Musculoskeletal Disorders in Road Construction Workers

by

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Abstract

This research focuses on the mitigation of musculoskeletal disorders in road construction workers, which is the most common and reoccurring injury amongst construction workers. Musculoskeletal Disorders (MSDs) are often associated with strain on the muscle tissue and joints while completing a task in a fast and uneven pace, or while lifting in an unfamiliar or uncomfortable position. This observation shows real issues with the construction industry and how medical issues are maintained, and for the time being there is not an effective method of doing so. According to Workplace Safety North, current evolutions of certain PPE are ineffective and do not necessarily mitigate MSDs but rather weaken the body and put it more at risk when not using these PPEs. Recent data has shown that nearly forty percent of time off requests in Ontario have been due to MSDs. This thesis proposes an in-depth study of daily processes and challenges faced by road construction workers, using data collection methods such as observational studies, interviews, and surveys. A one-to-one scale model will assist with assessing the ergonomics and with establishing a full-bodied human interaction design. A solution will be developed for road construction workers, this will also help further the public's understanding of MSDs and their causes and mitigation methods. Furthermore, this will offer a solution to help with construction times, with less workers taking time off there will be more workers completing the tasks at hand.

Acknowledgements

To all who were there,

This project would not have been possible without the constant support from my friends, family, classmates, and advisors. The acts of kindness contributed from all parties have helped me push forward into the world of design and cement myself as a true designer.

I would like to thank my father; over the years he has taught me about manufacturing processes and has helped me understand the manufacturing side of design. He has helped me build projects and obtain all the material for the projects. My fathers never ending support for my career choice has been my inspiration to push forward.

I would like to extend another acknowledgment to my peer Drew Robinson, without his expertise in model making I would not have been able to produce a 3D printed model. His willingness to help me has been a true highlight of this project and one I will never forget, thank you Drew.

I would like to thank Catherine Chong, Sandro Zaccolo and Reece Bennett for persevering with me through this project and helping me gain a better understanding for concept generation, styling, and overall helping me pursue this design direction. With all their guidance I was able to push forward with a design that we had all envisioned from the beginning.

I would also like to thank Anonymous Advisor, a project coordinator at PCL Construction for sitting down with me to speak about the complex construction industry and all facets of safety. Anonymous Advisor would say that safety is the number one priority on all construction sites, and that statement has done more to design this project than any other. Thank you, Anonymous Advisor.

One final congratulations to all the 4th year students on making it past the strangest year of our program, despite the anticlimactic ending we have done and made it to the end.

Cheers,

Timothy Entin

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CHAPTER 1- Problem Definition

Problem Definition

Urban life is constantly branching out from major cities, providing many opportunities for citizens to travel effectively and safely. Roads represent the growth of a civilization and an increasing economy as well as a growth in population. The impressive network of roads throughout Canada symbolizes the unification of different cities and provinces, as well as represents the ever-increasing population growth in Canada. Road construction workers today face challenges that are often unseen, and not highlighted in mainstream life. Unlike physical dangers such as falling or injury by impact, there are injuries that are unseen and often go undiagnosed due to the lack of awareness and education about the causes of these types of injuries. These injuries are better known as Musculoskeletal Disorders (MSDs), an injury of muscle tissue which progressively grows in pain the longer it goes untreated. Some causes are the repetition of a task which is strenuous on muscle tissue, and the preforming a strenuous task in an uncomfortable position, which can exacerbate muscle tissue due to the nature of the position the worker may be lifting in. MSDs do not include musculoskeletal injuries or disorders that are the direct result of a traumatic event, such as a fall, being struck by or against an object, being caught in or on something, a vehicle collision, or workplace violence (Workplace Safety & Prevention Services). Currently, road construction workers use simple equipment such as lifting belts and constant exercise before and after work, however this may not always be effective. The need is being addressed primarily with workplace programs and reoccurring follow ups with workers.

Rationale and Significance

The construction industry in Canada is dominated by males, while females were projected to taking a mere 9.1% of construction workers in Canada in 2017, according to Statistics Canada (Statistics Canada, 2011). The subtle lack of women in the industry indicates the field is striving for inclusion, however, still focuses on the male to provide strength and stability to aid the construction site. It should also be noted,

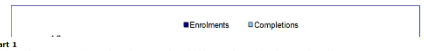


Figure 2 Women among enrolments and completions in registered apprenticeship training programs, by non-traditional trade group, Canada, 2007. Retrieved from https://www150.statcan.gc.ca/n1/en/pub/89-503-x/89-503-x2010001-eng.pdf?st=yUSJ9mOh

since 1996 there has been an increase in the number of workers aged 55 and older, while the number of workers aged twenty-five to thirty-four has been only slightly increasing. This poses the question as to why there is an increasing amount of older workers, compared to a younger and newer generation of workers. This thesis will use the following questions to aquire further information to obtain information regarding the topic.

Key Questions:

1. How may we mitigate musculoskeletal disorders in road construction workers?
2. What current safety equipment is being used to mitigate MSDs?
3. How do workers go about their day with a MSDs?
4. What impact would the mitigation of MSDs have on construction times? Would it help worker efficiency?
5. Which areas of the body are most impacted by MSDs?

User interviews, literature reviews, video analysis, observational studies and ergonomic studies are all the research tools that will be used to aid answer these questions to help build a better understanding and create a solution to the problem definition.

Background / History / Social Context

Road construction workers are responsible for one of the staples of urban life, building our pathways and enabling future infrastructures. There is presently a lack of understanding how construction workers injure themselves, aside from the most common injuries which are results of falls, or physical injuries such as being struck by an object. MSDs are the most common workplace injury resulting in over 40 percent of all Workplace Safety & Insurance Board (WSIB) lost-time injuries in Ontario (Ontario Ministry of Labour, 2012). The Canadian government has acknowledged MSDs as serious injury and has built an extensive program surrounding the prevention of MSDs in construction workers. This program is informative and offers information about how an MSD can occur and states

safe practices that construction workers should take to prevent these types of injuries. However, these injuries still occur, and are very commonplace in jobs with material handling such as construction.

Having spoken with a Project Coordinator at PCL Inc, it was stated, maintaining a timeline is crucial for all organizations involved. Injury times are assumed, but still cause setbacks in the timeline, as the employee must be replaced and finding replacements also takes time. Less injuries throughout the site would mean there would be less setbacks, which would allow for the projects to be completed as scheduled. Less injuries would also mean less injury payouts, which in return save money for construction companies and union related workers.

There are currently many preventative measures for MSDs, many being in the form of a product intended to restrict motions which may aggravate the injury as well as informative government issued presentations and instructional videos. However, these methods are not all effective, safety equipment being one of the culprits, and providing false claims of prevention, when in fact there is no evidence to support its claims. The construction industry is quite literally building the future, and the response to safety in the workplace has been on a rise, however mainly covering more obvious injuries and dangers of the workplace.

CHAPTER 2 - Research

2.1. User Research

The objective of this chapter is to present the user beyond simply their job title, and to understand the persona in question. The research topic in question, is analyzing the different types of challenges road construction workers and the industry are currently facing today. 40% of all worktimes requested in Ontario are due to MSDs, causing work delays, and high costs for employers to compensate for injured workers. The areas of focus for the user research will include benchmarked products, user needs, user demographic, surveys, and interviews of those in the industry.

2.1.1 User Profile – Persona

Name: Miguel Perez

Age: 26

Occupation: Road Construction Worker

Income: $46,000/ year

Education: High School Diploma

Relationship Status: In a Relationship

Location: Toronto, Ontario

Career/ Volunteer: Career

Years of Service: 6 Years

Social: Works with 7 other workers

Hobbies: Strength Training, Spending time with Family, Soccer, Cooking

Figure 3- Short of Workers, U.S. Builders and Farmers Crave More Immigrants. Retrieved from https://www.nytimes.com/2019/04/03/business/economy/immigration-labor-economy.html

A road construction worker persona is developed, a fictious person, who fits the demographic, motivation and background based off demographic research. The user persona aims to focus the design intent from the product to the user. A fictional breakdown of the user is described below:

"Miguel shows a great attitude at work, and always ensures the wellbeing of others before his own. Miguel always ensures that all those around him are aware of what he is doing and will double check everyone's work for the day. Miguel is a hardworking man, and is liked by all his coworkers, and is deemed as a reliable worker and friend."

Below is a description of Miguel's relationship to his Personnel Protective Equipment (PPE):

"Miguel started working at a young age and was less prone to injuries related to musculoskeletal disorders (MSDs), however there are no exceptions to whom may receive a MSDs. At 23, Miguel was lifting in an uncomfortable position, and tore some muscle tissue in his bicep and back. Ever since then Miguel ensures that he is lifting securely and has a lifting belt, along with a compression sleeve around his arm. Miguel understood that MSDs do not go away once they are healed, in fact it is easier to injure that same spot again."

According to Statistics Canada, there are predominantly more men in the construction industry, with females taking up 9.1% of the construction sector in Canada. In recent times, the construction industry has had an escalation of older workers above the age of 35 joining the workforce, however these older workers do not exceed the number of younger workers, which has been at a plateau, for several years. Younger workers do tend to be more productive and have a more physical life outside of work.

Construction workers start their days early, usually at 6 in the morning and tend to work an 8-hour day, with a 30-minute break. The work tends to be exhausting physical labour, but can also range from les demanding work, which is often rotated amongst workers. Construction workers are always working with other and very rarely seen by themselves on a site, this largely due to safety concerns.

In an interview with Anonymous Advisor of PCL Inc, he mentioned that the construction site is often seen as a serious environment, he went on to mention that the workers are some of the best people to be around and tend to lead very interesting lives outside of work. Byers also mentioned the workers

tend to make the site interesting and create an entertaining environment. In their off time, construction workers have many hobbies, the examples given by Byers were: Motorsports (F1, MotoGP), Sports (Soccer, Baseball), Exercise and spending time with their families.

Construction worker income ranges from $30k – 74k in Canada, this range is dependent on their performance, and ability as they age. Workers starting at the age of 18, tend to be on the lower income range, due to the lack of experience, and accountability for the worker. However, older, and more experienced workers have a higher liability and more experience that is valued more. Education has also come into account, those with a high school diploma will tend to stay towards the lower half of the income, but the ones with bachelor's degrees tend to be working not only as construction workers but can reach up the ladder to a higher paying position because of their education.

The predominant ethnicity among construction workers is shown in demographics as largely being foreign-born, this statistic is also showing an increase by 2036, however the Canadian-born workers seem to be increasing as well but nowhere near as much to equal foreign-born workers.

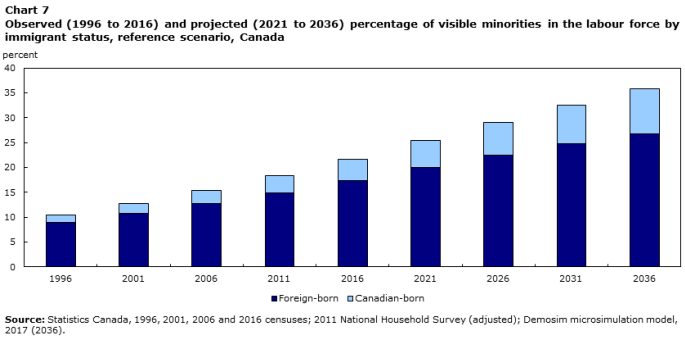


Figure 4 - ***The labour force in Canada and its regions. Retrieved from https://www150.statcan.gc.ca/n1/pub/75-006-x/2019001/article/00004-eng.htm***

User	Description
Primary	Road Construction Worker
Secondary	Medical Professional/ Trade Workers
Tertiary	Civilians/ Family

A primary user can be described as road construction worker, or someone on the construction site.

A secondary user can be described as a medical professional, and other trade workers, those who are not indirectly intended to use the product.

A tertiary user can be described as someone who is not directly using or necessarily even touching the product but may be involved with those using the product.

Primary User Profile

Demographics		**User Behaviour**		**Personality**		**Cognitive Aspects**	
Age	18-55	Frequency of Use	On site, weekdays	Focus on the Job	↑	Technical Skill	↑
Gender	Predominantly Male (~91%)	Duration	8.5 hours a day	Self-Efficiency	↑	Pre-Requisite Knowledge	↑
Ethnicity	Foreign (+70%)	Social	High-Social	Changeability	↑		
Income	Middle Class ($30,000 to $74,000)	Level of Focus	High	Uncertainty Avoidance	↑		
Education	High School Diploma	Location	Residential – Rural/ Urban				

2.1.2 User Observation – Current User Practice

User observation was conducted via email, video interviews, as well as visiting construction sites in person to conduct the necessary observations.

Regular tasks were observed via visiting the construction at a distance due to Covid-19 and safety protocol.

Name	Company	Job Title
Anonymous Advisor	PCL Inc	Project Coordinator

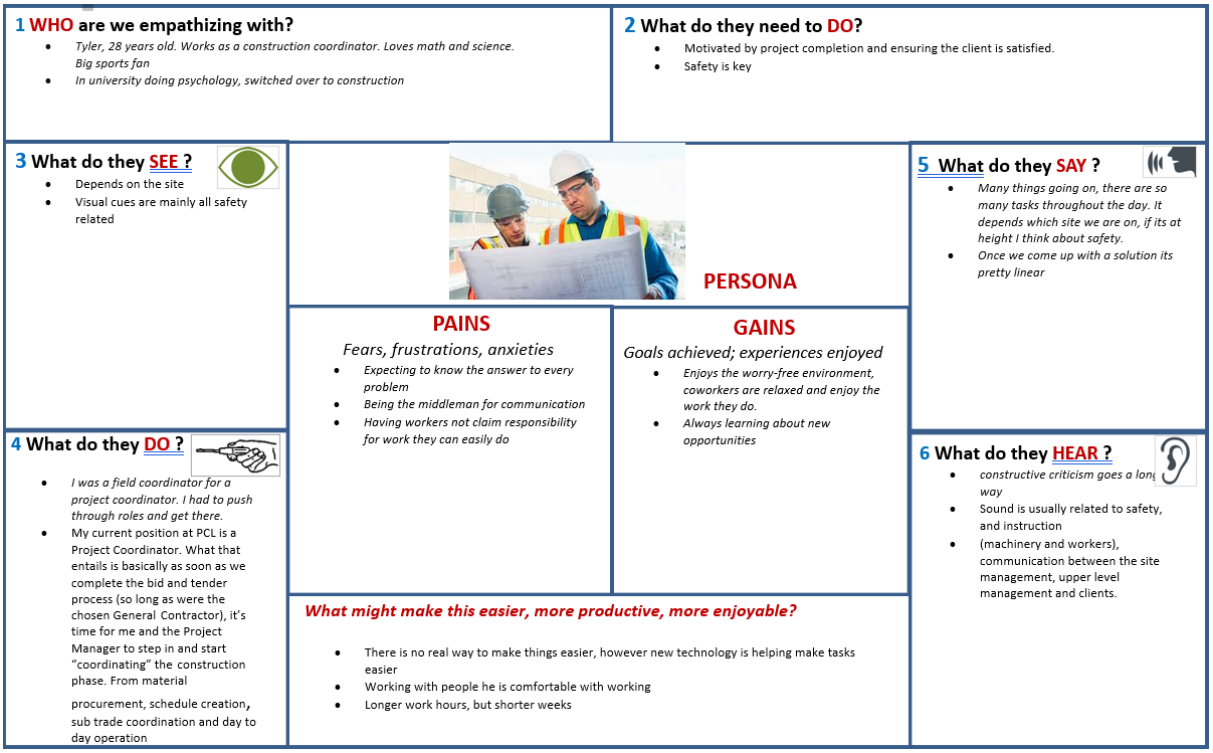
The working environment of a road construction site involves a plethora of heavy machines and open excavation, hence a lot of dangers presented to a construction worker. All workers were wearing protective equipment, such as a hard hat, steel toe boot, especially insulated pants, and a visibility vest. After interviewing Byers, he provided helpful information about the safety on a site, information that would not be noticeable at first glance. He mentioned the need for verbal communication, so that all workers in the vicinity are aware of the environment.

During the interview, safety seemed to be the largest concern for Byers, being a project coordinator, he highly stressed the importance of safety and its importance to maintain orderly construction and staying on schedule. When unsafe practices are performed, it slows down the entire site, because everything must be stopped to ensure the safety of others not aware of the situation.

One of the greatest challenges for the construction industry is the weather, Toronto has an unpredictable weather pattern, and the weather has been a factor of danger to many sites, in fact construction sites often go through a preparation to ensure inclement weather does not affect the site.

2.1.3 User Observation – Activity Mapping

Empathy Map Canvas



Major Take-aways from the Empathy Map

The major take-aways from this empathy map were that safety is key on a construction site. All throughout the interview, the user was stressing the importance of the safety of the construction workers and those around the sites, such as pedestrians. For the hear, see, and say sections, the topic of safety was something that came up right away. The empathy map also shows the need for improvement in the field. The user mentioned that the work schedule should be improved and changed. His suggestion is one that is quite common and suggests replacing the current 5-day work week, with a 4-day work week. This would work by extending the hours and work only Mondays to Thursdays. He mentioned this would improve productive, because Fridays tend to be unproductive, he came to this conclusion after observing construction workers just wanting to get a start on the weekend and not working as much. The observation he brought forward was very interesting, and considering the

position he is in, of constant observation it is one that can bring an interesting development to the industry.

Understanding the User

The user being observed is Anonymous Advisor a project coordinator for PCL Construction, however since Anonymous Advisor is not a front-line construction worker the tasks observed had to be written from his perspective, however Anonymous Advisor has had experience as a construction worker and thus was able to explain the daily activities of one.

The users step onto the construction sight as early as 6am to start the day and will usually start with a debrief of the tasks to be done for the day. Each new worker is given a tour and safety break down of the site to ensure everyone is on the same page. The standard set of PPEs is brought to the site, and every worker must wear their equipment while on site, this is heavily regulated and if a worker is not wearing the proper equipment, they will be given the proper equipment.

While using a heavy machine the workers have a spotter to look out for any accidents that may occur, it is the spotter's job to convey information effectively to the worker driving, and to keep others out harms way. The driver is responsible to trust his spotter as well as seek out any risks while performing their job as well. Safety cannot and will not be ignored and is the number one priority on each construction site.

2.1.4 Human Factors – Research of Existing Products

Forklift Crane

Existing products incorporate human factors effectively, however, seem to ignore the prolonged use of such safety equipment may hinder the user. There are such products that fall in the realm of industrial equipment, and completely sidestep the risk of physical injury, such as a small crane that can be attached to a forklift.

Figure 5- ***Retrieved from https://www.globalindustrial.ca/p/material-handling/forklifts-attachments/cranes-hooks/best-value-forkli-telescoping-jib-boom-crane-4000-lb-capacity?infoParam.campaignId=T9F&gclid=Cj0KCQiA48j9BRC-ARIsAMQu3WQwfPJM7QD_Lf6E7PvHM***

This device easily converts your forklift into a mobile jib boom crane. Simply slip the forks of your counter-balanced forklift truck into the fork pockets of the jib boom and attach the provided safety chain to the forklift truck mast.

Exoskeleton

ShoulderX V3 is the world's most advanced shoulder-supporting exoskeleton. The device counterbalances the weight of an arm or tool, comfortably redistributing loads onto the wearer's hips. shoulderX enables one to perform chest to ceiling level tasks for longer durations or with less effort.

During simulated overhead tasks, shoulderX has reduced muscle activation by up to 81%. Study participants reported reduced exertion across the shoulder, neck, and back regions and use of the exoskeleton was preferred by all over the unassisted condition.

Figure 6 – ***Retrieved from*** **https://www.suitx.com/shoulderx**

Human Factors

In terms of human factors, the forklift crane is simple to attach, using two people to attach it to the forklift's spurs, after which it should be secured in place. The exoskeleton suit features an adjustable suit which can mount on the user's shoulders and offers a reduction in load for the user.

The differences between the two products highlights the human factor of design, where as the forklift crane does not have additional features to aid people to equip it, the exoskeleton suit is capable of being put on by one person with relative ease.

2.1.5 Safety and Health – Research of Existing Products

The need for a product to mitigate a safety and health concern has been on the rise in construction, mainly due to ineffective nature of current products such as a lifting belt, which is a restrictive motion device, but not one that mitigate muscle strain, or the injuries brought on by repetitive actions.

Figure 7 – ***Retrieved from*** **https://www.roguecanada.ca/rogue-ohio-lifting-belt**

A lifting belt is effective for lower back strain, the restrictive motion device ensures the user does not bend the lower back while lifting. A rather simple solution for a painful and expensive injury.

Safety and Health

The safety and health of each construction worker is important, and as mentioned previously, is the number priority of each construction site. Due to the high requirement of good physical health, a lot of the construction workers have physical activities outside of work according to Anonymous Advisor.

2.2 Product Research

This chapter focuses on the current products available to the market and how it aids users and where there are draw backs. This chapter will also take a glance at the functionality, aesthetics, materials, manufacturing, and sustainability of existing products.

Initially ten products were examined, with four products being critically analyzed for the sake of this report.

Product Name	Product Image	Product Reference
Crown RC Stand-up Forklift		https://www.crown.com/en-ca/forklifts/rc-stand-up-rider-counterbalanced-truck.html
Rogue Lifting Belt		https://www.roguecanada.ca/rogue-ohio-lifting-belt
ShoulderX V3		https://www.suitx.com/shoulderx

Jib Boom Crane Arm		https://www.globalindustrial.ca/p/material-handling/forklifts-attachments/cranes-hooks/best-value-forkli-telescoping-jib-boom-crane-4000-lb-capacity?infoParam.campaignId=T9F&gclid=Cj0KCQiA48j9BRC-ARIsAMQu3WQwfPJM7QD_Lf6E7PvHMTBKOWesEojsgV8PX3pdJgkzLuqOLzPVfKQaAplqEALw_wcB

2.2.1 Benchmarking – Benefits and Features

The product benchmarking for this thesis consisted of highlighting important features of the four analyzed existing products. Each product is available for the consumer and is proven to be effective at its task in the field. These products were specifically chosen because of their relevance to safety and workplace efficiency, being able to offer workplace improvement while being safe alternative.

Key Benefits of Comparable Products	
Keyword	
Comfort	
Convenience	
Safety	

Key Features of Comparable Products	
Keyword	
Comfort	
Other	
Safety	
Power Trains	
Suspension	

2.2.2 Benchmarking – Functionality

After critical analyzes of the four products two functions came out as the primary focuses, efficient transportation on a construction site and a varying amount of MSDs mitigation methods. On the surface, these two categories offer many benefits when applied together provide a design opportunity.

Transportation functionality allows for workers to traverse construction sites in reasonable time and while providing comfort to the driver. The importance of comfortable driving extends to mitigating MSDs, with excessive vibrations only furthering the issue.

The mitigation methods give the workers comfort in their movements, allowing them the freedom to move within certain areas to mitigate an MSD, for example the lifting belt ensure the lower back is straight while lifting heavy objects. Or even a method such as an exoskeleton suit which not only helps workers lift comfortably but also restricts certain motions that may exacerbate the issue.

2.2.3 Benchmarking – Aesthetics and Semantic Profile

Taking a glance at the current products which offer efficient transportation and those that help mitigate MSDs, there is a commonality, these products do not overlap with their functions. Most products share the one purpose and often do not stray far from their functions.

Figure 8 – ***Retrieved from https://www.michigancat.com/***

Equipment such as a standing forklift offer a compact solution, however visually these designs appear heavy and bland and the same goes for the forklift crane jib, a heavy and non-human centered design offering no handles for the workers to use to attach the jib. While being an effective device to expand the functions of a forklift, it does offer benefits to the user and can spur other injuries.

Other equipment such as an exoskeleton suit visually represents strength and visually reduces a lot of the apparent weight with thin parts. However, this creates the assumption of a high price tag often associated with these heavily engineered components.

The form of these products all varies for its purpose, a CAT caterpillar is an appropriate size for its purpose, however, is very bulky, unlike an exoskeleton suit which is built to be as light as possible.

The use of colour is very important through the construction industry, with yellow or orange being used on most machines, these two colours easily brings all workers attention to whatever is moving on the site. Colours such as red may identify a dangerous moving component or something difficult to use. The use of colours is important within machinery, these colours signify the difficulty of getting into the machine using a certain handle or step, green is used for relative ease, whereas red means the worker can enter with great difficulty (Godwin et al., 2014).

Figure 9 – ***Retrieved from https://www.workplacesafetynorth.ca/sites/default/files/resources/Heavy%20Equipment%20Ergonomics%20-%20Dr.%20Alison%20Godwin%20-***

For the most part, construction equipment is made using stainless steel or aluminum, the machines will come with a coat of protective paint to aid with anti-corrosion (Avion, n.d.). Most exterior metal parts seem to have a matte finish, except for the components that are required to aid workers into the equipment, in that case the metal is finished with a textured pattern which will maximize grip. Plastic components are typically matte finish, this is because there is simply no purpose for a glossy component to be on a construction site.

Figure 10 – *Retrieved from https://www.avionalloys.com/top-metals-used-in-heavy-machinery-equipment/*

Construction equipment lack emotion and have very little expression, understandably these vehicles do not need a loving expression because they are simply made to get dirty. This in of itself is an expression, representing the nature of these pieces of equipment, the rough and dirty nature of a construction site asks for the machines to not be made with complex and expensive curves or components. This

utilitarian aesthetic is effective in conveying the function of the equipment, especially with the exposed parts and fasteners and the rigid lines and simple paint jobs.

It is very unlikely a heavy piece of equipment will be able to do small intricate task, and it is assumed that it will not be able to achieve this. Whereas something as light as an exoskeleton suit may be perceived to not be able to aid lifting extremely heavy components or seen as fragile. There is clear product perception being made, with large equipment being able to achieve more of the heavy work with ease.

2.2.4 Benchmarking – Materials and Manufacturing

The materials chosen for this project are standard material choices for construction equipment, raw metals, paint to protect the metal, plastics for components such as buttons and joysticks. There will also be glass covering for the screen functions. Rubber components for grip and durability for parts such as the handles and other parts of the buttons. The materials chosen are fairly standard materials found on modern components with the exception of copper wiring and lithium for the electric powertrain.

2.2.5 Benchmarking – Sustainability

There are few sustainable initiatives in modern day construction equipment, as discussed before the steps technology has taken are beneficial however compared to other industries construction is failing to catch up. Some modern equipment has an economy mode or on-demand throttle, “economy mode or on-demand throttle is another useful technology in loaders. “This technology provides engine power automatically and only when it’s needed. The result is up to 20 percent fuel savings” (*Sustainable Technology on Construction Equipment*, n.d.). On-demand throttle is not a new technology, but a useful technology being implemented in construction, however with the industry moving into electric powertrains it is slowly becoming obsolete.

2.3 SUMMARY

Following the interview with Anonymous Advisor, a lot of information about standard safety was presented. The most important information was in the form of what should the equipment feature to protect the user. Firstly, the protective grate was added after Anonymous Advisor mentioned that tempered glass is very shatter prone and constantly replacing the glass is not cost effective, hence Anonymous Advisor suggested a protective grate made of metal, in the case of an accident the metal would simply deform instead of shattering which would pose an risk of injury to the operator. The addition of a wider viewing port was also added, since mirrors are not always implemented on construction equipment the added value of a wide viewing angle provides the operator with optimal protection. Anonymous Advisor suggested having larger diameter wheel in the back, this offers stability in the rear where the counterweight is placed.

The major take-aways from this empathy map were that safety is key on a construction site. All throughout the interview, the user was stressing the importance of the safety of the construction workers and those around the sites, such as pedestrians. For the hear, see, and say sections, the topic of safety was something that came up right away. The empathy map also shows the need for improvement in the field. The user mentioned that the work schedule should be improved and changed. His suggestion is one that is quite common and suggests replacing the current 5-day work week, with a 4-day work week. This would work by extending the hours and work only Mondays to Thursdays. He mentioned this would improve productive, because Fridays tend to be unproductive, he came to this conclusion after observing construction workers just wanting to get a start on the weekend and not working as much. The observation he brought forward was very interesting, and considering the position he is in, of constant observation it is one that can bring an interesting development to the industry.

CHAPTER 3 – ANALYSIS

3.1 Analysis- Needs

Road construction workers today, have incredible safety measures with constantly updating protocols, new and safer machinery and workers who are constantly aware of the situation at hand. However, these safety measures at times can get in the way of user satisfaction and are often designed with only the ergonomics in mind, and at times the ergonomics are centered on rather large men, this completely negates the smaller men in construction, and not to mention women as well.

3.1.1 Analysis – Needs/Benefits Not Met by Current Products

Current products for road construction workers assist in varying ways, and may be price irregularly, for example a simple lifting belt may cost anywhere from the range of $40.00 CDN- $85.00 CDN, while an exoskeleton suit may cost in the thousands. There is a wide variety of products that may help workers with MSDs, however none of these products directly help with mitigation of MSDs. The products available at a reasonable cost are going to be referred to as restrictive motion devices. A restrictive motion device is a device that simply restricts the motion of a user, for example a lifting belt is put on the lower back area of a user and ensures that the lower back stays straight while lifting.

There is also a long line up of anti-vibration gloves, and anti-vibration shoes, these products are intended for those either using machines with high vibrations or standing on vibrating platforms for a long duration of time. Anti-vibration gloves are primarily used by jack hammer operators, while anti vibration shoes are used by those using large machinery with active moving parts.

