Design of a Movable Platform for ABB Robot

HAMKTech Robotics Research Group

HAMK
UNIVERSITY OF APPLIED SCIENCES

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Subject of bachelor's thesis Design of a Movable Platform for ABB Robot

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ABSTRACT

The purpose of this thesis was to design a movable platform for the ABB Robot with a braking and a docking mechanism, making it suitable to work alongside a CNC lathe machine. This thesis work was commissioned by the HAMKTech Robotics Research Group; one of the 'Research & Development' departments of Häme University of Applied Sciences, situated in Riihimäki.

The primary objective of this thesis project was to design a simple, mechanically firm, yet inexpensive movable platform for the ABB IRB 140 3 robot or any robot model of similar size, which would be later produced and used in machining applications alongside a CNC lathe machine. Creating a braking and docking mechanisms for the platform were the two primary mechanical requirements for the design.

The thesis project started with lab-based research on the robot and the lathe machine followed by web-based research on the development of the platform. Several sessions were carried out to learn to use PTC Creo Parametric for the 3D design of the platform. Multiple visits to the robotics lab and discussions with the supervisor during the brainstorming process helped in successful design of the platform. Virtual simulation and strength analysis were conducted to test and amend the design. Thus, the general design approach; background research, ideation, concept-design, analysis, and documentation were implemented for the completion of the thesis work.

This thesis describes design in detail, list of components, cost estimation and details on assembly design which will be used by the commissioning party as a reference to produce parts of the platform and to assemble the parts at the robotics research lab. This thesis work can also be a helpful reference for further amendment and optimization of the design.

Keywords ABB IRB 140 3, braking, docking, movable, platform.

Pages 47 pages + appendices 12 pages

CONTENTS

List of abbreviations:

HAMK	Hämeen Ammattikorkeakoulu
ABB	ASEA Brown Boveri
CNC	Computerized Numerical Control
IRB	Industrial Robots
PTC	Parametric Technology Corporation
3D	3(Three) Dimensional
FEM	Finite Element Model
mm	Millimeter
kg	Kilogram
DFMA	Design for Manufacturability and Assembly

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1 INTRODUCTION

1.1 Background

We humans have relentlessly evolved throughout the history because of the continuous quest for more and more amenities and sophisticated facilities. We have come a long way out and have seen lot of technological advancements rather it be the invention metal axes or the invention of robots. The pursuit for ease and effective execution of complicated tasks led to the invention of robots. Robot are such sophisticated machines that contributes a lot in the well-being of modern-day society.

Multiple kinds of robots have been developed till date. Generally, they are used in industrial sectors, including consumer goods, electronics, automobiles, materials-processing and many others. Industrial robots are typically used in applications such as machine tending, welding, assembly and material handling. This thesis work is about the design and assembly of a functional platform for ABB IRB 140 3 robot which is used for machining applications in research lab situated at HAMK University of Applied Sciences. However, the design of the platform is not specific to the ABB IRB 140 3 robot and can be used further along with other collaborative robots of the same size.

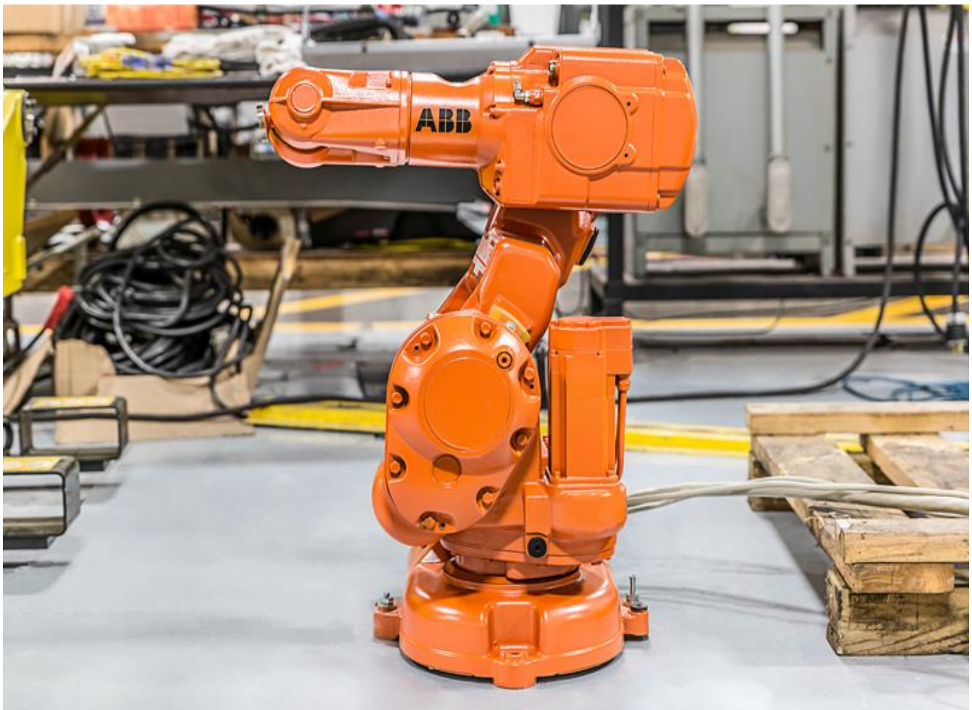

Figure 1 Example of 'ABB IRB 140 3' Robot (ABB IRB 140 3 Robot Model of Robotworx, 2018)

Robot as shown in Figure 1 is small yet very fast, compact and powerful 6-axes multipurpose robot. It can handle payload up to 6 kg and can reach to up to 810 mm. It can be floor mounted, inverted or wall mounted at any angle. It is very flexible, robust and has a collision detection feature making it very safe and reliable.

1.2 Commissioning party and goals

HAMKTech Robotics Research Group is one of the ‘Research and Development’ departments of HAMK University of Applied Sciences which is actively carrying out research and project related to industrial application of robot ranging from product packaging to product manufacturing. The main aim of this group is to provide flexible learning and research environment to engineering students with maximum use of collaborative robots present at the research lab.

This group have been using a ABB IRB 140 3 robot to feed metal parts into a CNC lathe machine for machining but they were missing a movable platform for the robot that could easily transport the platform to machine feeder and would dock in a specific place to help ease the machining operation. To help solve the problem, I was assigned to design a movable platform with features like braking and docking mechanisms, as part of my bachelor’s thesis.

1.3 Thesis plan

Table 1 Thesis plan describes the roadmap of thesis set during initial phase.

Table 1 Thesis plan

Research Description	Week	Goals
Thesis Agreement and Thesis Plan	6	To plan a roadmap for thesis work
Research on ABB IRB140 3 robot and platform	7	To set a clear goal for the research
Idea development and discussion	8	To get complete picture of final design
Analysis and possible Iterations in Idea	9	To finalize the design idea
Finalization of Idea and Discussion with supervisor	10	To discuss and approve the idea
3D modelling & Work Simulation	11-13	To design the platform using Creo Parametric
Modelling iterations and modifications	13-14	To modify and enhance the quality of design
Analysis on robustness, reliability and performance of 3D models (FEM Analysis)	15	To analyze the mechanical aspects with software like ANSYS
Discussion with lead supervisor and modifications	16	To approve the final design
Final documentation and Presentation of Research	17-22	To prepare a thesis workbook

2 MECHANICAL DESIGN PROCESS

An engineering design process is a series of complex interlinked steps with some strategic approaches. Mechanical product design also has similar steps as other engineering design process.

While designing the platform the process as illustrated in Figure 2 was followed;

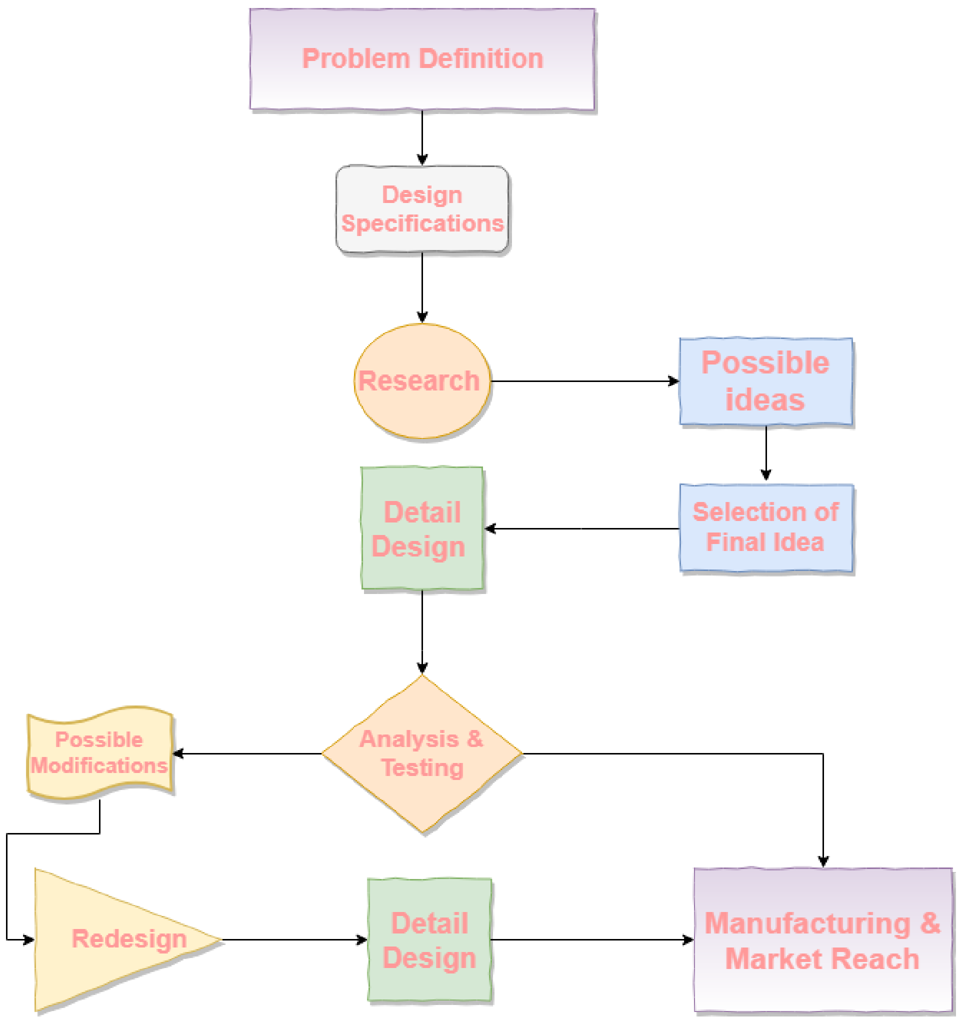

Figure 2 Mechanical Design Process

2.1 Definition of problem

The first and foremost step in design is definition of the problem, where a problem is formulated in clear and unambiguous terms once a need is identified. After the need is identified, the engineering problem solving process starts with defined goals.

Similarly, in research lab of HAMK University of Applied Sciences a need was identified. There was a problem transporting an ABB robot platform to a CNC machine feeder. Every time it required 2-3 people and a forklift to transport the platform to the CNC machine and same amount of effort to transport the platform out of the CNC machine. The other problem they encountered was with the docking system of the platform. Every time the robot needed to be calibrated before working as the chances of placing the platform to a specific place was minimal all the time. Therefore, they required a platform which would be easily transported to CNC machine and out of it including a breaking mechanism and a docking mechanism along with it. Braking mechanism was to hold the platform in a stable position while the docking mechanism was to place the platform in a specific position eliminating the need of robot calibration.

The problem has been defined and targets have been set. Now the next step is the design specifications.

2.2 Design specifications

In this process, the requirements of the commissioning party are carefully analysed, and the scope of design is set. The necessary aspects of design such as functions, technical features, cost analysis and timings are outlined during this process.

While designing the platform various specifications were analysed as per the requirements set by HAMKTech Robotics Research Group and as illustrated in Table 2.

Table 2 Design Specifications

Aspect	Specifications
Function	The basic requirement of the design is a movable platform that can be transported easily and has a braking and a docking mechanism.
Size	The platform needs to be spacious enough for robot operations. Outer dimensions should be minimum 1060×800×1800. (in mm)
Aesthetics	The platform shall look like a cuboid. Platform need to have at least two-layer shelves: one for the robot and the other one for its processor and components.
Cost	The total manufacturing cost and material cost shall not exceed 2000 euros.
Components	The platform needs to have various components like wheels, brakes, docking locks, glass doors, aluminium profiles. Components and materials shall be chosen taking care of market availability, robustness and cost.
Safety	The platform needs to have safety doors and roofs to prevent disturbances during robot operation. Use of door locks and side covers should be considered.
Manufacturability &Assembly	The components of platform shall be designed to make the manufacturing process and assembly simple and easy.

2.3 Research and Scope of design

Research on gathering important information on the product design and figuring out the scope of design is another important step in design process. All the pertinent information needs to be collected for a successful and detail product design.

Before designing the platform, all the necessary scope was explored as the research group already had a stationary platform shown in Figure 3 working alongside the lathe machine. Studies on replacing the platform and design of the platform with additional technical features were conducted. Possibilities of using commercially available products were taken into considerations to save time and money later for the assembly and manufacturing process. Some questions that were considered during this phase were:

- Is there a real need for the framework to be redesigned and rebuilt?
- What are the existing problems?
- What advantages does the existing solution have?
- What features can be used from the existing solution into the new solution?
- What are the economic constraints?
- What are the safety factors that needs to be considered?
- What problems can be encountered during the manufacturing & assembly process?

All these possibilities were considered, and research work was carried out based on this which helped gather all the relevant information for the design.

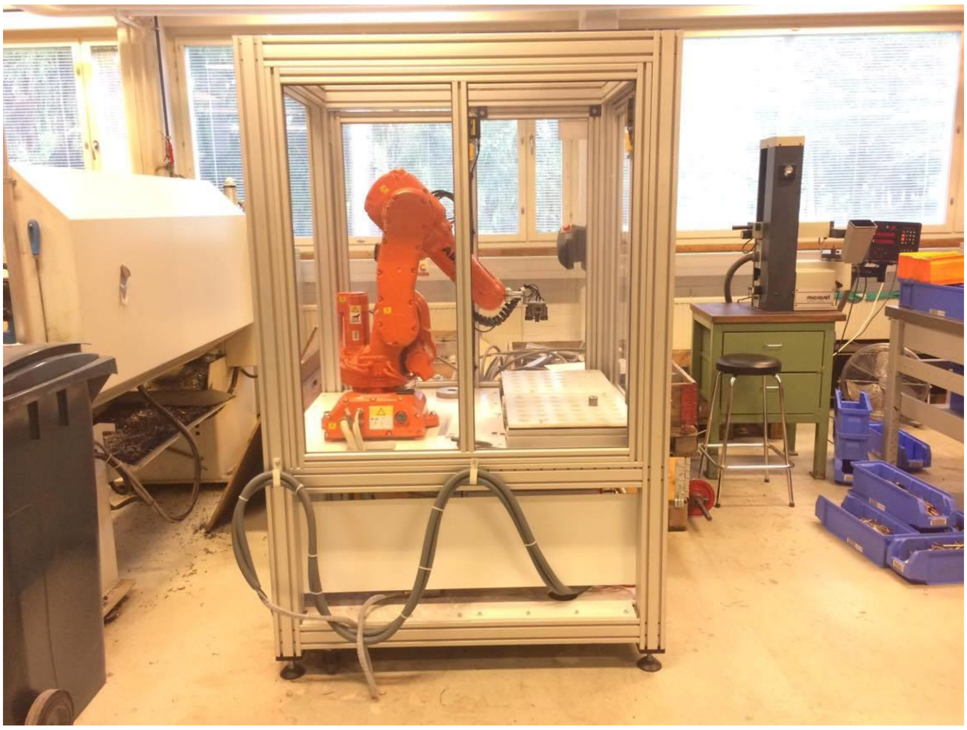

Figure 3 Exisiting platform with ABB IRB 140 3 robot

Figure 4 CNC lathe machine in HAMKTech Lab

Before searching for design solutions of the platform, the workstation was analysed, and details of the CNC machine were taken out. The CNC machine in Figure 4 is Leadwell CNC T-6 M machine used for machining purpose.

Lab based studies on the workstation were conducted and the basic idea on the placement of platform and the CNC machine was figured out as described with a sketch in Figure 5. The figure shows a top view angle of the placement of robot platform and the CNC machine along with the position of the robot and the work piece trays.

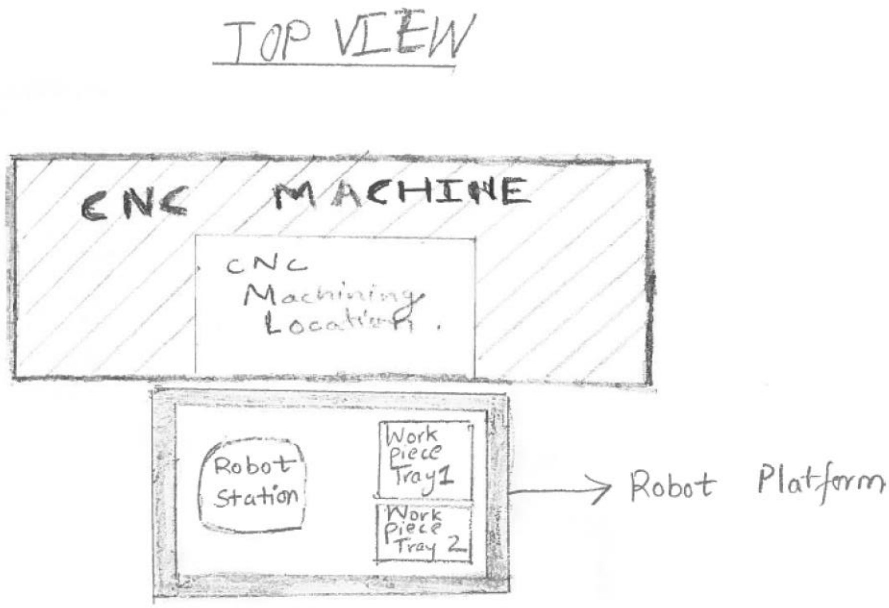

Figure 5 Workstation with platform and CNC machine

A 3D sketch of the placement of the robot platform and the CNC machine gives a clearer picture of the workstation as shown in Figure 6.

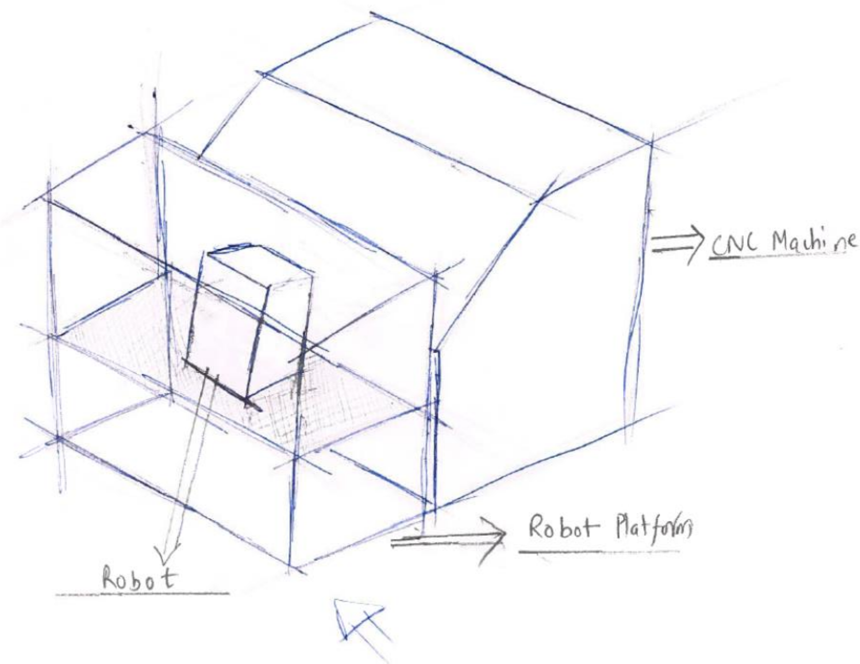

Figure 6 3D view of workstation with platform and CNC machine.

2.4 Design solution/ideas

Generating multiple solutions for a design is very important and here comparisons were made between the solutions. These multiple solutions were proposed and are explained as follows:

- Moving mechanism for framework solution

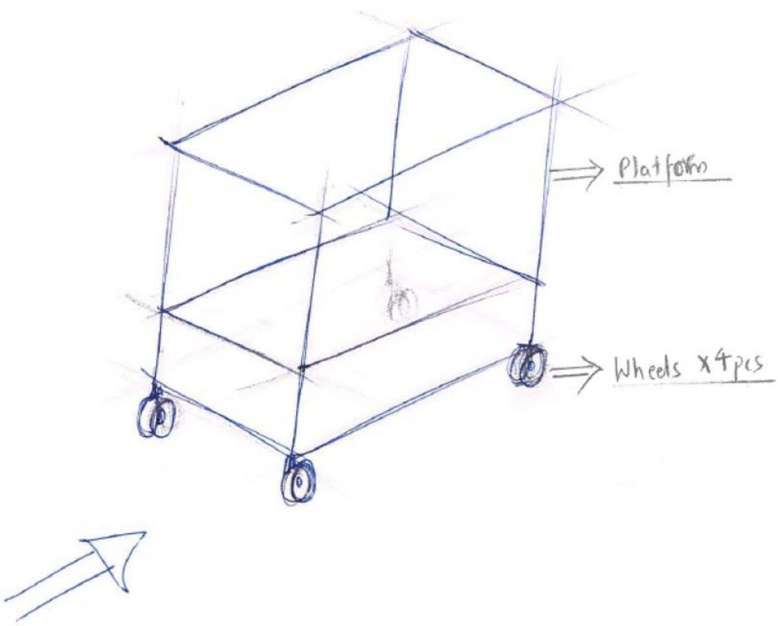

Figure 7 Sketch of Framework with Wheels

Sketch as shown in Figure 7 gives a basic insight of the moving mechanism of the framework. One of the design requirements was that the framework should be able to maneuver swiftly from one place to another. Addition of wheels to the bottom of the platform is the most basic solution to the problem. Use of 4 standard caster wheels was proposed for this mechanism.

Use of caster wheels is the obvious solution but choosing right kind of wheels is another important factor to be considered. Use of commercially available caster wheels was the best option for the platform as it would eliminate the need of design and production of it saving time and effort.

Caster are wheeled device which are mounted onto larger objects enabling the objects to move freely from place to place. There are different kinds of caster commercially available in market and its variety are based on it's size, function, materials.

Figure 8 Swivel caster (left) & Fixed caster (right) (TENTE Products)

In Figure 8, on the left side there is a swivel caster which allows movement in all directions. Swivel caster in the figure has a braking lever attached to it but swivel casters without brakes can also be found. There different types of braking option available for swivel casters such as directional lock brake or total lock brake. Our design solution needs a braking mechanism so use of swivel casters with brake was considered.

On the right side of Figure 8 there is a fixed caster. Fixed casters are also called rigid casters and they only can move in forward or backward positions. They are stronger than swivel casters and are also available with different braking options. Using 2 swivel casters and 2 fixed casters was proposed as one solution as 2 rotational casters were enough for directional movement. 2 fixed casters were proposed because it would be beneficial for installing braking mechanism which are discussed in next section under 'Breaking design solution'.

