0	0	0	0	0	24V 120W	0	0
Weight	29 kg	27.2kg	27 kg	~25lbs	n/a	66 lbs	n/a	n/a
Material	Solid Aluminum	steel	Powder coat paint	n/a	Powder-coated metal frame	Aluminum alloy frame	Carbon fiber, aerospace grade aluminum, tactical mesh, ballistic fiber, Kevlar webbing	Metal frame, plastic tray, fabric
Dimensions	81.3 x 81.3 x 175 cm	60.96x 62.23x 101.6 cm	50.8 x 74.9 x 115.6 cm	Work surface: 50.8 x 76.2 cm	22.5'' X 18.1'' X 30.9'' (in)	Unfolded: 38.5″ × 19.3″ × 31.5″ Folded: 15.3″ × 19.2″ × 28.3″	n/a – small when collapsed. No max extension measurement available	n/a - baby/child size
Storage	Low	Low	Low	None	Low	Low	None	Medium

Collapsible	Low	Low	Low	High	Medium	High	High	High
Modularity	High	High	High	Medium	Medium	High	High	Medium-High
Comfort	Low	Low	Low	Medium	Low	High	Medium	High
# of Users	1	1	1	1	1	1	1	1
Design Elements Comparison Table								
								
Overall Form (categories below reflect type of product selected)	Tall, slender vertical structured	Tall, robust, slender, Thin, Structured	Tall, robust, wide, thin, boxy	Short, wide, slim	Tall, robust, slender, Thin, Structured	Short, wide, slim,	Short and long, slim.	Medium height, wide, structured.
Shape (Geometric, rectilinear, Ellipsoid, Cylindrical)	Geometric, rectilinear	Geometric, rectilinear	Geometric, rectilinear	Geometric, rectilinear	Geometric, rectilinear	Geometric, rectilinear	Geometric, rectilinear	Geometric, rectilinear
Repetition (arrays of hoes, arrays of lines)	No	No	No	No	No	No	No	No
Pattern (repeating unit of shape and form	No	No	No	No	No	No	No	No
Balance	Vertica	Vertical	Vertical	Balance,	Vertical	Asymmetry	Vertical	Vertical/fr