3.1.2 Latent Needs

Latent Needs	Benefit Statements
Comfort	Offers comfort in the form of proper ergonomics, to ensure workers can stand for long duration of time and use components effectively.
Transportation	Offers effective transportation in the site, while being able to transport heavy loads.
Productivity	Capable of completing tasks effectively, no hesitation in the operation of the product
Organization	Capable of helping the user effectively manage the site, all while having a noncomplex interior to allow for ease of use.
Less Injuries	Being capable of not having to do the heavy lifting themselves, the users will find that there will be less injuries due to the lack of physical energy exerted.

3.1.3 Categorization of Needs

A categorization of needs was laid out to effectively understand the needs and wants of the user, this table helps put into perspective exactly what is needed and wanted from the workers on site.

Needs/ Wants
Efficiency
Cost
Transportation
Less Injuries
Safety
Ease of Use
Style
Comfort
Organization

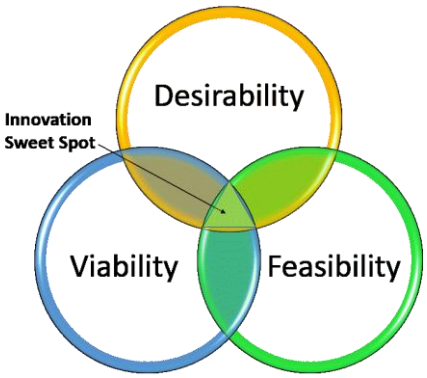


Figure 11 *Retrieved from- https://medium.com/innovation-sweet-spot/desirability-feasibility-viability-the-sweet-spot-for-innovation-d7946de2183c*

3.1.4 Needs Analysis Diagram Desirability

Construction workers come into work to simply work, their need for safety has not been overlooked the machines construction workers use are all very safe and have many ways to keep the operator safe. Despite the dangerous tasks' construction workers accomplish each day, there is always the desire for safety around each of these tasks. The need for a different design direction is needed, many regulations are now changing

to ensure human ergonomics are met effectively, such as creating seats which are set at an offset angle to prevent unnecessary neck movement and creating handle and steps following certain guidelines.

Viability

As MSDs are now becoming a more known issue amongst workers, there is an extension of safety presentation to help mitigate MSDs, construction sites are required to give frequent breaks to those using machines with additional risks to MSDs, such as machines with excessive vibrations, there is also a healthy rotation of workers using machines which are difficult to get into. Construction equipment companies are now progressively designing equipment with the user in mind, and workers in the industry are all in support of safer equipment for all to use.

Feasibility

MSDs do not only affect the users, it also effects construction sites, and the economy of the company as well. MSDs are the most common workplace injury resulting in over 40% of all lost-time injuries in Ontario (Ontario Ministry of Labour, 2012). These injuries change the way an entire construction site operates, when a worker is injured and out for recovery this will bring many different implementations of staying on schedule, which can be difficult with even one less person. Mitigating MSDs also brings the companies economy into play, the company pays the injured workers for the time they are off duty, and at times be asked to pay for medical bills. Less workers injured and off work means that the project stays on schedule/ no construction delays and prevents the company from paying additional fees to workers.

3.2 Analysis – Usability

User observation is used to develop an understanding of the user and to develop a User Journey Map. These observed activities followed a user on a construction site for the first time, the user was shown the different tasks he would need to complete daily.

3.2.1 Activity – Workflow Mapping

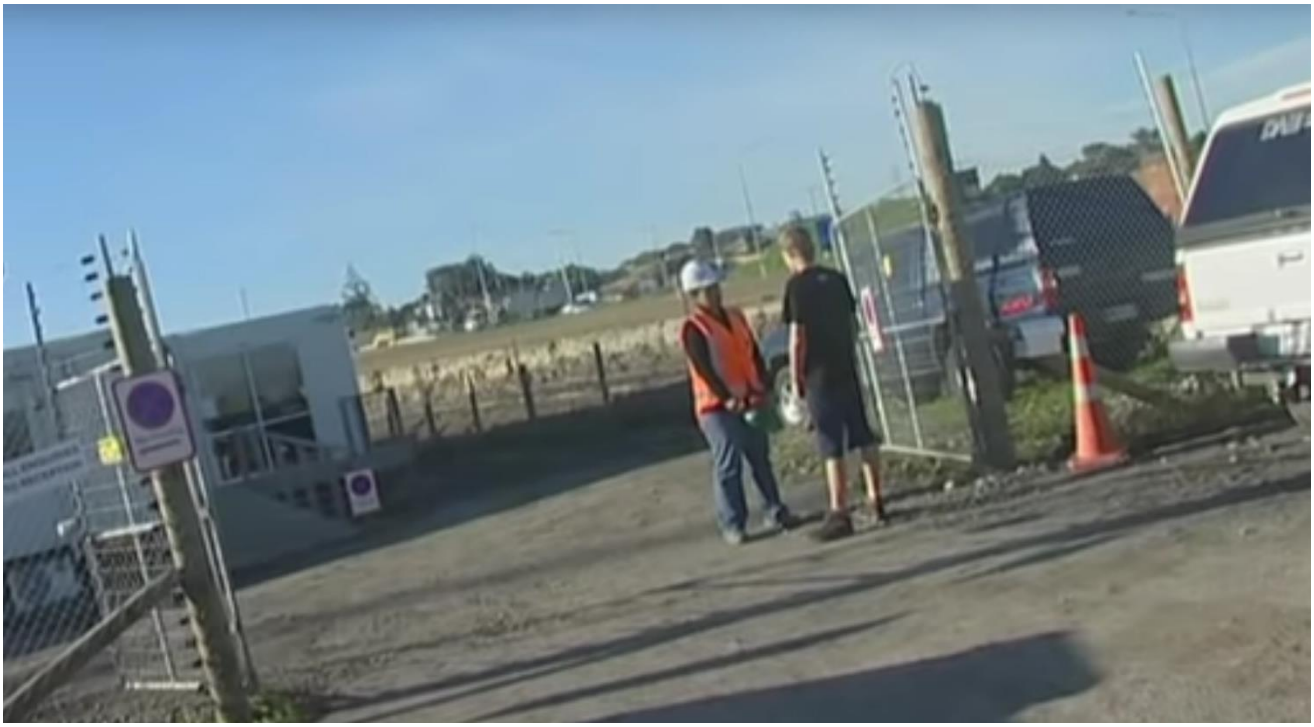


Figure 12– ***Retrieved from https://www.youtube.com/watch?v=f8a95Nkg2fA***

Activity 1	Steps/ Process	Base User Experience	Potential for Improvement
Preparation On-site Arrival	- Meet with site manager - Get familiarized with PPE	- User is greeted at site and explained the brief for the day - User is given PPE and learns the value of protection	- Rather than meeting outside on the site, this should have happened indoors - User should have came prepared with PPE in hand

Figure 13 – ***Retrieved from https://www.youtube.com/watch?v=f8a95Nkg2fA***

Activity 2	Steps/ Process	Base User Experience	Potential for Improvement
Traffic Control	- Climb onto the truck and attach harness - Pass cones to the other worker to place onto the road	- The user mentioned the task was very fast paced - The user did enjoy the task	- The fast-paced nature of the task could be achieved with a similar machine - The motion was repetitive, and a risk of an MSDs

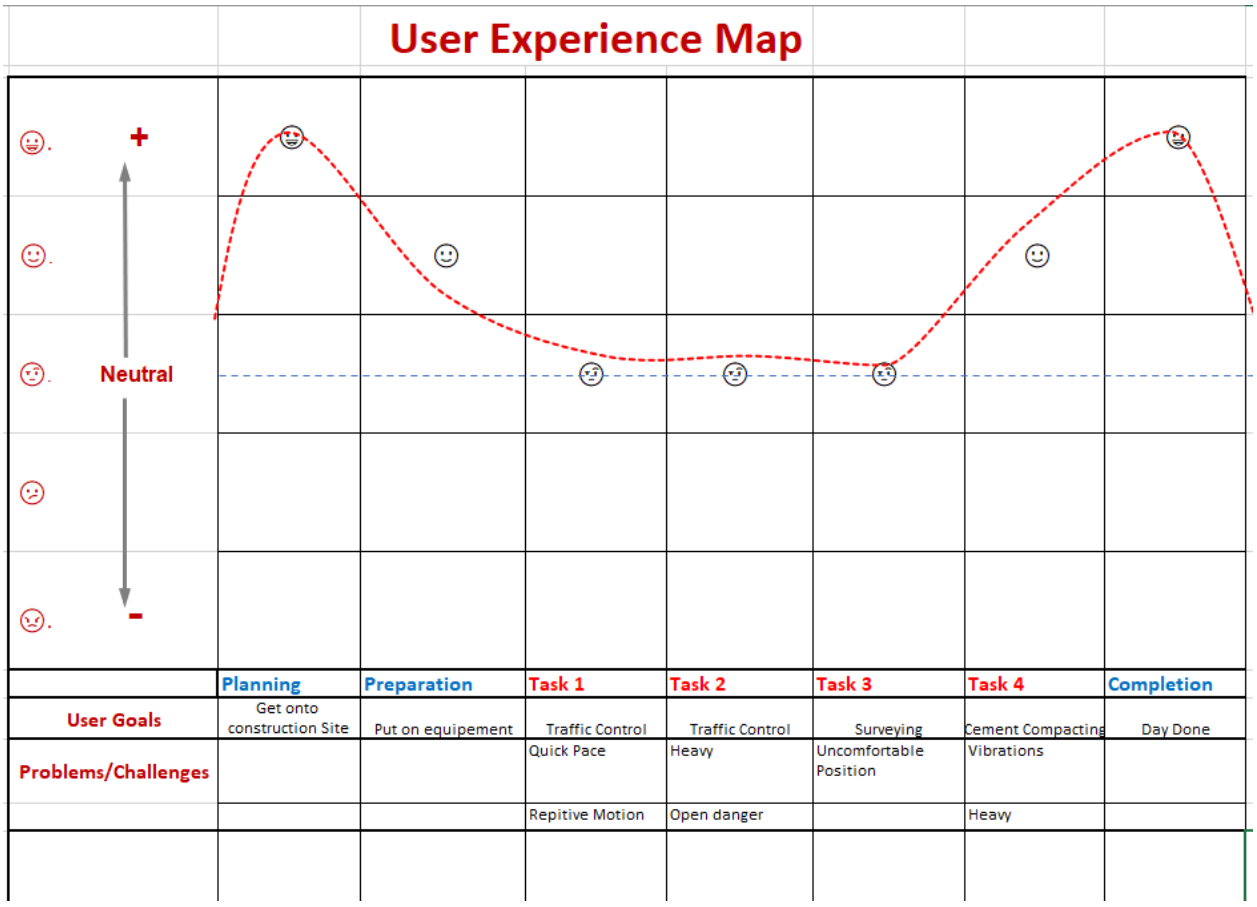
Figure 14 – ***Retrieved from https://www.youtube.com/watch?v=f8a95Nkg2fA***

Activity 3	Steps/ Process	Base User Experience	Potential for Improvement
Land Surveying	- Find flat land - Locate surveying points - Hammer the surveying machine into place	- The user enjoyed this task less - The task was something the user was not accustom too	- While the user was hammering the fasteners, he was in an uncomfortable position, another MSDs risk

Figure 15 – ***Retrieved from https://www.youtube.com/watch?v=f8a95Nkg2fA***

Activity 4	Steps/ Process	Base User Experience	Potential for Improvement
Cement Compacting	- Learned to use compactor - Uses compactor to flatten dedicated area	- Easy to use and enjoyed the task - Mentioned it was easy to control the compactor	- Heavy object, pushing and pulling is uncomfortable - Vibrations - Both of these are MSDs risks

3.2.2 Activity – Experience Mapping



	Planning	Preparation	Task 1	Task 2	Task 3	Task 4	Completion
User Goals	Get onto construction Site	Put on equipement	Traffic Control	Traffic Control	Surveying	Cement Compacting	Day Done
Problems/Challenges			Quick Pace	Heavy	Uncomfortable Position	Vibrations	
			Repitive Motion	Open danger		Heavy	

As observed on the experience map, the user begins the day happy with the new challenge, however as the day progresses it is clear they begin to develop a neutral reaction to the work being done. During the heavy workloads he is having a neutral reaction, this is understandable since these jobs were labour intensive, however what is interesting is his reaction to the compactor. While he is using the compactor, his mood elevates and he can clearly say he enjoyed the experience, seeing this shows that he is happier with work that is easier and less labour intensive. The compactor only needs to be pushed and pulled, and these actions are relatively easy to do. This observation shows that users would much rather prefer to have a job that is less labour intensive but still provide the satisfaction of getting a difficult task complete.

3.3 Human Factors

Introduction

Modern construction equipment faces vigorous safety testing to maximize human well-being and system performance. Modern day equipment is simply functional, it offers the ability to work in difficult terrain and achieve tasks that would otherwise take a person a long time to accomplish. Equipment today faces many issues regarding human ergonomics such as: Line-of-sight and visual field, Seating Quality, Cabin Space, Control Layouts and Ingress and Egress.

As it currently stands, modern equipment has been produced similarly for decades with no major changes to address these issues. Line-of-sight and visual field issues can be fixed with a larger opening available for the user to see, as well as providing mirrors with certain convex lens to see blind spots. The quality of the seating in modern equipment is acceptably comfortable, however the seating is often designed for a large percentile man. The key findings from the model were the clearance of the equipment, the ease of use, and most importantly mitigate MSD.

Literature Review

First and foremost, the step to get onto the platform of the miniature crane, this step is required to be close to ground enough for the smallest of people to be able to step on. However, considering the small percentage of women in the field, the height of this step cannot be compensated simply for a 5^{th} percentile woman. The clearance of the step is being placed at 16 inches, the handle to assist the user pull themselves up will be 41 inches above the ground, and the bottom of the handle will be 33 inches above the ground to help the lower percentiles. It is important to ensure 3 points of contact for the user (Godwin et al., 2014), these 3 points of contact are used to prevent an event (injury) from occurring. WSN took 359 cases of injuries, in which, 32% the users foot slipped, 6% missed a step and 6% Lost hand grip. Environmental factors were noted for 11% of all incidents and wet, icy, and muddy conditions were only indicated for less than 4% of the incidents. These injuries are contributed to poor design and a lack of consideration of human ergonomics.

Methodology

The ergonomic evaluation and analysis of current construction equipment design was conducted with the following considerations:

Objective(s)

The aim of the 1:1 size mockup is to understand the movement needed to enter and exit the equipment with ease, as well as the space around the user to ensure their comfort. The 1:1 model will be used to simulate the measurements of the handles and clearance to get onto the equipment, as well as figuring out the layout of the environment.

Decision(s) to be Made

The following interactions relevant to three specific major body part areas were investigated to minimize the negative experiences and maximize the positive experiences of:

1. Getting into and out of a stand-up crane (Legs)
2. Operating visibility (rear blind spots) (Head neck and Shoulders)
3. Interaction with operating controls (Hand and Arms)

Description of Users Targeted by Product

The target demographic were road construction workers working with moving equipment, the target ages observed were between 25-55. As it currently stands according to statistics Canada, most construction workers are male, as females take up only 9% of the work force, this means men were the primary users being observed.

Evaluation process

The evaluation process consisted of designing a full scale (1:1) ergonomic buck of the cabin which allowed for critical observation of the following:

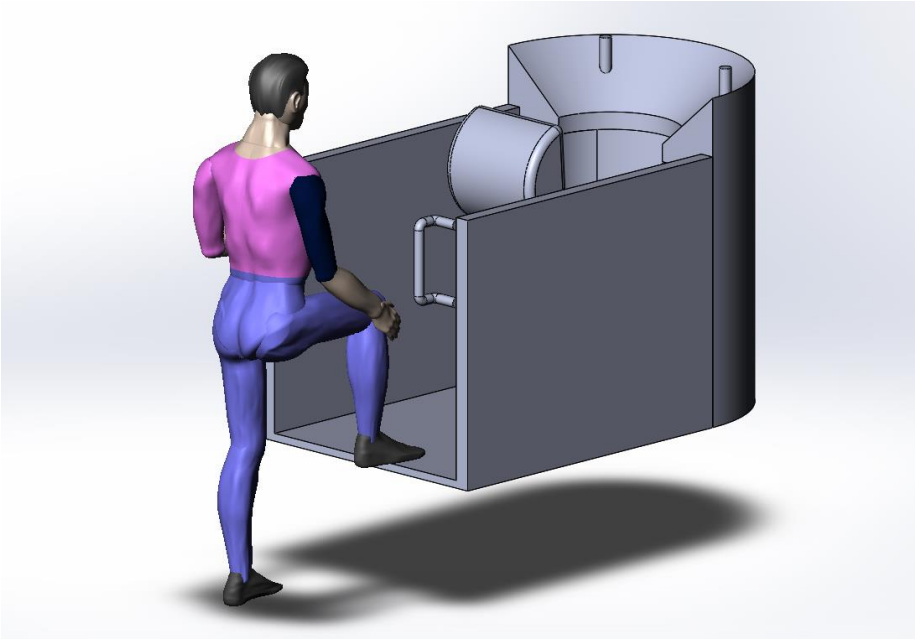
1. Observing how the user enters and exits the machine. (Ingress/Egress)
2. Observing how the user checks their rear blind spots and discovering how obstructive they are.
3. Documenting the inside of the cab. (Position of joystick, foot pedal, buttons etc.)
4. Identifying critical human dimensions affecting product use

Description of User Observation Environment Used in this Study

For this study, a user observation was performed in the program SolidWorks, using an accurate 90th percentile male.

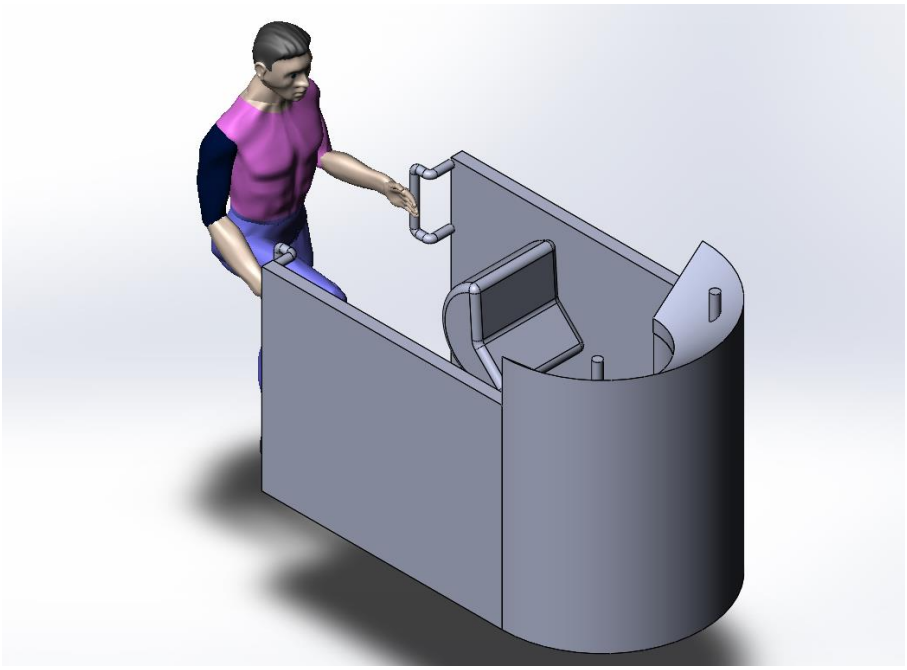
Results

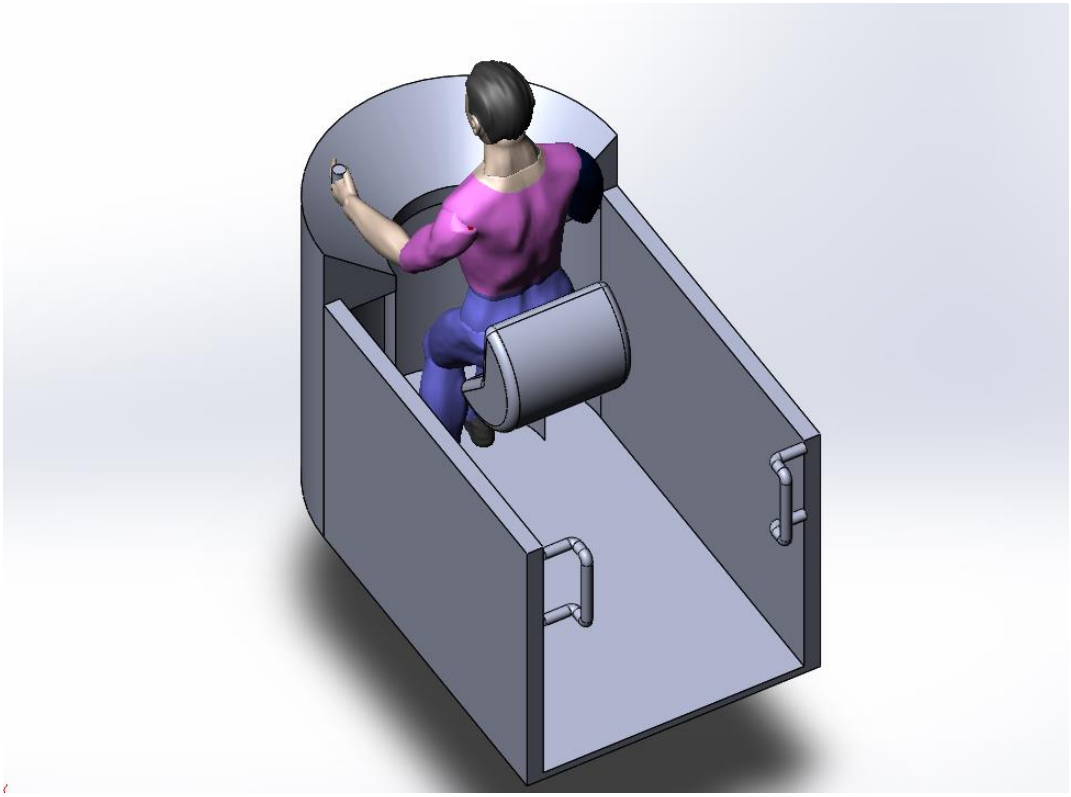
2)

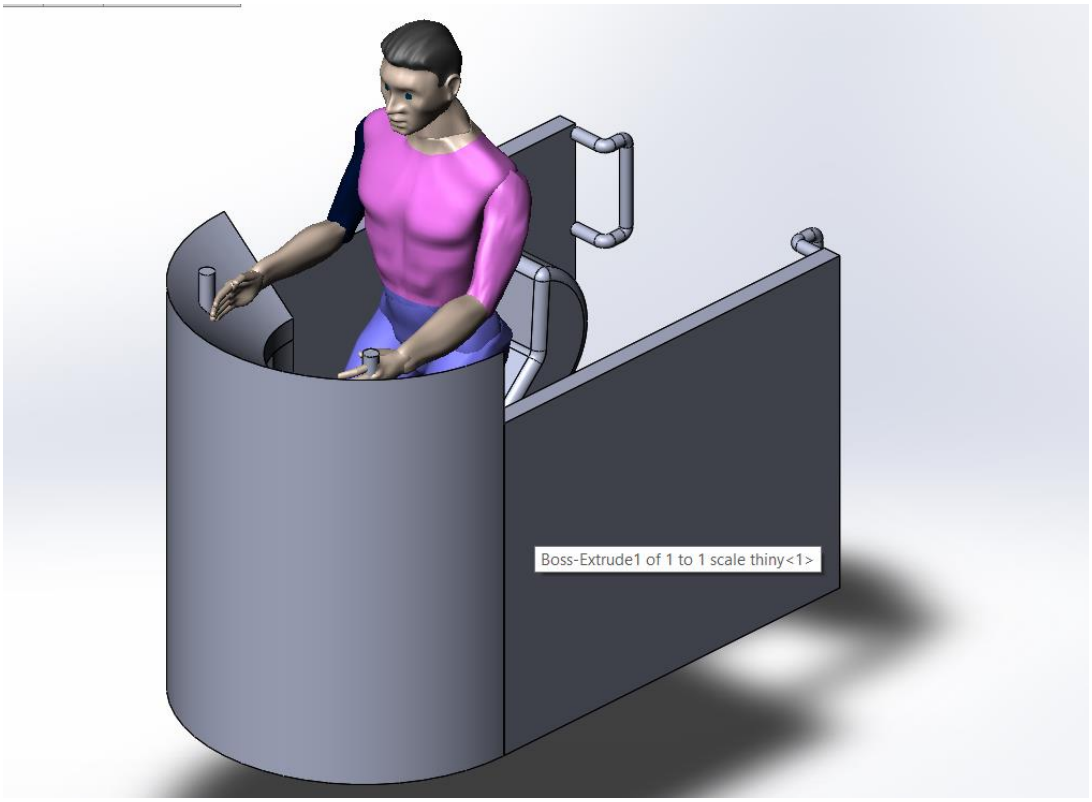


1:1 Scale Model

90th Percentile Man







ANALYSIS

Throughout this project there have been many components involved with human ergonomics, and while the design process is still on going there have many details that warrant a change based off the research complete for this study. The first point of human contact on the equipment would be the step up onto the platform, this platform is 16 inches above the ground, enough for the smaller percentiles to comfortably raise their leg above and to rest it on the ledge. The next point of contact would be the handles on the inside of the equipment, these handles are positioned 48 inches above the ground (at the highest point), and the handle extends down 10 inches to allow for the smaller percentiles to be able to use the handles as well. The ingress and egress of the equipment is often the most dangerous part of the equipment, according to the WSN 359 cases of injuries, 32% the users foot slipped, 6% missed a step and 6% Lost hand grip. Environmental factors were noted for 11% of all incidents and wet, icy, and muddy conditions were only indicated for less than 4% of the incidents. These injuries are contributed to poor design and a lack of consideration of human ergonomics (Godwin et al., 2014). The general

rule of thumb is to have 3 points of contact for ingress and egress to decrease the risk of injury to the user, and this case the 3 points are the two handles on the inside of the equipment and step up to the platform. The second point of human contact would be the control panel and standing seat, these next few ergonomic considerations were made to consider the large 95th percentile, since the seat is adjustable and could accommodate all other below 95 without any problems. The seat should be able to rotate, a study WSN shows that there is significantly less neck rotation when the seat is capable of swivel, and thus reducing the possibly of a user hurting their neck. Around the cabin area there are different lines of sight, the rear of the cabin is exposed, the sides are exposed and protected by a grate to ensure the safety of the user within. The angle at which the control panel is set to should be functionally comfortable for all, the panel is set at 40 degrees, this angle offers comfort for those sitting and/ or standing. Along with human ergonomics, there are other portions of construction equipment, that are required to be adhered to. For example, the cabin needs to have a consistent temperature throughout the cabin due to the fear of heat exhaustion. However, temperature consistency would not be a concern due to the open back nature of the equipment. The open back of the equipment also helps sound travel throughout the equipment, as sounds are very important on a site, it is of upmost importance that all alarms and people are heard. Another human consideration would be to colour code the ergonomic portions, such as handles and steps, making sure these aids to the user are highlighted in a bright colour such as green and/ or yellow. The joysticks used to control the equipment's arms are 21 inches apart, and 14 inches away from the user's chest, this offers enough space for the arms to be held at 135 degrees, this angle offers the maneuverability needed to move the wrist back and forth, and side to side without discomfort for a long duration of time, or at the least until the mandated break away from machinery.

Limitations and Conclusion

Identifying critical human dimensions affecting product use were as follows:

1. The side pillars block the operators view considerably. (Pushed Back)

2. The operator must exert reasonable force to climb onboard. (A Lower Step)

3. Operator cannot see all that is behind him. (Full Swivel Seat)

Some Ergonomic Issues That Are Still Not Yet Resolved

Some of the user needs are still resolved, for example: the swivel seat, the functionality of the pedals, and simple questions such as how the user may interact with the equipment in such a way that may harm the user and/ or the equipment? The swivel seat is still a question mark in this equation, there is a need for comfortable seating to prevent standing on a vibrating platform, how ever implementing the seating may be complex and may interfere with important components within the construction of the equipment. Another rather large question mark are the gas and brake pedals, since the user is using a standing seat, the pedals would need to have a unique operation method to prevent accidental activation. Understandably the user does not go out of their way to harm themselves or the machine when on a construction site, however it is crucial to ensure, if such an event does occur, it will not harm the user in any significant way.

Alternate possibilities for the future

The side pillars of the equipment were blocking the sight of the operator, to resolve this problem the opening for the user has been extended backwards, now offering a wider line of sight. The step to the platform may be considerably high, for future revision, depending how further research may proceed, an extra lower step may be added to offer an easier step up. This extra step may be a retractable step that can be retracted after being in use, to protect this step from any damage. The swivel seat may be a difficult consideration to add, however considering the benefits it brings it is a worthy addition to the equipment. Furthermore, these findings helped to create a design brief for the final design.

3.4 Aesthetics & Semantic Profile

A design aesthetic can and will make or break the first impression of a design, and depending on the need for the product, the aesthetic needs to represent the capability of the product. For example, a modern-day vehicle, will be given a sleek and aerodynamic aesthetic, regardless of the vehicle they are all designed to be efficient in every aspect. The aesthetic of a piece of construction equipment is very industrial, there is no need for an aesthetic, because these pieces of equipment are simply made to function.