2.4.1 Braking design solution

Two options were proposed for the braking design solution during the ideation phase.

Option 1: One option was the use of a foot operated braking lever that would sit in a shaft connecting the two wheels as in Figure 9.

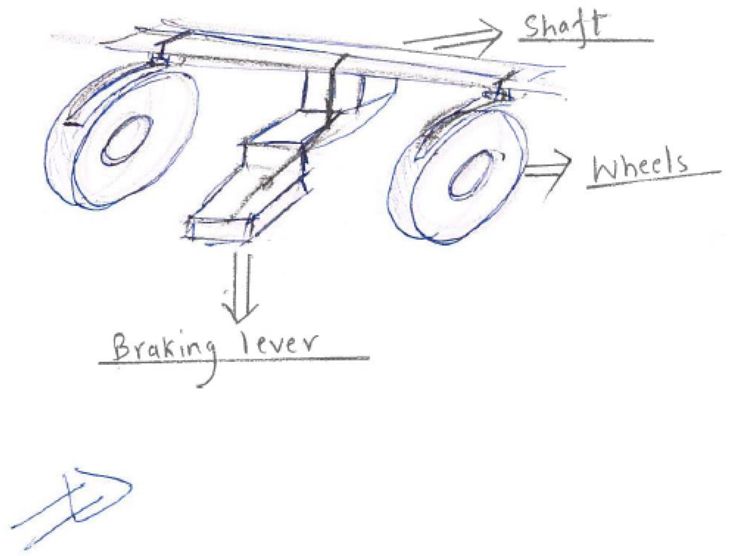

Figure 9 Braking solution with use of foot braking lever

Option 2: Other option was the use of of a hand operated braking lever that would sit in a handle rod as in Figure 10. Wires would connect the lever and the drum brakes in the wheel. When the lever is pressed drum brake release allowing the wheels to move and when lever is released drum brakes would activate braking the wheels. This solution was inspired from central locking baby strollers.

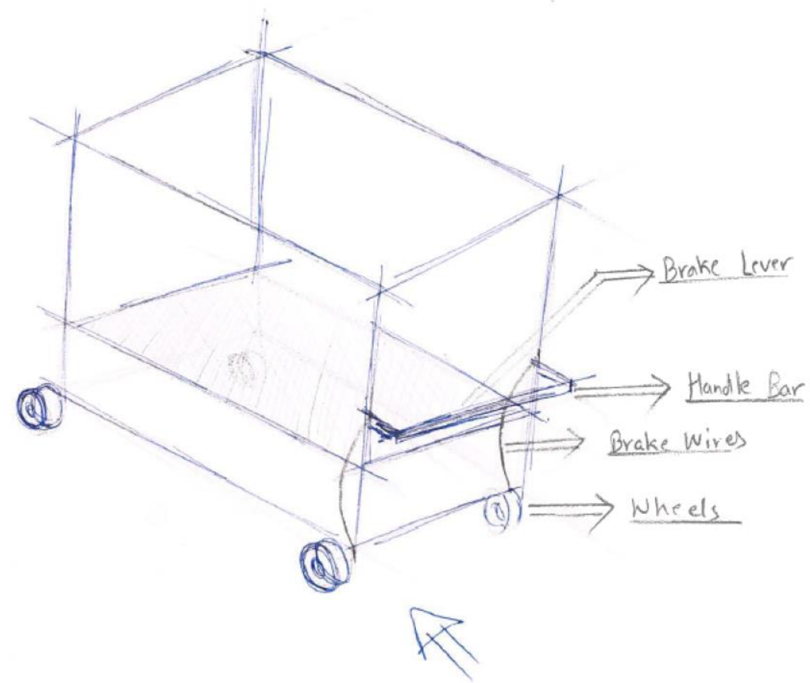

Figure 10 Braking solution with hand braking lever

2.4.2 Docking design solution

The robot platform needed to be docked or placed in the destination, which is in front of the CNC machine in a fixed location every time. So, the docking system must be very accurate without any tolerances.

For the docking mechanism, three options were proposed during the ideation phase.

Option 1: One option for the docking system was the use of linear gliding rails and wheels like the use of sliding mechanisms in drawers, car seats or doors.

Two beams would be placed in front of the CNC machine perpendicular to it and including the gliding bracket as shown in Figure 11. While wheels would be attached to the platform that would be inserted into the bracket when docking action is needed.
Additionally, two bolts would be inserted down the bracket to lock the platform in a specific position.

During the proposal for this particular solution another solution for the docking wheels was also proposed. Instead of using the wheels in the platform a sliding rail that could fit inside of the bracket could also be used for this kind of system. Since our platform would already have caster wheels it woukd help it to slide into the destination.

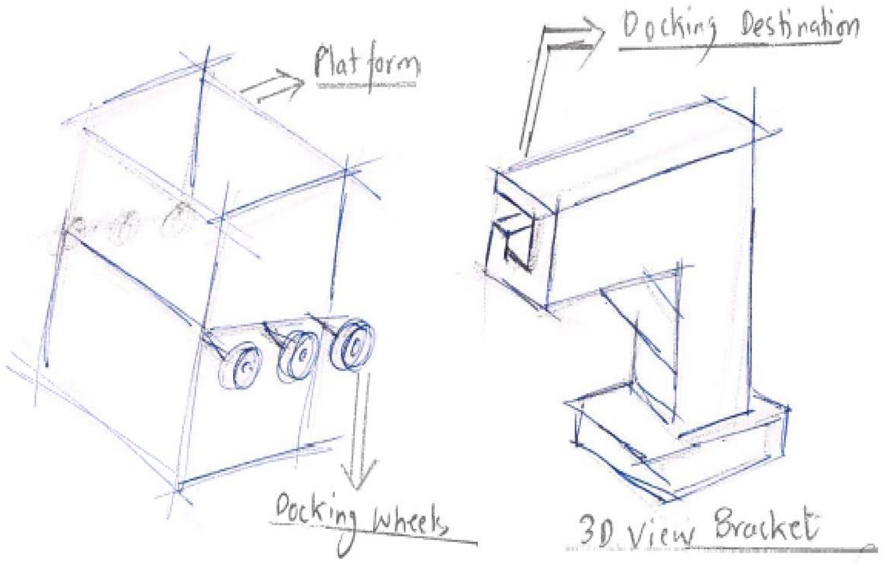

Figure 11 Docking Sytem with Gliders

Option 2: Another option was the use of a floor bracket similar to the docking system of wheelchairs in a car.

As shown in Figure 12, a bolt would be installed at the bottom of the platform and it would dock into a floor mounted bracket.

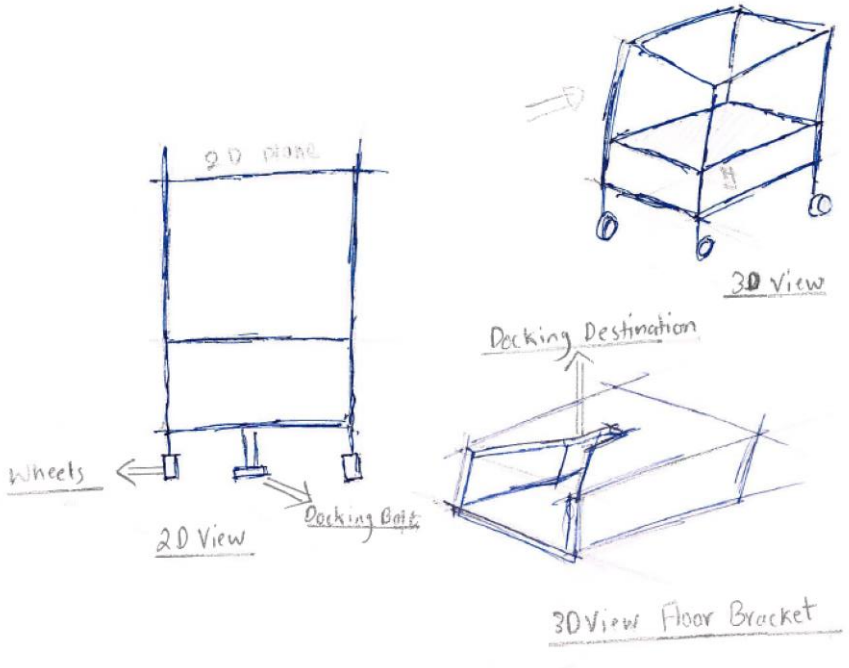

Figure 12 Docking system with Floor Bracket

Option 3: Another option was the use of magnets with male-female docking alignments as shown in Figure 13. Male Magnets would be fitted in the platform and would be docked into a female destination which would be fitted into a beam.

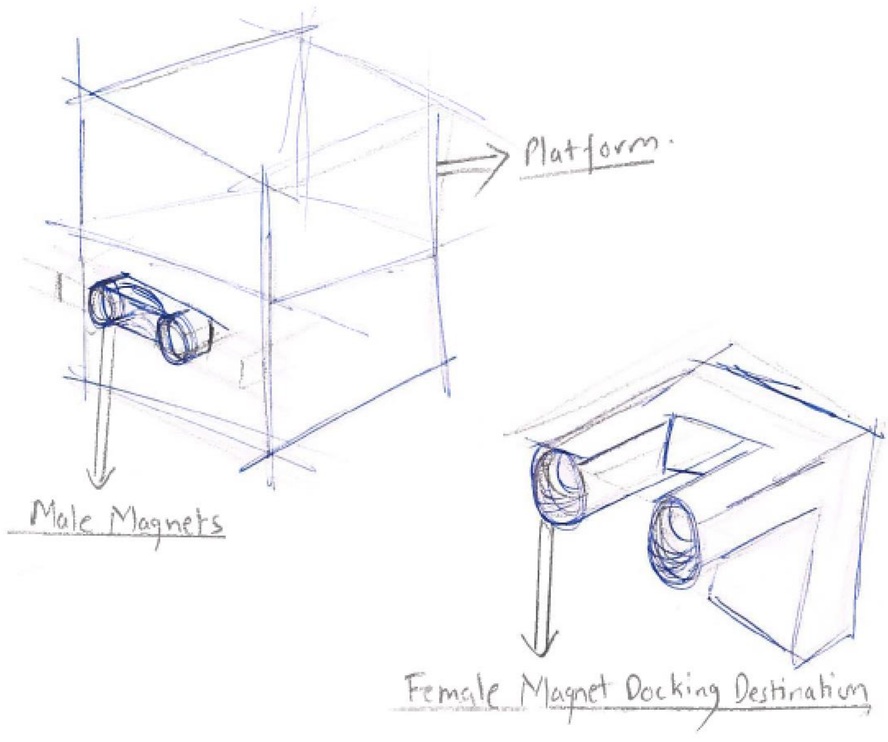

Figure 13 Docking System with use of Magnets

2.5 Finalization of idea

Before proceeding into the next phase which was the 3D design, design solutions had to be compared, and the best solution was chosen taking the advantages and disadvantages into consideration.

During finalizing the solutions for the platform and its braking and docking mechanism all the proposed options were compared and some alterations were also considered. All the possible solutions were compared and are tabulated in Table 3 and The use of caster wheels was chosen for our design but the use of a correct braking system was also to be considered. So some alterations to this solution were proposed, which is the use of levelling caster wheels.

Figure 14 Levelling Caster Wheels

Levelling caster wheels as een in Figure 15 incorporate both the moving mechanism and a braking mechanism with strong hold. The use of levelling casters has following advantages:

- Levelling casters are designed to withstand heavy loads so it is very beneficial for the platform.
- Levelling casters are stable than swivel casters and fixed casters. It won’t wooble around.
- Levelling casters are easy to operate.
- Levelling casters have lower profile which keeps the platform close to the needed height.
- Levelling casters are designed to not scrap or damage the floors.

Figure 15 Operation of Levelling Casters

Using a levelling caster is very easy. As shown in Figure 15, it has a thumbwheel adjustment. Turning the thumbwheel in clockwise direction would lower the base making the platform stationary while turning it in anticlockwise direction lifts the base up and hence platform can be moved.

Table 4.

Table 3 Comparision of Braking Mechanism Solutions

Solution	Advantages	Disadvantages
Foot Operated Braking with a Lever	- Very easy braking system - Easy design & assembly - Cheap	- Doesn't provide strong hold for platform/ unstable - Need different brakes or swivel casters with brakes for other set of wheels.
Hand Operated or Central Locking Braking	- Easy operation with hand - Cheap - Good hold for the platform	- Need of extra components like wires, handles. - Need different brakes or swivel casters with brakes for other set of wheels.

The use of caster wheels was chosen for our design but the use of a correct braking system was also to be considered. So some alterations to this solution were proposed, which is the use of levelling caster wheels.

Figure 14 Levelling Caster Wheels (Caster Connection - Leveling Casters, n.d.)

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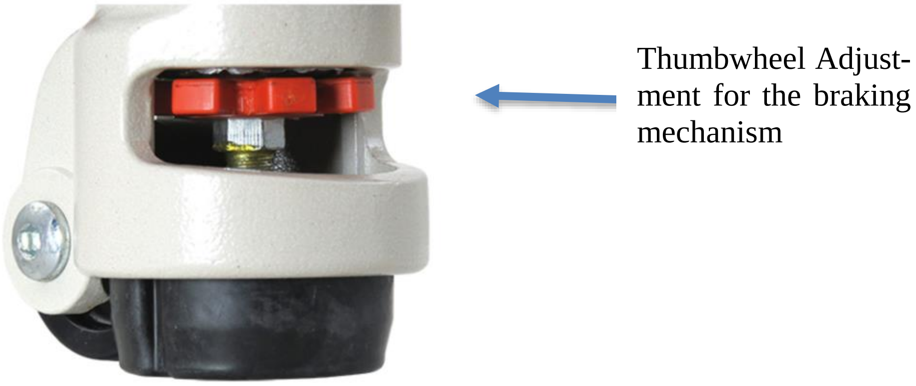

Figure 15 Operation of Levelling Casters (Caster Connection - Leveling Casters, n.d.)

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Table 4 Comparision of Docking Mechanism Solutions

Solution	Advantages	Disadvantages

Docking system with gliding rails	- Easy operation - Simple Design & Assembly - Cheap	- Slight difficulty in adjustment/ insertion of gliding elements.
Docking system with floor brackets	- Commercially available - Time saving solution	- Difficulty in docking bolts to destination as the platform is bigger
Docking system with magnets	- Simple Design - Use of less components	- Complex operation as metals are attracted to magnets - Expensive

For the docking mechanism, solution with gliding rails was chosen as it was inexpensive, easy to operate and had a simple design. Despite a slight difficulty in its adjustment in the destination gliding rails, this was better than the other two solutions and was also recommended by the supervisor.

3 DESIGN OF COMPONENTS

The next step in the design process was the detail design where the 3D model was created, 2D drawings were drawn, materials were finalised, specifications met, and cost figured out. This is the most important phase in design. The platform and the necessary features were designed in detailed and are explained in detail in this chapter.

3.1 3D modelling

In engineering or product design field 3D design plays a vital role. It is a graphical representation of any product or feature that can be used to analyse the products before building or manufacturing it. This saves time, money and labour in product development since necessary iterations for design are done in computerised 3D models.

The platform and its features were 3D modelled in CAD software; PTC Creo Parametric 4.0

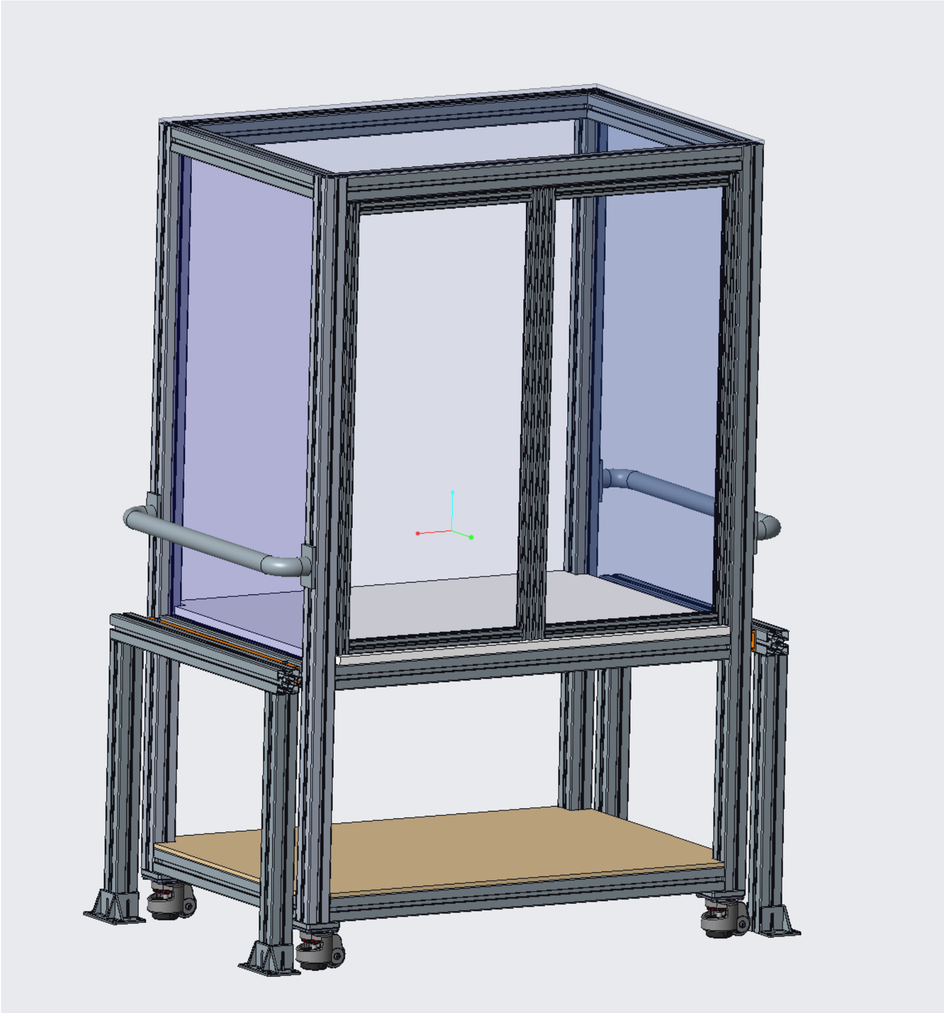

Figure 16 3D view of the Platfrom

Figure 16 shows the basic 3D view of the platform and the necessary features. All the necessary components are described below in this section and the necessary accessories are described in chapter 3.4.

3.1.1 Framework

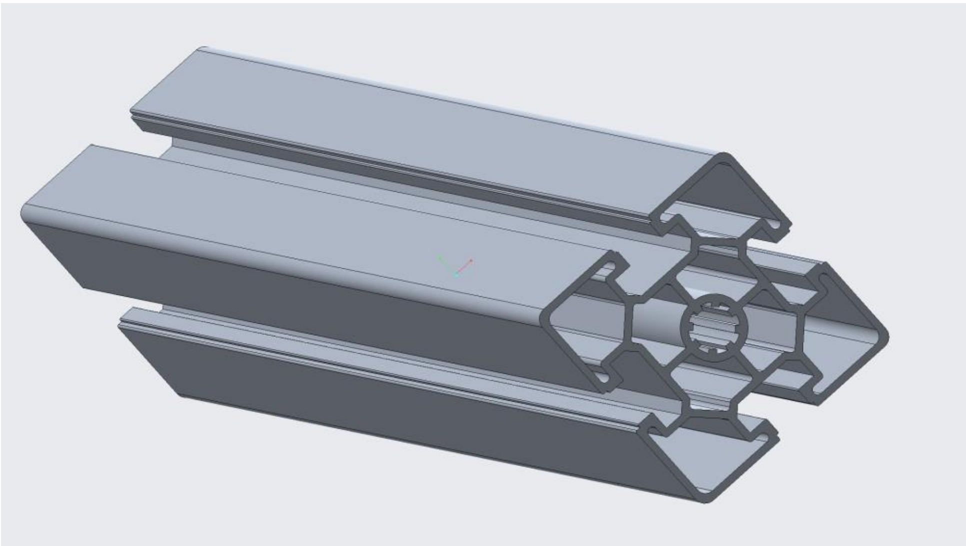

Figure 17 T-slotted Aluminium profile

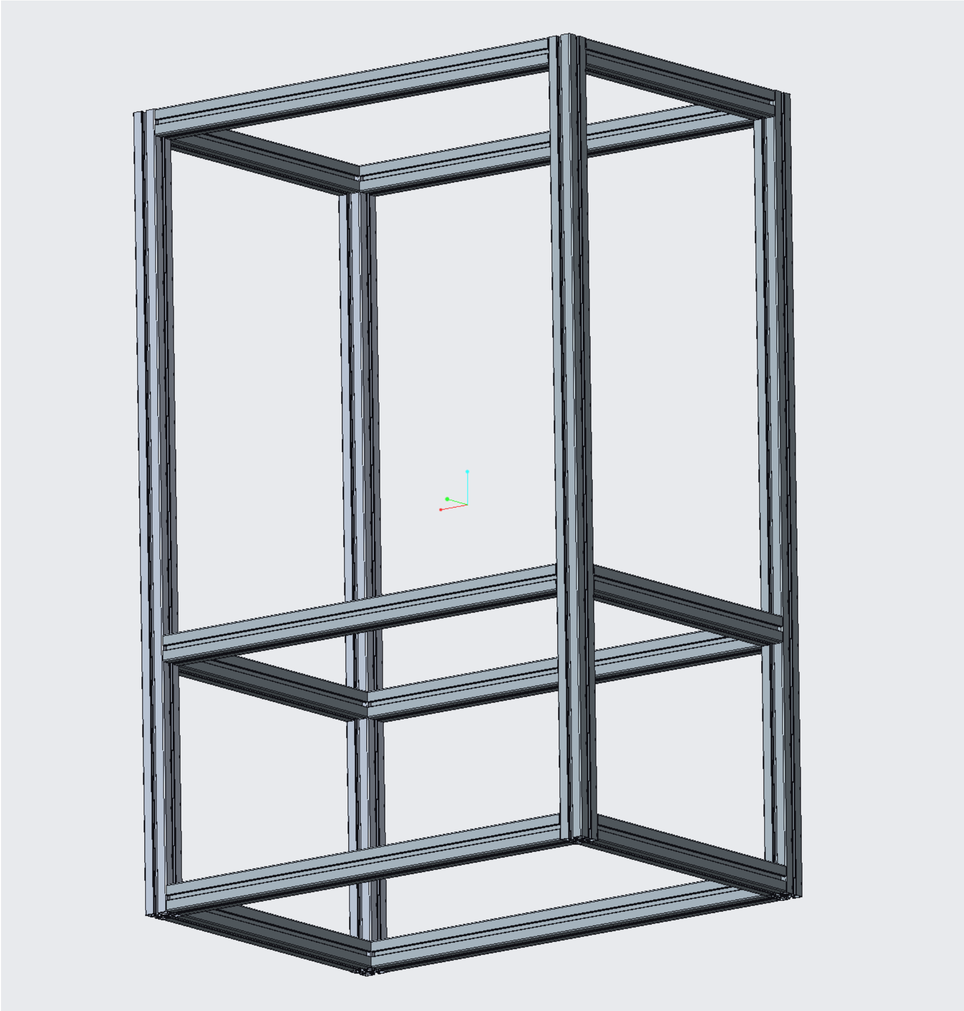

Figure 18 3D Model of Framework Assembly

The design started from the design of the framework or the main body. T slotted extruded aluminium profile was modelled and the framework was assembled together with three different length of aluminium profiles.
Figure 17 shows the 3D model of aluminium profile and Figure 18 shows the assembly of the framework.