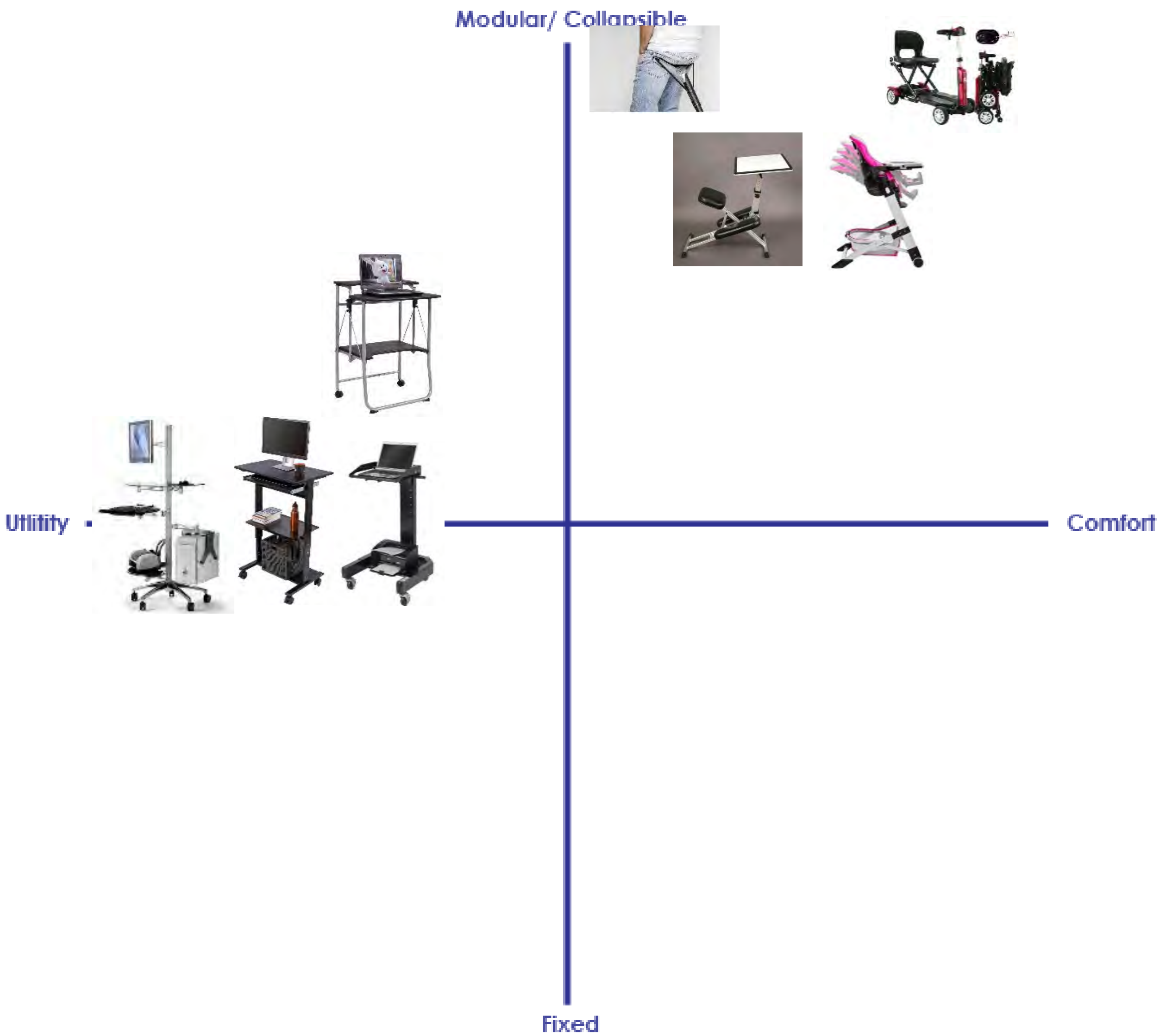
(symmetry etc.)	l balance	symmetry	symmetry	Hierarchy elements	symmetry		Symmetry	ontal symmetry
compact	No	No	No	Yes	Yes	Yes	Yes	Yes

Conclusion:

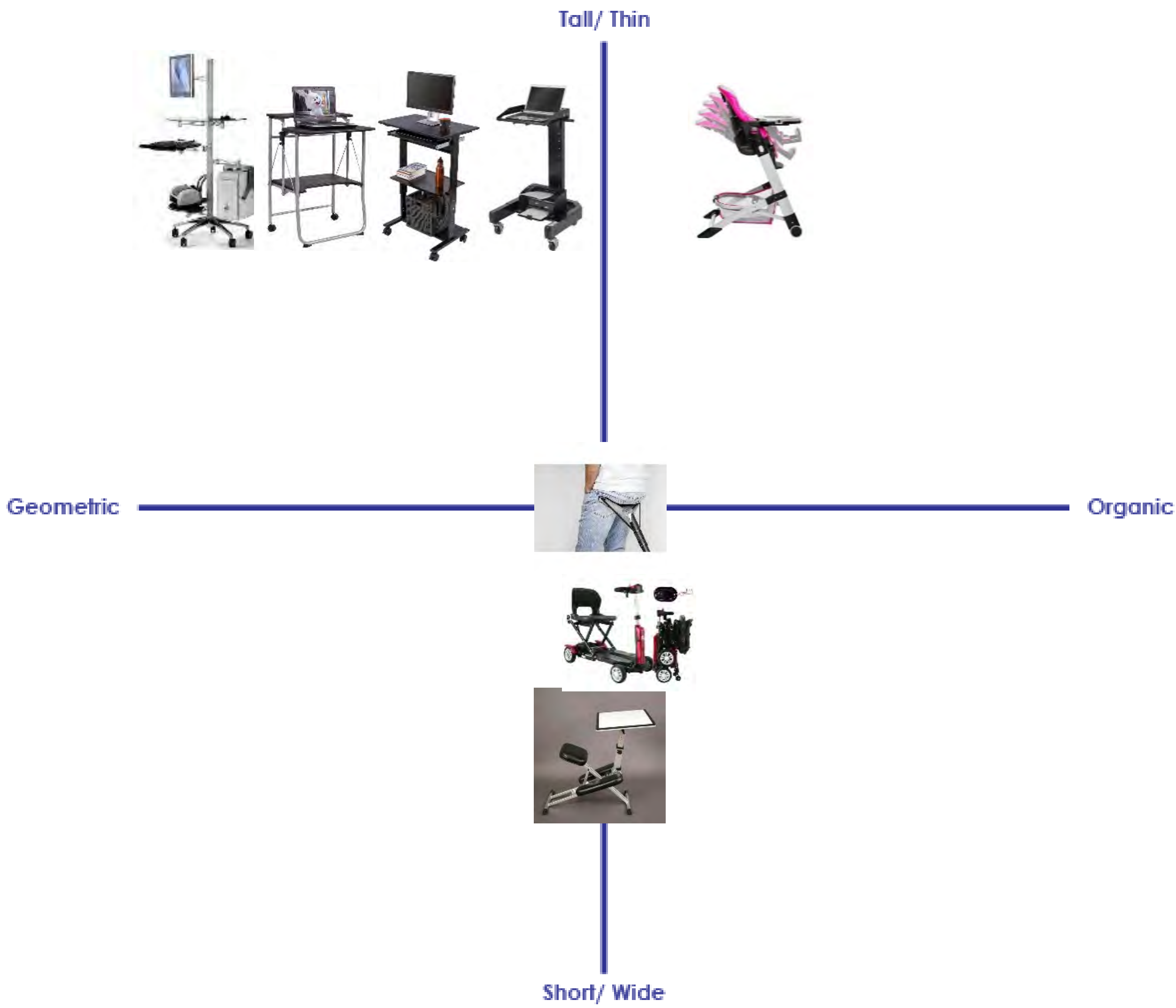
The above table showcases a detailed analysis on the current solutions for modular stations and tools. Although they may not all pertain to PLC programmers or systems integrators as a modular workstation- besides collapsible tables and chairs- have not been explored enough, they are helpful to analyze in order to seek opportunity when developing design solutions. One of the concepts for this thesis will work on improving their factory workstation, while the other may focus on developing a helpful tool. The above were chosen as they comply with the needs of a plc programmer and systems integrator. These needs are focused on modularity, ergonomics, convenience and utility. Because of this the form of many of the products for benchmarking chosen are focused aesthetically more on the utility rather than their form. Their function informs their form. Most of the modular systems are not powered by a motor, except for the modular scooter.

Benchmarking 2 – Comparing Pairs of Features on X-Y graph

The chart below was created in order to analyze the feature aspects the eight products chosen in section 1. The X-Y Graph focuses on displaying the findings in a scatter plot in order to define potential design opportunities.



The chart below was created in order to analyze the aesthetic aspects the eight products chosen in section 1. The X-Y Graph focuses on displaying the findings in a scatter plot in order to define potential design opportunities.



Conclusions

Examining both X-Y graphs, it can be shown that the most ergonomic and comfortable where the products where those that also offered more modular solutions, rather than the ones that were focused on utility and had less motion. The same products that focused more on the comfortable and ergonomic side were also aesthetically a but wider, shorter and more organic in shape than those that focused on utility and has less motion. The form of these products where focused on a taller and more geometric shape.

Benchmarking 3

This area will focus on examining the main demographic information of each product through its marketing. The benefits and features were examined through frequency of text analysis in the advertisements and specifications of the eight products identified. Below are the results of the top works used for benefits and features.