However, this functionality is considered an aesthetic, the functional look is simple since all it must convey is the ability to accomplish the task it was designed to do. The approach to the design is to symbolize strength and stability, much like other construction equipment, these designs are capable of withstanding large threshold of weight, a partly due to the design but also due to the material chosen to be on the equipment.

The aesthetic that needs to be conveyed is strength and stability, a wide and rigid body is ideal to convey stability. Much like a sports car which is low and wide and is interpreted as very stable vehicle. Construction vehicles are also geometric, very rarely are their organic shapes incorporated into the design.

Many portions of the design need to suggest safety, such as a caged area to protect from projectiles on the construction site. There is also an absence in sharp component on the exterior of the equipment, also for the sake of safety.

Other component may be parts such as wheels track for traction throughout the construction site. Tracks are commonly seen throughout construction sites, primarily used for effective traction and because of how quickly regular rubber wheels wear down on a construction site.

Some of the inspiration for the form can be attributed to that of a Sperm Whale, the bulkhead of a whale resembles strength and power, and a shape that is mimicked in many designs symbolizing hydrodynamics and strength. The uneven shape of the whale head shows the structural integrity of the whale’s head. As odd as this comparison is, the head of a sperm whale is mimicked a lot in luxury cars to symbolize regality.

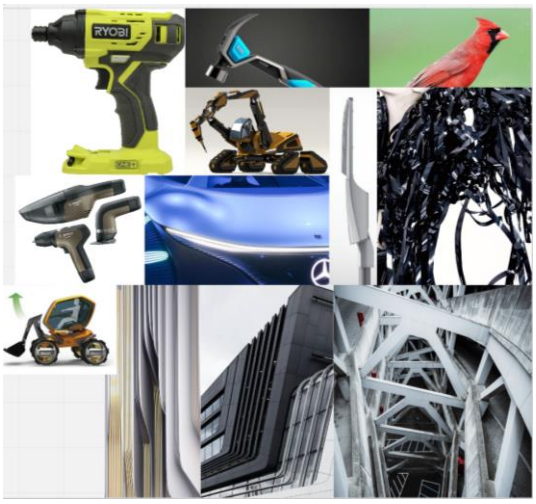


Figure 16 – Mood Board

3.5 Sustainability – Safety, Health and Environment

Safety

Safety is the top priority on every construction site, and according to Anonymous Advisor is the first aspect of a construction site that is taught to all new workers. There are many safety precautions available on a site, including all workers being familiar with the layout of the site, and being aware of all moving machinery. In Ontario, nine workers were killed between January 1st and August 31, 2015, seven of these deaths were directly related to heavy machinery. In 2014 six workers were killed by moving vehicles or equipment (Ministry of Labour, Training and Skills Development, 2015). Safety protocols are largely the responsibility of the worker to maintain, as per the Ontario Ministry of Labour states that workers must “ensure”, this implies the workers must be the ones always staying aware and keeping others safe.

Health

Current equipment is quite large and has the capability of moving heavy parts for hours on end, the consequence of moving heavy objects are high consumptions of fuel and high emissions. Heavy equipment uses low torque gear ratios, which require a lot of force to move, this adds to large amounts of emissions. For those on site this can impact their lungs and overall health: asthma, cancer,

cardiovascular health, mental health, and neurological diseases. (National Institute of Environmental Health Sciences, n.d.).

Environment

These findings have offered a large learning opportunity, the construction industry has been falling behind in the race to remain sustainable, and with these changes hopefully that will change in the future. Firstly, starting with the powertrain, looking into the two emerging sustainable sources of energy: hydrogen and electric. As beneficial as hydrogen fuel cell production would be to the Canadian economy, it would not be the effective choice for construction equipment, the sensitive hydrogen tanks would become a liability to a construction site. The electric powertrain not only takes up less space but would also be safer to the construction site and its workers.

Components using rubber such as the tracks and button covers would use recycled rubber and reclaimed rubbers to help manufacture these components. Interior details such as seats can be manufactured using vegan leather which would prevent the need for cow hide and holding the leather together would be a thread made of recycled plastic bottles. This type of thread is already being used in the footwear industry, primarily being used by Adidas the thread is made and provided by a company called Parley.

The metal structure will be made of reclaimed metal, and any off cuts will be repurposed to be used again, creating a cycle of always using what could have been used.

All plastic components will be made of reclaimed plastic water bottles, and other plastics that have not been disposed of properly.

3.6 Feasibility & Viability

Viability

Current construction equipment uses material to enclose the operator, to enclose the sensitive equipment such as hydraulics and cables and heavy-duty materials to close off the equipment from the elements of a construction site.

Construction equipment today uses common weather resistant metals on exterior components and on structural parts of the equipment. The current use of carbon alloys is not uncommon at all, carbon-based alloys provide similar corrosion resistance and strength as metals but provide the benefit of also being lightweight. Carbon alloys are favoured amongst many metals due to their stability and extreme temperature resistance, however they are priced highly compared to other metals.

The use of plastics is also very common on construction equipment; however, they are mainly used around components which do not reach high temperatures. The use of rubber is mainly used on the outside of the vehicles, and primarily used for tires and tracks. Rubber is a good shock absorber, and for large scale machinery with large tires they consist of most of the shock absorption. Rubber is used on the tracks because of its flexibility, ductility and traction, construction sites are rough terrain, if there is a puncture in the track, the rubber will not give way for further damage.

Feasibility

Construction equipment from the manufacturing side is relatively quite simple, using simple manufacturing processes. The body work of the equipment is made by cutting the sheets of metal to size either via stamping or laser cutting. To create unique bodywork shapes the sheet metal will go through a pressing process till the desired shapes are achieved. All the components are then welded together, and through these processes third parties supply components such as hydraulics, wheels, suspension systems. These third-party components are assembled according to the technical requirements asked by the manufacturer.

3.7 Design Brief

Efficiency: Provide efficiency to the workplace, completes tasks with ease and does not cause hiccups to the work being completed.

Cost: Reasonably priced, inexpensive for purchase and runs at a low cost. As well as saves the site money by requiring less cost to operate.

Transportation: Comfortable transportation throughout the construction site.

Less Injuries: The use of equipment prevents injuries, as the construction does not need to do any physical labour.

Safety: The equipment features protection to ensure the safety of the operator.

Ease of Use: The machine is simple to use, with little time required to teach the operator the basic mobility aspects of the equipment

Style: The styling showcases an ability to work and lift heavy object while also having an aggressive nature to the design.

Comfort: The equipment does not cause any discomfort to the operator.

Organization: The equipment offers a level of organization that does not hinder the performance of the construction site.

CHAPTER 4 – DESIGN DEVELOPMENT

4.1 Idea Generation

This chapter will be demonstrating the design process of the proposed MSDs mitigation equipment, along with additional featurettes. The topic being intended for construction, it was important to create a piece of equipment that would not simply be another piece of existing equipment. The current industry was a piece of inspiration and provided information about the safety requirements of equipment along with standard components to be featured such as adequate ingress and egress, and safety features such as a diamond treadplate on the floor of the equipment.

4.1.1 Aesthetic Approach

The approach for this thesis was to create a piece of equipment that presented itself as a tough candidate for current equipment, to give the equipment an aggressive look ideally with an inspiration from an animal which possess power and agility.

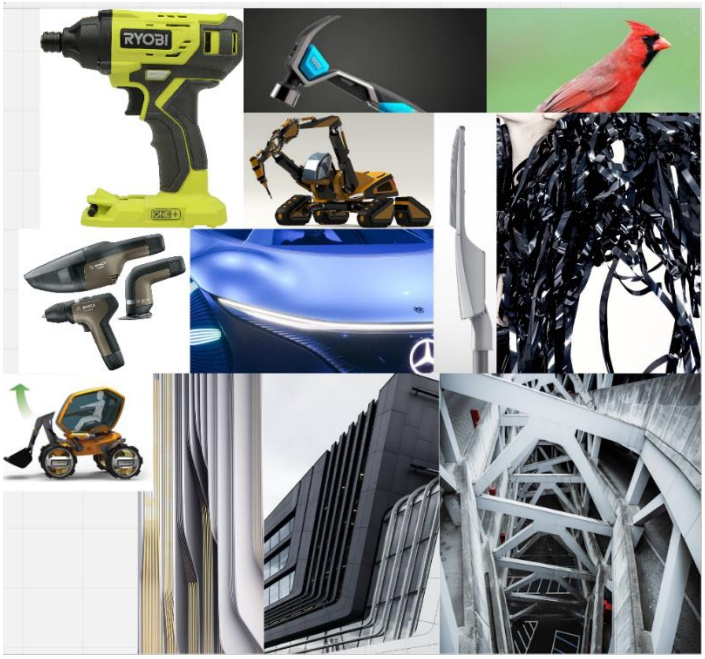


Figure 17 – Mood Board

4.1.2 Mind Mapping

a)

USER Primary, Secondary and Tertiary	**PRODUCT** Benchmarked Products	**ENVIRONMENT OF USE** Various Environments of Usage
Road Construction Workers (Primary): Ground level workers 22-45 Years old - Long hours (nearly 9 hours) - Mostly manual labour, consisting of lifting and repetition of tasks	**Physical therapy:** - Is not a preventative method - Does not focus on areas such as joints or tendons - Cannot relief portions of the spinal discs - Often comes with medication, and not a viable solution	**Construction Site (Road/Highway):** Road work, primarily done on roads and highways - Exposed to other vehicles on the road - Hot/cold temperature exposure - Dangers of the construction site
Equipment Operator (Primary): Crane operators, machine operators - Possible mismanagement of equipment - Constant repetition of work	**Knee Brace:** Helps with knee alignment and takes pain away from movement - Quality knee braces are expensive - Not recommended to wear one over a long duration of time due - Can weaken muscles if worn consistently	**Construction Site (Commercial):** Construction of commercial structures - Higher risk of falling - Dangers of a construction site - Accessibility
Supervisor (Primary): Oversees construction activities - Checking in on those with MSDs - Identifying MSDs or workers doing an action incorrectly	**Anti-Vibration Gloves:** Primarily used to reduce vibration while using hand tools with excessive moving parts - Not particularly effective at reducing vibration frequency - Must be fit perfectly to the worker as to not impede the worker	**Construction Site (Industrial):** Construction of manufacturing and processing plants - Higher risk of collapsing buildings - Higher exposure to dangerous conditions
Medical Personnel (Secondary): Emergency Medical Technicians - Arriving at the scene, which may be hazardous for emergency response vehicles - Getting to the person in need of help	**Kneepads:** Primarily used for workers on their knees for long duration of time - Kneepads can cut off circulation	**Medical Office:** Area to use for assessments - Accessibility for those with a MSDs - Limiting amount of space - Not enough resources

- Returning to the EMT vehicle	- If not fitted correctly can cause discomfort to ankles	
Physicians (Secondary): Office physicians - Difficulty diagnosing - Checking up with patients - Catering individual solutions	**Anti-Fatigue Matting:** A matt typically placed in area which standing is required for a long duration of time - Inefficient method - Must be moved to use in different areas - Collects dirt, and not a sustainable option	**Domestic Use:** Primarily home use - Family stigma may cause embarrassment to those with a MSDs - Limiting space at home
Researchers (Secondary): Design and conduct research to investigate preventative measures and treatments. - Researching patients with MSDs - Requesting certain actions to be done, which may inflame MSDs	**Shock-Absorbing Insoles:** Used on large scale machines with large amounts of vibrations - Very commonly used, however do not take into consideration long shifts over 4 hours - Not sustainable solution	**General Public:** Areas with a public presence, such as a store or recreational parks - Person with a MSDs may be uncomfortable in the area - General public stigma - Accessibility
Firefighter (Secondary): Provide relief at the scene of traumatic events - Providing the necessary care for patients - Arriving within a certain time frame	**Splints:** Used to reduce movement of joint areas - Not an effective solution - Does not account for stress put onto injured area	**Emergency Vehicles:** Ambulance & Firetrucks - Limited space in the vehicles - Uncomfortable ride, usually fast and bumpy rides
Carpenter (Secondary): Construct, repair, and install fixtures made from wood - Repetitive actions - Being in uncomfortable positions for long durations of time	**Back Belts:** Used to help keep users back straight while lifting - Not an effective solution - Does not account for repetition of stress	**Warehouse:** Large storage facilities - Large open areas, with difficulty getting around the building - Lot of risk factors
Family Members (Tertiary): Family members who have someone whose been affected by MSDs - Providing effective care for person - Adapting to changes of having someone in the family being affected by MSDs	**Exoskeleton:** Helps with lifting and reduce physical stress - Relatively expensive to purchase and maintain - Overall function is not always stable	**Mechanic Shops:** Auto shops - Very dirty, with many risk factors such as slippery grease
Civilians (Tertiary): Those witnessing construction - Discomfort while watching unsafe	**Massagers:** Provide heat and stress relief - Do not help mitigate pain	**Factories:** Factory floors - A lot of dangerous equipment

practices being performed	- Does not focus on the joints	- Difficult accessibility to areas in the factory

The problem being addressed is how to mitigate musculoskeletal disorder in construction workers with labour intensive positions. The importance of the problem being addressed, is that it possesses a solution to a problem which may be able to help long term issues and issues which can be prevented early on. The problem statement meets thesis criteria with the inclusion of full-bodied design and having to follow ergonomic to support the musculoskeletal disorder patients. The topic at hand can be a reusable piece of equipment in which many people can use, and the simple inclusion of adjustability can provide that sustainability aspect. And lastly, it improves human lifestyle, by not only preventing but hopefully providing better support for those with musculoskeletal disorders. This problem is an important to care for, the simple piece of equipment can help many avoid having life sustaining issues, and at the same time aid construction sites to finish in timely orders because less workers would be seeking for time off due to injury.