A T-slotted aluminium profile of dimension 60mm×60mm with four 10 mm slots was 3D modelled. The dimensions of the part were based on a commercially available aluminium profile. Three different length of the profile were used in the assembly of profile and are mentioned as follows:

- 4 sets of long profile of length 1800mm.
- 6 sets of medium profile of length 1080mm.
- 6 sets of short profile of length 680mm.

Considering the requirements set during the design specifications phase the framework was designed.

- The size of the platform was one of the most important requirements to be considered. The requirement set for the size of the platform was at least 1060(length) × 800(width) × 1800(height) in mm. In this design, platform framework has dimensions 1200(length) × 800(width) × 1800(height) in mm. The platform needed to be spacious enough for robot operations and for the work pieces. Figure 19 shows the working reach of the ABB IRB 140 3 robot.

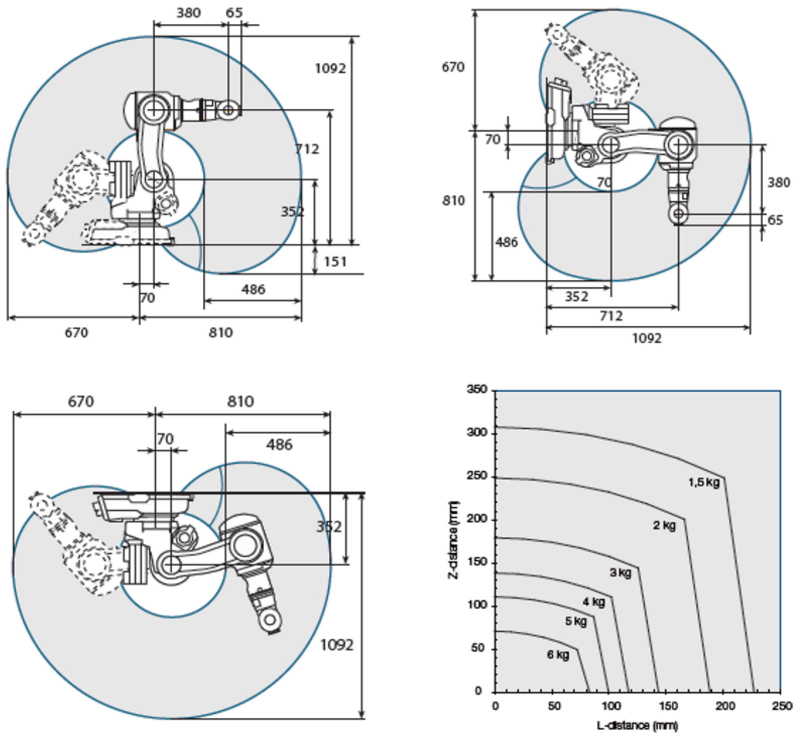

Figure 19 Working reach of 'ABB IRB 140 3' robot (ABB, 2019)

- Another necessary requirement was the shape of the platform and the layers of the platform. It needed to be a cuboid and needed to have two-layer shelves. One for the robot itself and the other for its processor. As shown in Figure 18, the bigger layer on the top was for the robot and the smaller one on the bottom was for its processor.

Hence, two of the important requirements were met after the completion of the framework design.

3.1.2 Shelves

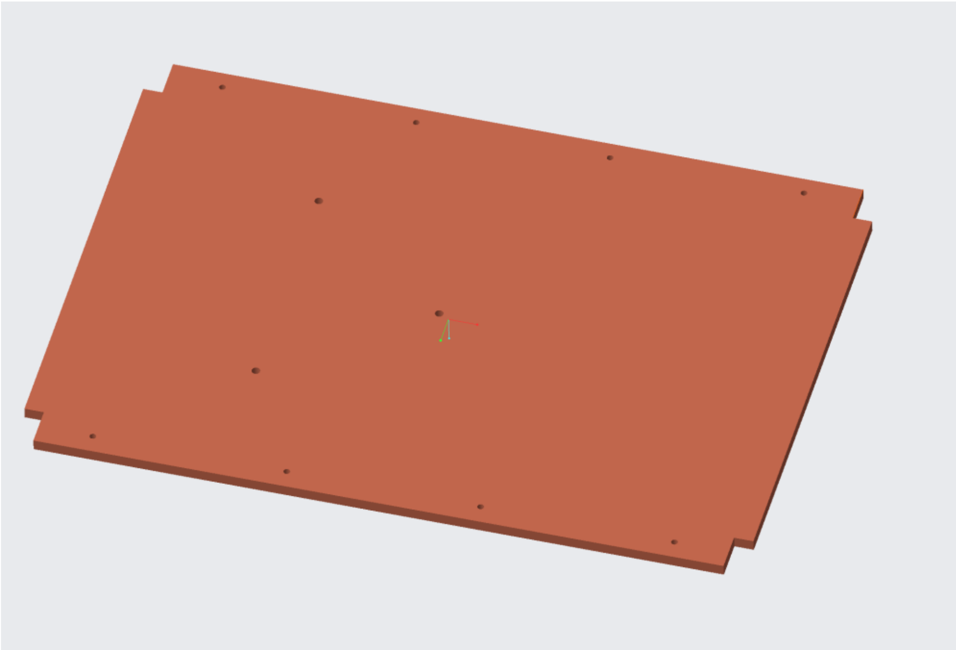

Figure 20 Middle Shelf for Robot and Workpiecees

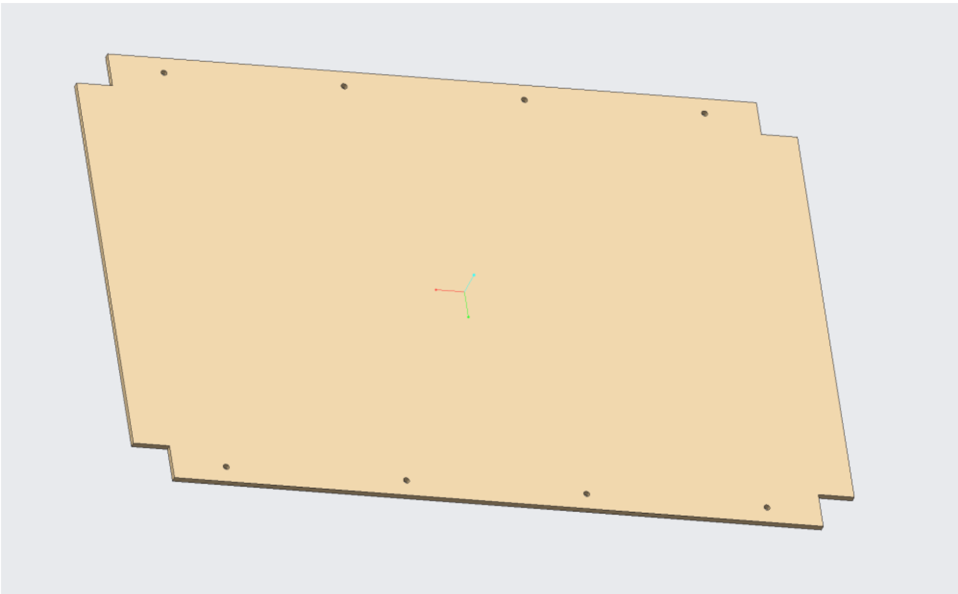

Figure 21 Bottom Shelf for Robot Processor

Shelves were the other important component that was designed. Two shelves were required as per the specifications. Figure 20 shows a 3D view of the middle shelf inserted into the middle part of the framework and Figure 21 shows a 3D view of bottom shelf laid on the bottom of the framework. The dimensions of the shelves are set to fit in the platform.

The middle shelf was for the robot and the work pieces and the bottom shelf is for the robot processor. Both the shelves had holes 8 holes of diameter 10 mm, which was for the bolts that attach them to the platform. In Figure 20, three holes of diameter 13mm in triangular order were designed. These holes were for the bolts that attaches the robot and the shelf together.

3.1.3 Doors and Hinges

Figure 22 Doors in the Platform

One of the requirements of the design was the inclusion of safety doors and glass panels. Safety components are needed to prevent any sort of disturbances during the robot operation. While the inclusion of safety doors will allow us to perform robot calibration and to place in and draw out work pieces.

As shown in Figure 22, there are two sets of doors only on one side of the platform. The side opposite to the platform is open as it should feed the work pieces in the CNC machine. While the sides adjacent to the side with doors, will be fitted with glass panels.

The door will include glass panel as well and the door framework is made up of T slotted aluminium profiles same as the main framework but of smaller size. The door will be attached to the main platform with hinges and will also include handle and locks.

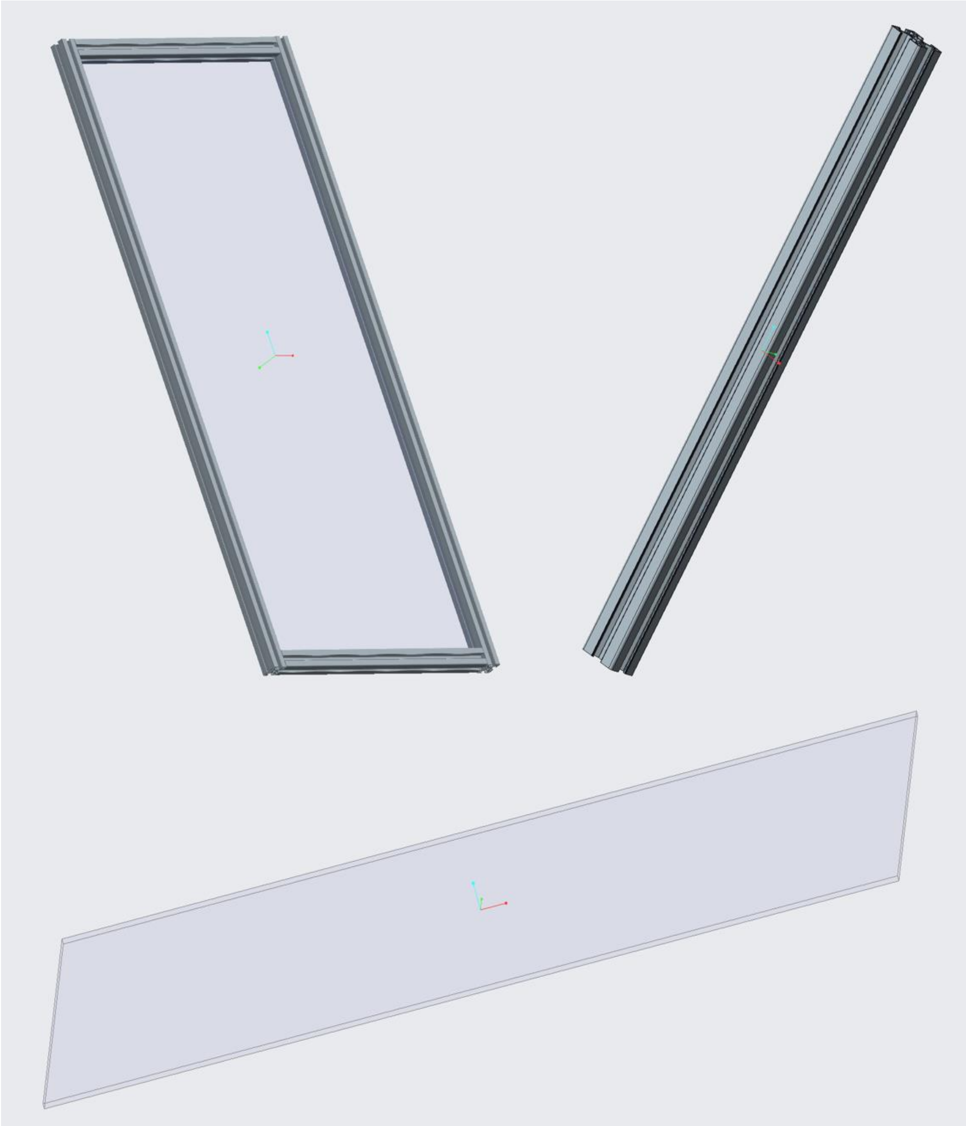

Figure 23 Door and its components (Aluminium Profile and Glass Panel)

Door for the platform is made up of T-slotted aluminium profile of two different lengths. Aluminium profile has dimensions 30 mm × 30 mm and two profile of lengths 473mm and 1089mm are used for the design of door framework.

Aluminium profile of smaller dimensions compared to the main body framework profile are used. There is no need for the door to be strong as it is for safety purpose.

A transparent glass panel is fitted in the door. Glass panel also serves as a safety component. Using transparent glass panel provides clear sight for the machining engineer working on the application. Glass panel have dimensions 1057 mm × 482mm × 6mm and are set to fit in the door frame. Aluminium profile has 8 mm T slot where the glass panel fits in along with a seal that fills the 2 mm gap in the slot.

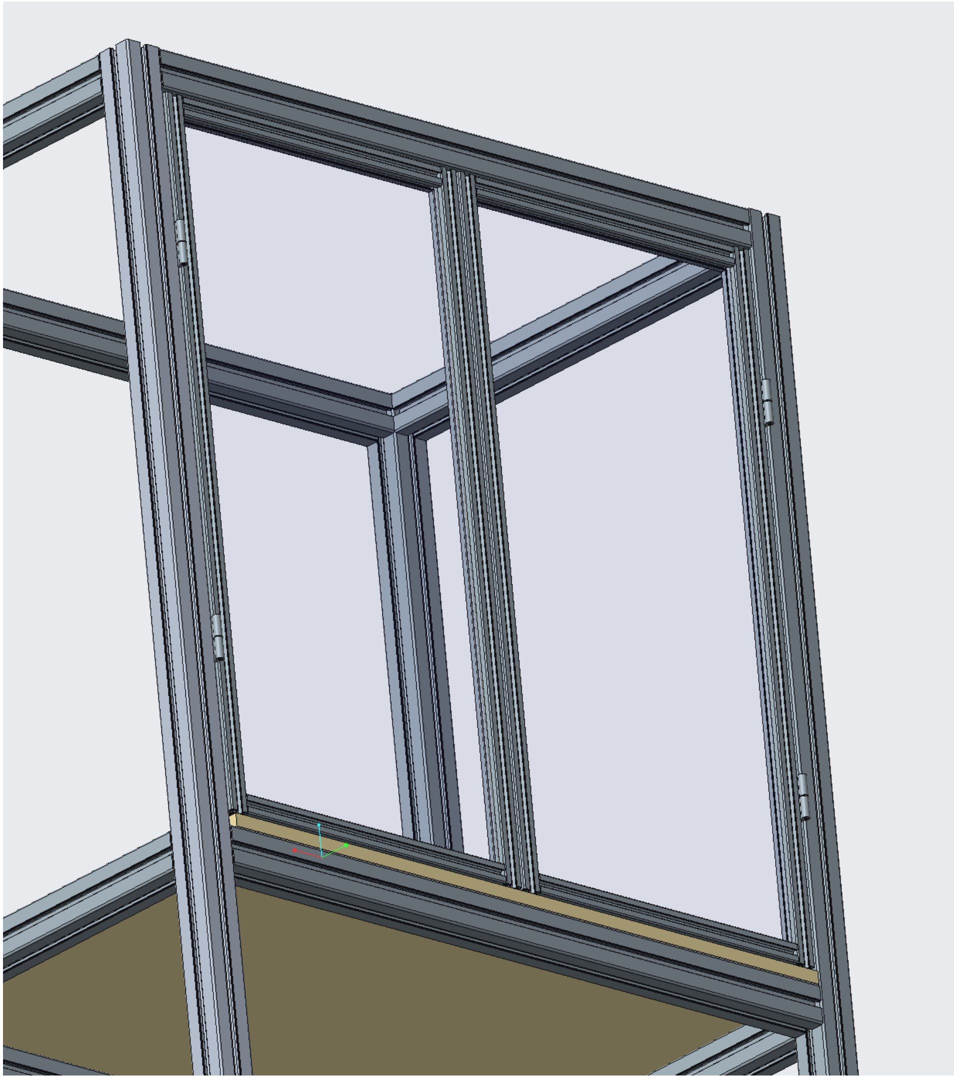

Figure 24 Position of Hinges for Doors

Doors will be attached to the main body framework with the help of hinges. 4 hinges, two for each door will be used for attaching the door to the framework. Figure 24 shows the position of hinges in the framework.

In next page, Figure 25 shows a 3D view of the hinge assembly Figure 26 shows exploded view of hinge assembly. Hinge assembly consists of:

- Two mounting panels; smaller one mounted to the door framework and the bigger one mounted to the main body framework
- A hinge pin where the mounting panels slide in allowing the door to be lift removable if needed.
- A hinge washer providing cushion between two panels.

Hinge allows the door to operate from 0º to 90º angle where 0º is when the door is shut and 90º is when the door is open. The holes for the bolts that attaches the hinge to the framework were dimensioned to align the holes accurately to the T slots of aluminium profile.

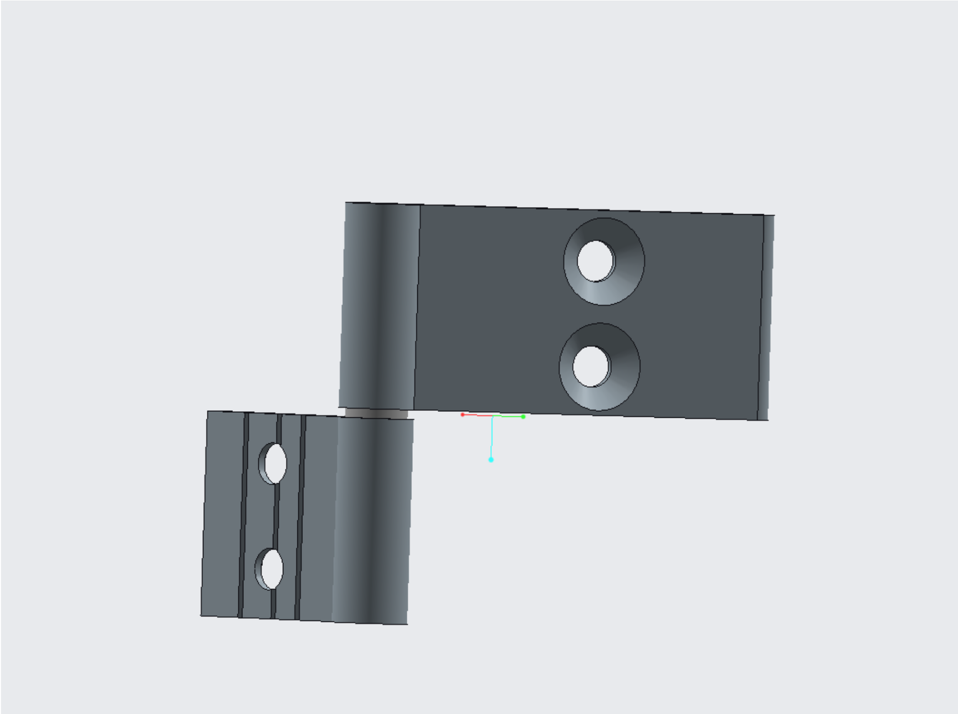

Figure 25 3D view of Hinge Assembly

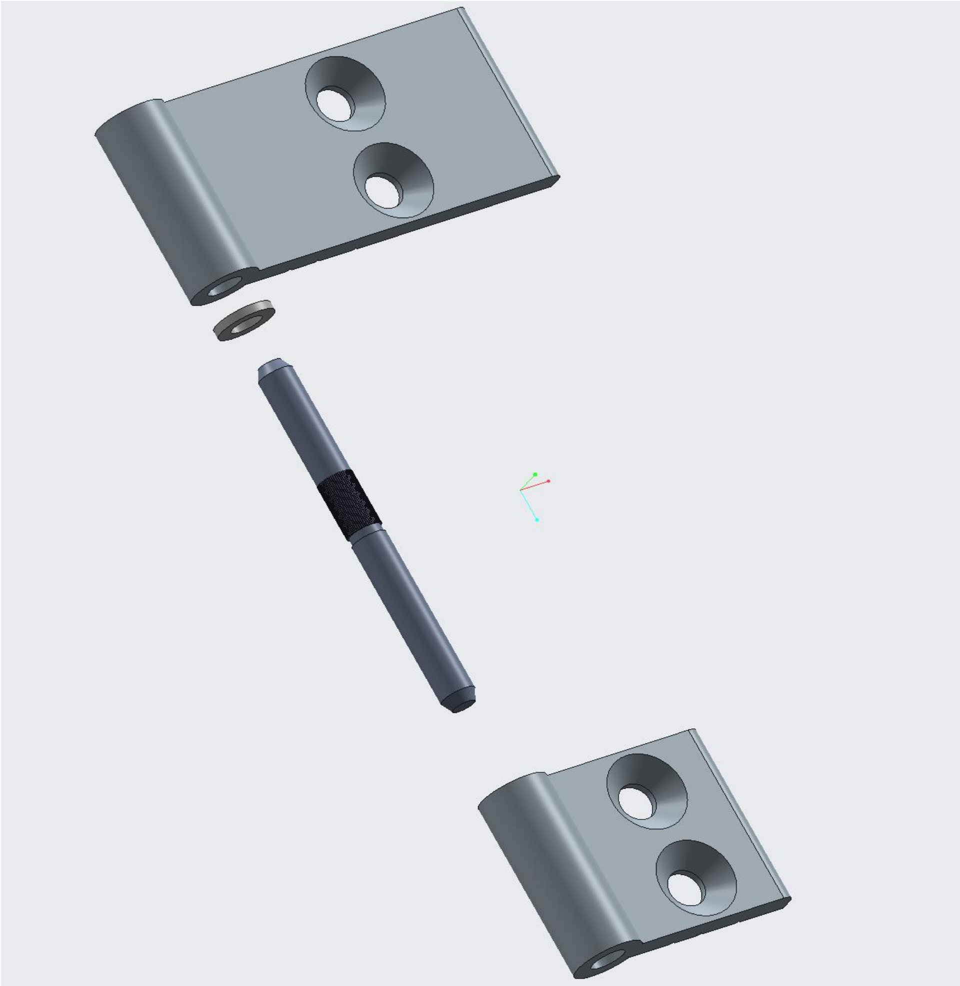

Figure 26 Exploded view of Hinge Assembly

3.1.4 Roof and Glass panel

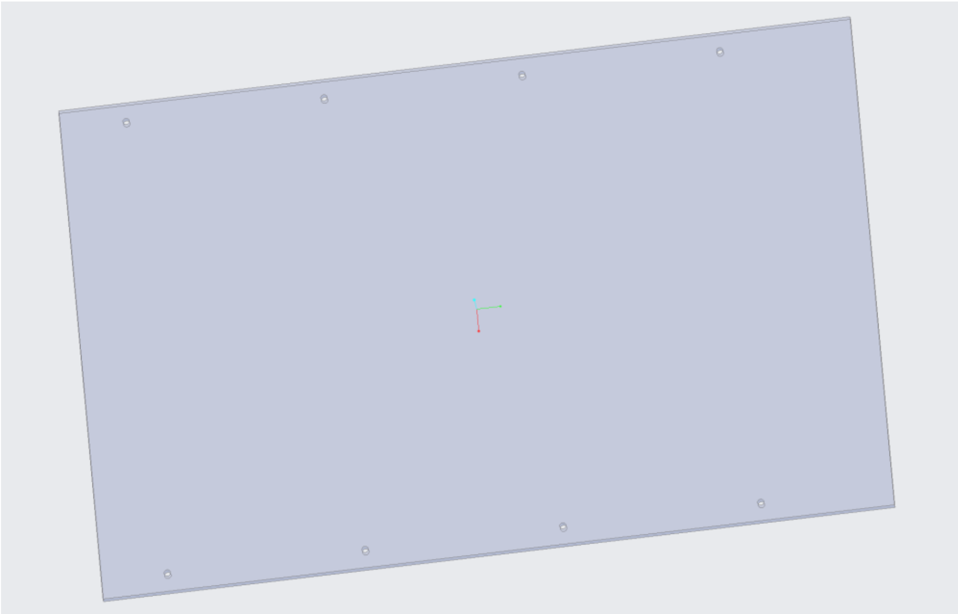

Figure 27 Safety roof

As mentioned earlier, glass panels and glass roofs should be used for safety purpose. Safety roof shown in Figure 27 will be fitted on top of the framework. It has holes for bolts that attaches the roof to the framework. Safety roof has dimensions 800mm × 1200mm × 10mm.