Features	
Mobility	8
Adjustable	7
Storage	4
Powder Coated	4
Aluminum	4
Steel	2
Glass	1
Rubber	1
Electronic	1

Benefits	
Lightweight	5
Ergonomic	4
Durable	4
Comfortable	3
Strong	3

Conclusions

After creating a frequency analysis chart to examine the features and benefits of the products chosen for benchmarking, the top words their synonyms within features described included mobility, adjustability, storage, powder coating, and aluminum. The Top benefits included items that were lightweight, ergonomic, and durable.

Discussion

The benefits of product benchmarking are that it allows people to create an analysis of similar products that are catered to the demographic, or other products which can be re-designed to the intended demographic. By doing this process, many similarities and differences can be noticed, which in turn showcase each products pros and cons. By gathering this information, it will help better in form different product niches.

Precisely, by doing this analysis I am now able to gather which information and design solutions better cater or can be applied to concept designs. What this information has informed my thesis is that the most common areas that the needs in the compared products address are; mobility (moving products), adjustability (transformative products), being light in weight, and ergonomics. In design, focusing on products that are more comfortable and collapsible, balanced in utility and aesthetic, and more stable are desired.

This information as well as the most dominated materials and finished being powder coating, and aluminum may help establish the materials my design solution will use. Even so, this will not be a limitation in exploring materials that can be better suitable for its design and function.

Thus, the updated needs statement is as follows:

To create a singular, modular, and adjustable workstation or tool that improves the; accessibility, comfort, workflow, efficiency, convenience and ergonomics of a Program Logistics Controller (PLC) Programmer and Systems Integrator. While being lightweight, convenient and balanced though form and function.

8.6 User Needs

Objective

To generate a needs statement for the thesis solution based off of research findings and initial product benchmarking. This will include discovering the benefits and features of products, and to relate that information to needs.

Scope: This search was be conducted through literature and internet research.

Summary Findings:

What the product does:

Improve the workflow of a PLC/ Mechatronics worker.

360 initial inquiry:

Who are your target market group? PLC/ Mechatronics workers

What does it do? Helps improve workflow and work life.

Where will it be done? Within an automation/ Robotics Factory, or Manufacturing factory requiring PLC programmers.

When is it done/used/needed? At Work, During factory production, Day & Night.

Why is it needed? To reduce effort, allows more flexibility in terms of carrying equipment, comfort depending on test, and easy accessibility.

Why would someone buy this product?

- reduced effort of carrying equipment
- allows flexibility to PLC programmer in terms of moving from station-to-station (Modularity)
- Added comfort for draining tasks
- Increased efficiency in workflow.

Benefits & Corresponding Fundamental Needs:

After examining a carrying bag and a gamers chair which can be used for programmers, the fundamental human needs which related to the product benefits were analyzed and displayed in the table below.

Needs	Benefits
Convenience	Ease of use, (doesn't give you any soreness), easy to store, speed of assembly and disassembly, portability

Comfort	Comfort for the programmer, (adjustable seat height and back angle, cushioning)
Environmental	Flexibility (has a wide range of configurations to best suit the needs of the individual programmer), Control (control and power over the movement and accessibility of the device).
Securing Resources	Value (price) – Best Solution for the best price + warranty
Safety	Durability and strength of device, load is secured and balanced, designed for the intended environment.

8.7 CAD Models

Computer Aided design models can be found in sections 4.7 and 5.3

8.8 Hard Model photographs

Hard/Final Physical Model Photographs can be found in sections 4.8 and 5.4.

8.9 Technical Drawings

Technical Drawings and data of the final thesis product can be found in section 5.5.

8.10 Manufacturing Cost Report

Please refer to 5.2.3 for the final approximated cost report.

8.11 Sustainability report

Please refer to sections 2.24, 2.25, 3.5, 3.6 and 5.6 for sustainability synopsis

8.12 TCPS 2: CORE


PANEL ON RESEARCH ETHICS
Navigating the ethics of human research
TCPS 2: CORE

Certificate of Completion

This document certifies that

Sandra Moros

has completed the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans Course on Research Ethics (TCPS 2: CORE)

Date of Issue: **4 September, 2019**

8.13 Participant forms

2019-20 Industrial Design Thesis Project HUMBER

- I understand that my participation in this study is confidential if requested. (i.e. the researcher will know but will not disclose my identity if requested)
- My identity will be masked if requested.
- I understand that the data from this study may be published.