4.1.3 Ideation Sketches

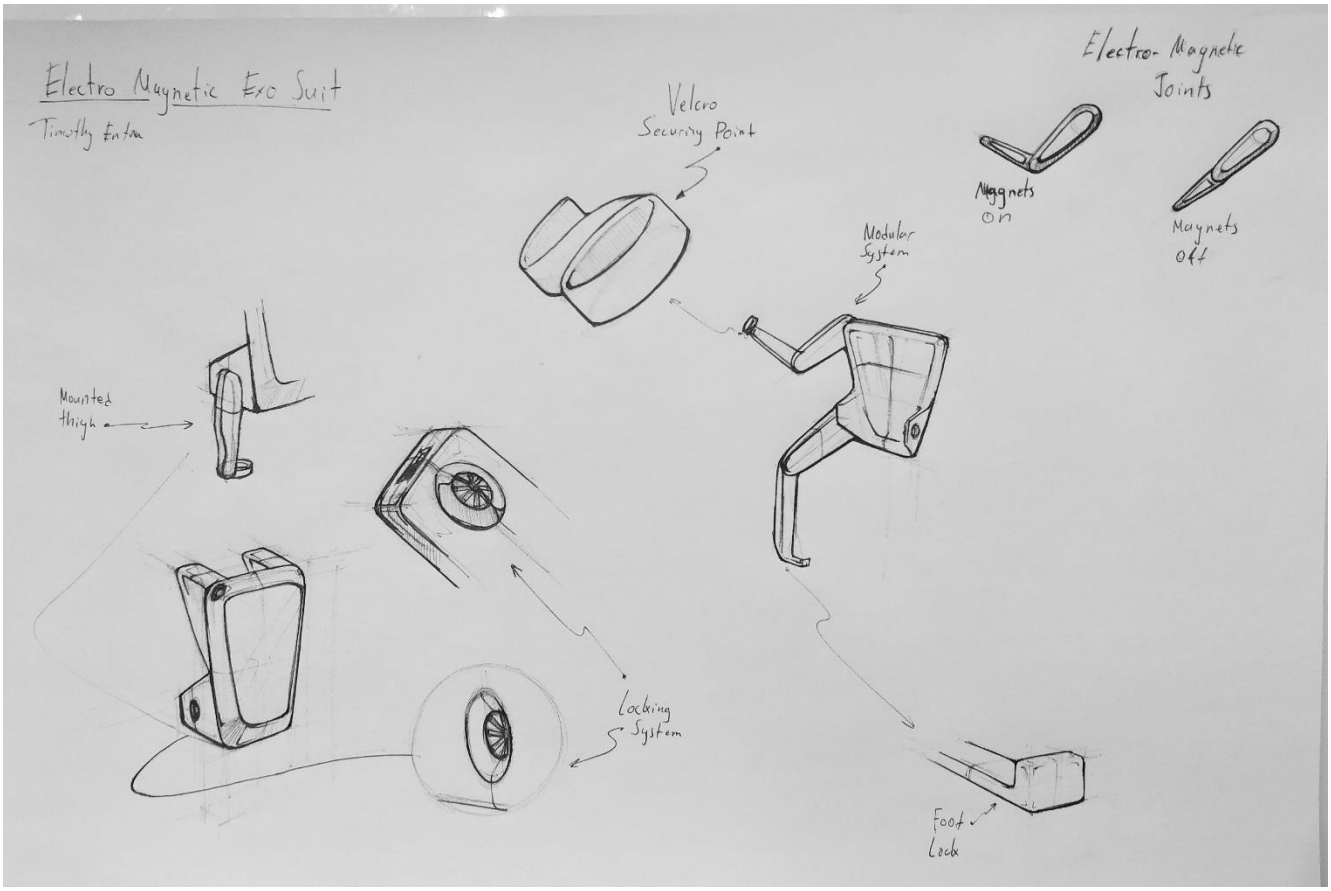


Figure 18 – Ideation 1

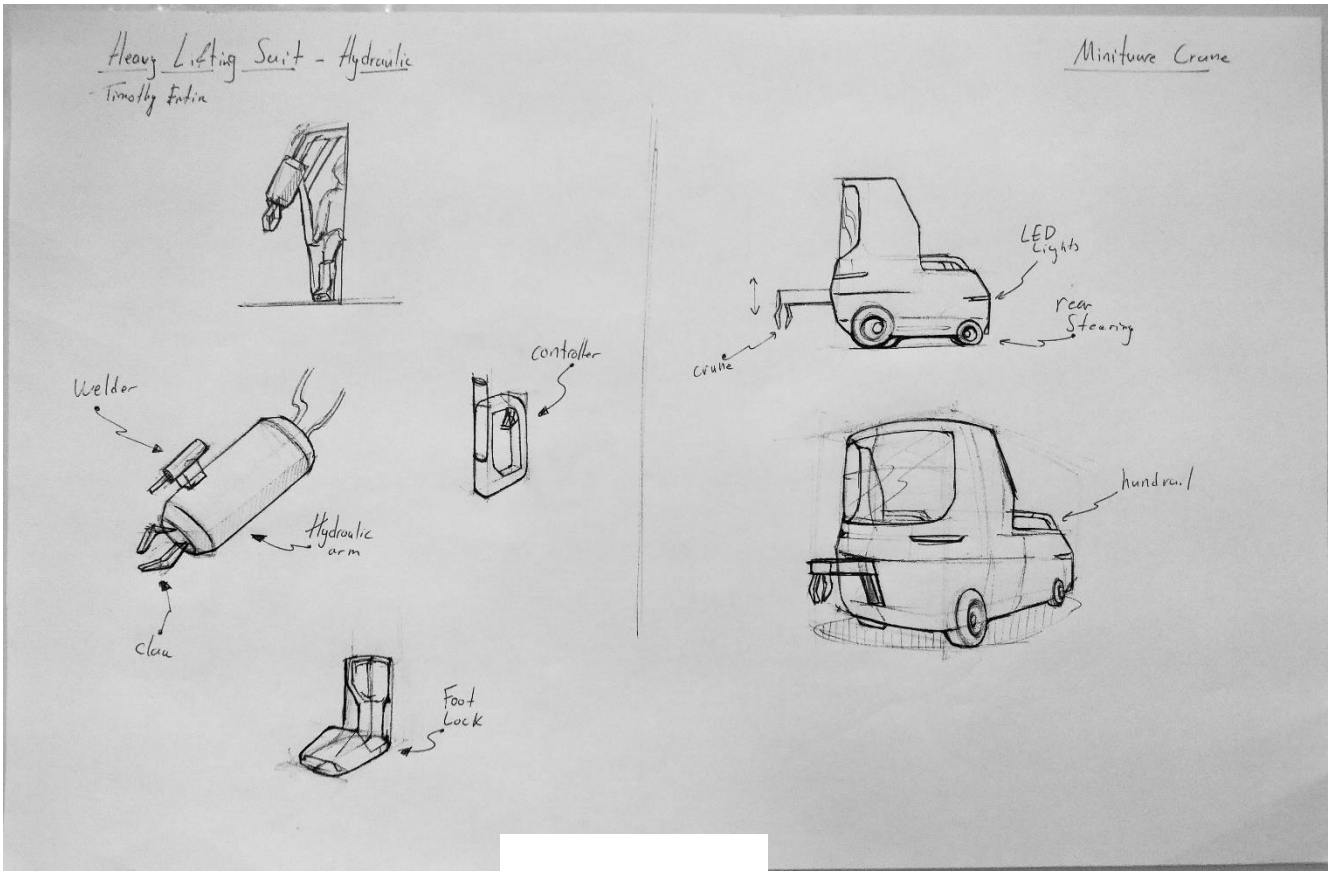


Figure 20 - Ideation 2

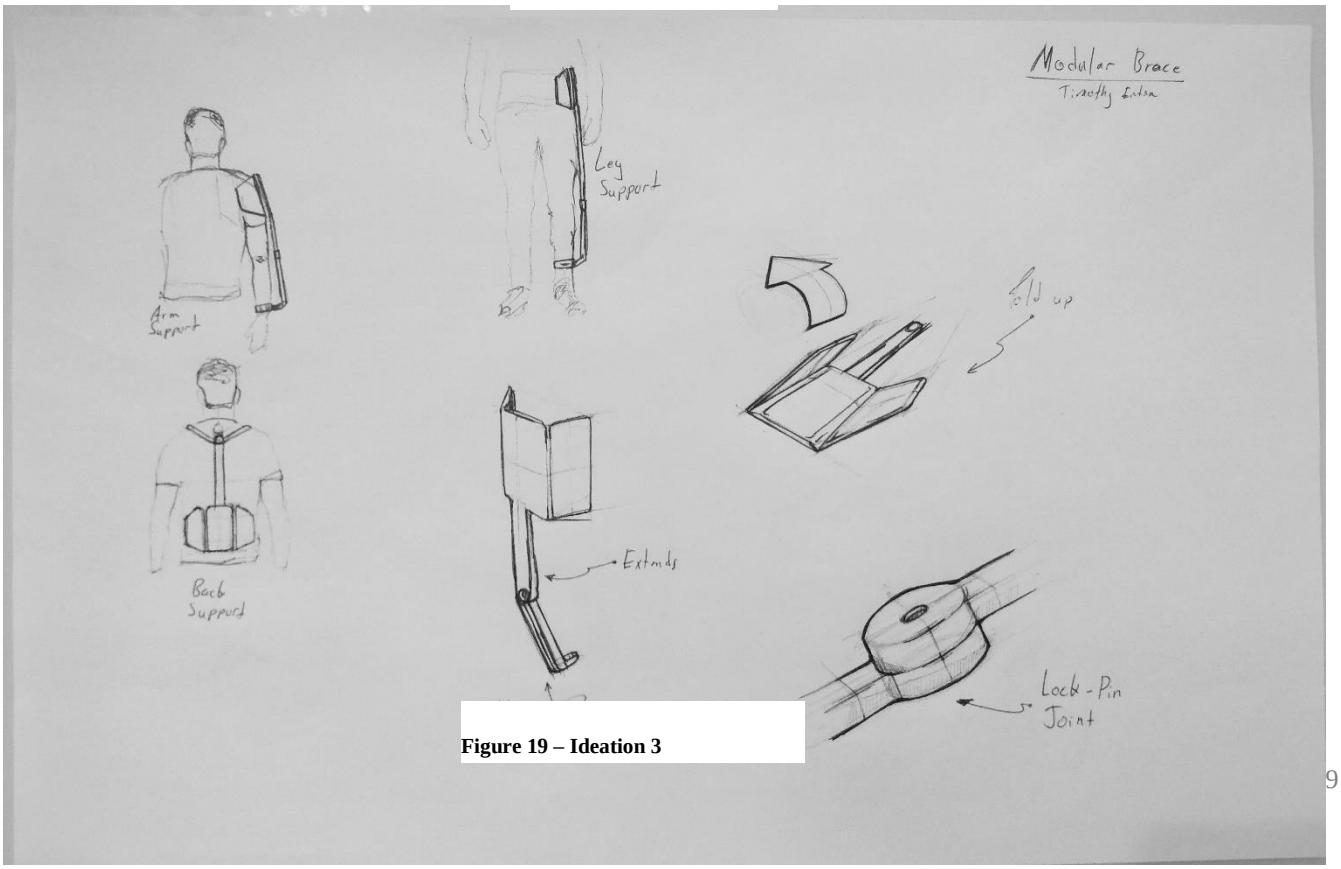


Figure 19 – Ideation 3

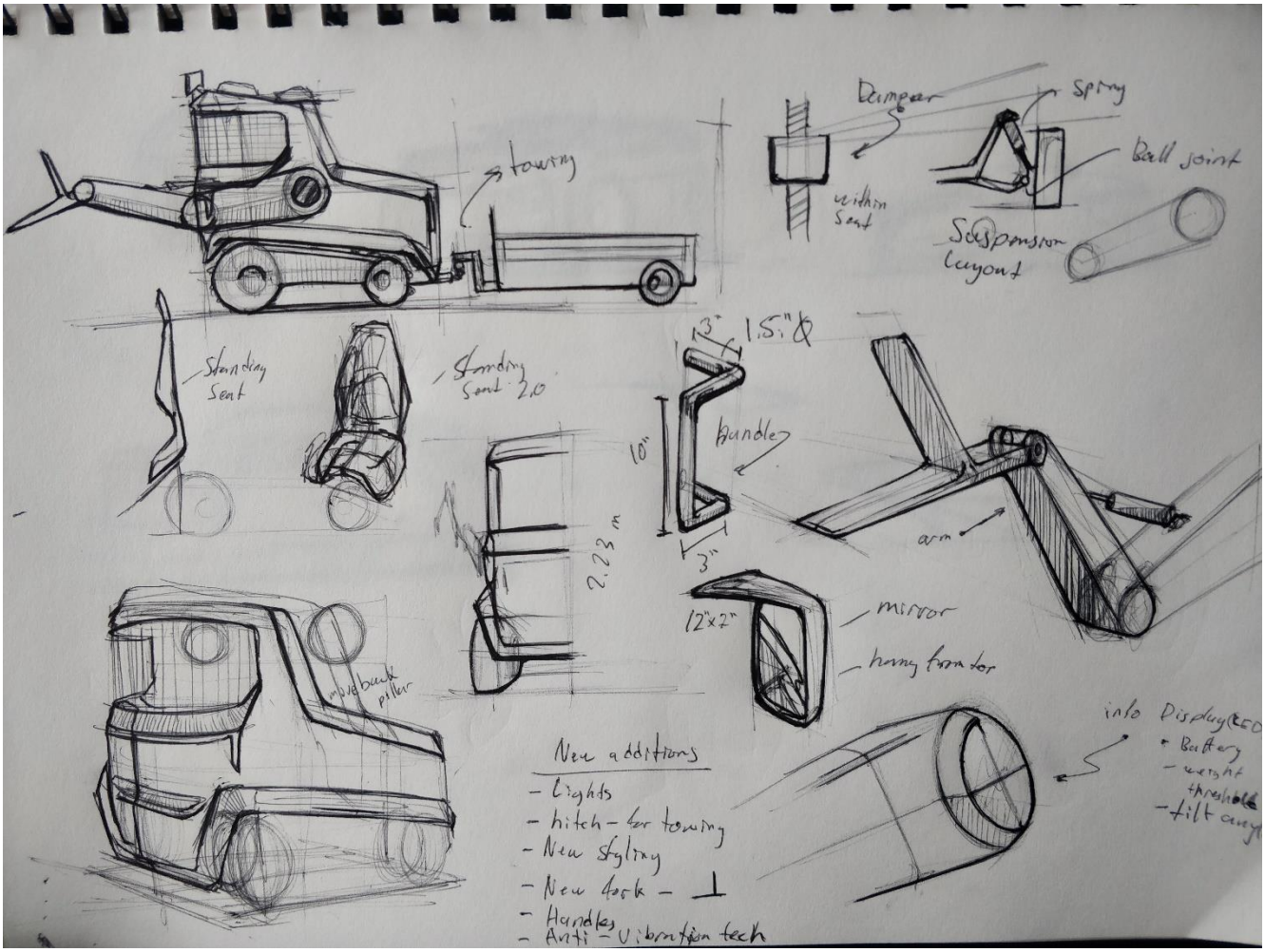


Figure 21 – Ideation 4

4.2 Preliminary Concept Explorations

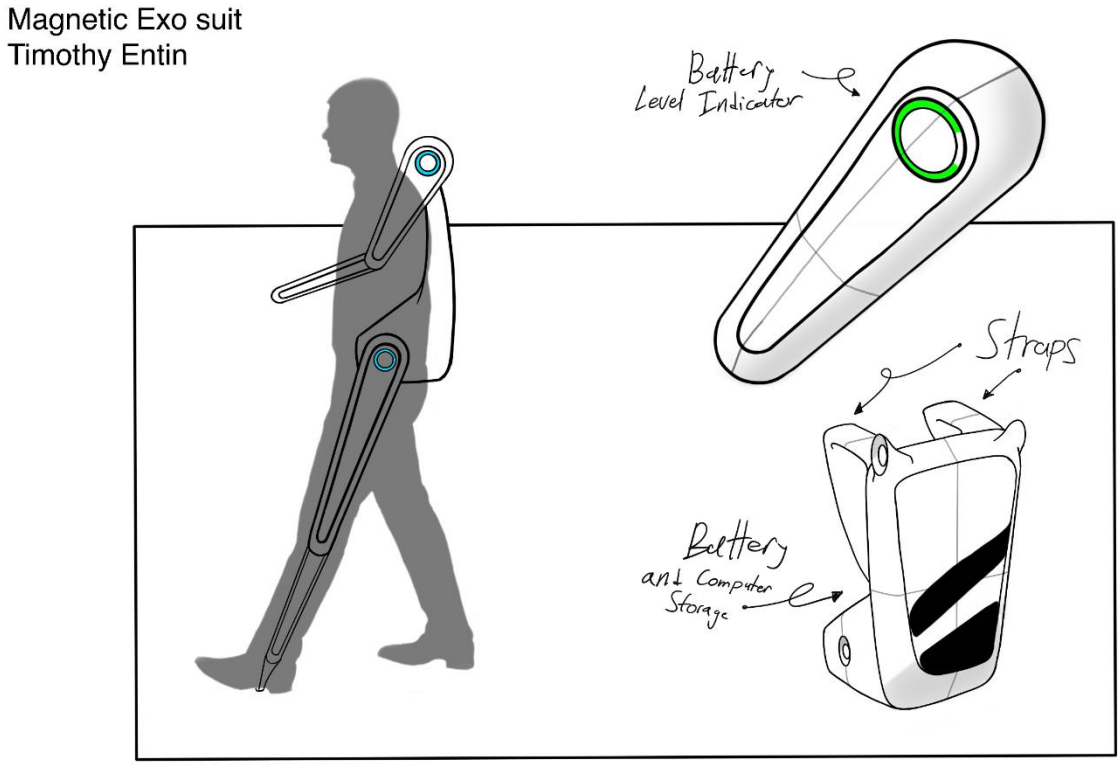


Figure 22- Concept Exploration

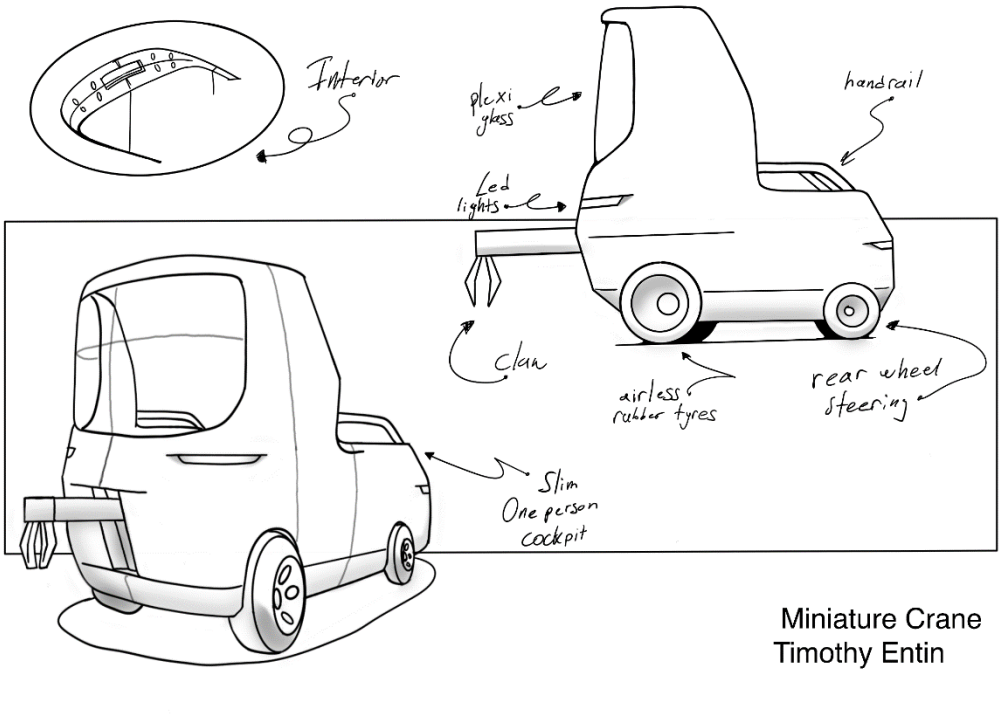


Figure 23 – Concept Exploration 2

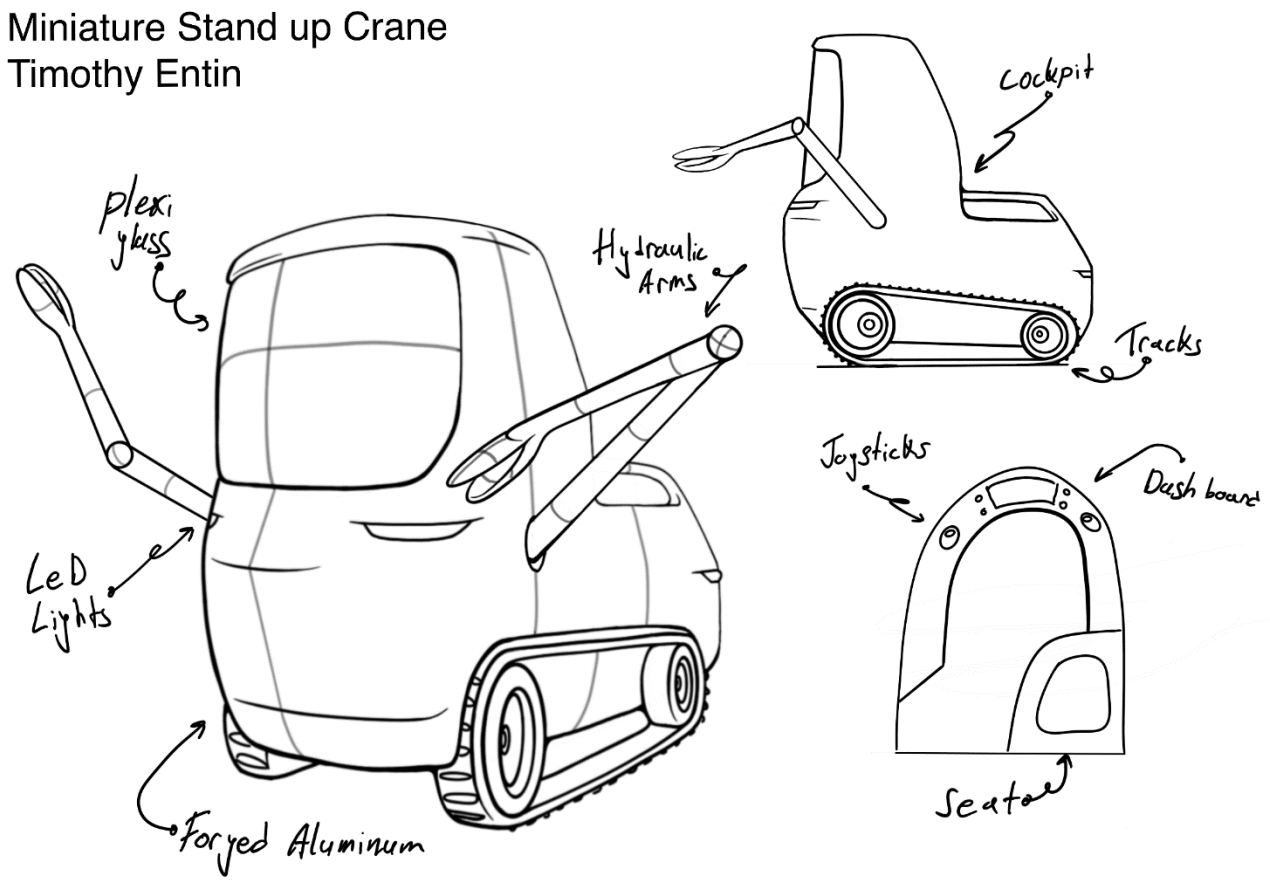


Figure 24 – Concept Exploration 3

The preliminary staged opened discussion about which design would better suit the construction site, an exo-skeleton suit although it is light weight and durable for work would not be suitable due to the maintenance which would be required to maintain the operation of the suit. The added expenses of the materials required for the suit would not make it a viable option for a construction which is already trying to minimize the costs.

The miniature standup crane/ forklift would be an easier piece of equipment to manage since most of the components would be like current models of construction equipment. The simple construction of most equipment provides a reasonable cost to construction site and does not cost an unreasonable amount to maintain. The cleaning and maintenance of this equipment would be efficient since this equipment is already built to be dirty and wet in some conditions.

4.3Concept Strategy

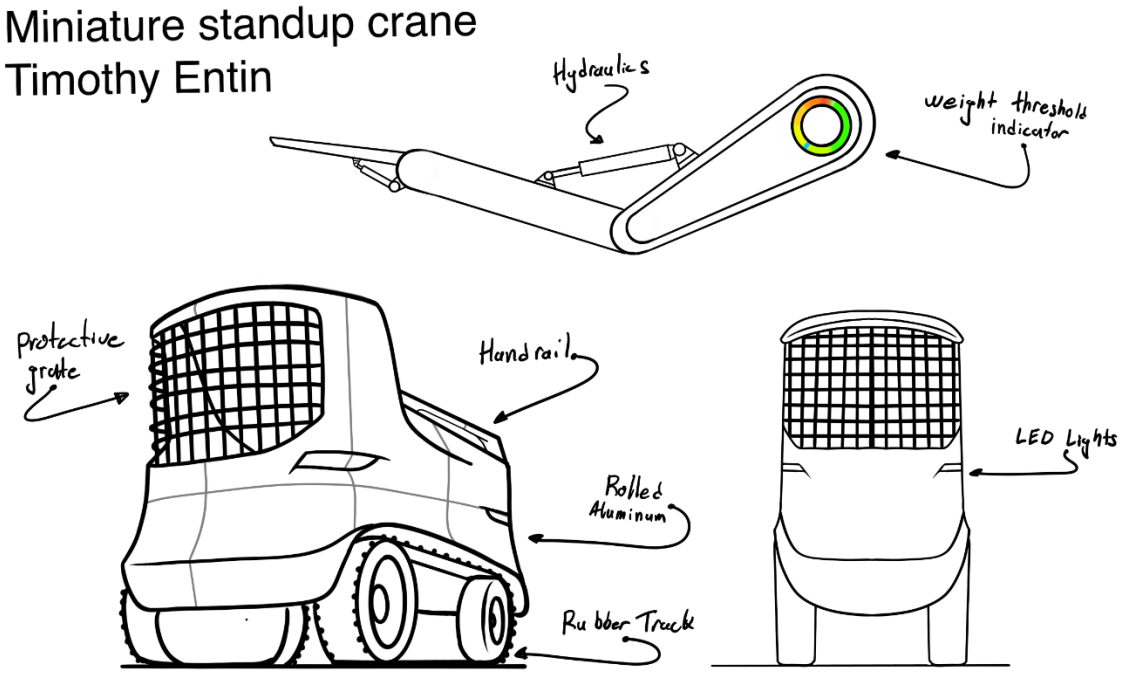


Figure 25 – Concept Strategy

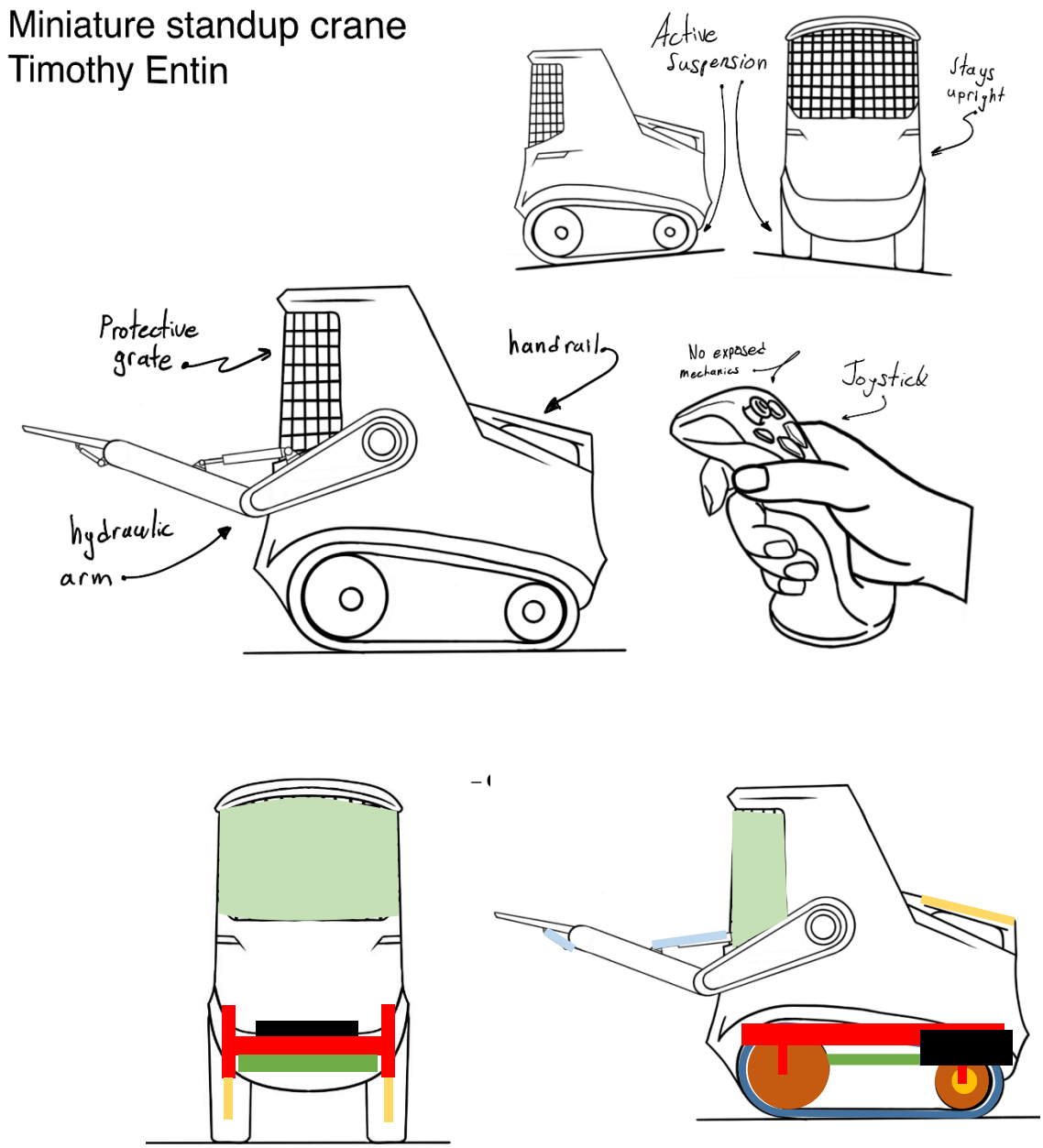


Figure 27 – Concept Exploration 4

4.4Concept Refinement

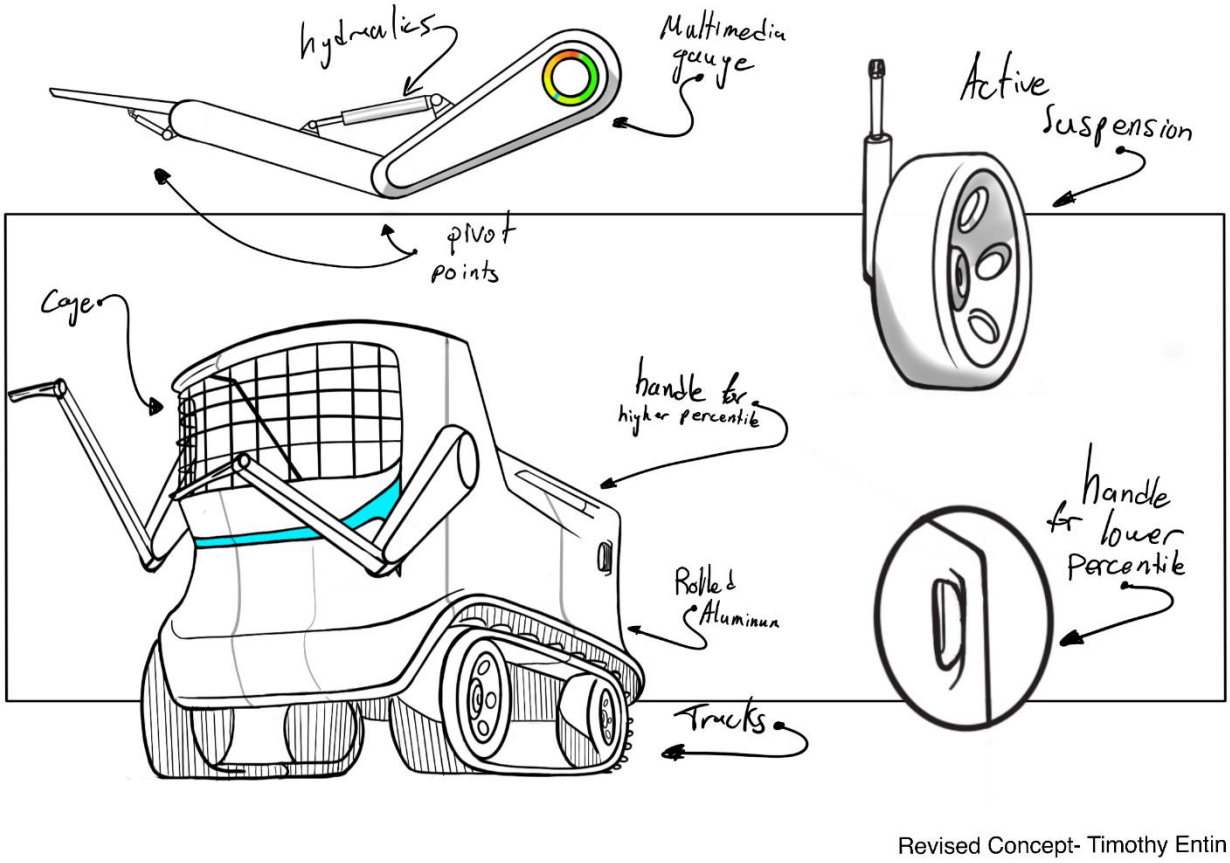


Figure 28 – Concept Refinement

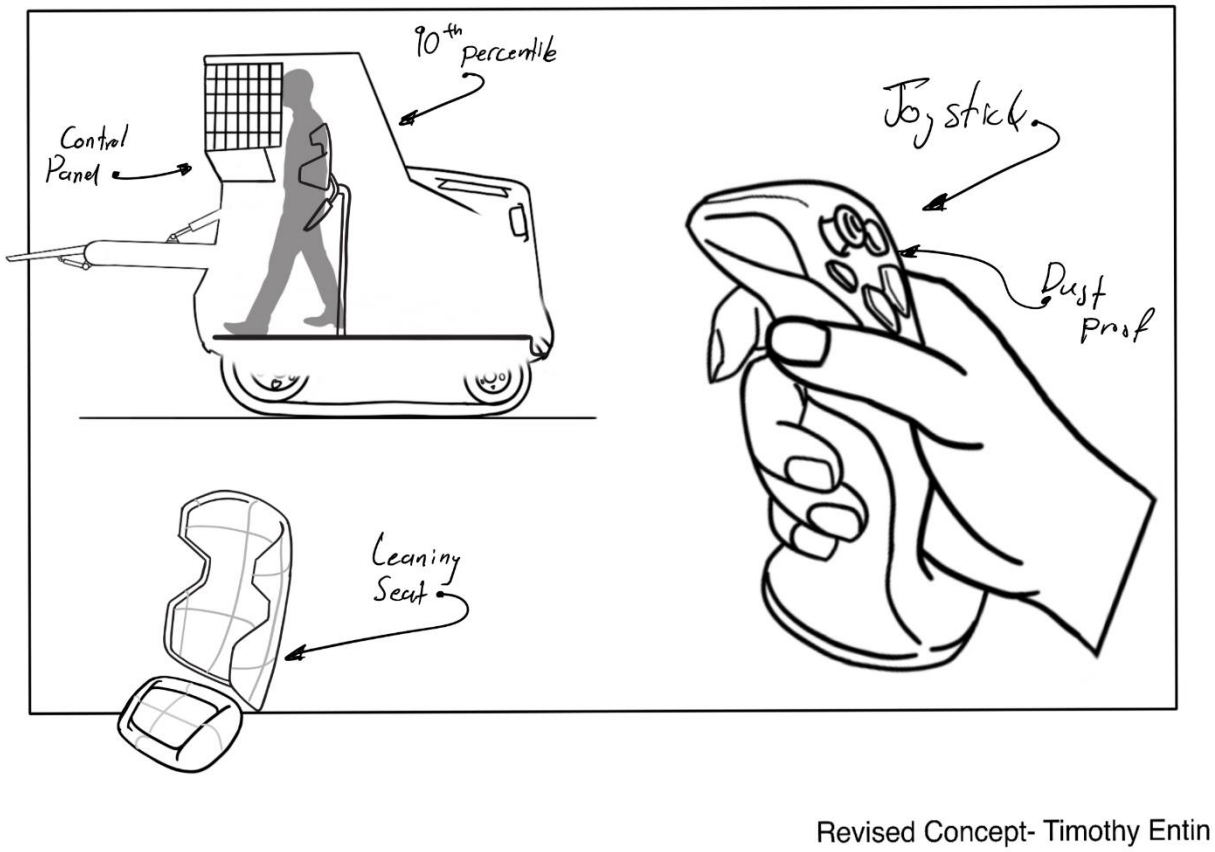
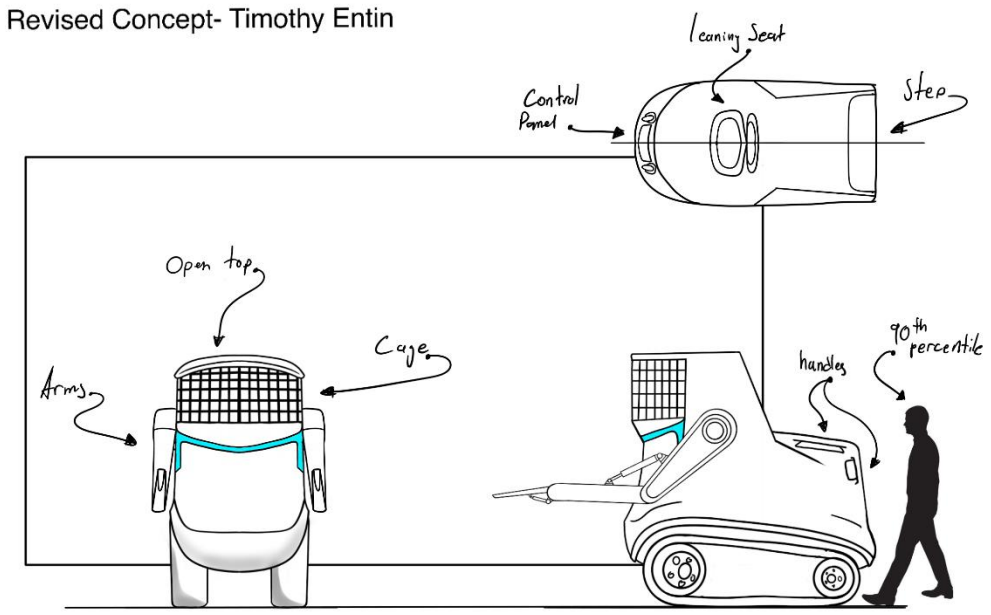


Figure 29 – Concept Refinement 2



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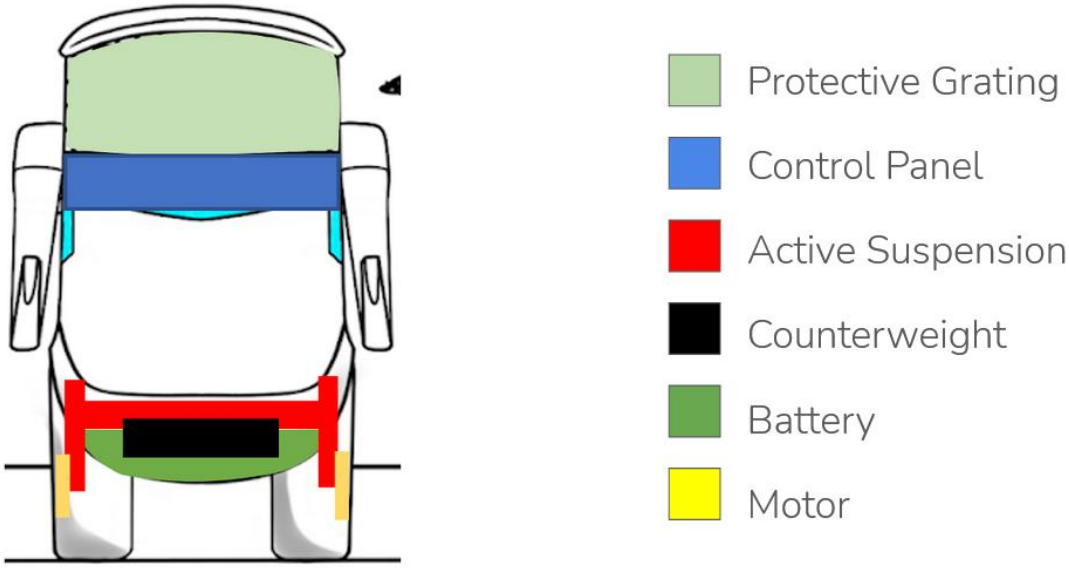


Figure 31 – Concept Refinement 4

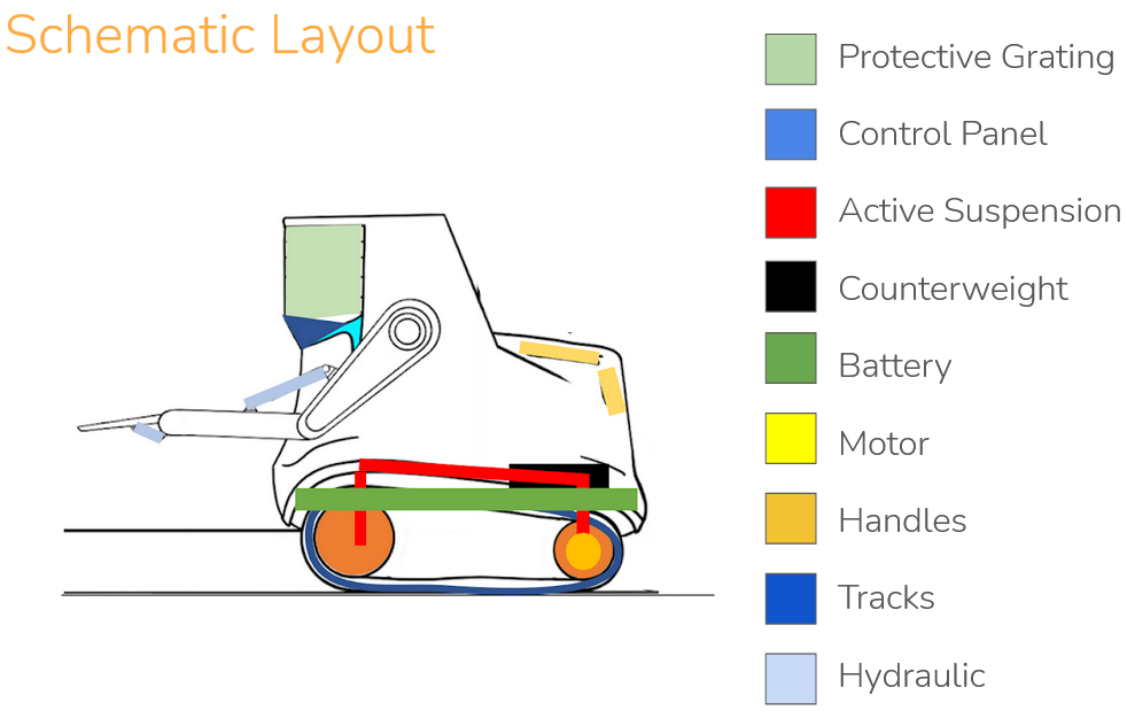
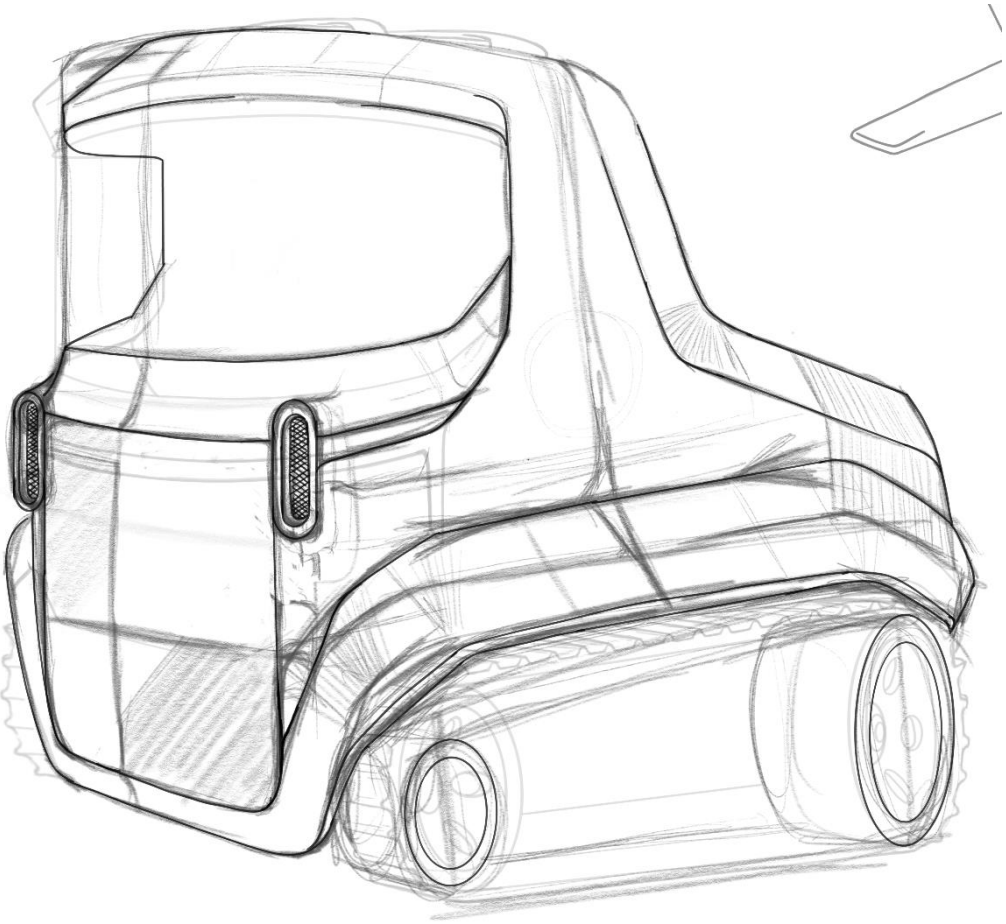