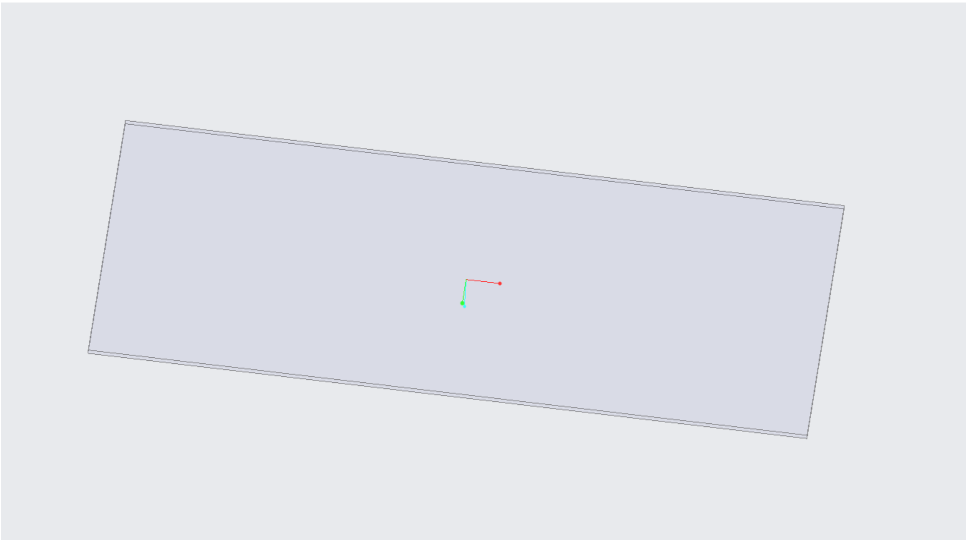

Figure 28 Safety Glass panel

While the glass panels will be fitted to the sides adjacent to the side with doors. Glass panel will be fitted on both the sides adjacent to the side with doors. Glass panel has thickness 6 mm and will fit in the 10mm T slot of the aluminium profile along with a seal installation. Glass panel dimensions are 1146mm × 706mm × 6mm.

Thus, use of safety doors, safety roof and glass panels solved the problem of safety requirements in the design.

3.2 Moving mechanism

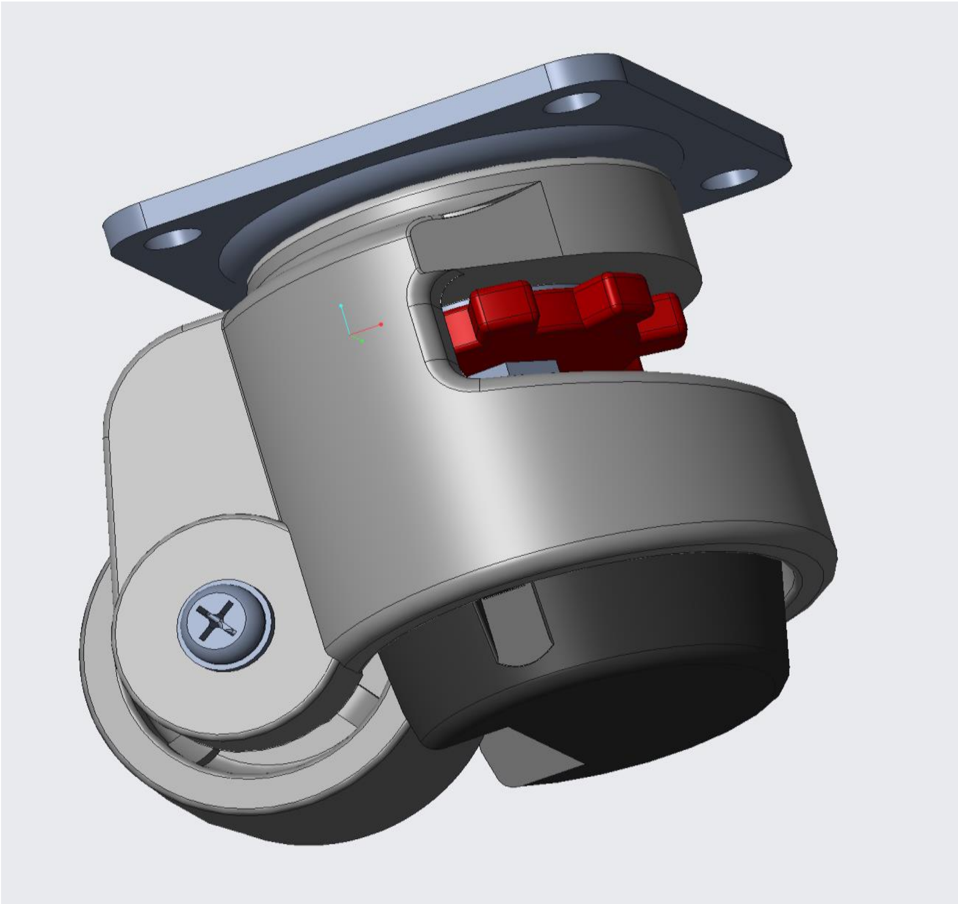

Figure 29 Levelling Caster Wheel

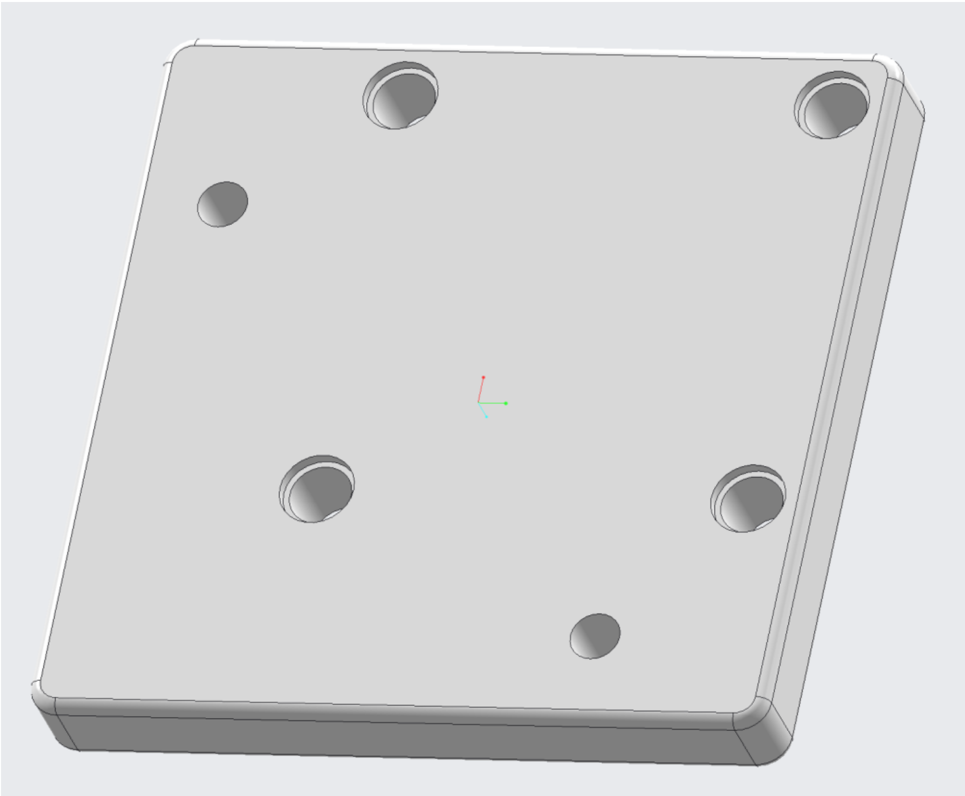

Figure 30 Caster Mounting Plate

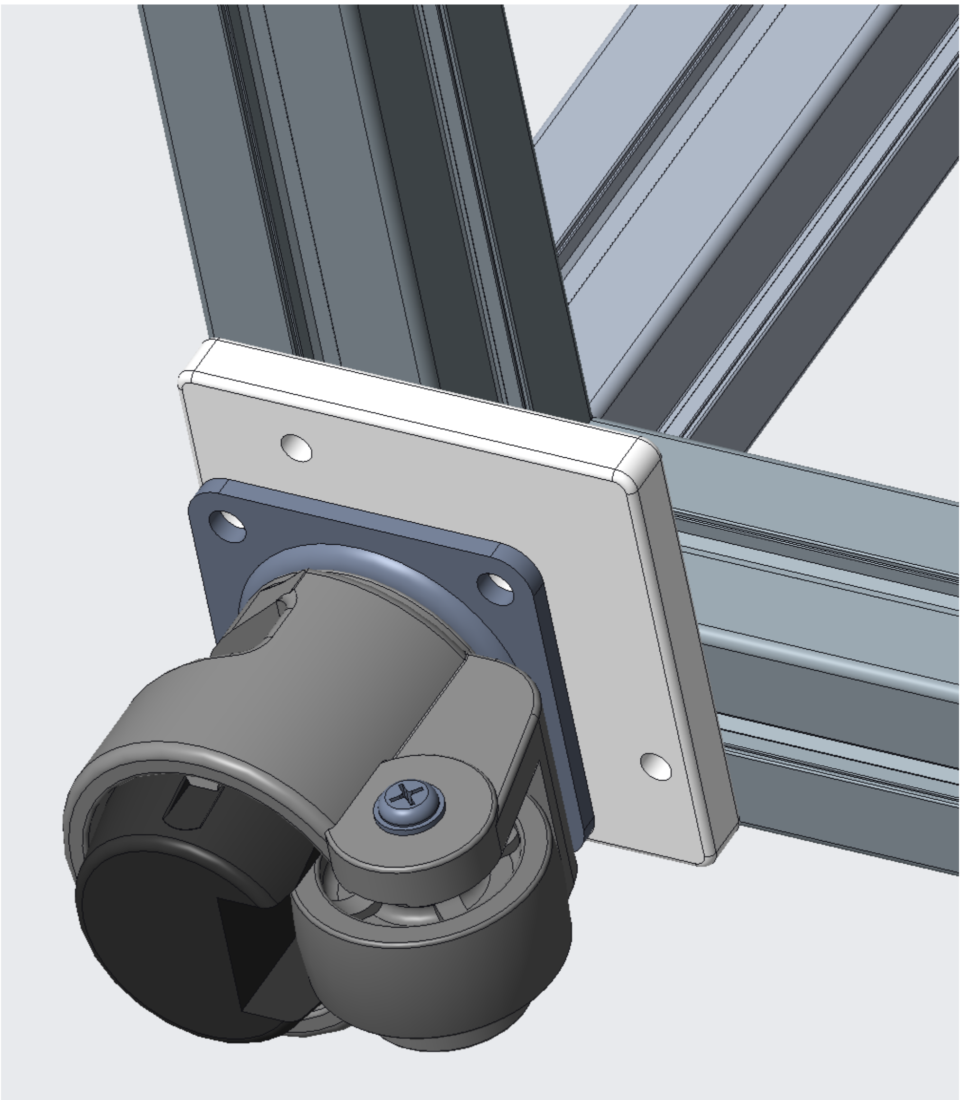

Figure 31 Caster wheel and plate mounted with framework

The platform needed to be portable and installation of wheels would make it portable. In the design levelling caster wheels are used as they are portable and has an additional braking feature incorporated in it. Thus, a suitable levelling caster wheel were designed as shown in Figure 29.

Additionally, a mounting plate was designed which mounts the caster wheels to the framework. Caster wheels would be mounted to the plate with four screws. InFigure 30, there are four threaded holes of 10 mm diameter which are aligned in square position and each of them are 70 mm apart. Caster needed to be mounted to the plate with screws as fastening with nut and bolts would be very difficult because of the framework.

There are two bolt holes of 10 mm which are aligned in L shaped position. These holes are for the bolts that mounts the caster plate to the framework. Both the hols are 15 mm apart from their respective edges.

Figure 31 shows the position of caster mounting plate, caster wheels and two bolt holes aligned coincident to the T slot of the aluminium profile.

3.3 Docking mechanism

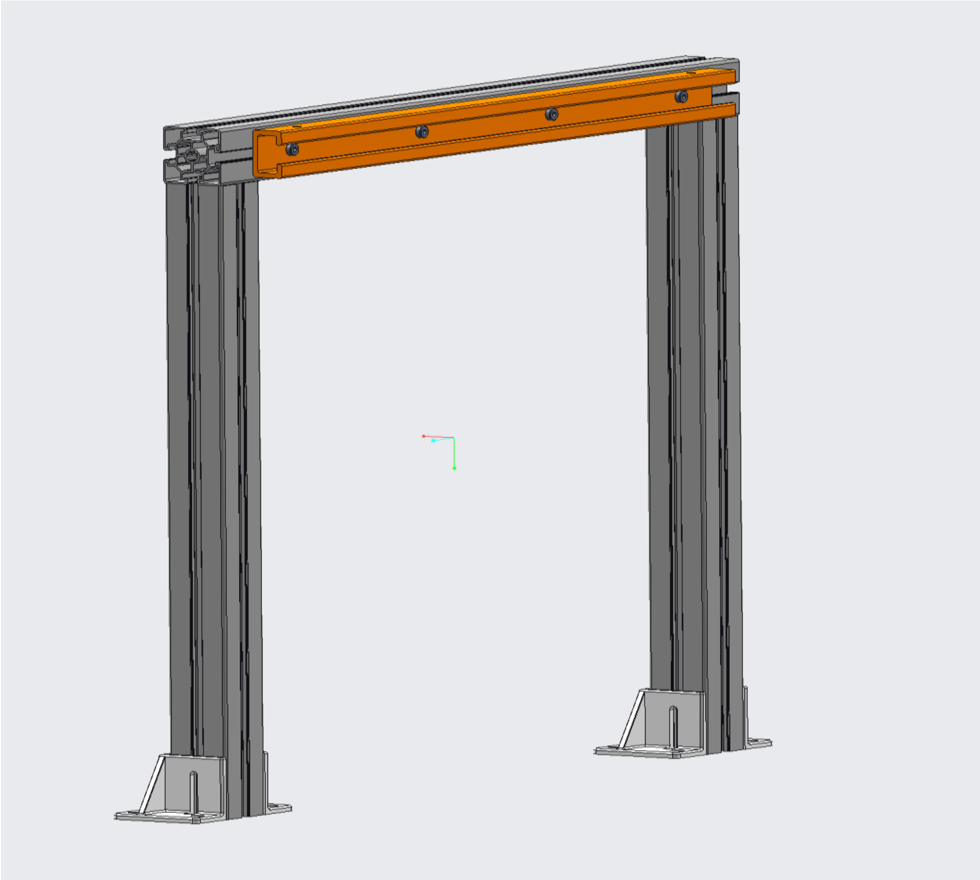

Figure 32 Docking Beam Assembly with Gliding Element and Floor Mounting Plate

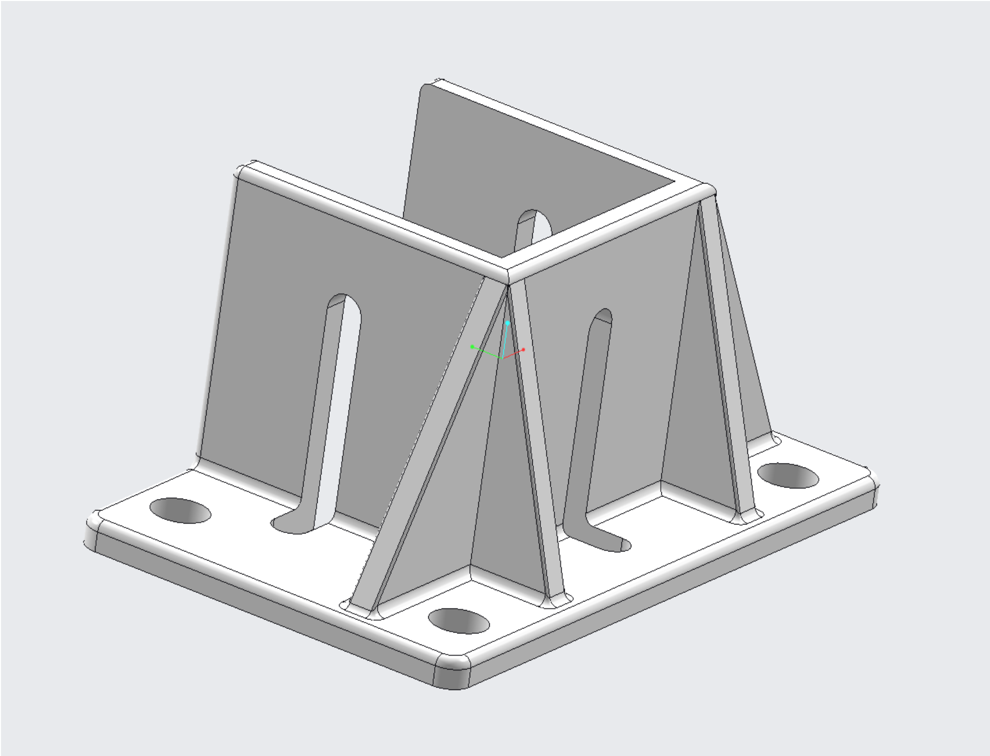

Figure 33 Floor Mounting Plate for Docking Beam

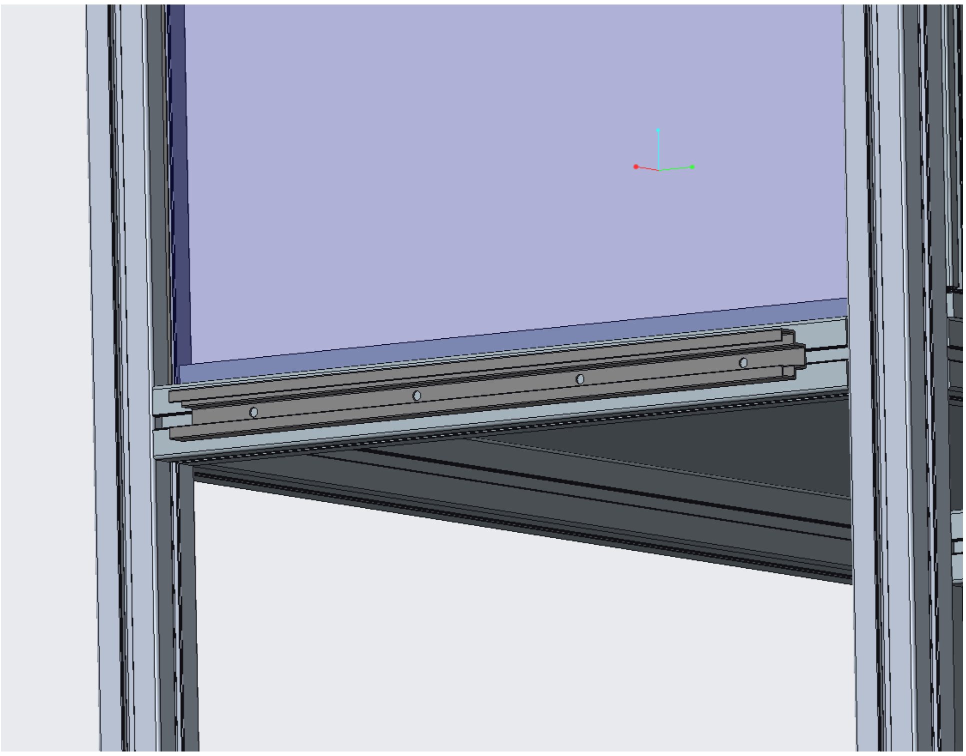

Figure 34 Gliding Element of Main Body Framework

Use gliding system with rails was the proposed option for the docking mechanism. In the design, two gliding rails were designed that would inter engage with one another. A docking beam assembly mounted to the floor would include one of the gliding rails as shown in Figure 32 and another gliding rails would be attached to the main body framework as shown in Figure 34. The orange coloured gliding element in Figure 32 acts as a 'female element' and the dark grey coloured element in Figure 34 acts as a 'male element'.

Docking beam assembly includes two vertical beams and a horizontal beam forming an inverted U-shaped structure and mounted to the floor with a floor mounting bracket which is shown in Figure 33. The beams are extruded T-slot aluminium profiles, exact same profile used in the main body framework. The length of horizontal profile is 800mm and the length of vertical profile is 670mm.

The female gliding element is of length 700mm and the male gliding element is of length 600 mm. Both the element has bolt holes that attaches them to their respective aluminium profiles. Additionally, the female gliding element has two bolt holes drilled from its top side through to their bottom side. These holes are for the bolt and wing nuts that acts as a stopper or lock system, when the framework slides through the gliding rails. Distance between these two holes is 600 mm same as length of the male gliding element. One set of bolt and wing nut are pre-installed in the gliding rail which acts as a stopper. While the other set of bolt and wing nut will be fitted once the framework slides through the gliding rail which acts as a lock. Thus, use of all these elements provides the docking of the platform to its specific destination.

Figure 35,Figure 36 and Figure 37 demonstrates how the docking mechanism step wise in three different steps.

Step 1: Firstly, the framework with the male gliding element is inserted inside the female gliding element and pushed until the end.

Step 2: Secondly, it is made sure that the gliding element reaches the end where a set of bolt and wing nut are present which will stop the framework.

Step 3: Lastly, when the holt is visible, another set of bolt and wing nut is inserted to lock the gliding elements.