I have read the information presented above and I understand this agreement. I voluntarily agree to take part in this study.

NEAL MOHAMMED
Name of Participant (please print)

Signature of Participant   Date October 8/19

Project Information
Thank you very much for your time and help in making this study possible. If you have any queries or wish to know more, please contact me at Ph: (437) 351-1112, email: sandra.morosg@gmail.com.
My supervisors are:
Prof. Dennis L. Kappen, dennis.kappen@humber.ca, 416 675 6622 xt 4832,
or Prof. Catherine Chong, catherine.chong@humber.ca, 416 675 6622 xt. 4672

2019-20 Industrial Design Thesis Project HUMBER

- I understand that my participation in this study is confidential if requested. (i.e. the researcher will know but will not disclose my identity if requested)
- My identity will be masked if requested.
- I understand that the data from this study may be published.

I have read the information presented above and I understand this agreement. I voluntarily agree to take part in this study.

DAVE EVANS
Name of Participant (please print)

Signature of Participant   Date Nov 1st 2019

Project Information
Thank you very much for your time and help in making this study possible. If you have any queries or wish to know more, please contact me at Ph: (437) 351-1112, email: sandra.morosg@gmail.com.
My supervisors are:
Prof. Dennis L. Kappen, dennis.kappen@humber.ca, 416 675 6622 xt 4832,
or Prof. Catherine Chong, catherine.chong@humber.ca, 416 675 6622 xt. 4672

8.14 Approval forms

Humber Institute of Technology & Advanced Learning
Bachelor of Applied Technology – Industrial Design
IDSN 4002 Senior Level Thesis 1
Catherine Chong, Dennis Kappen, Sandro Zaccolo

School of Applied Technology
Fall 2019

THESIS TOPIC APPROVAL

STUDENT NAME
Sandra Moros

TOPIC TITLE

How may we aid the work-flow and/or workspaces of PLC programmers/mechatronics workers in the automation Industry?

TOPIC DESCRIPTIVE SUMMARY

This thesis explores and aims to achieve a design solution which improves the accessibility, comfort, workflow, efficiency, convenience and ergonomics of a Program Logistics Controller (PLC) Programmer and mechatronics worker. Current ergonomic limitations that exist involve; physical positioning in which users interact with their equipment, transportive means of their equipment and themselves, and workspaces that consider both modularity and ergonomics. The design solution will focus on reducing the affects (such as; awkward positioning, strains, soreness, load bearing, and discomfort) that current limitations present. This proposal will focus predominantly on user observations, interviews, and surveys from those involved and affected by the PLC programming and automation Industry. In order to evaluate an analyze the ergonomics, human factors, and full-bodied design, a scaled and modelled design solution will be created. The outcome, is to help establish and propose new ergonomic and efficient solutions for current and future PLC programmers/mechatronics workers and technicians. Designing a modular workstation or device with human ergonomic considerations could help improve and elevate existing solutions, and create and inspire new ones.

Student Signature(s)

Instructor Signatures

Date **October 1, 2019**

Date Oct. 8, 2019.

Humber Institute of Technology & Advanced Learning
School of Applied Technology
Bachelor of Applied Technology – Industrial Design
Winter 2020
iDSN 4502 Senior Level Thesis Project II
Dennis L. Kappen/Catherine Chong/Sandro Zaccolo

THESIS DESIGN APPROVAL FORM

NAME
Sandra Moros

TOPIC TITLE (Brand)
Ergonomic Modular Workstation for PLC Programmers and Systems Integrators

PS: Ensure that the visualization of the final design, side views and front views in Illustrator or Photoshop are required to be shown to us for securing an approval

Thesis design is approved to proceed for the following:

____ **CAD Design Phase**

____ **Rapid Prototyping and model building phase**

COMMENTS:

Signed

Catherine Chong / Dennis L. Kappen