Figure 32 – Concept Refinement



4.5 Design Realization

4.5.1 Physical Study Models

Figure 34 – Physical Model

Figure 35 – Physical Model

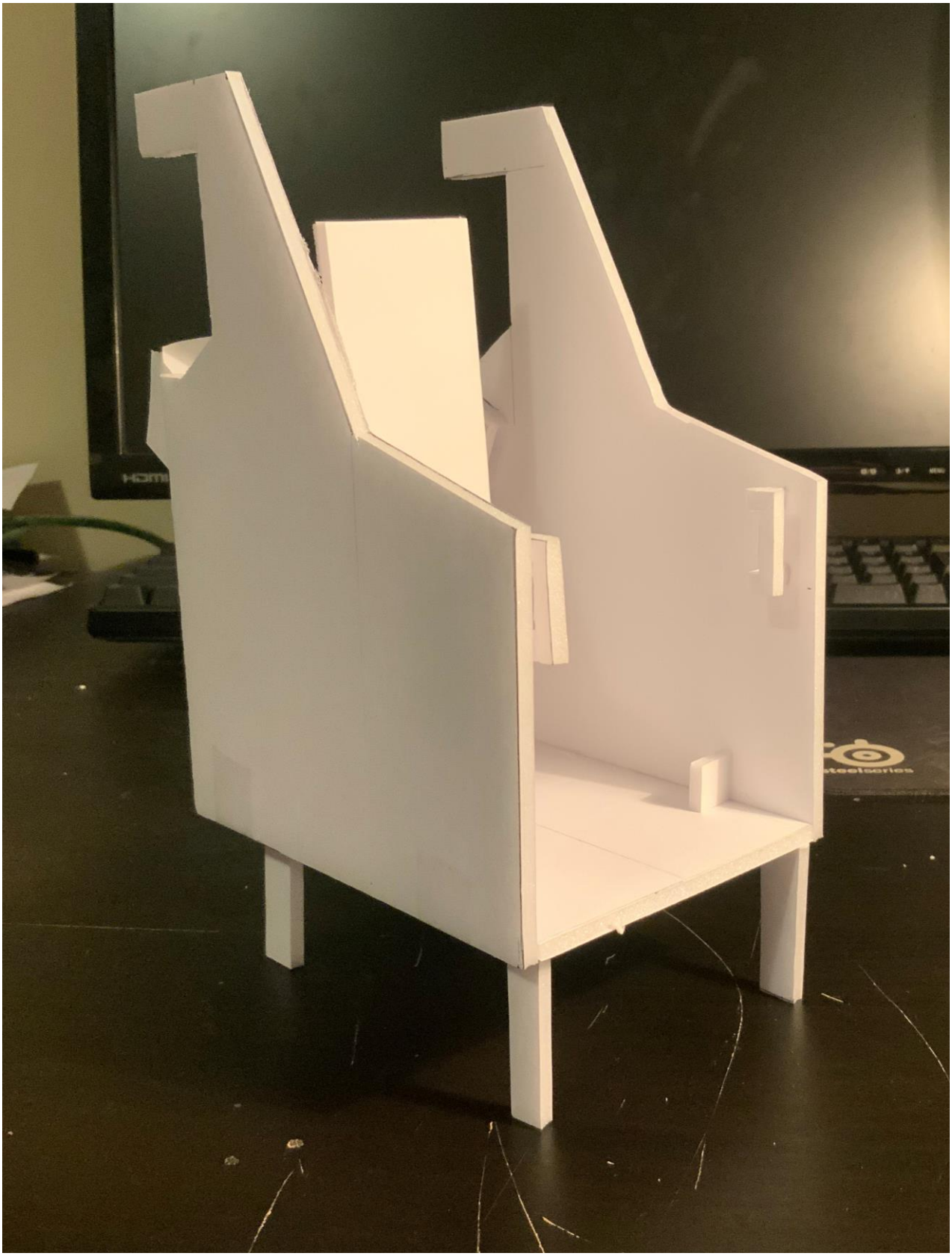


Figure 36 – Physical Model

Figure 37 – Physical Model

4.5.2 Product Schematic

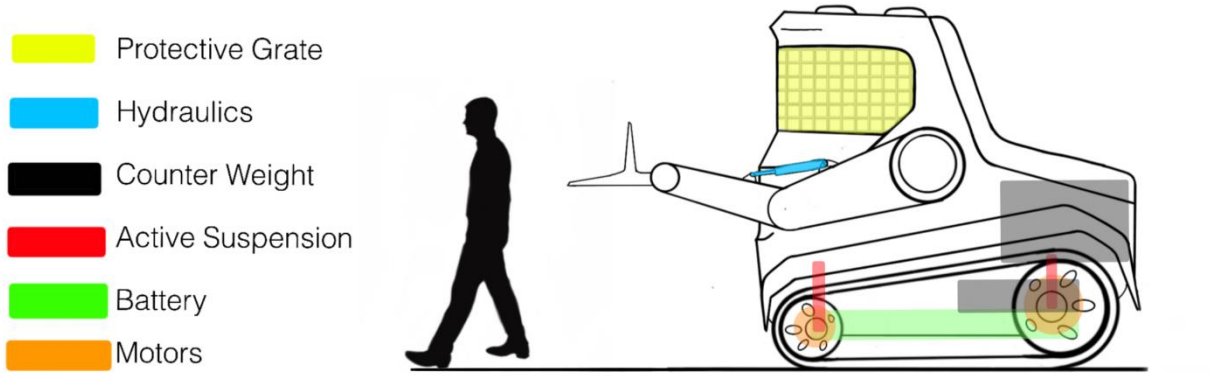


Figure 38 – Product Schematic

4.6 Design Resolution

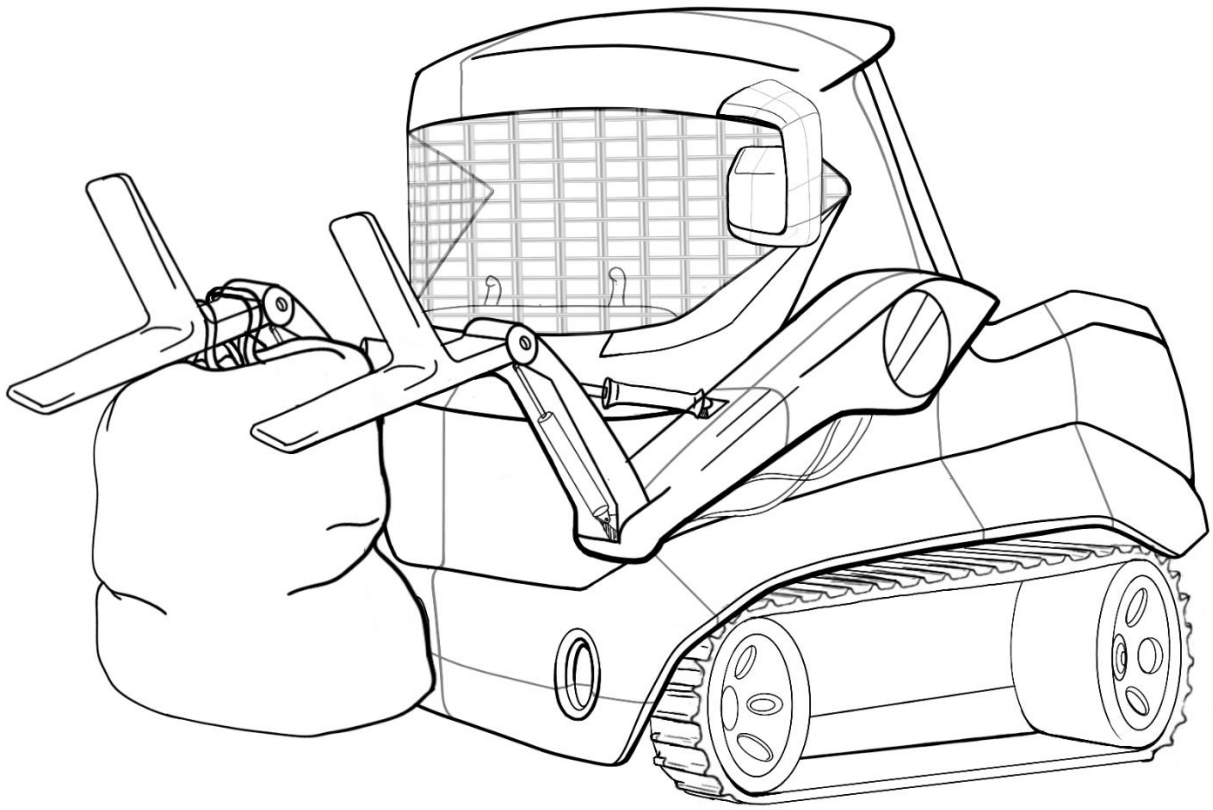


Figure 39 – Design Resolution

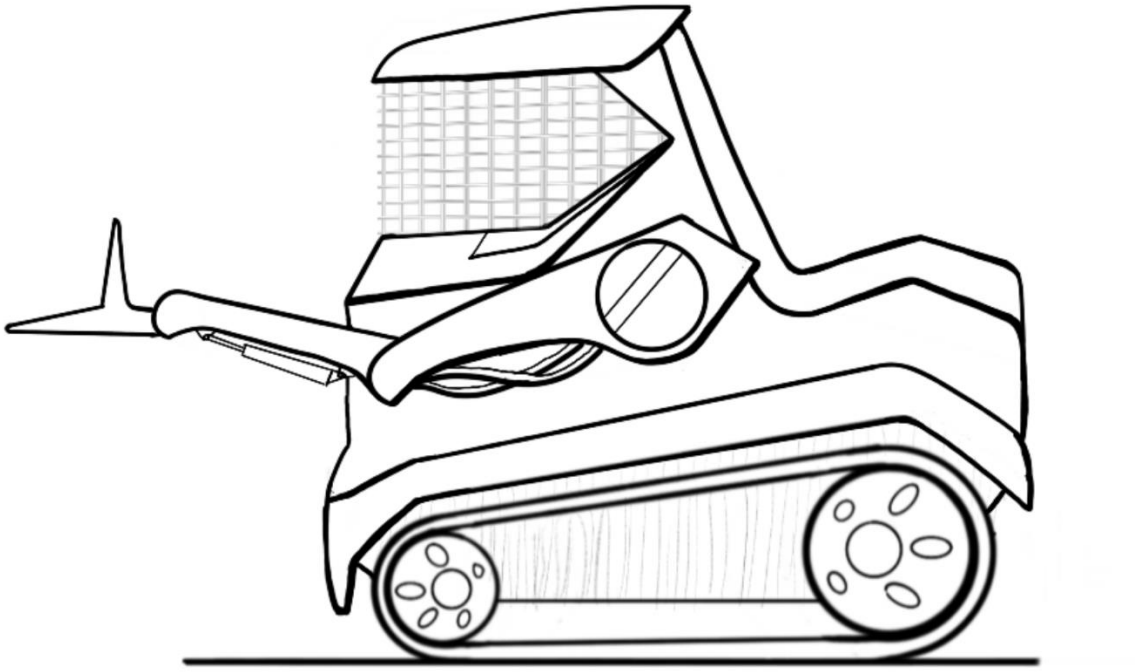


Figure 40 – Design Resolution

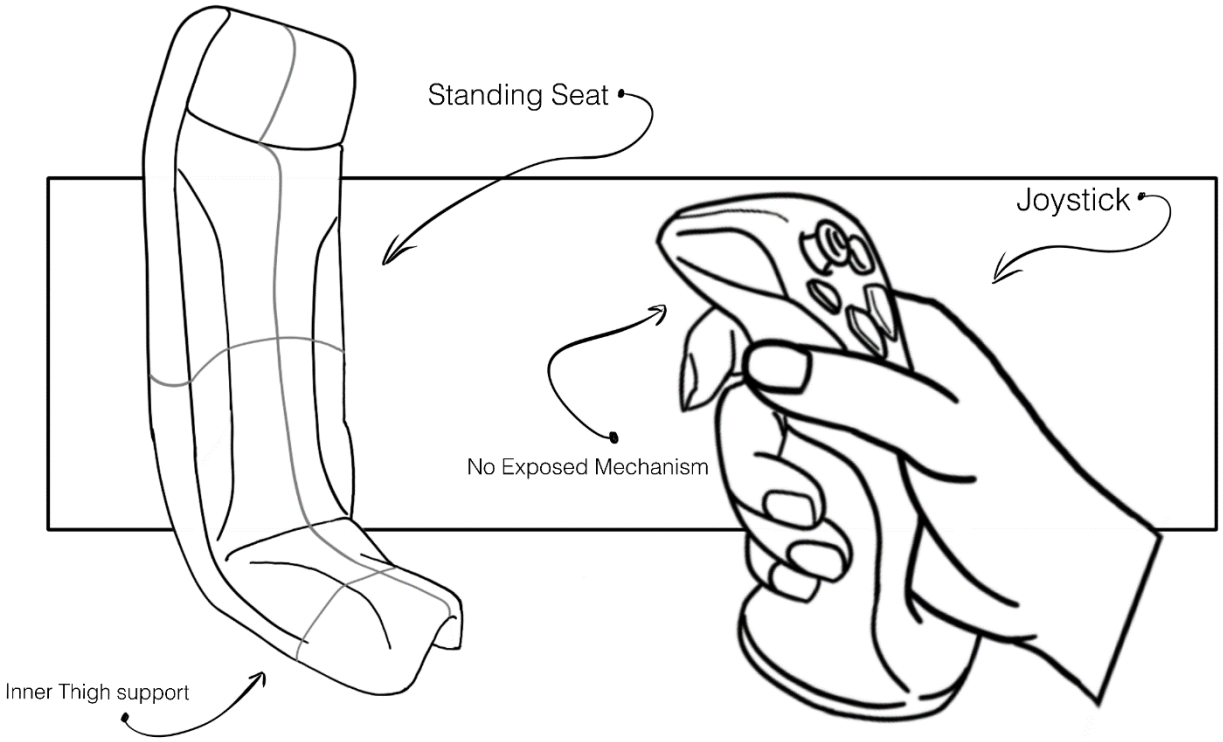


Figure 41 – Design Resolution

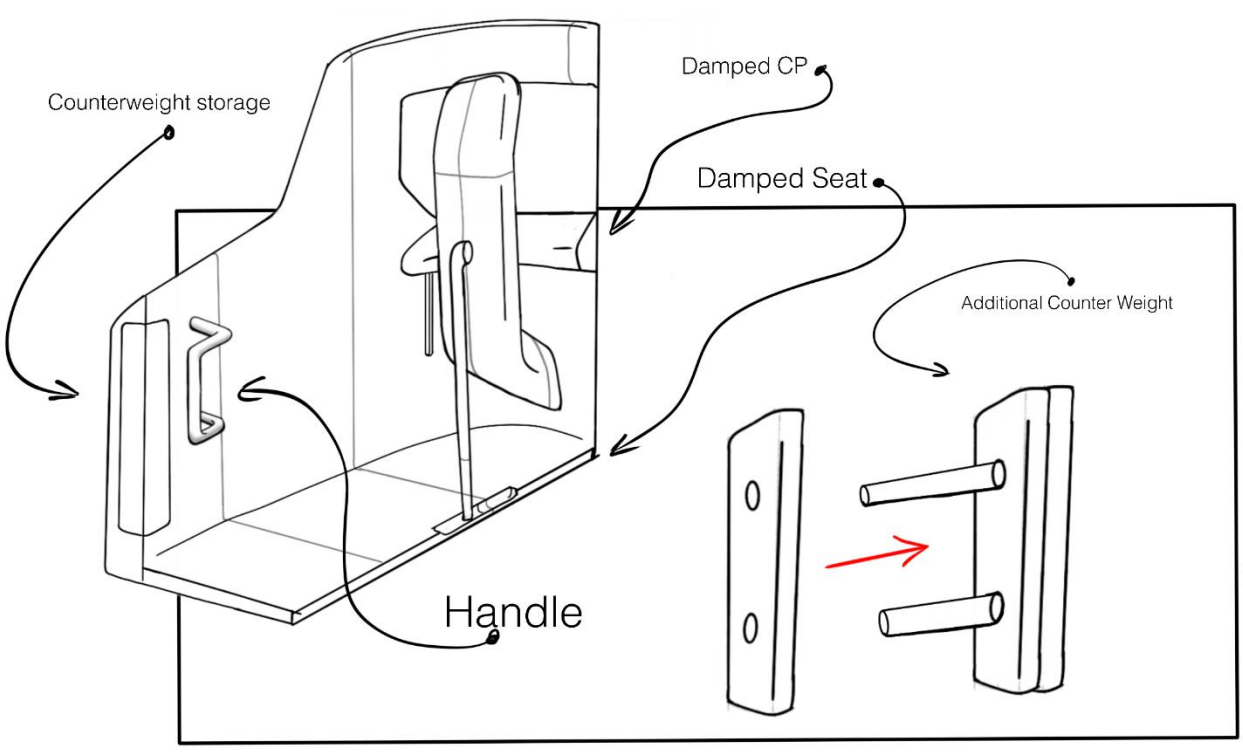
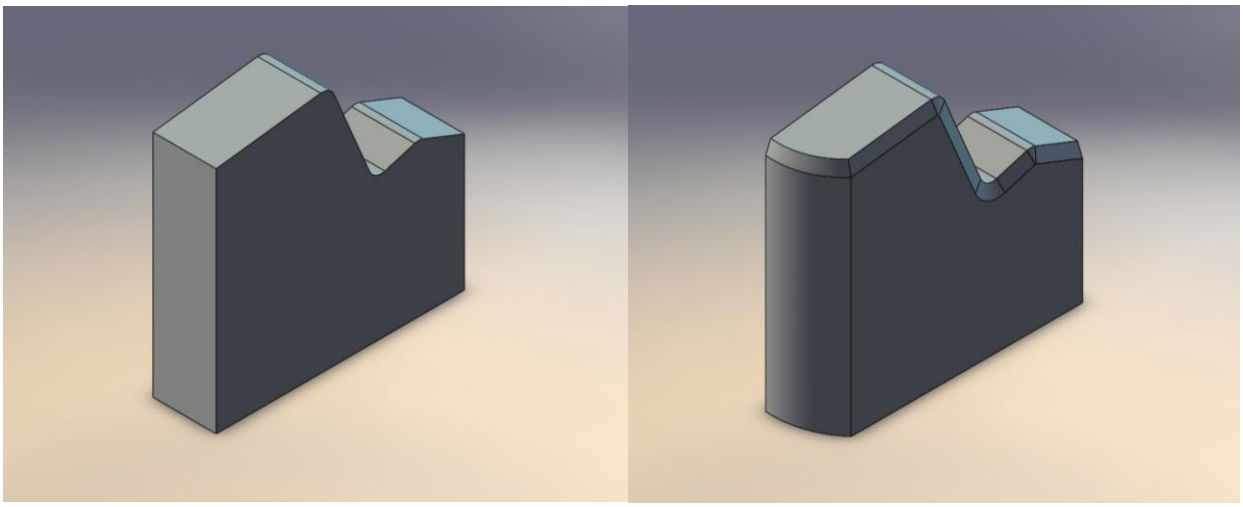
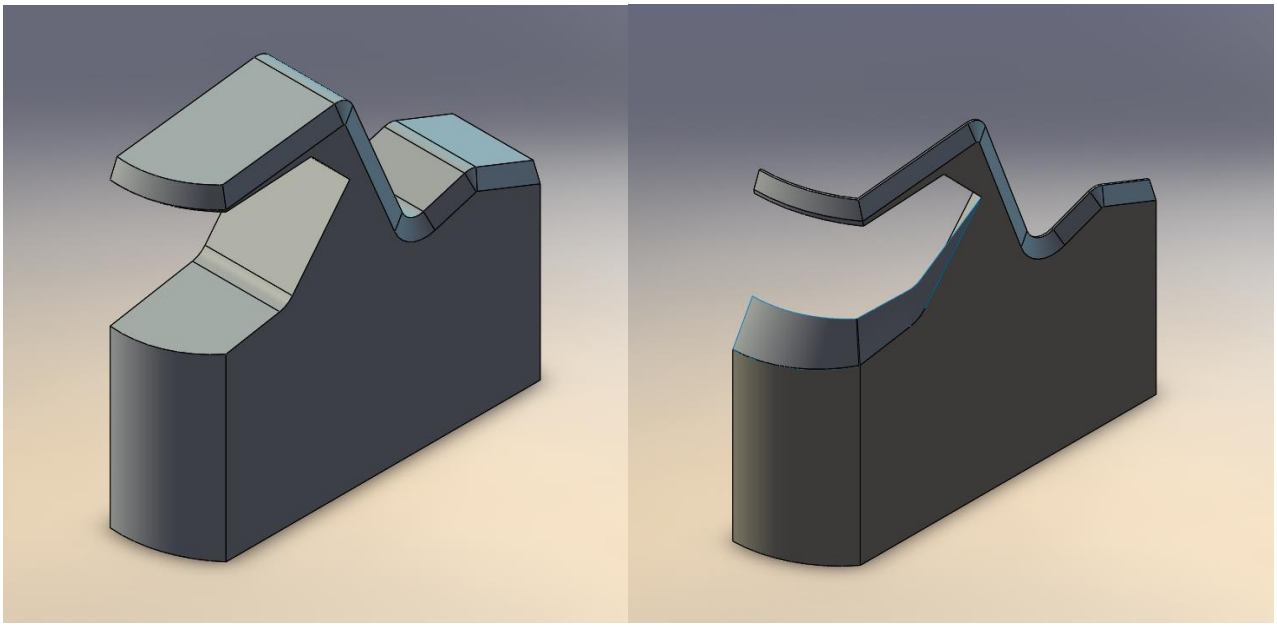
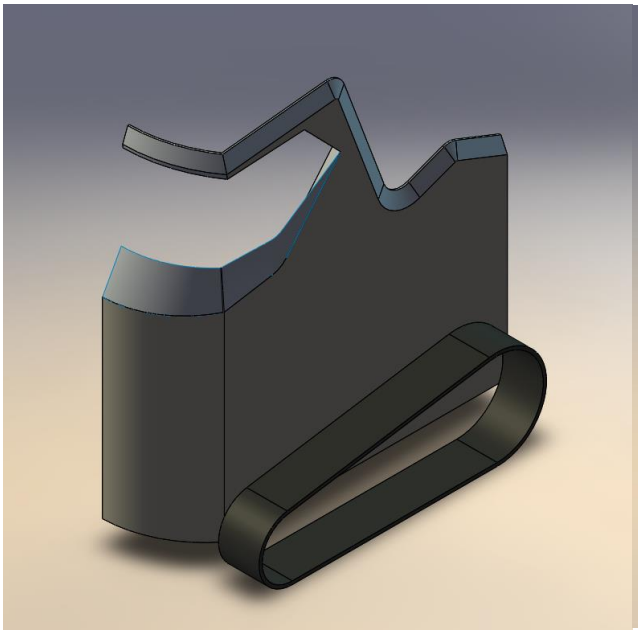