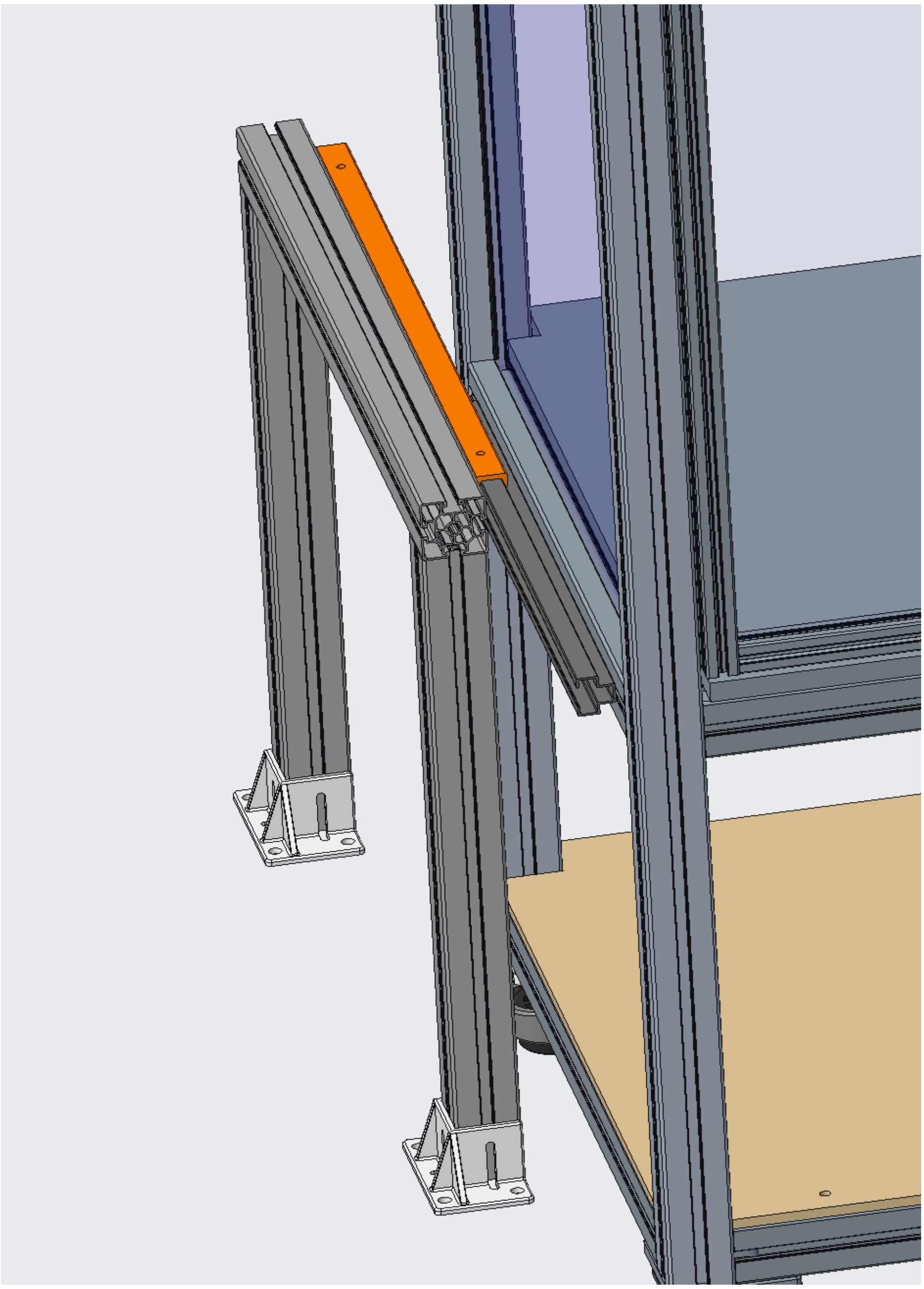

Figure 35 Sliding Framework inside the Gliding Element

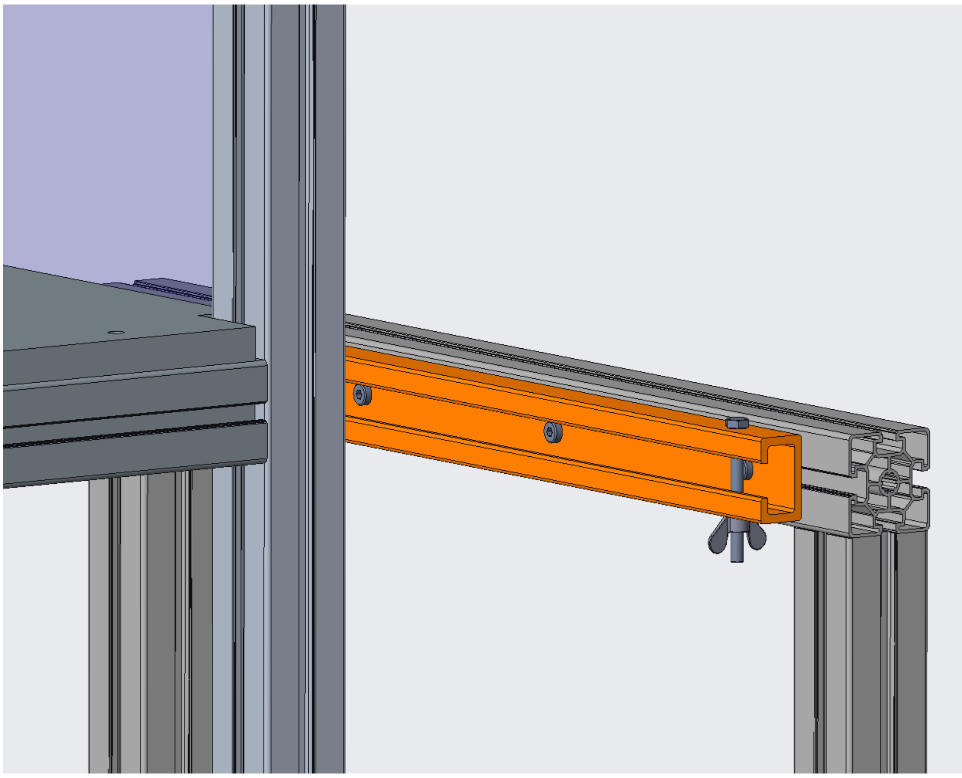

Figure 36 Bolt and Wing Nut acting as a Stopper

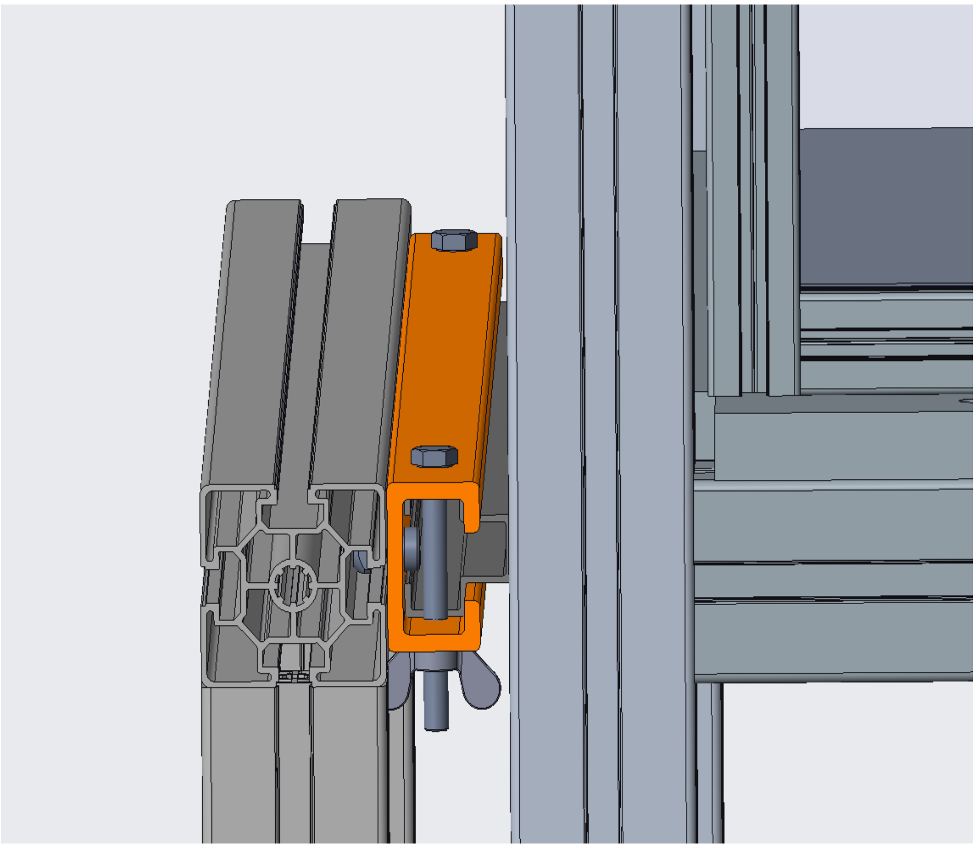

Figure 37 Second set of Bolt and Wing Nut acting as Lock

3.4 Accessories

Some important accessories were designed for the framework, glass panels and doors to make it aesthetically pleasing and easy to operate certain components, especially door. They are explained below:

Handle for Framework: Two handles for the platform was designed as it would make the transferring of the platform simpler. Use of handle rod eliminate the need of pushing the platform as the end user can use the handle to manoeuvre it freely.

Two handles are used and are positioned in the platform at the midpoint of the vertical profile as shown in Figure 38. Handles have hollow U- shaped profile and have bracket at both ends with holes in it. Hollow profiles are welded to the bracket. They are attached to the profile with T-slot nuts and bolts.

Figure 38 Position of handles in the Framework.

<u>End Caps:</u> End caps were designed to cover up the aluminium profile ends of door framework and docking beam profile, to make the platfrom look good.

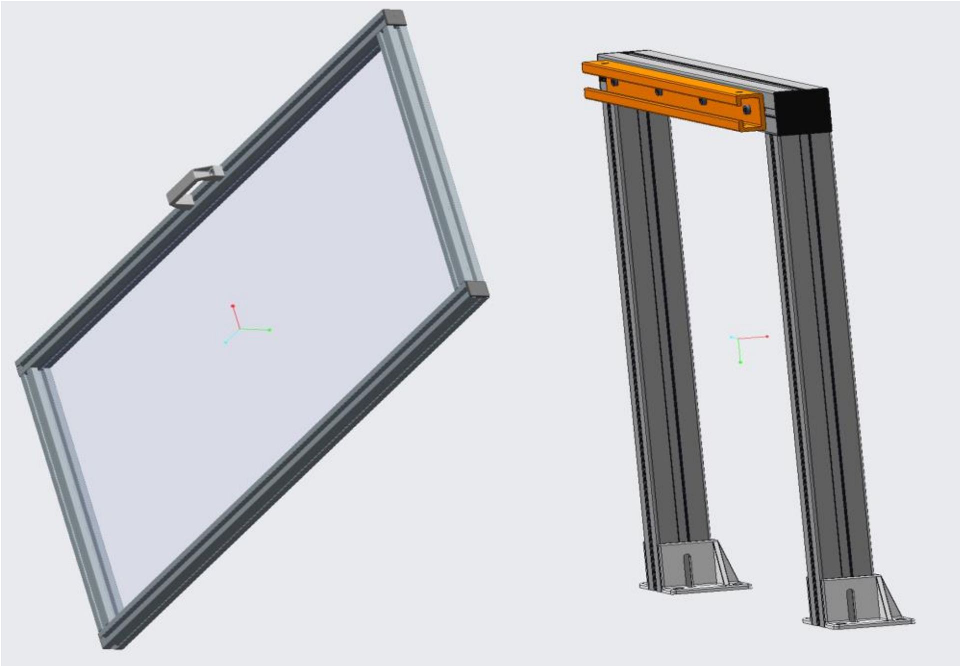

Figure 39 End Caps of Aluminium Profiles

<u>Door Handle:</u> Door handles were designed for the door which would help the end user to open and close the doors easily and are placed at the midpoint of the vertical side of the door. They are attached to the door framework with T- slot nut and bolt.

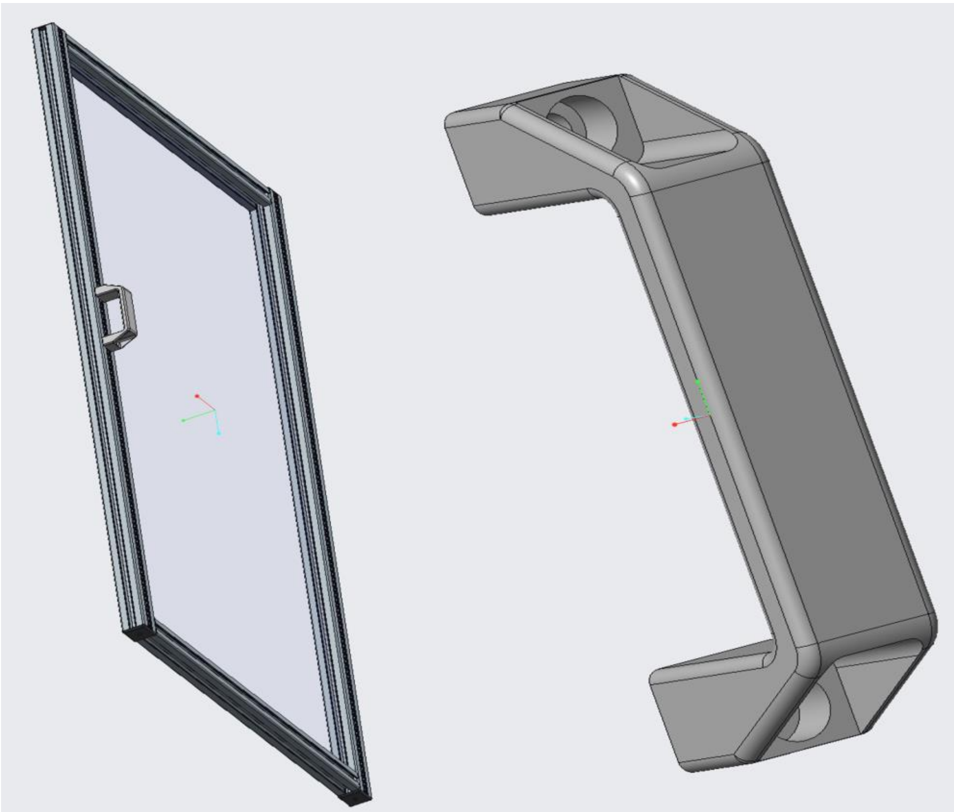

Figure 40 Door Handle and its position in door

<u>Magnetic Catch for Door:</u> For the door to stop and hold in a closed position magnetic catch was designed as shown in Figure 41 and is attached to the middle shelf with screws. The position of the catch is shown in Figure 42. Magnetic catch consists of a bracket with magnet attached to it and a plate that will be attached to the door framework. This plate has a hole in between for screw which will attach it to the door.

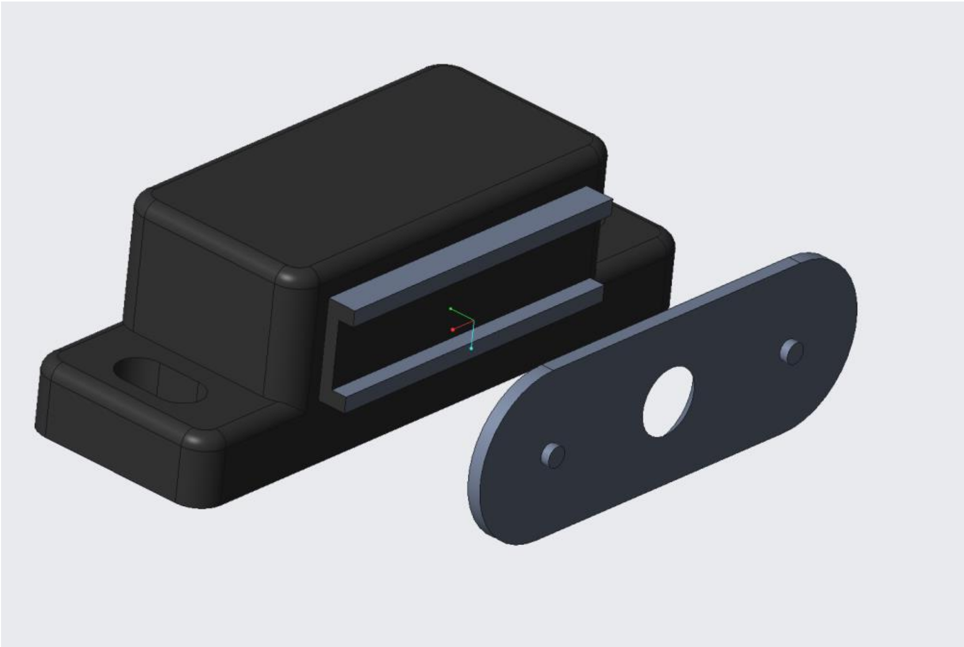

Figure 41 Magnetic catch for Door

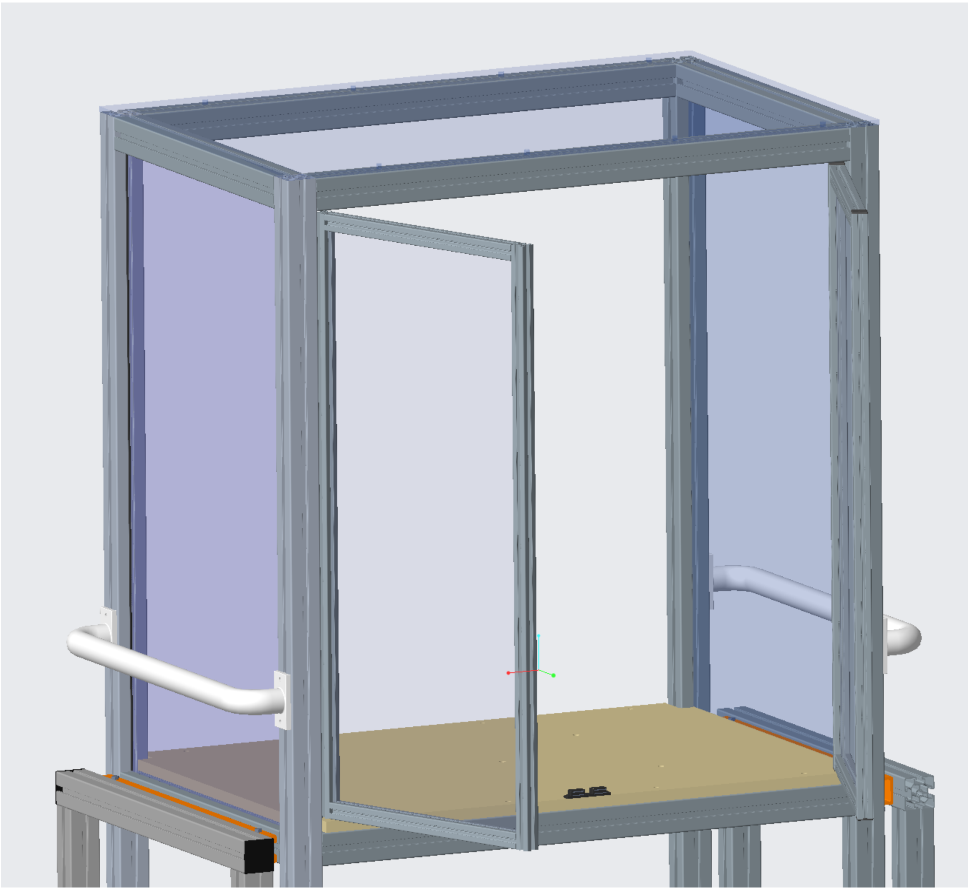

Figure 42 Position of magnetic catch in the shelf

Glass Seal Installation: A rubber gasket was designed to seal the glass panel which fits into the T-slot of aluminium profiles. This gasket provides and air and water-resistant seal and provides cushion for the glass panel. It is 6.8mm thick and 12 mm long and fits in the T-slot as shown in Figure 43. This gasket will be used everywhere where the glass panels are used in the platform except the roof glass panel.

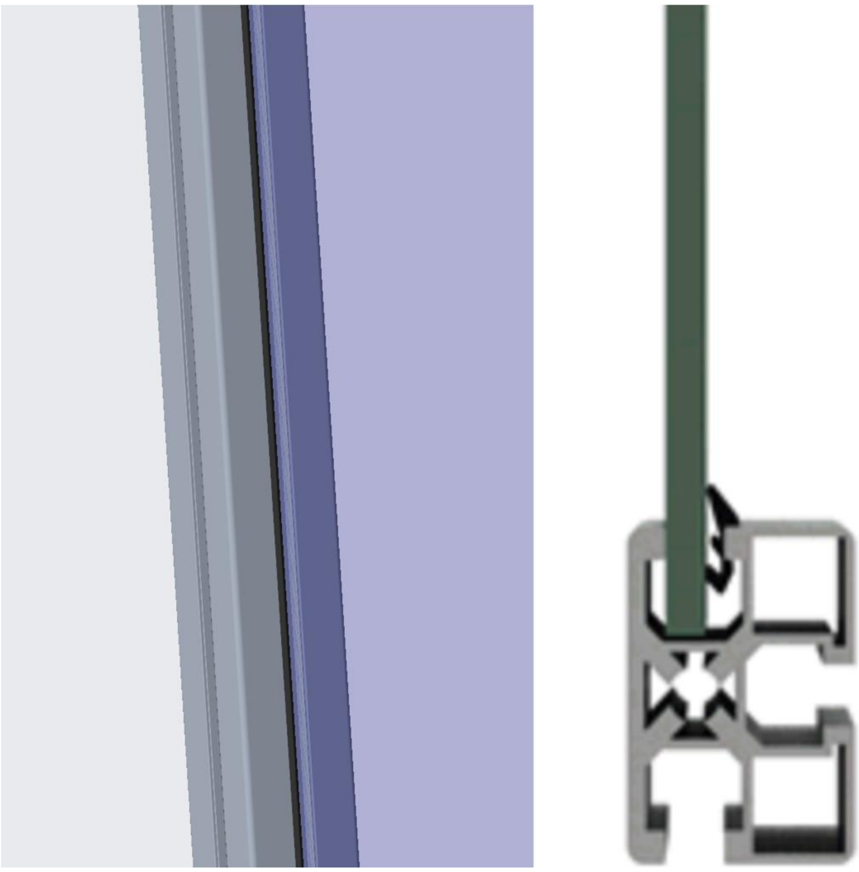

Figure 43 Glass Seal Installation for the Glass Panels and its Position (Minitec Framing)

3.5 Material selection in design

Material selection is one of the important steps in product design. The main aim of the material selection is to select material to minimize the cost while obtaining maximum performance.

There are certain factors that should be considered before selecting a material such as:

- Functional Design Requirements which might include load, stiffness or dimensional constraints
- Physical constraints of the product which might include size, cross sectional area, shape, mass properties
- Objectives or the product functions
- Aesthetic factors
- Market Availability
- Case specific factors such as heat, corrosion, electrical conductivity

After considering the factors all the suitable material should be compared before finalizing the material choice. Similar process was followed during the material selection process.

3.5.1 Selection of profile material

In previous section '3D Modelling', use of aluminium profiles have been stated while explaining the details of the design. However, there is a comparison of different probable materials based on the cost factor and strength properties.

Table 5 Comparision of Profiles for Framework

Extruded Aluminium Profile	Steel Square Beam
For a 60×60 (mm) cross sectional beam weight varies in range 2.60 kg/m to 3.89 kg/m	For a 60×60 (mm) cross sectional profile weight varies in range 3.56 kg/m to 5.19 kg/m
Cost per unit length of 60×60 (mm) profile is 20 euros (in meters)	Cost per unit length of 60×60 (mm) profile is 8 euros. (in meters)
Moment of Inertia for 60×60 (mm) profile is: I(x) – 32.41 cm^4 I(y) – 32.41 cm^4	Moment of Inertia for 60×60 (mm) profile is: I(x)- 30.3 cm^4

The reason for choosing the extruded aluminium profile is primarily it's weight to strength ratio. It is very light weight and makes the whole platform light and at the same time very stable. The other reason for using the aluminium profile is its profile structure. It incorporates slots that makes addition of different components such as doors, shelves and glass panels easy. Moreover, assembling extruded profiles are simpler compared to square beam profiles.

3.5.2 Selection of caster wheels

Caster wheels support the framework and hold the weight of the platform and robot. So, a correct caster wheels needed to be selected in order to withstand all the loads. The levelling caster wheel selected for the platform can withstand load up to 300 kg. The load of robot, processor and platform doesn't exceed 250 kg. If it were to exceed more than 300 kg other caster wheel which can withstand 500 kg is considered as an option. More information in

Appendix 4

Appendix 4.

Besides the load factor caster wheels of correct size needed to be selected. Since the profile selected for deign is 60mm × 60 mm, casters needed to be slightly larger or equal to the size of the profile. Thus, slected catser wheel is a levelling caster wheel with dimensions of mounting plate 90mm × 90mm.

3.5.3 Selection of shelves material

Shelves are the platform where the robot is mounted, and its processor is placed. The shelf placed in middle needs to be strong enough to withstand the load of the mounting robot and the shelf placed in the bottom needs to withstand the load of the processor. So, shelf material was to be chosen considering the load and thickness of the shelf also needed to be considered to mount the robot. Another important consideration was the weight of the shelf itself, since using a lighter material would reduce the total weight of the platform.

Table 6 Comparision of Shelf Materials

Aluminium Extruded Flat Profiles	Laminate or Melamine Boards
Comparatively heavy and multiple profiles need to be assembled to make a board	Light and various sizes of boards are commercially available
Possibility of drilling holes but robot mounting is challenging	Possibility of drilling holes and robot mounting is easy
Expensive	Cheap

Since, using laminate or melamine boards reduces the total weight of platform and mounting the robot and placing the processor is easy this choice was finalized. Both the laminate and melamine board can be used as it has similar properties, but laminate boards are preferred because of its impact resisting capacity.

Two shelves of thickness 20mm for middle shelf and 10mm for bottom shelf are used in the design.

4 WORK SIMULATION

Simulation and analysis are another important process in product design. It is used to examine the details of design and is very important to figure out design mistakes. Design mistakes can be sorted or modified by redesigning before manufacturing the product thus saving time, labour and money. Simulation and analysis are very common in practice of concurrent engineering. Concurrent engineering allows the design and analysis to run simultaneously. Similarly, in this design, work simulation was performed simultaneously when designing the platform.

Visual Components Premium 4.1 was used to perform work simulation. Visual Components is a powerful 3D simulation and visualization software with a possibility of performing robot simulation.

Robot simulation was performed with the designed platform and workpieces were designed in the software. The main aim of work simulation was to compare the size of designed platform with the working periphery of the robot.

Figure 44, Figure 45 and Figure 46 shows stepwise operation of robot.

First Step: Robot picks up the unmachined work piece from the black tray.

Second Step: Robot feeds the work piece to the CNC machine and returns to platform. Machining operation is performed.

Third and Final step: Machined work piece is placed in the blue tray.

In the figures, placement of the platform in front of the CNC can also be seen. There are two trays and workpieces inside of the platform and are placed next to each other. Black tray is for unmachined workpieces and the light blue tray is for the ready machined work pieces.

Robot has very wide working range of its arm, least being 670mm and maximum being 800mm. The dimensions of the platform are 1200mm × 800mm. Work pieces are aligned parallel to the shorter side while the robot is mounted in opposite corner parallel to longer side. Robot can work in all directions but in this case, it is programmed to work in specific working range. Machining location is also within the working range of the robot.

The result of the work simulation was positive and the proposed size of the platform in the design was finalised.

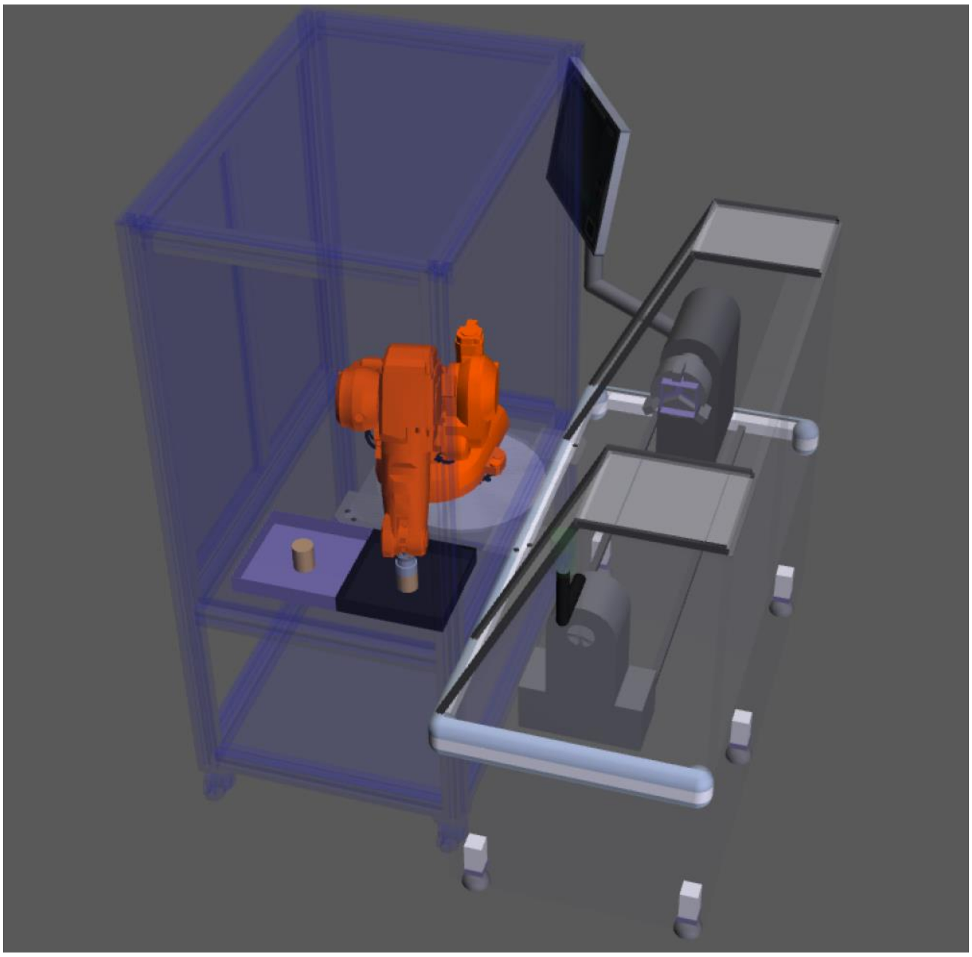

Figure 44 Robot picking up unmachined workpiece

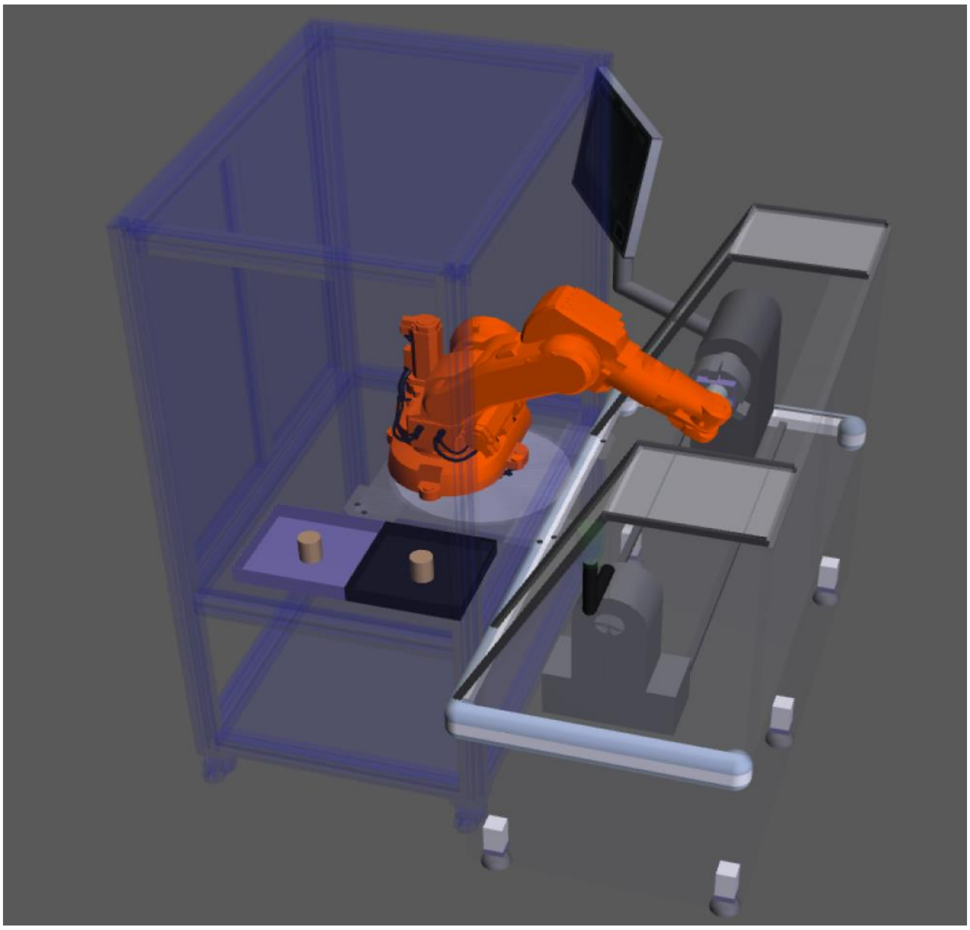

Figure 45 Robot Feeding the workpiece to CNC machine

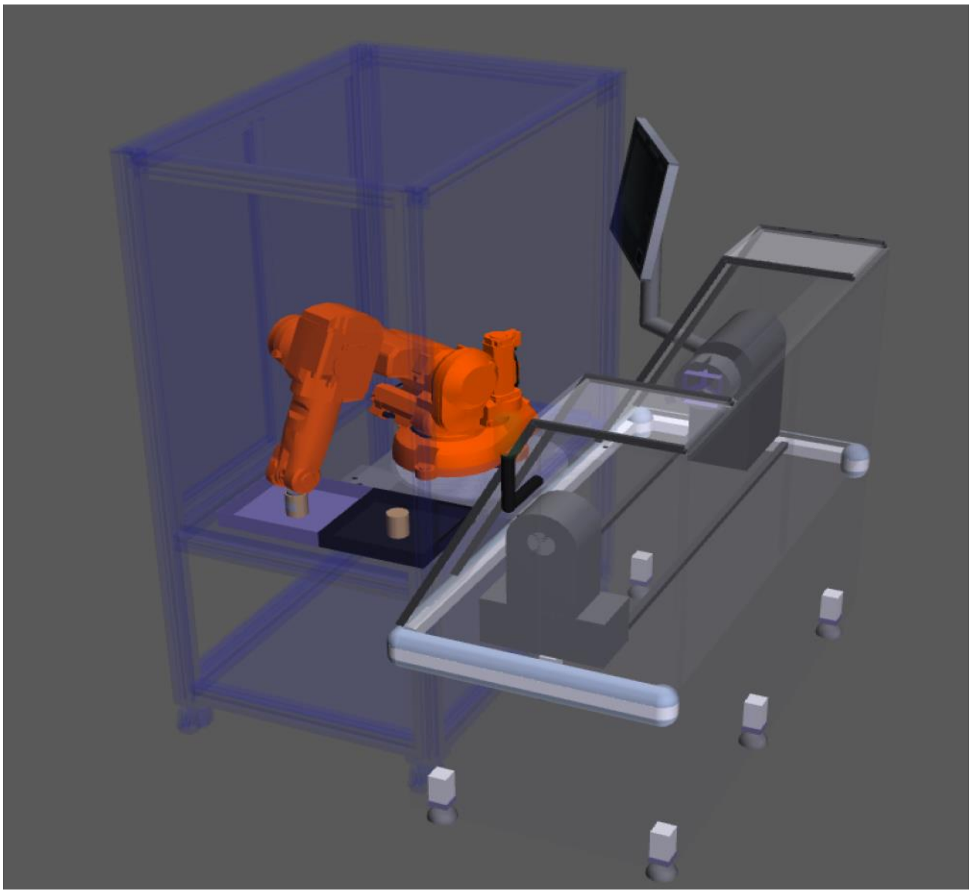

Figure 46 Robot placing the machined workpiece to tray

5 STRENGTH ANALYSIS

Like the work simulation, strength analysis or FEM analysis also allows us to test the components of design. FEM analysis helps us predict how a designed product reacts to forces, loads, vibrations and other physical factors. It gives us detail information about the occurring stresses, strains and deformations under given loading and constraints. FEM analysis was performed in PTC Creo Parametric 4.0.

In this case, strength analysis of the framework needed to be performed along with the shelf where the robot is mounted. Only static analysis was performed even though the robot moves and exerts dynamic forces on the platform. Dynamic analysis was not so important factor for this case since the robot operation is done at minimal speed.

5.1 FEM Analysis of shelf

The robot weighing 98 kg is mounted to the shelf placed in the middle of the framework. So, the shelf must withstand the load.

Middle shelf has dimensions 1128mm × 798mm and is 20 mm thick. It has L-shaped cuts on edges to fit into the framework. Laminate boards of same dimensions weighs 14-15 kgs.

A simple static analysis was performed for the shelf with 98 kg load on top of it and displacement constraints on the edges of the platform. The shelf is attached to the framework with holes and rests on the framework. Material plywood was assigned in Creo material properties as it has similar mass properties to laminate boards.

Von misses stress analysis result is shown in Figure 47.

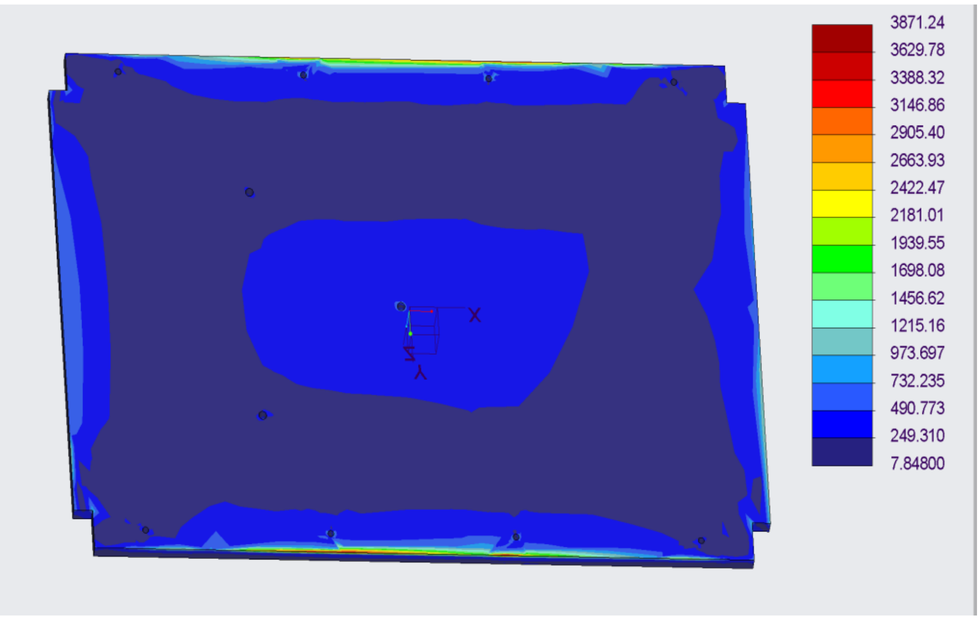

Figure 47 Von Misses Stress Analysis for Middle Shelf (Units kPa)

5.2 FEM Analysis of framework

Framework needs to be strong enough to withstand the load of robot, its processor and all the components attached to it. Caster wheels are attached on the bottom 4 corners.

Aluminium profiles are attached together with fasteners. The middle frames must withstand the maximum loads. A simple static analysis was performed with loads acting on the middle frames and the bottom frames with 4 displacement constraints on the 4 bottom corners.

Von Misses stress analysis result is shown in Figure 48. As seen in the figure the maximum stress occurs in middle frames.

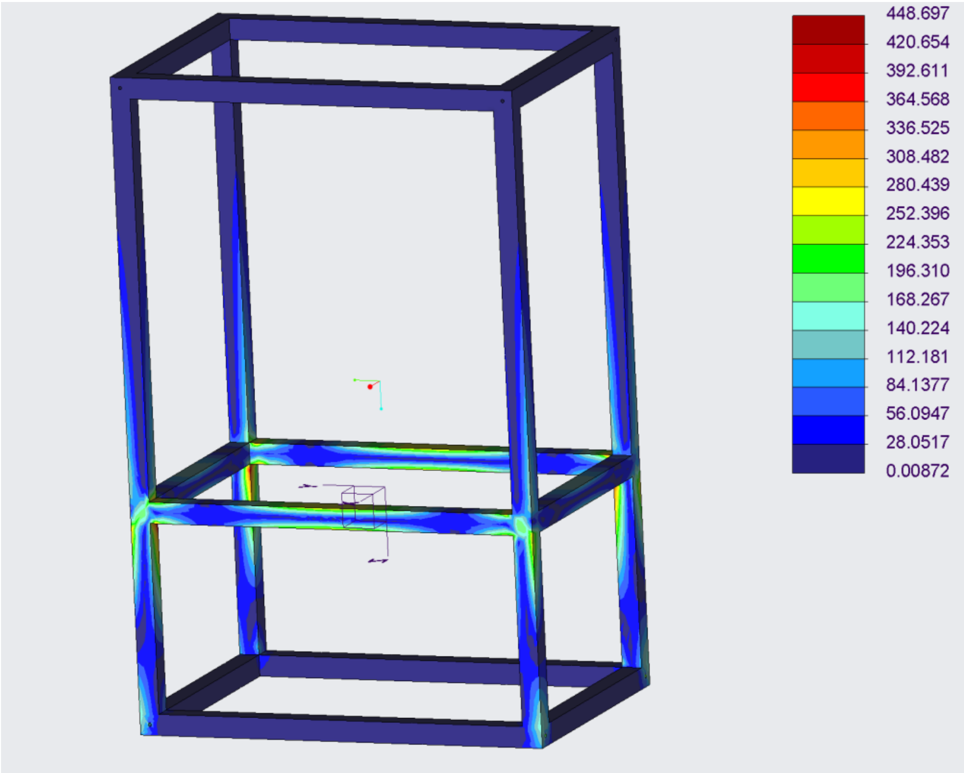

Figure 48 Von Misses Stress Analysis for Framework (Units kPa)

6 DESIGN FOR MANUFACTURABILITY AND ASSEMBLY

Design for Manufacturability and Assembly comprises of two methodologies; Design for manufacture which means design of a product with ease of manufacturing and Design for Assembly which means design of a product with ease of assembly. DFMA is one of the principles of concurrent engineering and has various benefits in product development such as lowering cost, increasing the quality, less iterations in design and quicker time to production.

In this design, there are few parts that need to be manufactured so design for manufacturability was to be considered. While the platform is a result of assembly of framework, doors, panels and shelves design for assembly also needs to be considered.

6.1 Manufacturing of parts

In this design, most of the parts are commercially available but there are few parts that needs to be manufactured specifically. There is possibility of replacing these parts with commercially available parts but with slight modifications, which is recommended for these parts.

Some parts that needs to be manufactured are tabulated in Table 7 along with the recommended manufacturing process and estimated time.

Table 7 Manufacturing Process and Estimated Time for Parts Manufacturing

Part/Component	Needed Materials	Manufacturing Process	Estimated Time
Handle for Framework (2 pcs)	1000 mm long steel tube and two aluminium plates.	- Bending for the tube. - Machining or water cutting for the plates. - Lastly, welding to the tube.	- 10 minutes for bending - 10 minutes for machining
Docking beam mounting plate	Several steel/aluminium plates	- Machining or water cutting of pieces - Welding to join	- 2 hours for machining/water cutting - 1 hour for welding
Caster Mounting Plate	Aluminium plate	- Machining	10 minutes
Hinge Upper plate	Steel/ Aluminium plates	- Machining of plates - Welding to join	- 10 minutes machining - 1-hour welding
Female Gliding Element	Aluminium Profiles	- Drilling for holes	10 minutes
Male Gliding Element	Aluminium Profiles	- Drilling for holes	10 minutes

6.2 Assembly

In order to build up the platform several components are assembled together. Assembly is a stepwise process for this design. The main aim was to use less components to assemble to reduce cost and, in the meantime, make the assembly easy.

Different kind of fasteners are available for assembling slotted aluminium profiles. Using correct and strong fastener was one of the tasks. Use of a kind of fastener is recommended which doesn't required drilling of holes in the aluminium profile. Since drilling holes require certain time and takes certain portion from the budget.
In this design, power lock fasteners are used to assemble the aluminium profiles because of its benefits compared to other fasteners such as:

- Power lock fasteners are used to attach profiles at 90º angles without need of drilled holes.
- Same fasteners can be used to assemble all the profiles which reduces the kind of parts leading to cost effective design for assembly.
- Use of power lock fastener is fast, easy and adjustable at any dimensions.
- It provides greater resistivity to loads than other fasteners as set screws present in the fastener gives lock washer effect.

Figure 49 Power Lock Fasteners in use (Minitec Framing)

Figure 49 shows three easy steps of using power lock fasteners in profile assembly. A set power lock fastener has threee components; a screw that fits inside profile hole, a slide plate where profile T slot slides into and a hex screw that tightens the profile together.

To install a power lock firstly, the screw is driven into the center hole using a driving tool as it requires certain force. Then the profile is slided into the power lock. Since power lock are adjustable proper positioning of the profile is required. Lastly, hex screw is tightened using tightening tool.

Aluminium framework and the door framework in this design are assembled using same power lock fasteners.