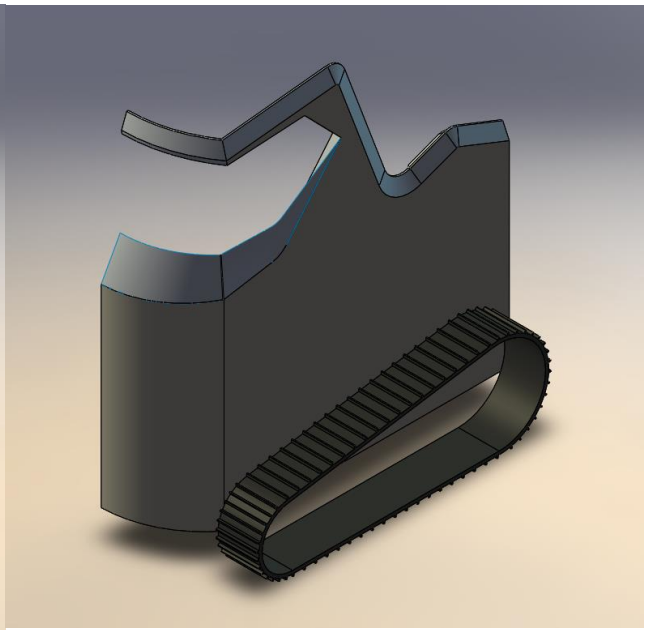
Figure 42 – Design Resolution

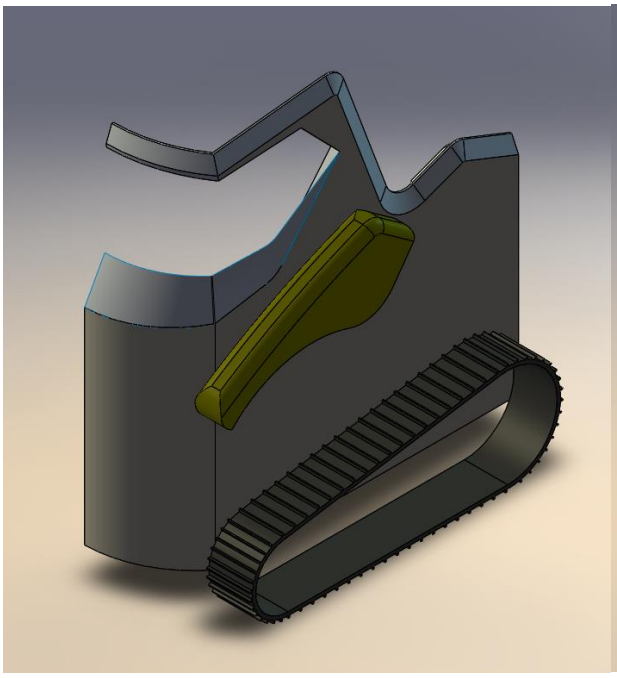
4.7 CAD Development

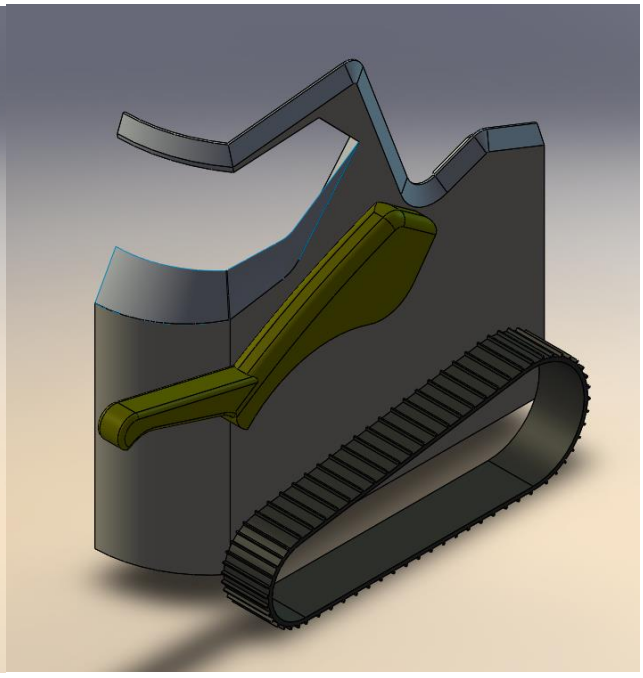


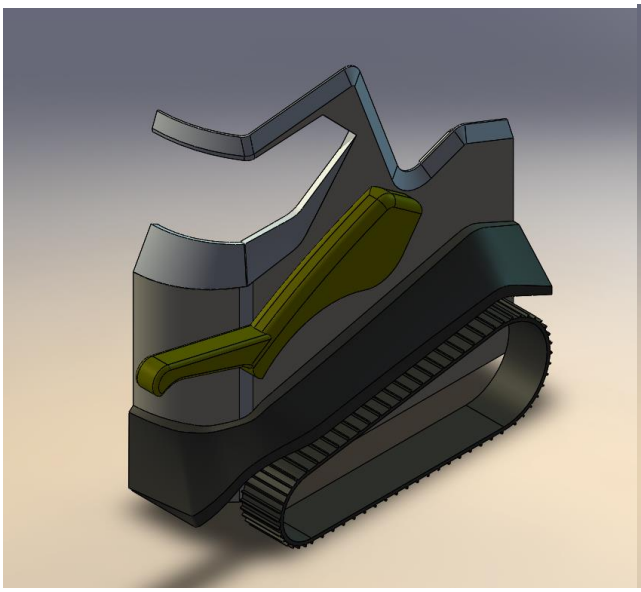


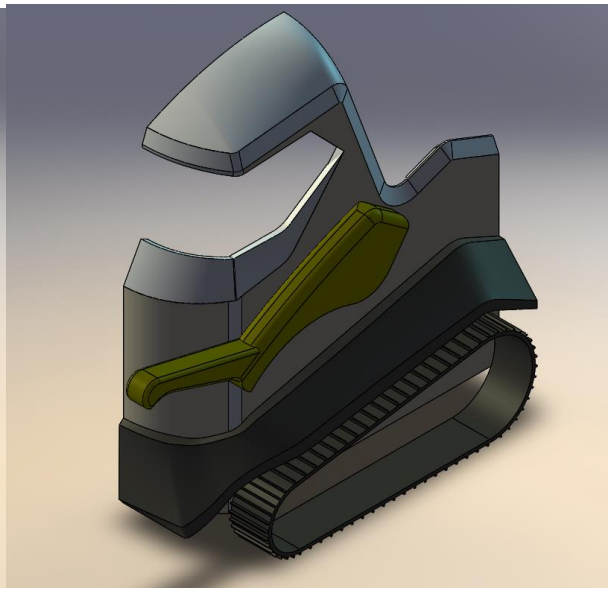


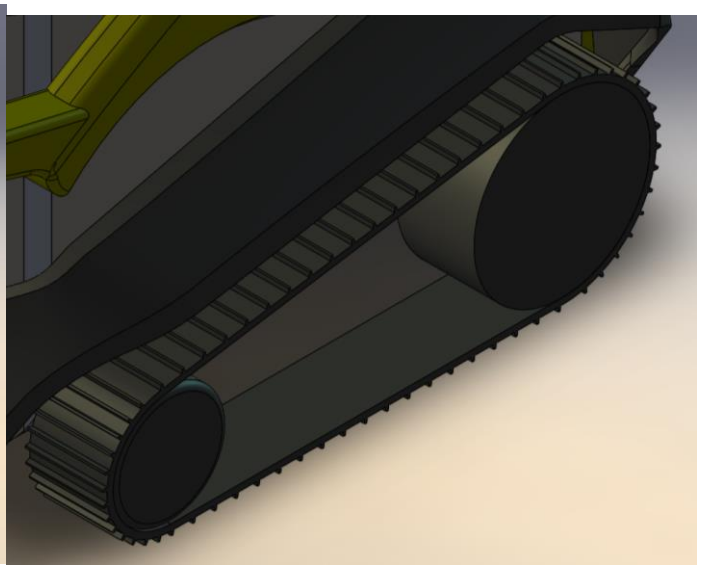


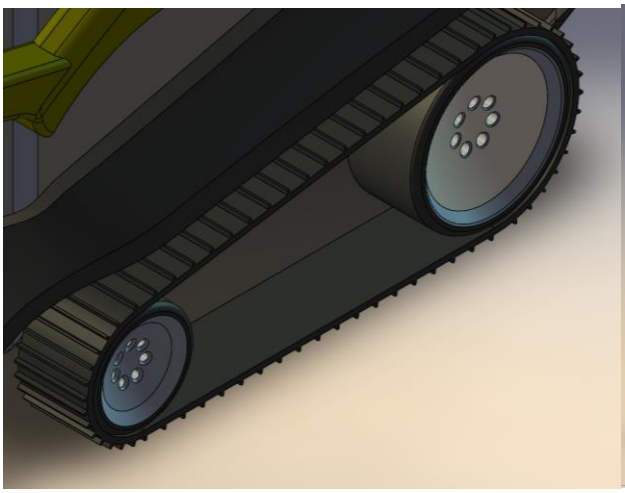


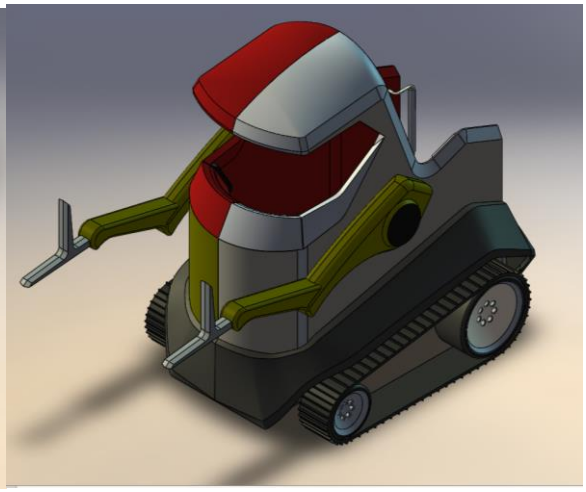


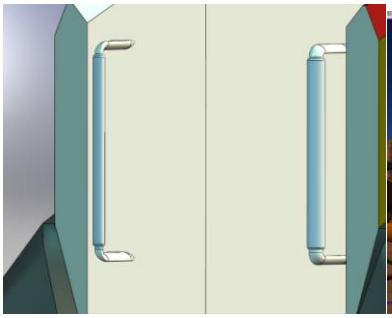


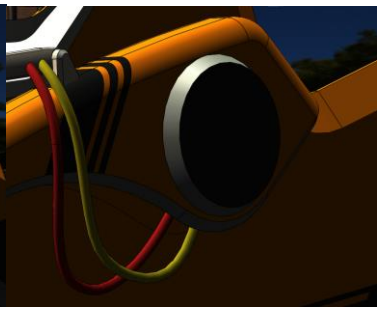












4.8 Physical Model Fabrication

Figure 43 – Physical Model Fabrication

The model was printed using PLA filament, in separate components.

Figure 44 – Physical Model Fabrication

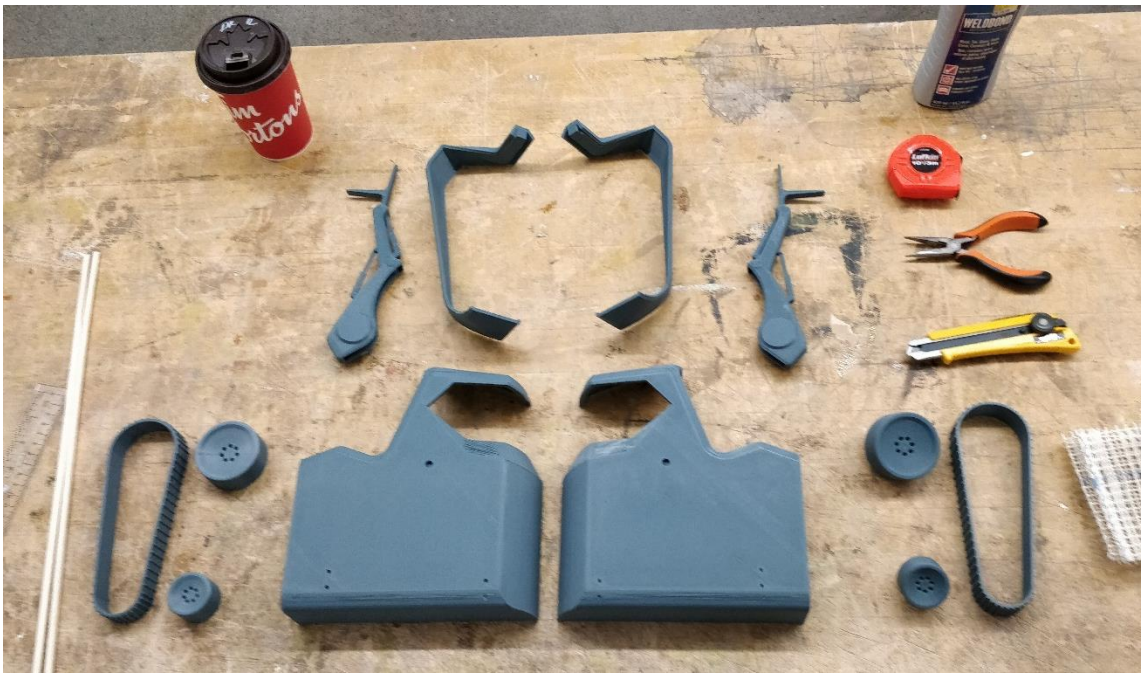


Figure 45 – Physical Model Fabrication

Figure 46 – Physical Model Fabrication

CHAPTER 5 – FINAL DESIGN

5.1 Summary

Description:

Montaro is a mitigation method for musculoskeletal disorders, a piece of equipment that put measures into place to ensure construction workers will not have to put themselves in harm's way when completing tasks that they inflame an MSDs.

Explanation:

The construction industry reports many injuries, however in Ontario over 40% of reported injuries were MSD related. Another source of injuries was the ingress egress, according to the WSN 359 cases of injuries, 32% the users foot slipped, 6% missed a step and 6% Lost hand grip. Environmental factors were noted for 11% of all incidents and wet, icy, and muddy conditions were only indicated for less than 4% of the incidents. These injuries are contributed to poor design and a lack of consideration of human ergonomics (Godwin et al., 2014). Using modern safety standards along with advice from a Project Coordinator from PCL construction a variety of modern safety piece were included to always protect the operator. This thesis focused on providing a comfortable solution to the mitigation of MSD, most mitigation methods today are simply a presentation from the construction company or a governments labour injury page. Any products that help mitigate MSDs are restrictive motion devices which prevent the body from doing certain motion which may inflame the users' injuries. For example, a lifting belt (which is a restrictive motion device), will restrict the user from bending their lower back while lifting heavy objects. Montaro is a human centered design tasked to mitigate MSD when in use, with the added benefit of an ergonomic interior to ensure the operator is always comfortable, there are also mass tuned dampers within the control panel and seat to prevent vibrations from effecting the operator while in use. The steps and handle are designed with standard ingress and egress regulations to ensure the user always has 3 points of contact when entering and leaving the vehicle.

Benefit Statement:

Montaro is a unique take on construction equipment not currently seen in the industry. The unique design and take on the mitigation methods and agile movement provides efficiency throughout the workday. The electric powertrain provides instantaneous torque to the tread providing excellent traction and movement on any terrain found on a construction site. The MSD mitigation methods offer strain free use of the vehicle for prolonged use, this allows for more work to be done throughout the day and avoiding time needed to switch drivers; it is not uncommon for the operators to switch out very often because of risks such as vibrations, so the Montaro simply uses mass tuned dampers to mitigate this problem.

5.2 Design Criteria Met

5.2.1 Full Bodied Interaction Design

Montaro is designed for construction workers and ensure comfortable use when operating. The ingress of the vehicle is introduced with two handles spaced out comfortably and made to be a length, so it is comfortable for any percentile to grab a hold of. The step is placed at a height which will play favour for each percentile, the shorter percentiles can grab the handles and at that time they can place their foot onto the step which has a grip tape like texture. The taller percentiles have an easier time getting in, with 3 points of contact being easily accessible. This decision to create the vehicle more accessible for taller percentiles was based off statistics comparing the varying heights of construction workers, this also does mean women are not the primary focus of the ergonomics. Females were projected to taking a mere 9.1% of construction workers in Canada in 2017, according to Statistics Canada (Statistics Canada, 2011), this statistic put the primary ergonomic focus on male construction workers.

The seat located in front of the control panel is adjustable to a preferable height and can be set a certain distance away from the control panel. The standing seat is made out to fit all sizes comfortably due to its adjustable middle section, which is meant to be cradled between the legs of the user. The seat is made with a durable leather to ensure the user does not slip and with the cushioning will feel

comfortable for a long duration of time. The seat does rotate to allow the user to enter and adjust the seat before entering the cockpit area.

5.2.2 Materials, Processes and Technology

Current construction equipment uses material to enclose the operator, to enclose the sensitive equipment such as hydraulics and cables and heavy-duty materials to close off the equipment from the elements of a construction site.

Construction equipment today uses common weather resistant metals on exterior components and on structural parts of the equipment. The current use of carbon alloys is not uncommon at all, carbon-based alloys provide similar corrosion resistance and strength as metals but provide the benefit of also being lightweight. Carbon alloys are favoured amongst many metals due to their stability and extreme temperature resistance, however they are priced highly compared to other metals.

The use of plastics is also very common on construction equipment; however, they are mainly used around components which do not reach high temperatures. The use of rubber is mainly used on the outside of the vehicles, and primarily used for tires and tracks. Rubber is a good shock absorber, and for large scale machinery with large tires they consist of most of the shock absorption. Rubber is used on the tracks because of its flexibility, ductility and traction, construction sites are rough terrain, if there is a puncture in the track, the rubber will not give way for further damage.

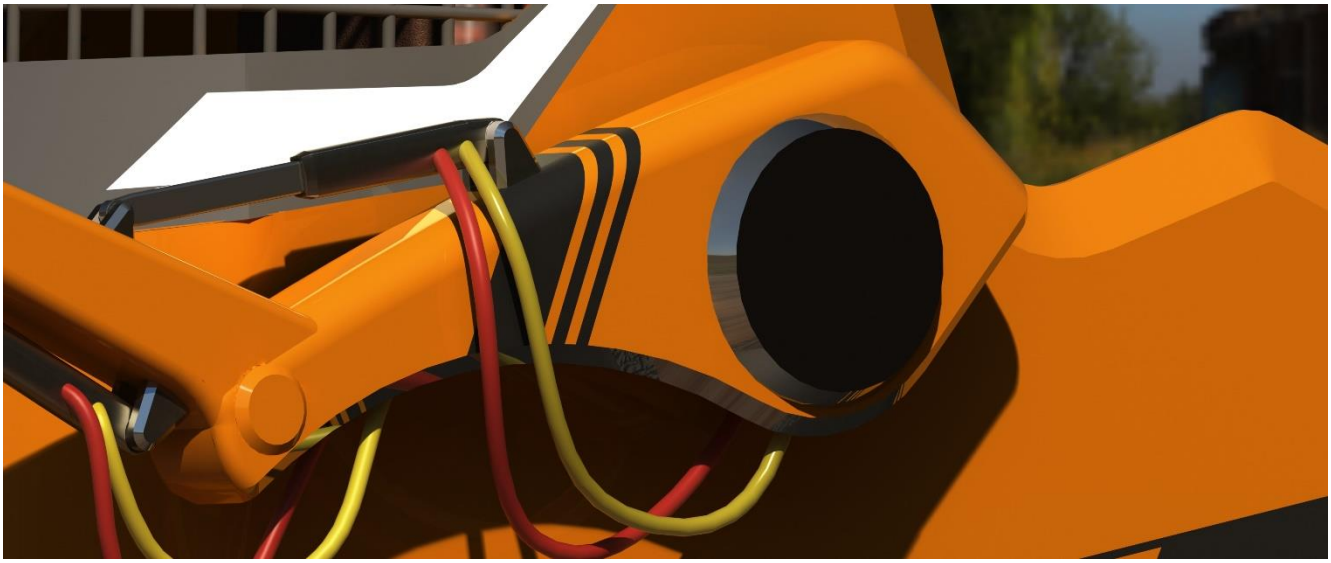
Construction equipment from the manufacturing side is relatively quite simple, using simple manufacturing processes. The body work of the equipment is made by cutting the sheets of metal to size either via stamping or laser cutting. To create unique bodywork shapes the sheet metal will go through a pressing process till the desired shapes are achieved. All the components are then welded together, and through these processes third parties supply components such as hydraulics, wheels, suspension systems. These third-party components are assembled according to the technical requirements asked by the manufacturer.

5.2.3 Implementation – Feasibility & Viability

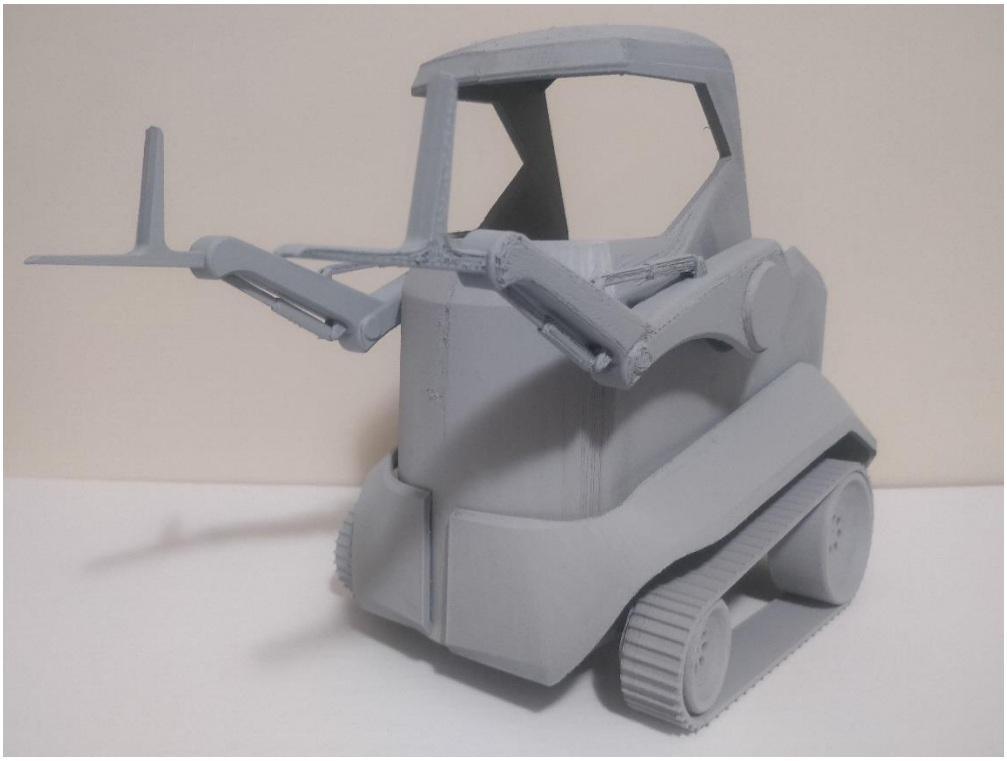
Material(s)	Quantity	Estimated Cost
Aluminum 5052 (Body)	450 lbs.	$891
Aluminum 5052 (Protective Grate)	50 lbs.	$99
Cast Steel Cold-Rolled Coil DDS ASTM A1008 (Under Body)	250 lbs.	$170
HDPE	135 lbs.	$1420
Aluminum 5052 (Wheels)	25lbs. /per Wheel	$50 x 4
Active Suspension	1 per Wheel	$3,600
Cast Steel Cold-Rolled Coil DDS ASTM A1008 Forks	45lbs./Per Fork	$62
Hydraulics	4	$1600
LED Lights	2	$59
LED Panel (Display)	2	$120
Halogen Flood Light	6	$82
Joysticks	2	$250
Throttle Joystick	2	$160

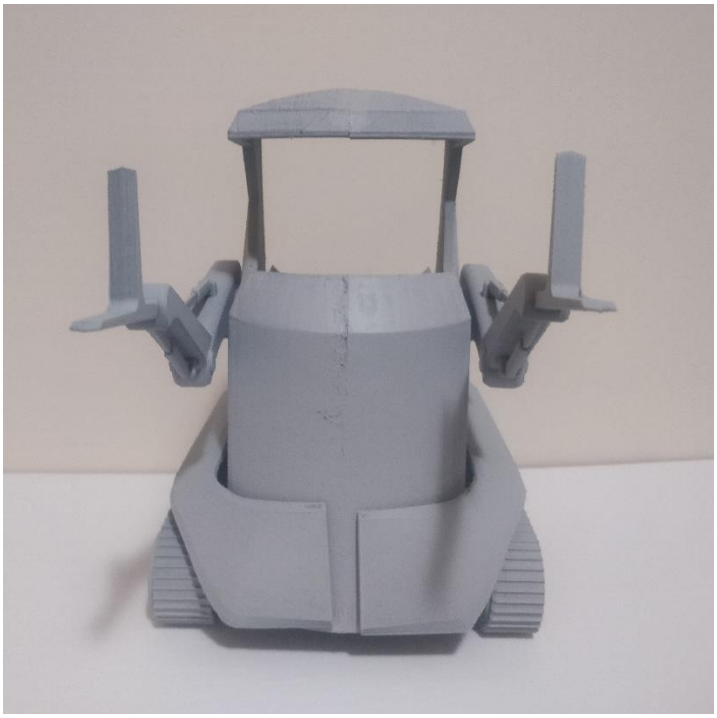
Standing Seat	1	$360
Battery	1	$19,100
Electric Motor	2	$3500
Cast Iron (Permanent Counterweight)	300 lbs.	$10.5
Cast Iron (Temporary Counterweight)	50 lbs. each x 8	$14
Handles	2	$52
	TOTAL COST	$31,749.5

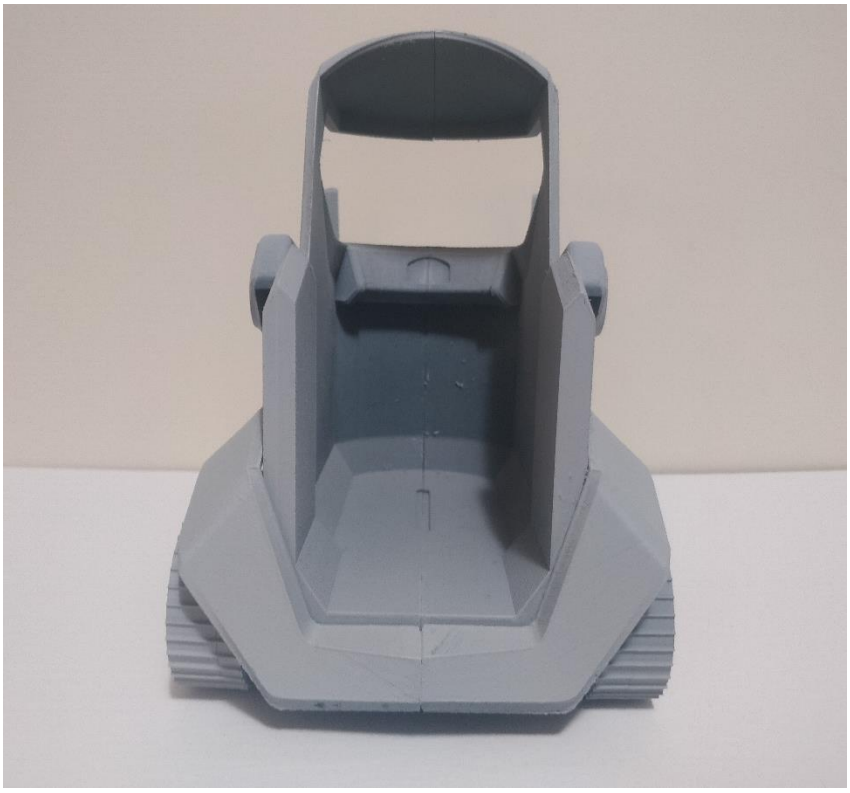
5.3 Final CAD Rendering



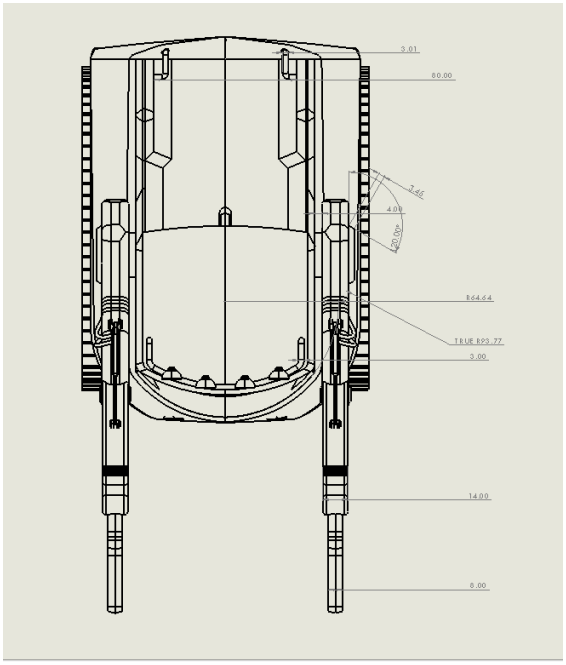
5.4 Physical Model

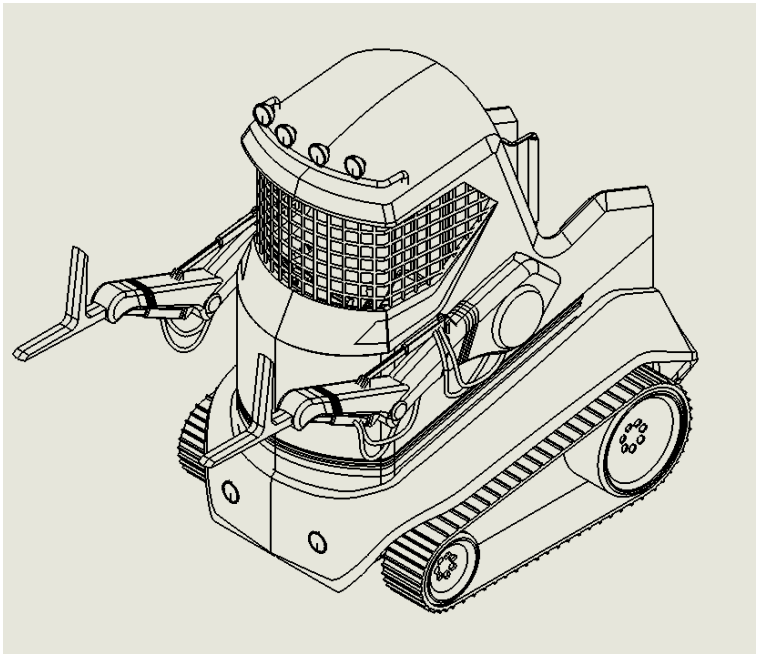


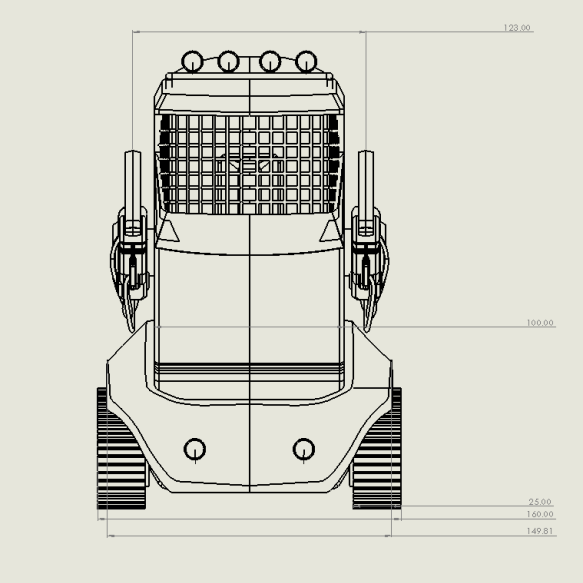


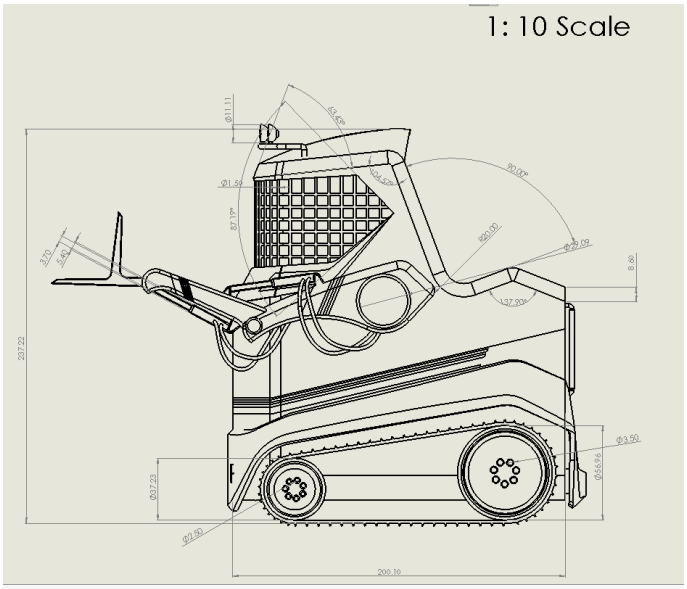


5.5 Technical Drawing









5.6 Sustainability

The construction industry has been falling behind in the race to remain sustainable, and with these changes hopefully that will change in the future. Firstly, starting with the powertrain, looking into the two emerging sustainable sources of energy: hydrogen and electric. As beneficial as hydrogen fuel cell production would be to the Canadian economy, it would not be the effective choice for construction equipment, the sensitive hydrogen tanks would become a liability to a construction site. The electric powertrain not only takes up less space but would also be safer to the construction site and its workers.