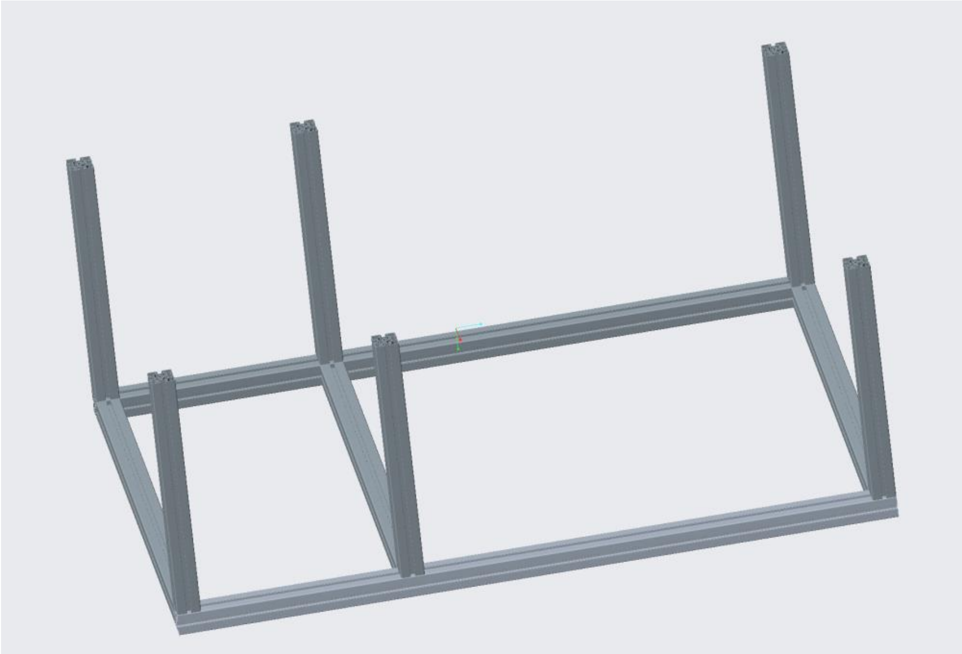

Figure 50 Assembly of Framework, Step 1

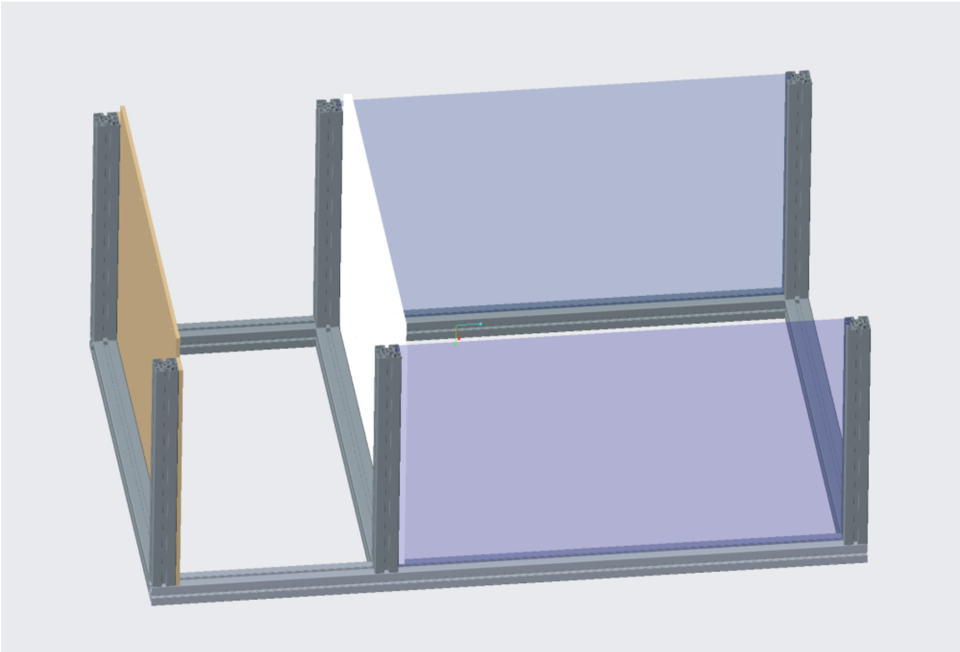

Figure 51 Assembly of Framework, Step 2

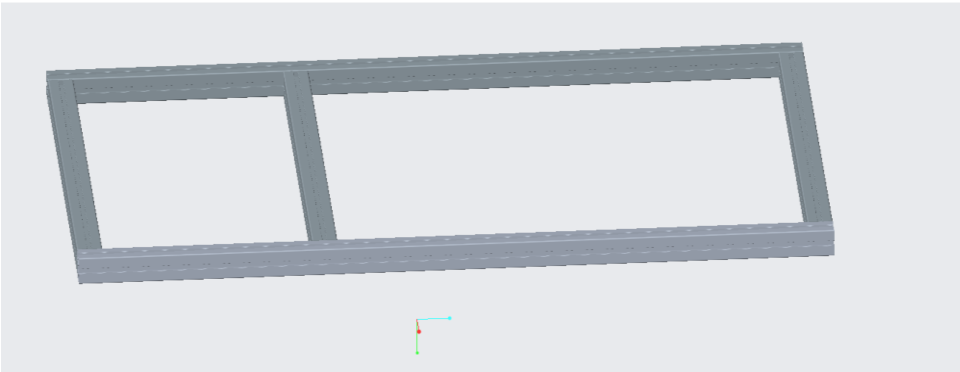

Figure 52 Assembly of Framewor, Step 3

Figure 50, Figure 51 and Figure 52 shows three main steps of assembly of framework. Firstly, as shown in Figure 50 inverted table structure is formed with the profiles. Inclusion of shelves and panels is necessary which is obtained with stepwise assembly procedure. So, in the inverted table structure glass panels, glass seal, shelves and nut fasteners are inserted. Lastly, another assembly of profiles as seen in Figure 52 which are then attached to the main assembly.

After the framework is assembled, doors, shelves, caster wheels are attached to the platform. Door framework is assembled like the main framework since it also includes a glass panel.

To attach shelves, caster wheel mounting plate, door hinge, handles, gliding elements to the framework another type of fastener set is used, which is T-slot square nuts and socket head cap screws. T-slot nuts have a position fixing system which helps it stay on top of T-slot and helps in easier engagement with screws. Nuts should be inserted to the framework assembly beforehand to reduce unnecessary iterations of assembly. Similar size of socket head cap screw is recommended as it will be cheaper.

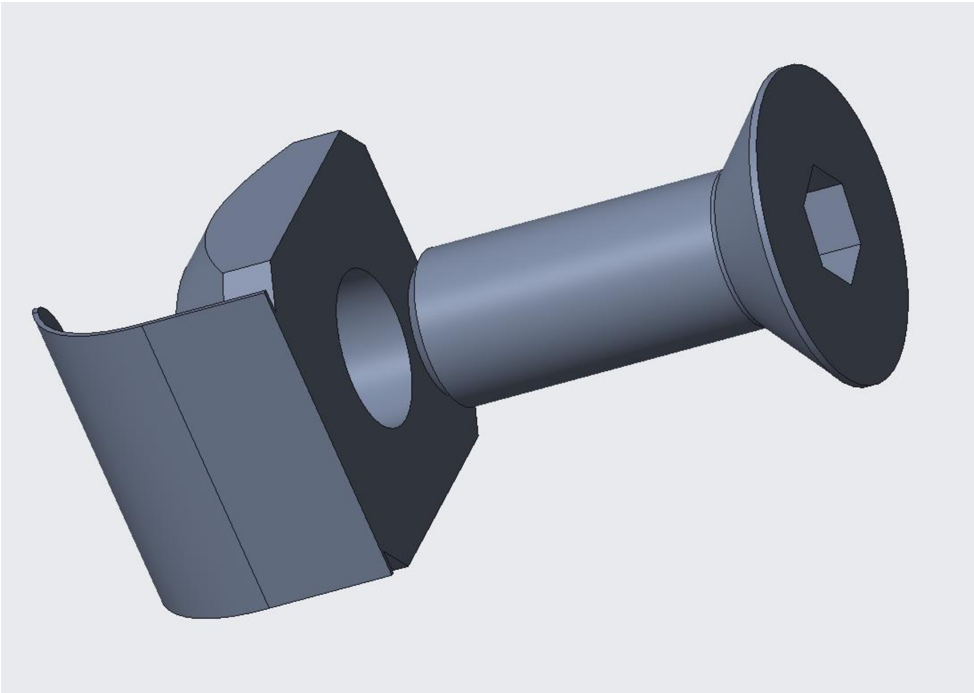

Figure 53 Set of T- slot square nut and socket head screw

As seen in Figure 53, the square shaped T-slot nuts fits into the T-slot of profile and has a position fixing element which helps the nut remain on top of T-slot. The socket head screw then tightens the fixing part to the profile.

Besides, power lock fastener, T-slot nut and socket head third type of fastener is used in this design which is tightening screw that is used while attaching caster wheels to mounting plate and magnetic catch to the middle shelf.

7 COST BREAKDOWN

Cost analysis is another important phase in product design. Generally, reducing the cost of product or limiting it to a certain budget is one of the main aims of product design. Cost must be defined during the design stages rather than before manufacturing or market reach.

In this design, there was a rough estimation of cost during the detail design phase. But there are few estimations of cost that could be figured out after the completion of design. In this design, cost of the final product includes two different cost types;

7.1 Cost of materials:

There are several commercially available which can be directly purchased from reseller. While there are certain parts which needs to be manufactured but the material that are used in it can be purchased. All this cost is referred as material cost.

Table 8 Parts list and their respective prices

Part/Component	**Quantity**	**Price Per Unit (in euros)**	**Total Price (in euros)**
T- slotted aluminium profile (60×60)	20 m	20	500
T- slotted aluminium profile (30×30)	5.5m	10	55
Laminate board (20mm thick & 10mm thick)	1 pc each	40	80
Gliding element Aluminium rails (Male & Female)	700mm each	30	60
Glass Panel	Multiple sizes cut	80/m^2	80
Caster wheels	4 pcs	50	200
Accessories	Different kinds	N/A	65
Hinge	4 pcs	9	36
Bolt and Wing Nut (Docking)	4 sets	8	32
Fasteners	Multiple	N/A	158
Steel Tube for Handles	2500mm	N/A	65
Aluminium Plate for Caster plate	4 pcs	10	40
Aluminium plate for Docking Beam plate	4 sets	10	40
Total			1411€

7.2 Cost of manufacturing and assembly:

Manufacturing process such as machining, water cutting, welding is done by experienced personnel which comes at certain rate. Assembling a profile also requires a human effort but, in this case, it doesn't account a significant amount. This type cost is referred as labour cost.

Labour cost = Working Time × Labour operating rate

From Table 7, total estimated working time for manufacturing process can be deduced which is roughly 5 hours.

In HAMK lab, machining specialist rate is approximately 100€ per hour.

Thus, Labour cost = 5(hrs) × 100(€/hrs) = 500€

Therefore, the total cost for this design accounts 1911€ which is within our estimated budget of 2000€ that was set during design specification phase.

8 RECOMMENDATIONS

The product designed in this thesis project has satisfied the requirements set by the commissioning party. However, there are certain aspects that could be modified and amended for better results, such as the reduction of the cost of the product and the docking mechanism solution.

The cost of manufacturing certain parts accounts to approximately 500€ which can be greatly reduced if the parts are replaced with commercially available parts.

The cost for manufacturing the floor mounting plate for docking beam is three times as expensive compared to the floor mounting plate available commercially. Since there were very few possibilities of using commercially available mounting plate for the 60×60 profile size, manufacturing it was one of the few alternatives. The other alternative was to replace the 60×60 profile size with a 45×45 profile size. 60×60 profile size was used in the design for docking beam because the framework profile was of same size and using same size profile also greatly reduces cost. Considering this exception, the use of a 45×45 profile size is highly recommended. Similarly, hinge upper part could be replaced with commercially available part but only if profile size of the door framework is altered. Altering the profile size for these two components would save approximately 300€.

Another recommendation is for the design of docking mechanism. This design was analysed by a Design Specialist from HAMK, Mr. Jaakko Vasko. As per his recommendations, an alternative docking mechanism was suggested which included just one of the docking beam assemblies with a wedge-shaped male element fitting into a similar wedge-shaped female element. Wedge-shaped parts have tapered sides and inserting them into a tapered female element is comparatively easy.

From the current design, he suggested it would be slightly difficult to insert the male gliding element into the female gliding element as the height of the docking beam and the height of the platform should exactly coincide, with absolute zero tolerance. He concluded it would cause some minor problems assigning the tolerance and inserting the elements together. Thus, he suggested using wedge-shaped docking elements which would eliminate the problem. However, the locking mechanism still needs to be designed if this alternative is used.

9 CONCLUSION

The HAMKTech robotics research group has been actively conducting research work and project related to robotics. This thesis work was conducted as a part of the process.

The main aim of this thesis work was to design a movable platform that would be later manufactured and used in lab work alongside a CNC lathe machine. There were various requirements and all the requirements were achieved.

All the necessary research was done prior to starting the design of the platform and a systematic design approach was followed until the end. All the possible solutions were discussed with the supervisor and the best solution was always chosen to proceed further. The design was the most time-consuming phase followed by analysis and market research about the necessary parts. Simulation and analysis helped approve the design and cost breakdown was also approved by the commissioning party. Therefore, this project was successful.

This thesis work contains pictorial representation of the 3D design, a product strength analysis, work simulation, assembly and manufacturing guidelines, a parts list and a cost breakdown of the product which will be further used by student assistant of the research group to build the platform and use it in machining operations. All the relevant information retrieved from the web are attached as references or appendices. Thus, this thesis work will work as a guidebook for the student assistant of the research group.

However, there is still room for improvement of the design, as product design is such field which always demands improvement. Thus, this thesis work could work as a helpful reference to student assistants for further design amendments.

To conclude, this thesis project was a great experience to me as a designer. I have learnt various technical skills and broadened my knowledge about product design. I got an opportunity to explore new fields of mechanical engineering, such as work simulation, docking systems and information on aluminium profiles. This experience and knowledge gained will be helpful for me as a future mechanical engineering professional.

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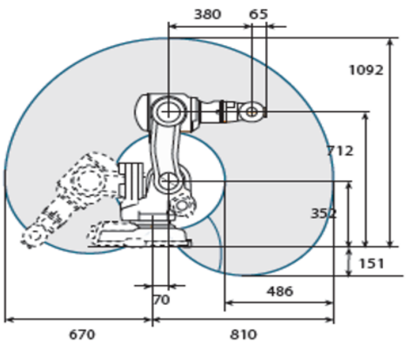
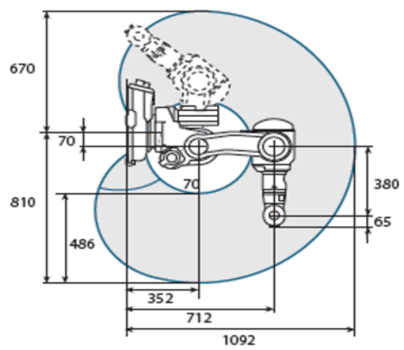
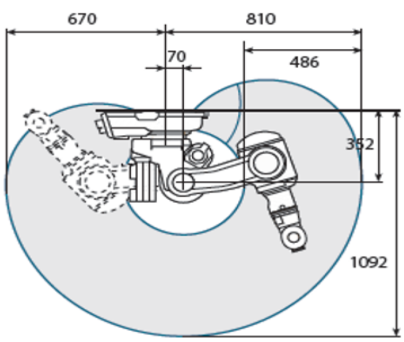
Appendix 1 TECHNICAL DATA OF IRB 140 ROBOT

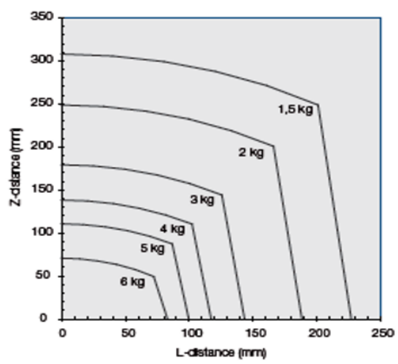
Specification

Robot versions	Handling capacity	Reach of 5th axis	Remarks
IRB 140/IRB 140T	6 kg	810 mm	
IRB 140F/IRB 140TF	6 kg	810 mm	Foundry Plus 2 Protection
IRB 140CR/IRB 140TCR	6 kg	810 mm	Clean Room
IRB 140W/IRB 140TW	6 kg	810 mm	SteamWash Protection
Supplementary load (on upper arm alt. wrist)			
on upper arm		1 kg	
on wrist		0.5 kg	
Number of axes			
Robot manipulator		6	
External devices		6	
Integrated signal supply	12 signals on upper arm		
Integrated air supply	Max. 8 bar on upper arm		
IRC5 Controller variants:	Single cabinet, Dual cabinet, Compact, Panel mounted		





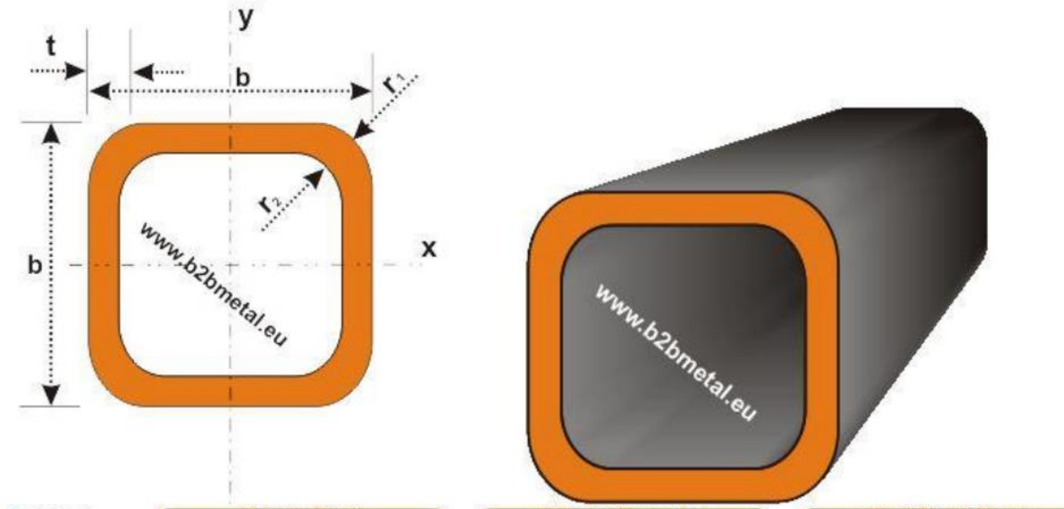




Appendix 2

Appendix 2 TECHNICAL DATA OF HOLLOW SQUARE BEAM

EN 10219:1997



Nominal dimensions	Thickness	Corner radius		Nominal weight 1m	Cross-section	Second Moment of Area	Radius Of Gyration	Section Modulus	Plastic Modulus	Torsional Constants		Section Surface Area
		External	Internal							Inertia	Modulus	
b	t	r1	r2	M/m	A	I	r	Z	S	J	C	As
mmxmm	mm	mm	mm	kg/m	cm2	cm4	cm	cm3	cm3	cm4	cm3	m2/m
20	2	4	2	1.05	1.34	0.692	0.72	0.692	0.877	1.21	1.06	0.0731
20	2.5	5	2.5	1.25	1.59	0.766	0.694	0.766	1	1.39	1.19	0.0714
25	2	4	2	1.36	1.74	1.48	0.924	1.19	1.47	2.53	1.8	0.0931
25	2.5	5	2.5	1.64	2.09	1.69	0.899	1.35	1.71	2.97	2.07	0.0914
25	3	6	3	1.89	2.41	1.84	0.874	1.47	1.91	3.33	2.27	0.0897
30	2	4	2	1.68	2.14	2.72	1.13	1.81	2.21	4.54	2.75	0.113
30	2.5	5	2.5	2.03	2.59	3.16	1.1	2.1	2.61	5.4	3.2	0.111
30	3	6	3	2.36	3.01	3.5	1.08	2.34	2.96	6.15	3.58	0.11
40	2	4	2	2.31	2.94	6.94	1.54	3.47	4.13	11.3	5.23	0.153
40	2.5	5	2.5	2.82	3.59	8.22	1.51	4.11	4.97	13.6	6.21	0.151
40	3	6	3	3.3	4.21	9.32	1.49	4.66	5.72	15.8	7.07	0.15
40	4	8	4	4.2	5.35	11.1	1.44	5.54	7.01	19.4	8.48	0.146
50	2	4	2	2.93	3.74	14.1	1.95	5.66	6.66	22.6	8.51	0.193
50	2.5	5	2.5	3.6	4.59	16.9	1.92	6.78	8.07	27.5	10.2	0.191
50	3	6	3	4.25	5.41	19.5	1.9	7.79	9.39	32.1	11.8	0.19
50	4	8	4	5.45	6.95	23.7	1.85	9.49	11.7	40.4	14.4	0.186
50	5	10	5	6.56	8.36	27	1.8	10.8	13.7	47.5	16.6	0.183
60	2	4	2	3.56	4.54	25.1	2.35	8.38	9.79	39.8	12.6	0.233
60	2.5	5	2.5	4.39	5.59	30.3	2.33	10.1	11.9	48.7	15.2	0.231
60	3	6	3	5.19	6.61	35.1	2.31	11.7	14	57.1	17.7	0.23

Appendix 3 TECHNICAL DATA OF T-SLOTTED ALUMINIUM PROFILE

Features:

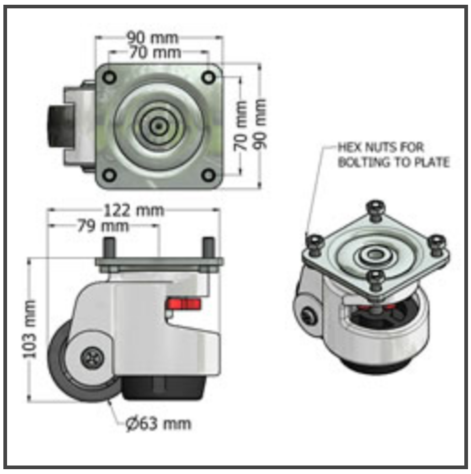
- Medium duty
- Profile ideal for large safety guarding, enclosures, and workstations
- Has four 10mm T-slots
- Center-bore is for an M12 or 1/2-13 tap

Technical Specifications:

Material	6063-T6 Aluminum
Finish	Clear Anodized
Weight	2.60 kg/m (1.749 lbs/ft)
Surface Area	9.60 cm2
Length	6 meters (236 in) (19.68 ft)
Moment of Inertia	I(x)= 32.41 cm4
	I(Y)= 32.41 cm4

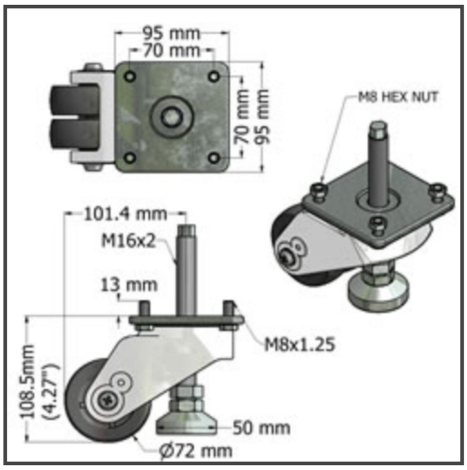
Appendix 4

Appendix 4 TECHNICAL DATA OF LEVELLING CASTER 600F



TECHN. DATA / ITEMS SUPPLIED	
- Cast aluminum frame, powder coated Ivory	
- Black nylon wheel Ø63mm (2.5 in)	
-Qty 4, M8 x 20 zinc plated hex bolts	
- Qty 4, M8 hex nuts	
-Pad designed to lift system up to 10mm off wheel	
- M8 hex nuts must be slid in from the end of MiniTec Profiles. For convenience, consider ordering qty 2, M8 square nuts with position fixing when mounting as shown in center picture.	
Load max.	- 300kg (660 lbs)
- Weight	- 1.38 kg

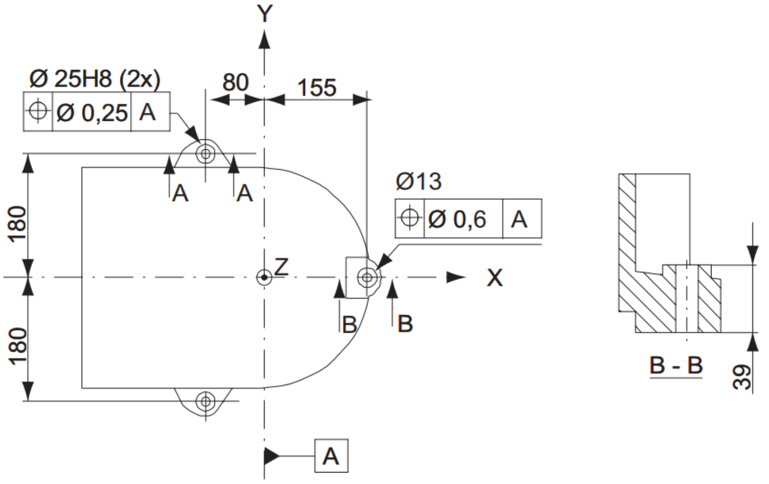
Appendix 5 TECHNICAL DATA OF LEVELLING CASTER 100A/F



TECHN. DATA / ITEMS SUPPLIED	
- Cast aluminum frame, powder coated Ivory	
- Black nylon wheel Ø72mm (2.83 in)	
-Qty 4, M8 x 20 zinc plated hex bolts	
- Qty 1, Steel leveler, zinc plated	
- Qty 4, M8 hex nuts	
- M8 hex nuts must be slid in from the end of MiniTec Profiles. For convenience, consider ordering qty 2, M8 square nuts with position fixing when mounting as shown in center picture.	
- Leveler can lift the wheel 50mm (2") off the floor	
Load max.	- 499kg (1,100 lbs)
- Weight	- 1.9 kg

Appendix 6 TECHNICAL DATA OF ROBOT MOUNTING BASE

Illustration



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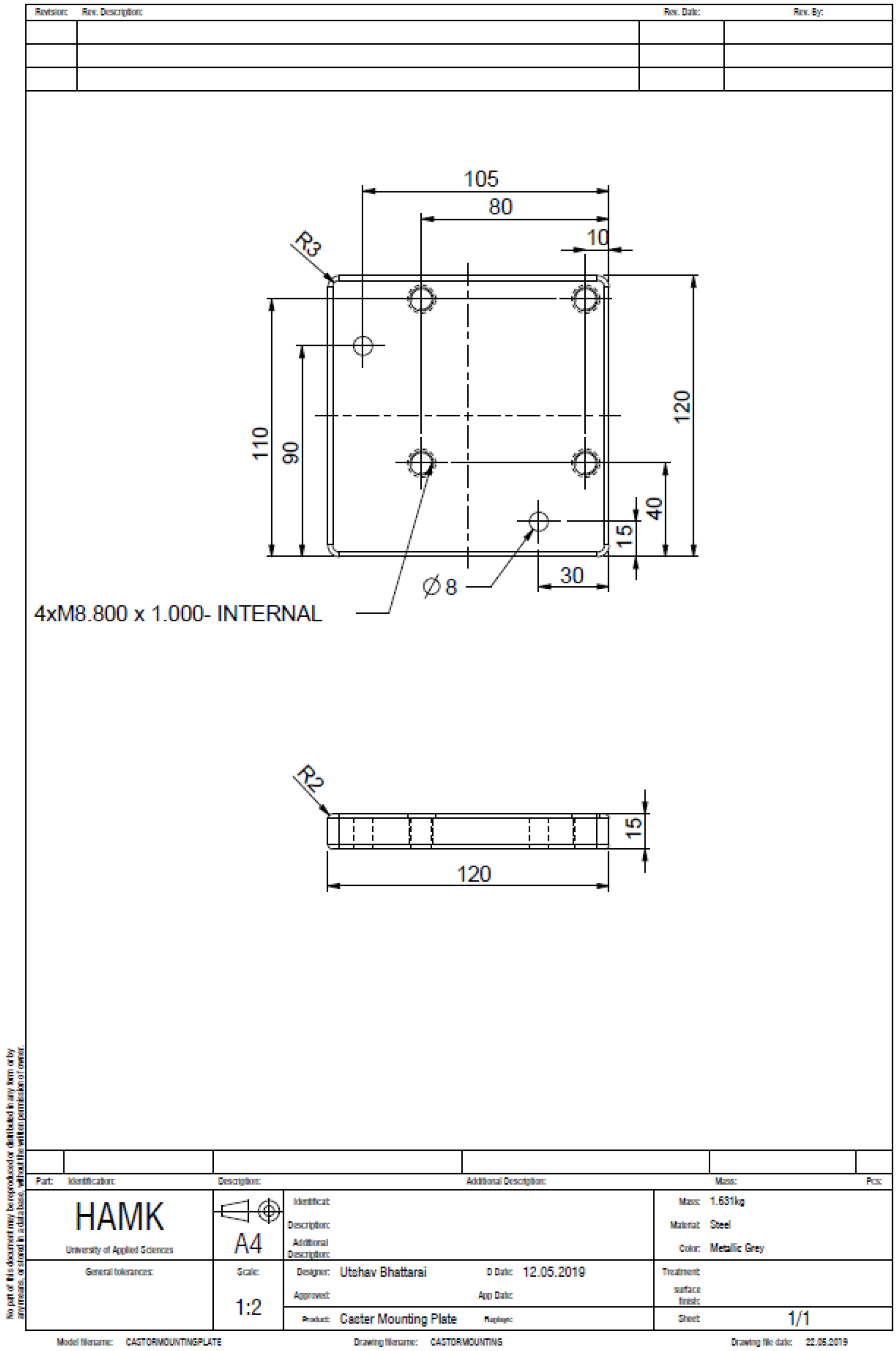
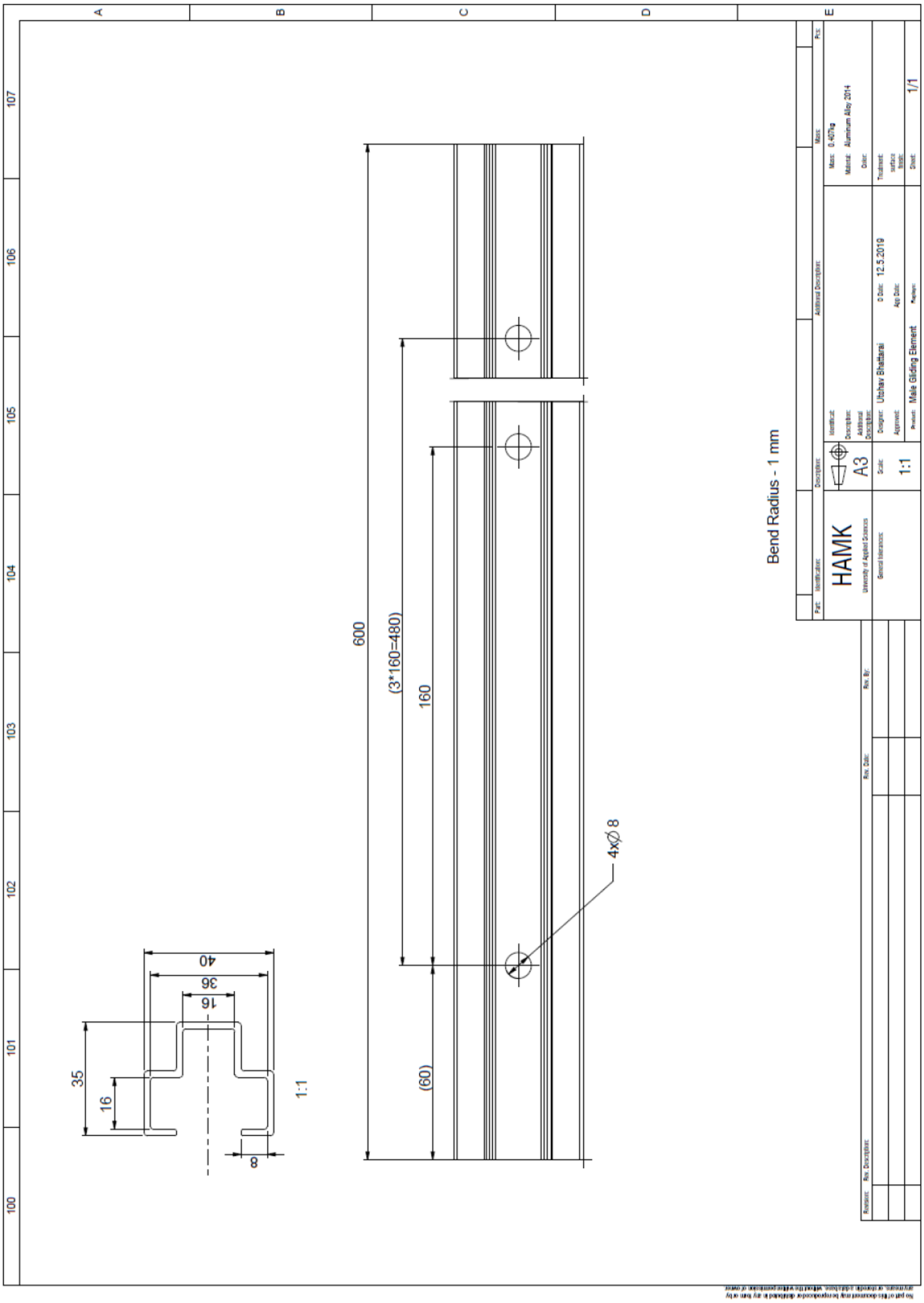
Appendix 7 Technical Drawing of Caster Mounting Plate

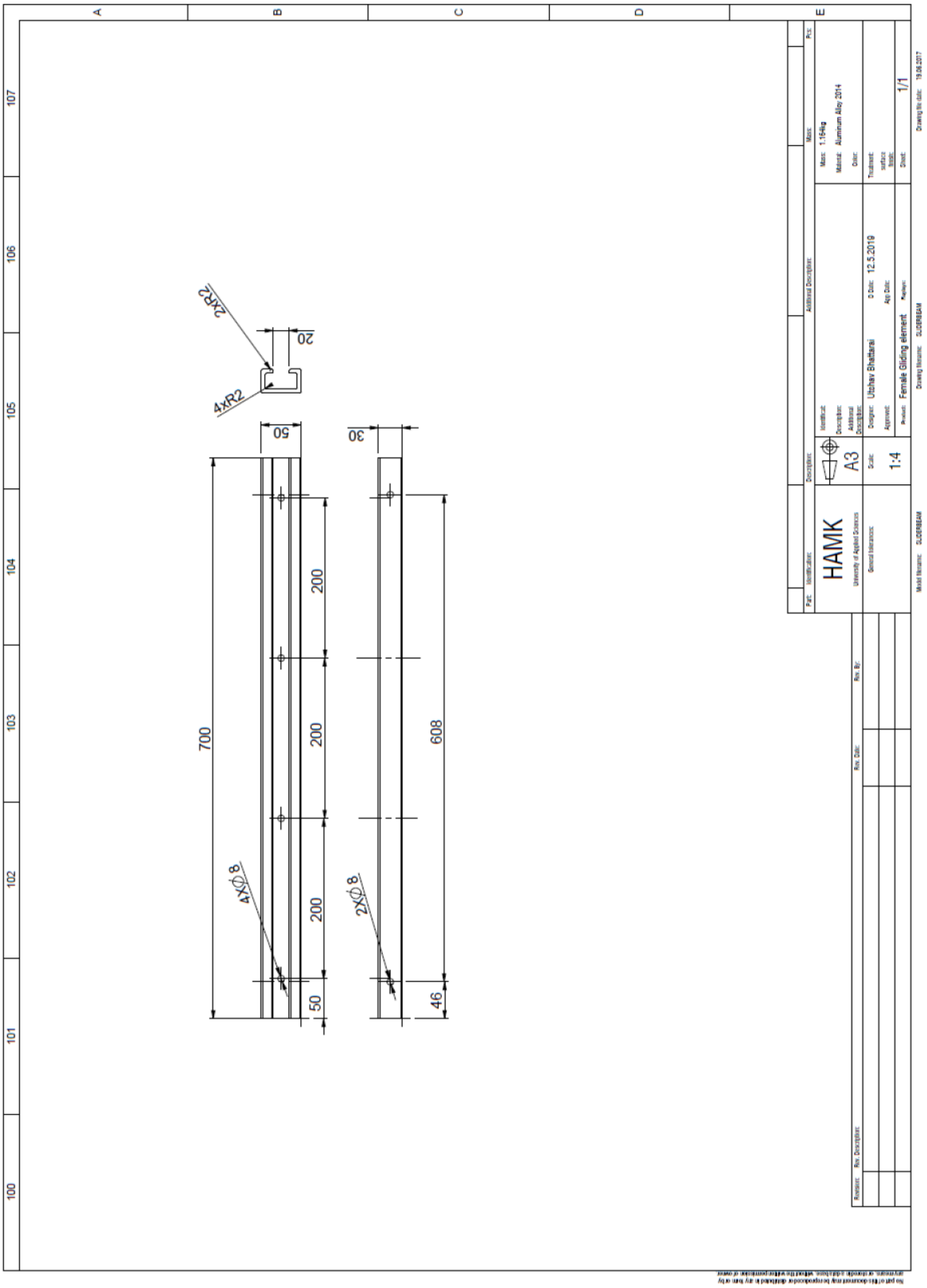


Appendix 8

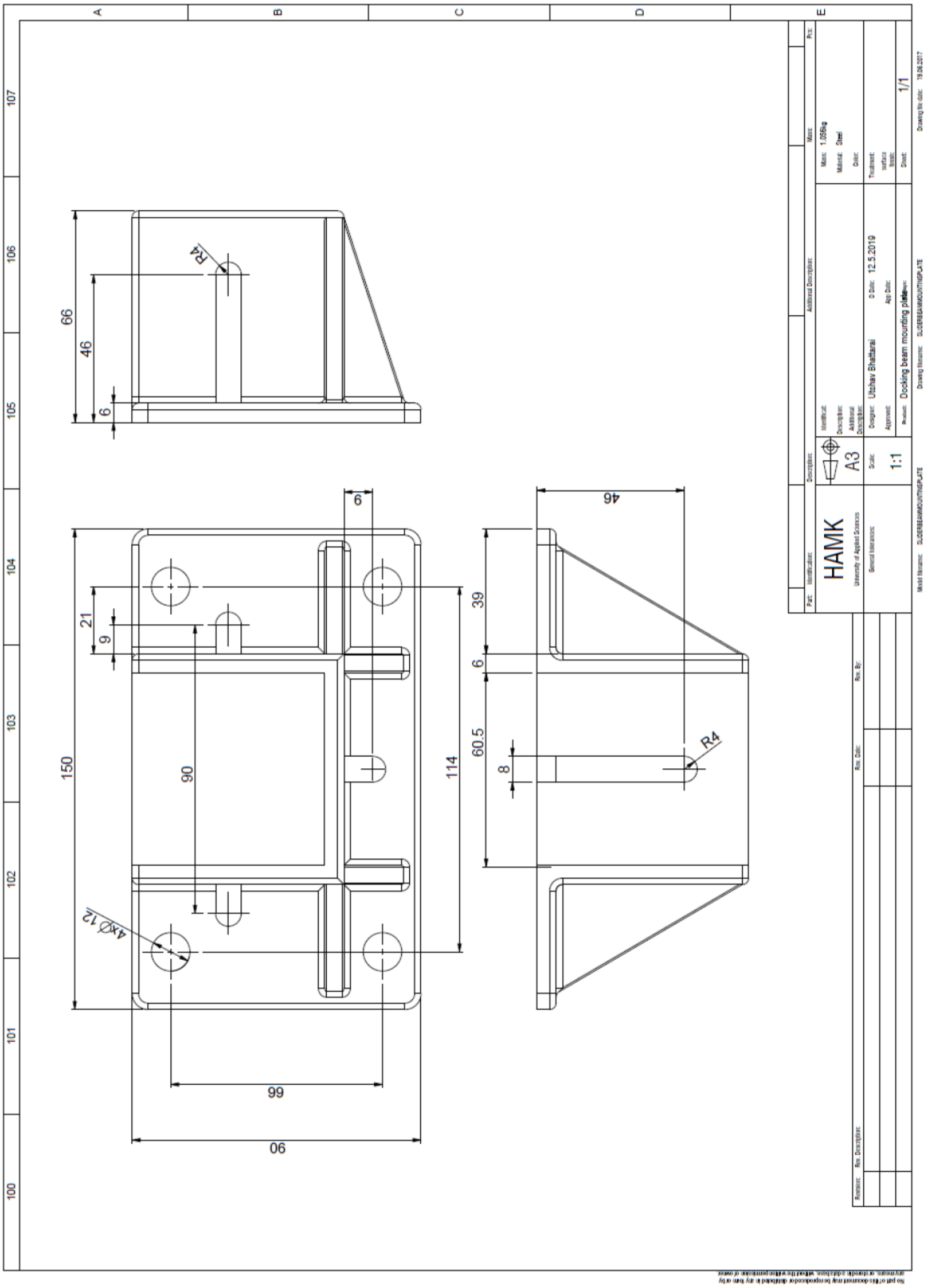
Appendix 8 Technical Drawing of Male Gliding Element



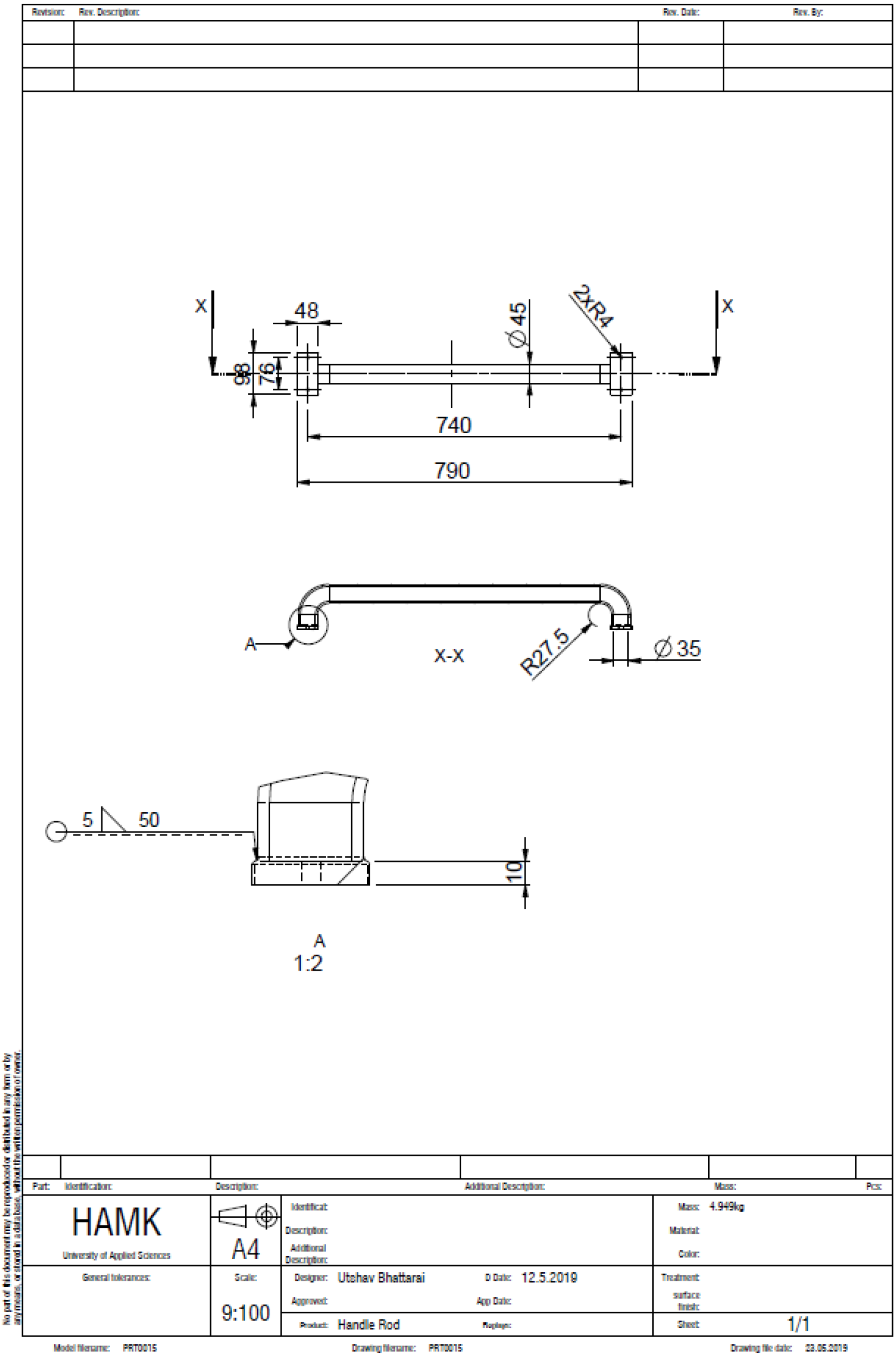
Appendix 9 Technical Drawing of Female Gliding Element



Appendix 10 Technical Drawing of Dockinng Beam Mounting Plate



Appendix 11 Technical Drawing of Handle Rod



Appendix 12 Product Parts List Breakdown

Product	Quantity	Manufacturer/Seller
T-Slotted Aluminium profile 60×60	3 × 6 m = 18m	Minitec Framing/ Profican/ FramingTech
T-Slotted Aluminium profile 30×30	1 × 6 m = 6m	Minitec Framing/ Profican
Levelling Caster Wheels	4 pcs	Minitec Framing USA/ Bickle Germany
Hinge L 45/45	4 pcs	Minitec Framing/ Framing-Tech
Power lock Fasteners	30 pcs	Minitec Framing
Square nut M8 with spring Meta L	68 pcs	Minitec Framing
Hex Socket Cap screw M8×16	68 pcs	Minitec Framing
Polycarbonate clear 1200×800	1 m^2	Minitec Framing
Door Handle	2 pcs	Minitec Framing
Magnetic Catch	2 pcs	Minitec Framing
Foot 45 GD S	4 pcs	Minitec Framing/ Scratch parts in machining lab
Insert Seal 6	10 m	Minitec Framing
Gliding Element	N/A	Aluminium profiles in lab/ Alumeco/ Stena Recycling
Caster Plate	4 pcs	Stena Recycling/ Minitec Framing

- Minitec Framing: http://www.minitecframing.com/index.htm
- Profican: https://profican.fi/
- FramingTech: https://www.framingtech.com/
- Bickle Germany: https://www.blickle.com/
- Alumeco Oy: https://www.alumeco.fi/
- Stena Recycling: https://www.stenarecycling.fi/