Components using rubber such as the tracks and button covers would use recycled rubber and reclaimed rubbers to help manufacture these components. Interior details such as seats can be manufactured using vegan leather which would prevent the need for cow hide and holding the leather together would be a thread made of recycled plastic bottles. This type of thread is already being used in the footwear industry, primarily being used by Adidas the thread is made and provided by a company called Parley.

The metal structure will be made of reclaimed metal, and any off cuts will be repurposed to be used again, creating a cycle of always using what could have been used.

All plastic components will be made of reclaimed plastic water bottles, and other plastics that have not been disposed of properly.

CHAPTER 6 – CONCLUSION

Conclusion

Urban life is constantly branching out from major cities, providing many opportunities for citizens to travel effectively and safely. Roads represent the growth of a civilization and an increasing economy as well as a growth in population. The impressive network of roads throughout Canada symbolizes the unification of different cities and provinces, as well as represents the ever-increasing population growth in Canada. Road construction workers today face challenges that are often unseen, and not highlighted in mainstream life. Unlike physical dangers such as falling or injury by impact, there are injuries that are unseen and often go undiagnosed due to the lack of awareness and education about the causes of these types of injuries.

These injuries are better known as Musculoskeletal Disorders (MSDs), an injury of muscle tissue which progressively grows in pain the longer it goes untreated. Some causes are the repetition of a task which is strenuous on muscle tissue, and the preforming a strenuous task in an uncomfortable position, which can exacerbate muscle tissue due to the nature of the position the worker may be lifting in. MSDs do not include musculoskeletal injuries or disorders that are the direct result of a traumatic event, such as a fall, being struck by or against an object, being caught in or on something, a vehicle collision, or workplace violence (Workplace Safety & Prevention Services). Montaro is a unique take on construction equipment not currently seen in the industry.

The unique design and take on the mitigation methods and agile movement provides efficiency throughout the workday. The electric powertrain provides instantaneous torque to the tread proving excellent traction and movement on any terrain found on a construction site. The MSD mitigation methods offer strain free use of the vehicle for prolonged use, this allows for more work to be done throughout the day and avoiding time needed to switch drivers; it is not uncommon for the operators to switch out very often because of risks such as vibrations, so the Montaro simply uses mass tuned dampers to mitigate this problem.

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Appendix

A) Discovery

Video Internet Search

Find 5+ videos and select the best 3.

Video #1

URL: https://www.youtube.com/watch?v=OP1dImqMswk

Title: **PPE | Safety Hazardous Equipment at Construction Site**

Length: 8:38

Brief Description: This video, although it may have been difficult to understand due to a language barrier was very helpful. The video discussed the types PPE (Personal Protective Equipment) used by construction workers on the job site. The video also discussed the colour coding system

Video #2

URL: https://www.youtube.com/watch?v=f8a95Nkg2fA

Title: **A Career in Road Construction (JTJS12007)**

Length: 6:56

Brief Description: The video covers a day in an apprentice shoes and covers many tasks. The apprentice is taught how to go about the construction site, and how to communicate with the other workers.

Video #3

URL: https://www.youtube.com/watch?v=Qsdq9yEwgWs

Title: **POV: Day In The Life Of A Construction Foreman**

Length: 17:58

Brief Description: The video covers a simple project, which involves pouring concrete, for steel tubing being placed into the ground. The video showcases a construction worker, working with his coworkers to finish the task. A lot of the video is content that is not entirely useful, but that is quickly seroconverted by

Survey Questions

When the objective is to narrow down the inquiry from a topic to a specific focus, the survey emphasis is on those tasks or jobs central to the activity, and to determine the main pain points for the user or rate limiting tasks. Below are possible questions for such a survey.

Core Questions

- How long are the work hours? And how long are the breaks?
- Are the working conditions suitable for safe work habits?
- What are some pieces of safety equipment that you use to help prevent a Musculoskeletal Disorder?
- How are you informed about the dangers of a Musculoskeletal Disorder?
- Approximately, how many hours are requested off, due to a Musculoskeletal Disorder?
- How are other workers affected by Musculoskeletal Disorder?
- How long may someone need to recover to working condition from a Musculoskeletal Disorder?

- How often throughout the day are you straining yourself?

Refinement Questions

- Have you ever experienced a Musculoskeletal Disorder?
- If yes, which area did it affect?
- If not, what are some precautions you take to avoid a Musculoskeletal Disorder?

Questions for Empathy Mapping

1. WHO are we empathizing with?

- ***Can you tell me about yourself?***
- ***Do you do this activity with someone else?***
- ***Tell me about how you got started doing this?***

2. What do they NEED TO DO?

- ***What motivates when you decide to do this task?***
- ***Where do you get your inspiration for doing this?***
- ***What's important to you to call the task finished?***

3. What do they SEE?

- ***Ask for a tour of their activity area / work area***

  Note layout of area / Note layout of their tool / aids
- ***Describe important visual cues while doing this task (if any)***

4. What do they SAY?

- ***What's going on in your head as you're doing this task? (what you say to yourself while doing this task)***
- ***What instructions do you give others related to any part of this activity (if any)?***
- ***What type of social conversation takes place when doing any of the related tasks involved (if any)?***

5. What do they DO?

- ***Are there any steps for this task that you had to prepare for in advance?***
- ***Where do you usually go to get your supplies / tools / equipment? Why do you go there?***
- ***Please go through the sequence of activities involved, as if you were instructing an 'apprentice'.***

6. What do they HEAR?

- ***Do you remember any comments people have made about you doing your task?***
- ***Describe important auditory cues while doing this (if any)?***
- ***How do the sounds of a construction site inform those on the site?***

7. What do they think and feel about…

A. PAINS: ***fears, frustrations, anxieties****…. "Coordinating is very frustrating, we are the middle man, we gotta excute everything and to have those trades come in late or early it messes up our schedule. I would say, being "the one" incharge of them is frustrating when someone is worried about it then you are"*

- ***Is there anything you find difficult about doing this? Why?***
- ***Regarding your goals doing this task, which were not yet achieved? Why?***
- ***What gave you the most grief, or frustration doing this?***

B. GAINS: ***goals achieved; experiences enjoyed….***

- ***Regarding your goals doing this task, which were achieved?***
- ***What is enjoyable about doing this?***
- ***How do you feel about the outcome? Why?***
- ***Tell me about a time doing this task that was enjoyable?***

"What other thoughts and feelings might motivate their behavior?"

- ***Anything that would make this easier while doing this task?.***
- ***Is there anything that would make it more productive?***
- ***Is there anything that would make the experience more enjoyable for you?***
- ***How do you come up with these solutions?***
- ***Are there more people going into construction?***

Result

Transcript

"Shown below is a sample of the transcript taken from the interview with the user.

The transcription was generated from …… *voice recording / transcription app / typed out responses."*

*Transcription should be in 5 pt font and have **headings** for the major tasks/ events undertaken, on 1 page.*

1. WHO are we empathizing with?

- ***Can you tell me about yourself?***

My name is Anonymous Advisor, I'm 28 years old. I work as a construction coordinator. I love math and science so made sense to put those two together. Big sports fan

- ***Do you do this activity with someone else?***

Yes, definitely a lot of teamwork involved.

- ***Tell me about how you got started doing this?***

Well I was in university doing psychology. And as I mentioned I like math and science, so I put those together and started working at a surveying company.

2. What do they NEED TO DO?

- ***What motivates when you decide to do this task?***

The end product and not disappointing the client, the end product is the biggest motivation, and keeping our schedule is the biggest motivation. Keeping our schedule and giving the client the best result. Seeing the end product, myself is also a large motivator.

- ***Where do you get your inspiration for doing this?***

Started when I was a kid playing with Legos and watching shows like mighty machines. Also talking with my brother and learning more about the industry has been inspiration.

- ***What's important to you to call the task finished?***

Quality assurance, quality control, safety. Safety is the most important. Making sure everyone is enjoying themselves.

3. What do they SEE?

- ***Ask for a tour of their activity area / work area***

  Note layout of area / Note layout of their tool / aids

My work area depends on what project is happening, so it can be a high rise, or a regular building site. It constantly changes.

- ***Describe important visual cues while doing this task (if any)***

Most of the visual cues have to do with safety, so we have a system for those allowed to be on the site and who's just visiting. We have clear indication what is safe to do and what isn't, basically the cues are mainly safety related.

4. What do they SAY?

- ***What's going on in your head as you're doing this task? (what you say to yourself while doing this task)***

There are so many things going on, there are so many tasks throughout the day. It depends which site we are on, if its at height I think about safety. And the board comes by I think how can I appease them. Just problem solving overall.

- ***What instructions do you give others related to any part of this activity (if any)?***

Once we come up with a solution its pretty linear, the instruction I give is simple, just the plan I'm given.

- ***What type of social conversation takes place when doing any of the related tasks involved (if any)?***

I have a great relationship with everyone working with me and keeping up those relationships help the company and clients. The conversations are everywhere but always beneficial.

5. What do they DO?

- ***Are there any steps for this task that you had to prepare for in advance?***

Yeah, in three years coming, I was a field coordinator for a project coordinator. I had to push through roles and get there.

- ***Where do you usually go to get your supplies / tools / equipment? Why do you go there?***

We have a purchasing team, so we usually let them know what we need, and they go out and get it. And the suppliers are really just companies that we have worked with for a long time and they can help out. But for small things we go out to home depot.

- ***Please go through the sequence of activities involved, as if you were instructing an 'apprentice'.***

They'll come in, and well do a site safety evaluation, and well give them a sticker proving that they have gone through the video. We give them emergency contacts like hospitals. Well discuss his scope of work, and make sure he is safe and is comfortable.

6. What do they HEAR?

- ***Do you remember any comments people have made about you doing your task?***

Oh yeah defiantly, constructive criticism goes a long way, and I've been told stuff calmly and have been yelled at

- ***Describe important auditory cues while doing this (if any)?***

Well I mean I'm always listening to yelling. Not all yelling is bad, just gotta listen. Gotta always be wary of smoke alarms. And we also have ear protection to ensure the safety of others. Always just listening for anything that may be going wrong. All of our alarms are also auditory, so its also a safety protocol.

- *How do the sounds of a construction site inform those on the site?*

As I mentioned before, there are certain auditory cues that we use, be it safety or other machines. We always trying to differentiate machines, or equipment to make sure everyone is aware. I'm going back to it a lot, but safety is key.

7. What do they think and feel about…

A. PAINS: *fears, frustrations, anxieties* *…. "Coordinating is very frustrating, we are the middle man, we gotta excute everything and to have those trades come in late or early it messes up our schedule. I would say, being "the one" incharge of them is frustrating when someone is worried about it then you are"*

- ***Is there anything you find difficult about doing this? Why?***

The difficult part is being expected to know quite a bit and solve problems that you have never encountered. Navigating the conversation so that you have the answer.

- ***Regarding your goals doing this task, which were not yet achieved? Why?***

Not really sure where my career would take me, it depends where I'm trying to go, I'm really at a fork path if you can say that. A lot of factors that go into it, and its just the beginning right now but its hard to say.

- ***What gave you the most grief, or frustration doing this?***

I would say, when people expect you to solve a problem right away, people are just impatient and don't want to do the task themselves. They can do it themselves, but they are just trying to put the responsibilities on us, and they don't want to have that responsibility on them. If things do wrong, they come for you quick and blame.

B. GAINS: *goals achieved; experiences enjoyed….* *"Seeing your product at the end, seeing the client satisfied, and being a part of that is really cool, and I'm never in the same spot, the job is always changing."*

- ***Regarding your goals doing this task, which were achieved?***

I always feel like I'm chasing, idk if I achieved my goals yet. I have advanced through the company quickly which is great, but I always feel like I'm behind because there is always something new to learn. The goal post always moves, and you always try evolve.

- ***What is enjoyable about doing this?***

Working with people, the construction industry is pretty free flowing, and you get to sometimes drop the f bomb and just be outside and its very laid back. Problem solving is also very fun, and enjoyable. The people make the job. Management always makes the workplace.

- ***How do you feel about the outcome? Why?***

Its sometimes god and sometimes bad, its pretty anxiety inducing, we gotta wait for weekends sometimes just for approval, and when one of our solutions gets approved its amazing.

- ***Tell me about a time doing this task that was enjoyable?***

My most enjoyable task was actually 3d scanning a floor of high-rise building, and I was scanning at like 4am and the city was quiet, and it was so cool.

"What other thoughts and feelings might motivate their behavior?"

- ***Anything that would make this easier while doing this task?***

If there was a magic book to give you all the answers ha-ha but working with others defiantly helps and new technology always helps.

- ***Is there anything that would make it more productive?***

I believe that if we did longer days, and shorter weeks and offer more overtime we would get more done. Working Monday thru Thursday is easier than for the Friday.

- ***Is there anything that would make the experience more enjoyable for you?***

I can't think of anything expect having my best buddies with me, if I get to pick my team, I guess that would be enjoyable, there are always people I prefer to work with.

- ***How do you come up with these solutions?***

Just on-site experience, and the superintendents are amazing people to lean back on. There is an endless amount of resources that we have, and to reach out to.

- *Are there more people going into construction?*

Because of COVID-19 there have been a lot of hires because it is an essential job. But now in general there a lot of new workers lately, and so many workers have requested time off until 2022 and receiving compensation, so there is a slight problem for when those workers come back because we don't know how we'll fit everyone back in.

B) User Research

This research focuses on the mitigation of musculoskeletal disorders in road construction workers, which is the most common and reoccurring injury amongst construction workers. Musculoskeletal Disorders (MSDs) are often associated with strain on the muscle tissue and joints while completing a task in a fast and uneven pace, or while lifting in an unfamiliar or uncomfortable position. This observation shows real issues with the construction industry and how medical issues are maintained, and for the time being there is not an effective method of doing so. All current evolution of products is flawed and do not mitigate MSDs but rather weaken the body and put it more at risk when not using these products. Recent data has shown that nearly forty percent of time off requests in Ontario have been due to MSDs. The primary users are road construction workers and those directly on construction sites. The secondar users are other workers, and medical personnel. The tertiary users would be family members and civilians around the construction sites.

User Demographics

Targeted demographic criteria for which general characteristics and information was sought included age, gender, ethnicity, income/ purchasing power, and education.

Image search for General Demographic Characteristics

A Google Image Search was performed to understand what typical road construction worker looks like

IMAGE	**DEMOGRAPHIC INFORMATION**
 Figure 1 - City of Thunder Bay. Retrieved from https://www.thunderbay.ca/Modules/News/search.aspx?feedId=38b137b4-fee8-473b-88e7-dab9c145d9b8	Age: 19-35 Gender: mixed, predominantly male Income: $28,000 - $43,000 Educational background: College Career/ Volunteer: Road Construction Worker
 Figure 2 – ANF News. Retrieved from https://anfenglish.com/news/construction-workers-are-most-exposed-to-coronavirus-42696	Age: 16-45 Gender: mixed, predominantly male Income: $22.10/ Hour Educational background: College Career/ Volunteer: Construction Worker

 Figure 7 - National Network for the Transportation Workforce. Retrieved from https://www.nntw.org/career-pathway/road-construction-manager/	Age: 29-50 Gender: mixed, predominantly male Income: $91,370 Educational background: College/ University Career/ Volunteer: Road Construction Manager

The following search terms were used:

- “Road Construction Worker”
- “Construction Workers”
- “Road Construction Manager”

Findings.

Findings have been collected in a Table.

Literature Search for Demographic Data

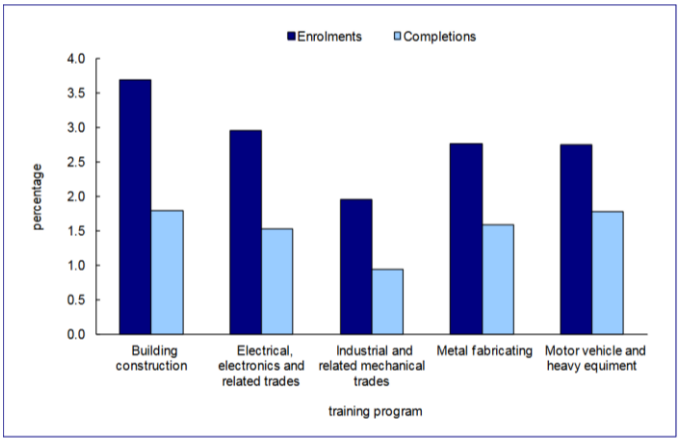
A literature search was also performed on the Humber Library website and Google to find statistical data relevant to road construction workers. The following search terms were used:

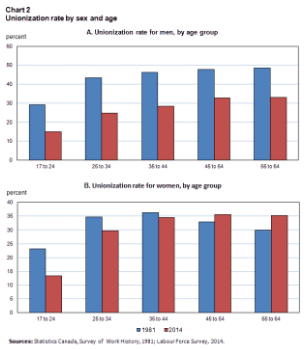
- “Road Construction Demographics”
- “Construction Worker Data”
- “Construction worker Survey”
- “Construction worker Statistics Canada”

Findings:

Findings have been summarized below according to the relevant categories: Gender; Age; Race and Ethnicity; Income and Education.

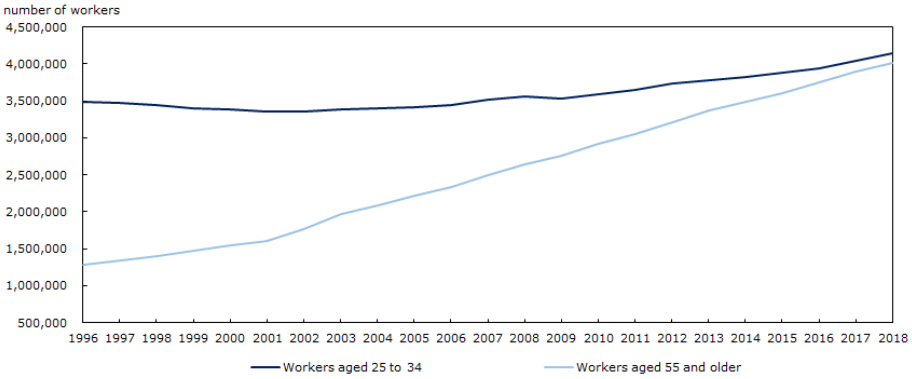
Gender: As inferred from the image search above most of the construction workforce is primarily dominated by males. Females taking a mere 3.6% of the workforce in 2007, however this has been slowly rising to 9.1% since 2017.





Age: As shown by this chart, workers aged 55 and older has been steadily increasing since 1996, while the younger workforce (25- 34) has not had as an aggressive incline. This statistic may also be in correlation to injury reports.

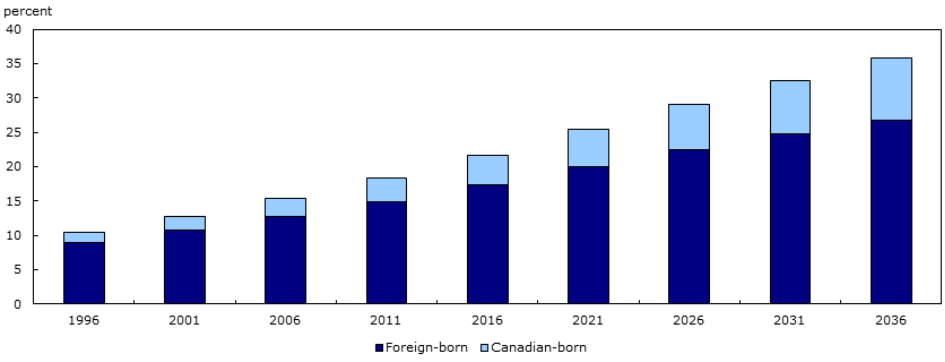
Chart 1
Number of younger workers (aged 25 to 34) and older workers (aged 55 and over), 1996 to 2018



Source: Statistics Canada, Labour Force Survey, 1996 to 2018.

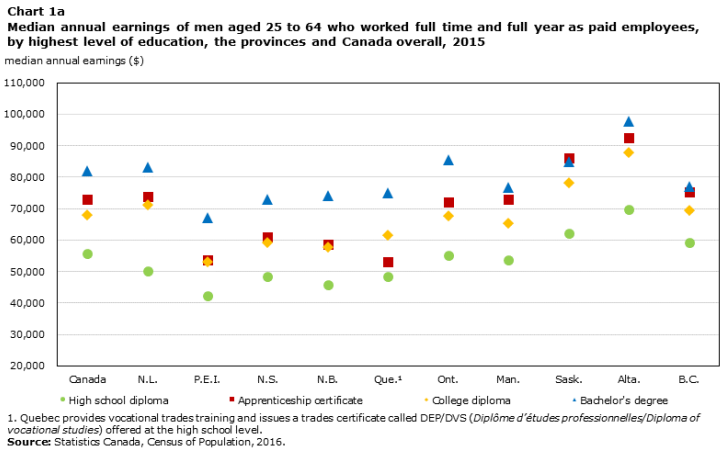
Race and Ethnicity: Again, as seen with the images the predominant ethnicity among construction workers is shown in demographics as largely being foreign-born, this statistic is also showing an increase by 2036, however the Canadian-born workers seem to be increasing as well but nowhere near as much to equal foreign-born workers.

Chart 7
Observed (1996 to 2016) and projected (2021 to 2036) percentage of visible minorities in the labour force by immigrant status, reference scenario, Canada



Source: Statistics Canada, 1996, 2001, 2006 and 2016 censuses; 2011 National Household Survey (adjusted); Demosim microsimulation model, 2017 (2036).

Education: This is hard to determine by simply looking at images, so the demographic data is key to figuring them out.



Income: The graph below indicates the income from all provinces ranges from $11-$33.5 an hour. This chart is representative of areas in which urbanization is happening quickly, as well as referencing the rurality of some provinces.

CONSTRUCTION TRADES HELPERS AND LABOURERS (NOC 7611-0)

2017	Wages ($/hr)		
Province/Territory	Low	Median	High
Canada	13	20	32.15
Alberta	16	23	35
Newfoundland and Labrador	12.67	19.5	33.58
Ontario	12.5	19	32
Québec	13	21.5	32
British Columbia	13	18	30.1
Nunavut	18	22	30
Saskatchewan	15	20	30
Yukon	18	23	29
Nova Scotia	11	17	27
Northwest Territories	17.4	21	26.49
Manitoba	13.5	18	26
New Brunswick	12	16.68	25.85
Prince Edward Island	11.25	14.5	18.7

Discussion / Conclusions

Based on the images above we get a general overview of who is working as a construction worker and what they look like. From the images it can be observed that the typical construction worker appears to be between the ages of approximately 18 to 55. It is also apparent that most construction workers are foreign-born. In these instances, the income is a harder statistic to infer as there is really no factor to base that on. An education level of at least a high school degree was inferred. College education was inferred on some occasion where there seemed to be more career construction workers, primarily site managers. With the statistical data in front of us, it's clear to see that the images portray a realistic view of the “average” construction worker.

Demographics of Construction Workers	
Age	18 - 55
Gender	Mostly Male (91%)
Ethnicity	Foreign
Income	$30k - $74k
Education	High School/Bachelor's Degree

Overall, most construction workers seem to fit into the classes of being a 26-year-old male of foreign ethnicity earning around $30k to $74K with a minimum of a high school diploma.

Primary User	Construction Workers
Secondary User	Medical Professionals/ Trade Workers
Tertiary User	Civilians/ Family

User Behaviour

A literature search was conducted to discover a construction workers trait relating to user behavior. For this search Google and the Humber Library website were used to extract relevant information. The following search terms were used:

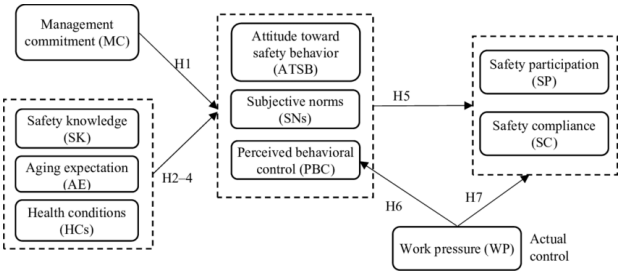
- “Construction Worker Behavior”
- “Construction Worker Mental Health”
- “Construction Workers Traits”
- “Construction Worker Income”

Findings

Findings have been summarized below according to the relevant categories: Activity Frequency; Duration of Activity; Group or Solitary Activity/level of focus; Motivation and lifestyle; Income Level & Purchasing Power; Location; Personality and cognitive aspects.

Model Behaviour:

Construction workers are expected to follow a safety model behaviour chart, this chart primarily focuses on safety and health checks, and focus on how age and commitment effect the attitude of a worker.



From this chart it is evident that there is a need for some reform to older construction workers, who are more likely to be injured on the job, “Workers who are between the ages of 34-35 are the most likely to be injured while working in construction” (National Safety Council, 2020). This chart also demonstrates a lack of decision making from older workers and displays their lack of a positive work attitude.

Social:

Due to the cooperative nature of the job, construction workers must be very vocal with those working around them. During apprenticeships, workers are told that cooperation is essential to the success of their job. This skill is stressed heavily throughout the apprenticeship. Over the past couple years however the scene at construction sites has been shifting. With more safety protocols, there are far less injuries, and many preventative measures in place today.

Lifestyle & Personality:

Construction workers are extremely active people; they spend a lot of time exercising and performing cardio. Even though being in good shape is a crucial requirement of being a construction worker many of them take pride in their health. To this point many have active hobbies they enjoy participating in on their time off.

Income Level:

Construction worker income ranges from $30k – 74k in Canada, this range is dependent on their performance, and ability as they age. Workers starting at the age of 18, tend to be on the lower income range, due to the lack of experience, and accountability for the worker. However, older and more experienced workers have a higher liability and more experience that is valued more. Education has also come into account, those with a high school diploma will tend to stay towards the lower half of the income, but the ones with bachelor's degrees tend to be working not only as construction workers, but can reach up the ladder to a higher paying position because of their education.

Location:

Construction workers tend to be in urban and rural parts of the country; road construction can quite literally take a worker anywhere. Since road construction tends to be done outside there are areas in which workers can rest, and or go to a food place nearby.

Conclusions

The variable found in this aspect of understanding the user had to do with the different employment conditions (career in either urban or rural locations) rather than the behavior characteristics.

User Profile Summary

User	Description
Primary	Road Construction Worker
Secondary	Medical Professional/ Trade Workers

User	Description
Tertiary	Civilians/ Family

Primary User Profile

Demographics		User Behaviour		Personality		Cognitive Aspects	
Age	18-55	Frequency of Use	On site, weekdays	Focus on the Job	↑	Technical Skill	↑
Gender	Predominantly Male (~91%)	Duration	8.5 hours a day	Self-Efficiency	↑	Pre-Requisite Knowledge	↑
Ethnicity	Foreign (+70%)	Social	High-Social	Changeability	↑		
Income	Middle Class ($30,000 to $74,000)	Level of Focus	High	Uncertainty Avoidance	↑		
Education	High School Diploma	Location	Residential – Rural/ Urban				

Conclusions

A construction worker is a middle-class citizen, working a typical 40 hour a week shift. Workers are also predominantly foreign, and between the ages of 18-55. Most workers have a high school diploma, however many who are seeking higher positions in the future have bachelor's degrees. Their personality on the job site tends to be attentive, efficient, and avoiding any uncertainty.

Persona

Name: Juan Carlos Perez

Age: 26

Occupation: Road Construction Worker

Income: $46,000/ year

Education: High School Diploma

Relationship Status: In a Relationship

Location: Brampton, Ontario

Career/ Volunteer: Career

Years of Service: 6 Years

Social: Works with 7 other workers

Hobbies: Strength Training, Spending time with Family, Soccer, Cooking

Profile

Juan Carlos Perez is a 26-year-old Mexican construction worker. He attended high school and received his diploma. He earns a yearly salary of $46,000 a year and has been a part of the work force for 6 years.

Juan Carlos began his career at 20 years old. He prides himself in keeping his family well fed and keeping up with his younger cousins in soccer.

User Behavior:

Juan shows a great attitude at work, and always ensures the wellbeing of others before his own. Juan always ensures that all those around him are aware of what he is doing and will double check everyone's work for the day. Juan is a hardworking man, and is liked by all his coworkers, and is deemed as a reliable worker and friend.

Juan's Relationship to his PPE:

Juan started working at a young age and was less prone to injuries related to musculoskeletal disorders (MSDs), however there are no exceptions to whom may receive a MSDs. At 23, Juan was lifting in an uncomfortable position, and tore some muscle tissue in his bicep and back. Ever since then Juan ensures that he is lifting securely and has a lifting belt, along with a compression sleeve around his arm. Juan understood that MSDs do not go away once they are healed, in fact it is easier to injure that same spot again.

C) Product Research

Product #1

Stand Up Forklift

https://www.crown.com/en-ca/forklifts/rc-stand-up-rider-counterbalanced-truck.html

Promotional Piece *(Highlight the Benefit)*

In a busy work environment, the Crown RC Series stand-up counterbalance forklift excels – whether on the dock or in an aisle. Its compact design gives the operator unmatched visibility, ultimate ergonomics, and revolutionary ride control.

For operators working in confined spaces, visibility is essential. To this end, the unique design geometry of the RC Series stand-up forklift outpaces all others where it counts the most: in trailers, narrow aisles, and areas congested with pedestrians, equipment, and products.

The power unit curves in on the right side (where operators look most often). This contour, along with the low-profile power unit translates into industry-leading visibility.

The mast and pillar design also enhance forward visibility. This has been achieved through the clean routing of hydraulics and chains as well as the orientation of the pillar itself.

It's proven operators who are comfortable and confident accomplish more. That's why Crown developed industry leading, innovative features into the RC Series forklift with the operator in mind.

The stand-up design gives operators the flexibility and comfort they need for faster throughput. Highlights include soft touch points, a revolutionary FlexRide suspension system, shock-absorbing padding, unrivaled workspace, and ease of entry/exit.

Crown's RC Series offers more than three times the protection of typical lift trucks from shocks and vibrations such as bone-jarring impacts over dock plates, expansion joints and rough floors.

A lift truck that enables its operator to perform at their best can substantially improve total operational efficiency. The RC Series stability and control features allow the operator to focus on the task at hand.

Crown's Access 1 2 3 Comprehensive System Control. With the technology, lift truck systems are constantly monitored and data is shared to modify performance based on real-time work conditions. These include traction, braking, steering, hydraulics, and other lift truck systems.

The RC Series stand-up forklift includes the Crown Intrinsic Stability System which is engineered to minimize the causes of unstable conditions for safety and efficiency. The Entry Bar Safety Switch encourages safe foot position within the operator compartment by reducing travel speed, sounding an audible alert, and showing a message on the display when depressed.

Features (*Highlight the Features)*

- 3 wheels
- Max. Lift Height 276 in
- Power 36 V / 775 - 1395 Ah
- Width 42 in
- compact design
- ultimate ergonomics, and revolutionary ride control
- The mast and pillar design also enhance forward visibility
- soft touch points, a revolutionary FlexRide suspension system
- three times the protection of typical lift trucks from shocks and vibrations
- lift truck systems are constantly monitored

Product #2

Lifting Belt

https://www.roguecanada.ca/rogue-ohio-lifting-belt

Promotional Piece *(Highlight the Benefit)*

The Rogue Ohio Lifting Belt is handcrafted not to compete with the world of mass-produced, sporting-goods-store weightlifting belts, but to offer a stronger, longer-lasting alternative for customers serious about strength training and investing for the long haul.

Made from 10mm thick, vegetable-tanned American leather, this 4" wide belt offers firm, consistent support; easing stress on the back and helping in both the reduction of post-workout pain and the potential long-term prevention of more serious injury.

The Ohio Belt is available in five sizes (see Fit Guide below), and includes a single-buckle design for quick, easy adjustments and a custom fit. The exact thickness of each belt may vary from slightly due to the properties of the leather. Users should also note that the belt, like any quality leather product, may require a brief "break-in" time for optimal contouring and comfort.

Our Ohio Belt is manufactured with pride in Columbus, OH, using quality USA leather and the skills of our in-house craftsmen. Each belt measures 4" in width and approx. 10mm in thickness, providing firm, heavy-duty support with quick adjustments via the single prong buckle.

Features (*Highlight the Features*)

- Stronger, longer-lasting alternative for customers serious about strength training and investing for the long haul.
- 4" wide belt offers firm, consistent support, easing stress on the back
- Reduction of post-workout pain and the potential long-term prevention of more serious injury
- Quick, easy adjustments and a custom fit
- Providing firm, heavy-duty support with quick adjustments via the single prong buckle.

Product #3

Urban Performance

https://www.suitx.com/shoulderx

Promotional Piece *(Highlight the Benefit)*

ShoulderX V3 is the world's most advanced shoulder-supporting exoskeleton. The device counterbalances the weight of an arm or tool, comfortably redistributing loads onto the wearer's hips. shoulderX enables one to perform chest to ceiling level tasks for longer durations or with less effort.

During simulated overhead tasks, shoulderX has reduced muscle activation by up to 81%. Study participants reported reduced exertion across the shoulder, neck, and back regions and use of the exoskeleton was preferred by all over the unassisted condition. Read the research paper: Experimental Evaluation of a Shoulder-Support Exoskeleton for Overhead Work: Influences of Peak Torque Amplitude, Task, and Tool Mass.

The third-generation industrial exoskeleton incorporates novel features based on the feedback obtained from numerous field evaluations across the globe and boasts a 40 percent reduction in weight compared to the version 2 without losing any of its industry-leading characteristics. Like its predecessor, the new design does not use electric power, does not need batteries, is available in multiple configurations such as fire retardant, dust-proof and water-resistant and is specifically designed to withstand the harsh environments found in construction sites, manufacturing plants, and shipbuilding facilities.

Features (*Highlight the Features)*

- **Optimized Support:** Support force gradually increases as the user lifts their arms and becomes near zero when the arms are lowered to one's sides, allowing the user to rest arms naturally or reach for tools on their tool belt.
- **Adjustable Support Level:** Support capacity can be quickly changed between 5-12 lbs per arm to accommodate different user arm weights, tools, and fatigue levels. No separate cartridges or gas springs.
- **Adjustable Support Angle:** Support angle can be quickly changed between 60 to 120 degrees of peak support angle to accommodate different user heights and types of task.
- **On/off Capability:** Each actuator can be quickly turned off, rather than doffing the suit, to prevent the device from impeding a worker during breaks or secondary tasks.
- **Adjustable Frame Size**: Tool-less adjustments allow the suit to fit a range of worker height, waist size, shoulder width, and arm length (5%-95% of human dimensions)
- **Optimized Load Transfer:** The lumbar supporting frame automatically conforms to each user's unique body shape, dispersing applied loads across a large surface area and reducing slippage (sagging) between the wearer and the exoskeleton
- **Active Cooling:** Optional fans blow air onto the user's back with adjustable intensity and angle to reduce thermal discomfort.
- **Lightweight:** shoulderX weighs 7 lbs. (3.17 kg)

- **Batteries Not Required:** Cleverly designed to reduce the risk of shoulder and arm injuries without the use of actuators and computers
- **Rugged:** Waterproof, dustproof, and easy to maintain
- **Modular:** One or two arm use, compatible with backXS V3 and legX.
- **Compatible:** Compatible with tool belts, allowing workers normal equipment to retain functionality
- **Quick Donning and Doffing:** Less than 30 seconds to put on or take off
- **Fire Rated:** Optional FR textiles are available for hot work

Product #4

Miniature Crane

https://www.globalindustrial.ca/p/material-handling/forklifts-attachments/cranes-hooks/best-value-forkli-telescoping-jib-boom-crane-4000-lb-capacity?infoParam.campaignId=T9F&gclid=Cj0KCQiA48j9BRC-ARIsAMQu3WQwfPJM7QD_Lf6E7PvHMTBKOWesEojsgV8PX3pdJgkzLuqOLzPVfKQaAplqEALw_wcB

Promotional Piece *(Highlight the Benefit)*

This device easily converts your forklift into a mobile jib boom crane. Simply slip the forks of your counter-balanced forklift truck into the fork pockets of the jib boom and attach the provided safety chain to the forklift truck mast.

Features (*Highlight the Features)*

- 153-3/4" Fully Extended; 86-1/4" Fully Retracted
- Safety chain welded to boom has grab hook for anchoring jib boom to truck
- Two hoisting hooks (one swivel, one rigid)
- Adjustable locking screw secures boom in any position
- 4 intermediate supports points under boom on 12" centers add support for long loads
- Slot lock for quick chain use
- Durable chip-resistant enamel finish

Using Excel to Sort Your Data

BENEFITS	Sort #1	Sort #2
From Promotional Material	DATA [On Menu Bar] → Sort	Groups like categories
visibility	Comfort: comfortable redistribution	*comfort* 5
space	Comfort: reduction of pain	comfortable redistribution
enhance forward visibility	Comfort: space	Control Features
stability	Comfort:Control Features	fit a wide range of workers
Control Features	Comfort:fit a wide range of workers	reduction of pain
Constntly monitored	Convenience: Constntly monitored	space
reduction of pain	Convenience: converts into crane	
veg tan leather	Convenience: easy adjustments	*Convenience* 7
easy adjustments	Convenience: long duration, less effort	Constntly monitored
comfortable redistribution	Convenience: one or two arm use	converts into crane
long duration, less effort	Convenience: quick take off	easy adjustments
fit a wide range of workers	Convenience: veg tan leather	one or two arm use
anti slip	Safety: anti slip	veg tan leather
one or two arm use	Safety: center support	quick take off
quick take off	Safety: durable	long duration, less effort
converts into crane	Safety: enhance forward visibility	
safety chains	Safety: safety chains	
center support	Safety: stability	*Safety* 7
durable	Safety: visibility	anti slip
		durable
		safety chains
		enhance forward visibility
		center support
		Stability
		visibility

FEATURES		Sort #1	Sort #2
From Promotional Material	Re-order: NOUN	DATA [On Menu Bar] →	Group like categories
ergonomics	Comfort: ergonomics	Comfort: comfort	**Comfort**
ride control	Comfort: ride control	Comfort: consistent support	Comfort: comfort
compact design	compact design	Comfort: ergonomics	Comfort: consistent support
visibility.	Safety: visibility	Comfort: ride control	Comfort: ergonomics
flexibility	Safety: flexibility	Comfort: soft touch points	Comfort: ride control
comfort	Comfort: comfort	Comfort: wide belt	Comfort: soft touch points
soft touch points	Comfort: soft touch points	Other: 4 intermediate supports points	Other 9
suspension system	Suspension: suspension system	Other: compact design	Comfort: wide belt
Lift Height 276 in	Other: Lift Height 276 in	Other: Lift Height 276 in	Other: 4 intermediate supports points
power 36v	Other: power 36v	Other: longer-lasting alternative	Other: compact design
Stronger	Other: Stronger	Other: Optional fans	Other: Lift Height 276 in
longer-lasting	Other: longer-lasting	Other: power 36v	Other: longer-lasting
wide belt	Comfort: wide belt	Other: quick adjustments	Other: Optional fans
consistent support	Comfort: consistent support	Other: Stronger	Other: power 36v
quick adjustments	Other: quick adjustments	Power: electric power	Other: quick adjustments
need batteries	Power: need batteries	Power: need batteries	Other: Stronger
electric power	Power: electric power	Safety: fire retardant	
fire retardant	Safety: fire retardant	Safety: flexibility	
dust-proof	Safety: dust-proof	Safety: Safety chain welded to boom	Safety 3
water-resistant	Safety: water-resistant	Safety: visibility	Safety: fire retardant
withstand the harsh environments	Suspension: Suspension withstand the harsh environments	Safety: dust-proof	Safety: flexibility
Optional fans	Other: Optional fans	Safety: water-resistant	Safety: Safety chain welded to boom
Safety chain welded to boom	Safety: Safety chain welded to boom	Suspension: suspension system	Safety: visibility
4 intermediate supports points	Other: 4 intermediate supports points	Suspension: Suspension withstand the harsh environments	Safety: dust-proof
			Safety: water-resistant
			Power Trains
			Power: electric power
			Power: need batteries
			Suspension
			Suspension: suspension system
			Suspension: Suspension withstand the harsh environments

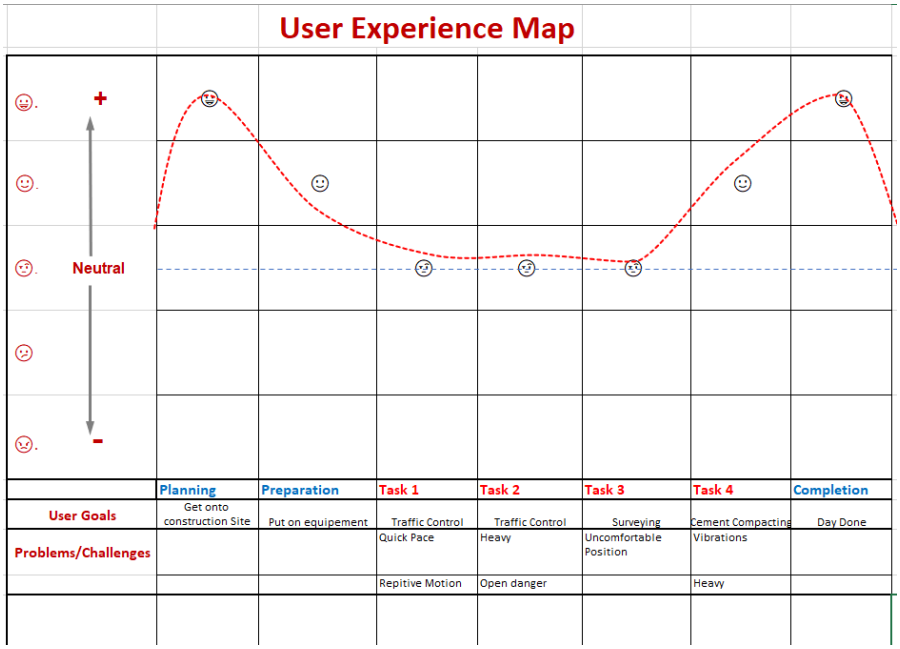
Benefits Table

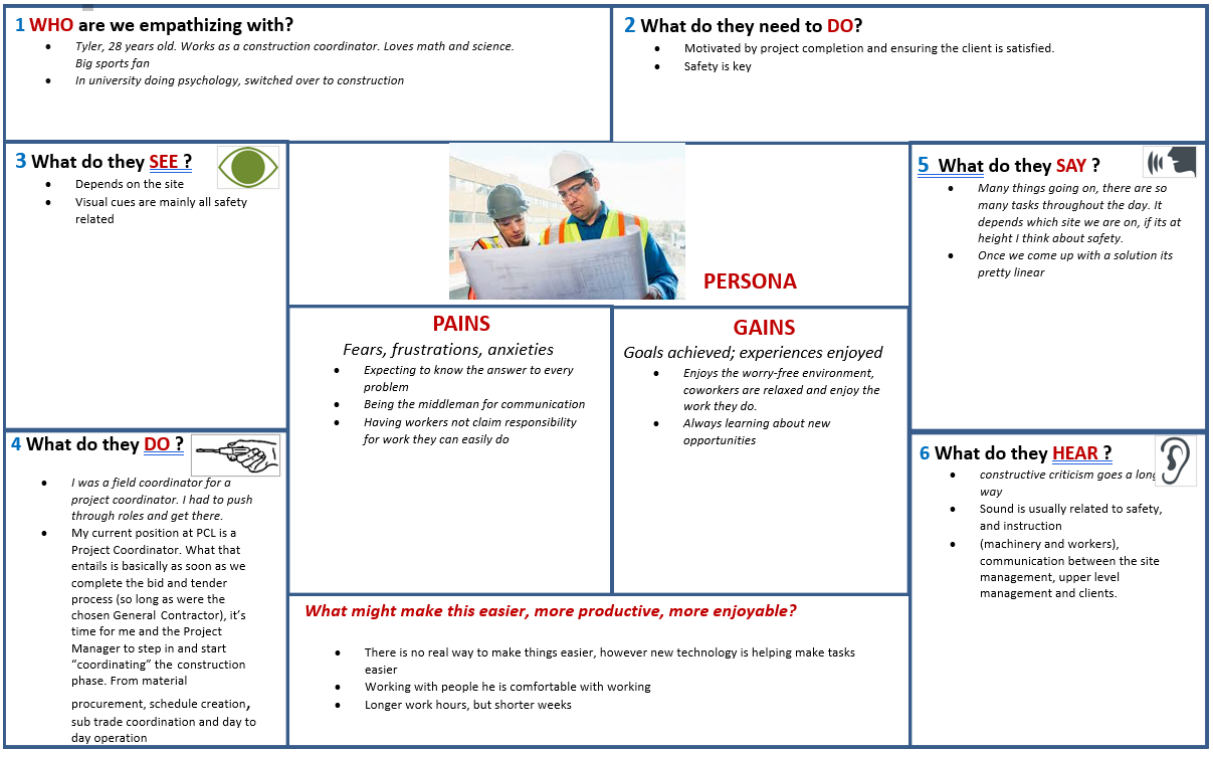
Key Benefits of Comparable Products	
Keyword	***Frequency***
Comfort	5
Convenience	7
Safety	7

Features Table

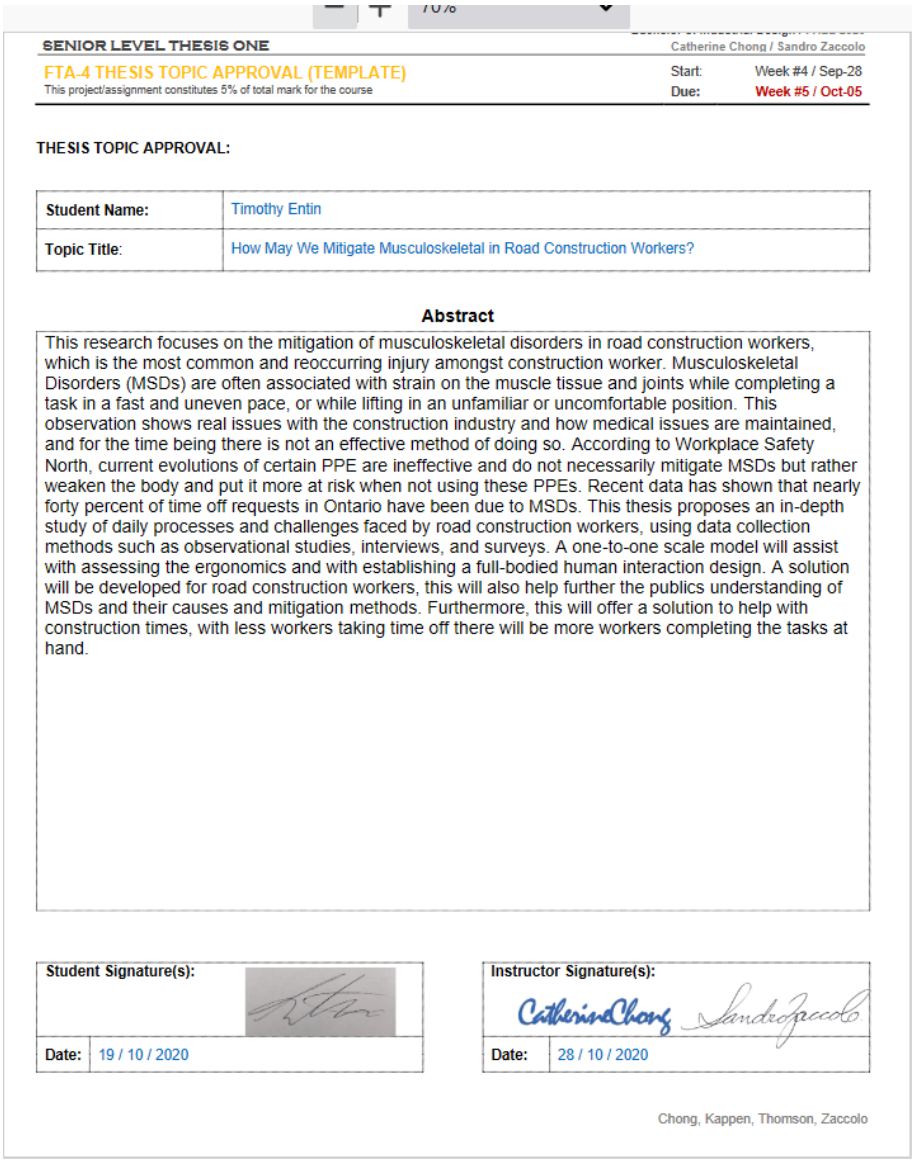
Key Features of Comparable Products	
Keyword	***Frequency***
Comfort	6
Other	8
Safety	6
Power Trains	2
Suspension	2

D) Analysis


User Experience Map
+
Neutral
-
Planning
Preparation
Task 1
Task 2
Task 3
Task 4
Completion
User Goals
Get onto construction Site
Put on equipement
Traffic Control
Traffic Control
Surveying
Cement Compacting
Day Done
Problems/Challenges
Quick Pace
Heavy
Uncomfortable Position
Vibrations
Repitive Motion
Open danger
Heavy


1 WHO are we empathizing with?
Tyler, 28 years old. Works as a construction coordinator. Loves math and science. Big sports fan
In university doing psychology, switched over to construction
2 What do they need to DO?
Motivated by project completion and ensuring the client is satisfied.
Safety is key
3 What do they SEE ?
Depends on the site
Visual cues are mainly all safety related
PERSONA
5 What do they SAY ?
Many things going on, there are so many tasks throughout the day. It depends which site we are on, if its at height I think about safety.
Once we come up with a solution its pretty linear
PAINS
Fears, frustrations, anxieties
Expecting to know the answer to every problem
Being the middleman for communication
Having workers not claim responsibility for work they can easily do
GAINS
Goals achieved; experiences enjoyed
Enjoys the worry-free environment, coworkers are relaxed and enjoy the work they do.
Always learning about new opportunities
4 What do they DO ?
I was a field coordinator for a project coordinator. I had to push through roles and get there.
My current position at PCL is a Project Coordinator. What that entails is basically as soon as we complete the bid and tender process (so long as were the chosen General Contractor), it's time for me and the Project Manager to step in and start "coordinating" the construction phase. From material procurement, schedule creation, sub trade coordination and day to day operation
6 What do they HEAR ?
constructive criticism goes a long way
Sound is usually related to safety, and instruction
(machinery and workers), communication between the site management, upper level management and clients.
What might make this easier, more productive, more enjoyable?
There is no real way to make things easier, however new technology is helping make tasks easier
Working with people he is comfortable with working
Longer work hours, but shorter weeks

J) Approval Forms



SENIOR LEVEL THESIS ONE
Catherine Chong / Sandro Zaccolo

FTA-4 THESIS TOPIC APPROVAL (TEMPLATE)
This project/assignment constitutes 5% of total mark for the course

Start: Week #4 / Sep-28
Due: Week #5 / Oct-05

THESIS TOPIC APPROVAL:

Student Name:	Timothy Entin
Topic Title:	How May We Mitigate Musculoskeletal in Road Construction Workers?

Abstract

This research focuses on the mitigation of musculoskeletal disorders in road construction workers, which is the most common and reoccurring injury amongst construction worker. Musculoskeletal Disorders (MSDs) are often associated with strain on the muscle tissue and joints while completing a task in a fast and uneven pace, or while lifting in an unfamiliar or uncomfortable position. This observation shows real issues with the construction industry and how medical issues are maintained, and for the time being there is not an effective method of doing so. According to Workplace Safety North, current evolutions of certain PPE are ineffective and do not necessarily mitigate MSDs but rather weaken the body and put it more at risk when not using these PPEs. Recent data has shown that nearly forty percent of time off requests in Ontario have been due to MSDs. This thesis proposes an in-depth study of daily processes and challenges faced by road construction workers, using data collection methods such as observational studies, interviews, and surveys. A one-to-one scale model will assist with assessing the ergonomics and with establishing a full-bodied human interaction design. A solution will be developed for road construction workers, this will also help further the publics understanding of MSDs and their causes and mitigation methods. Furthermore, this will offer a solution to help with construction times, with less workers taking time off there will be more workers completing the tasks at hand.

Student Signature(s):	
Date:	19 / 10 / 2020

Instructor Signature(s):	Catherine Chong Sandro Zaccolo
Date:	28 / 10 / 2020

Chong, Kappen, Thomson, Zaccolo

IDSN 4502
SENIOR LEVEL THESIS TWO

Humber ITAL / Faculty of Applied Sciences & Technology
Bachelor of Industrial Design / WINTER 2021
Catherine Chong / Sandro Zaccolo

CRITICAL MILESTONES: APPROVAL FOR CAD DEVELOPMENT & MODEL FABRICATION

Student Name:	**Timothy Entin**
Topic / Thesis Title:	**MSD solution for Construction Equipment**

THESIS DESIGN APPROVAL FORM

Thesis design is approved to proceed for the following:	[X] **CAD Design and Development Phase**
Comment:	Initial CAD progress reasonably as of week #11 / April 5th, continue with detailing and refinement. Must complete CAD before model fabrication.

Thesis design is approved to proceed for the following:	[X] **Model Fabrication Including Rapid Prototyping and Model Building Phase**
Comment:	Design development continue to progress as of week #11 / April 5th, upon completion of CAD by end of the week, can move forward to model fabrication from week #11 onward.

Instructor Signature(s):	CatherineChong SandroZaccolo
Date:	6th April 2021

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PANEL ON RESEARCH ETHICS
Navigating the ethics of human research

TCPS 2: CORE

Certificate of Completion

This document certifies that

Timothy Entin

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

Date of Issue: **2 October, 2020**

IDSN 4002 / 4502
SENIOR LEVEL THESIS ONE & THESIS TWO

HUMBER
Faculty of Applied Sciences & Technology
Bachelor of Industrial Design / FALL 2020 & WINTER 2021

INFORMATION LETTER

Research Study Topic:	How May we Mitigate Musculoskeletal Disorders in Construction Workers?
Investigator:	Timothy Entin – (647)-465-1457 – timothyentin@gmail.com
Sponsor:	Humber ITAL, Faculty of Applied Sciences & Technology (IDSN 4002 & IDSN 4502)

Introduction
My name is Timothy Entin I am an industrial design student at Humber ITAL, and I am inviting your participation in a research study on various problems that will discuss musculoskeletal disorders in construction workers, what are some of the current mitigation methods? and the procedures on a construction site.

Purpose of the Study
This study is being conducted as an aid in designing a piece of construction equipment with built in mitigation methods. The study will aim to better understand the effects/ causes of an MSD in a construction worker and how it is currently discussed and mitigated.

Procedures
If you volunteer to participate in this study, your activities in interacting in a construction site will be observed and documented. Your activities will be documented by means of a notation while around the construction site. You will also be asked questions pertaining to your occupation.

Confidentiality
Every effort will be made to ensure confidentiality of any identifying information that is obtained during the study. In the case of being recorded visually, your face will be masked /blurred or hidden. The information and documentations (photographs) gathered are all subject to being used in the final presentation of the study.

Participation and Withdrawal
Your participation in this study is completely voluntary and you may interrupt or end the study and the session at any time without giving a reason or fear of being penalized.

If at any point during the session, you feel uncomfortable and wish to end your participation, please let the moderator know and they will end your participation immediately.

Humber Research Ethics Board
This research project /course has been approved by the Humber Research Ethics Board. If you have any questions about your rights as a research participant, please contact Dr. Lydia Boyko, REB Chair, 416-675-6622 ext. 79322, **Lydia.Boyko@humber.ca**

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IDSN 4002 / 4502
SENIOR LEVEL THESIS ONE & THESIS TWO

HUMBER
Faculty of Applied Sciences & Technology
Bachelor of Industrial Design / FALL 2020 & WINTER 2021

INFORMATION LETTER

Conditions of Participation

- ✓ I understand that I am free to withdraw from the study at any time without any consequences.
- ✓ I understand that my participation in this study is confidential. (i.e. the researcher will know but will not disclose my identity)
- ✓ My identity will be masked.
- ✓ 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.**

Participant's Name	Participant's Signature	Date

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 about this Senior Level Thesis project, please contact me at the followings:

Phone: (647) 465-1457
Email: timothyentin@gmail.com

My supervisors are:

Prof. Catherine Chong, **catherine.chong@humber.ca**
Prof. Sandro Zaccolo, **sandro.zaccolo@humber.ca**

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IDSN 4002 / 4502
SENIOR LEVEL THESIS ONE & THESIS TWO

HUMBER
Faculty of Applied Sciences & Technology
Bachelor of Industrial Design / FALL 2020 & WINTER 2021

PARTICIPANT INFORMED CONSENT FORM

Research Study Topic: How May we Mitigate Musculoskeletal Disorders in Construction Workers?
Investigator: Timothy Entin – (647)-465-1457 – timothyentin@gmail.com
Courses: IDSN 4002 & IDSN 4502

I, Tyler Byers have carefully read the Information Letter for the project MSD Solution for Construction Workers, led by Timothy Entin A member of the research team has explained the project to me and has answered all of my questions about it. I understand that if I have additional questions about the project, I can contact Timothy Entin at any time during the project.

I understand that my participation is voluntary and give my consent freely in voice recording, photography and/or videotaping; with the proviso that my identity will be blurred in reports and publications.

Consent for Publication: Add a (X) mark in one of the columns for each activity

ACTIVITY		YES	NO
Publication	I give consent for publication in the Humber Library Digital Repository which is an open access portal available to the public	☐	☐
Review	I give consent for review by the Professor	☐	☐

Privacy
All data gathered is stored anonymously and kept confidential. Only the principal investigator /researcher Timothy Entin and Prof. Catherine Chong or Prof. Sandro Zaccolo may access and analyze the data. All published data will be coded, so that visual data is not identifiable. Pseudonyms will be used to quote a participant (subject) and data would be aggregated.

I also understand that I may decline or withdraw from participation at any time, without negative consequences.

I understand that I can verify the ethical approval of this study, or raise any concerns I may have by contacting the Humber Research Ethics Board, Dr. Lydia Boyko, REB Chair, 416-675-6622 ext. 79322, **Lydia.Boyko@humber.ca** or Timothy Entin, (647)-465-1457, timothyentin@gmail.com

Verification of having read the Informed Consent Form:

☐ I have read the Informed Consent Form.

My signature below verifies that I have read this document and give consent to the use of the data from questionnaires and interviews in research report, publications (if any) and presentations with the proviso that my identity will not be disclosed. I have received a copy of the Information Letter, and that I agree to participate in the research project as it has been described in the Information Letter.

Participant's Name	Participant's Signature	Date

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