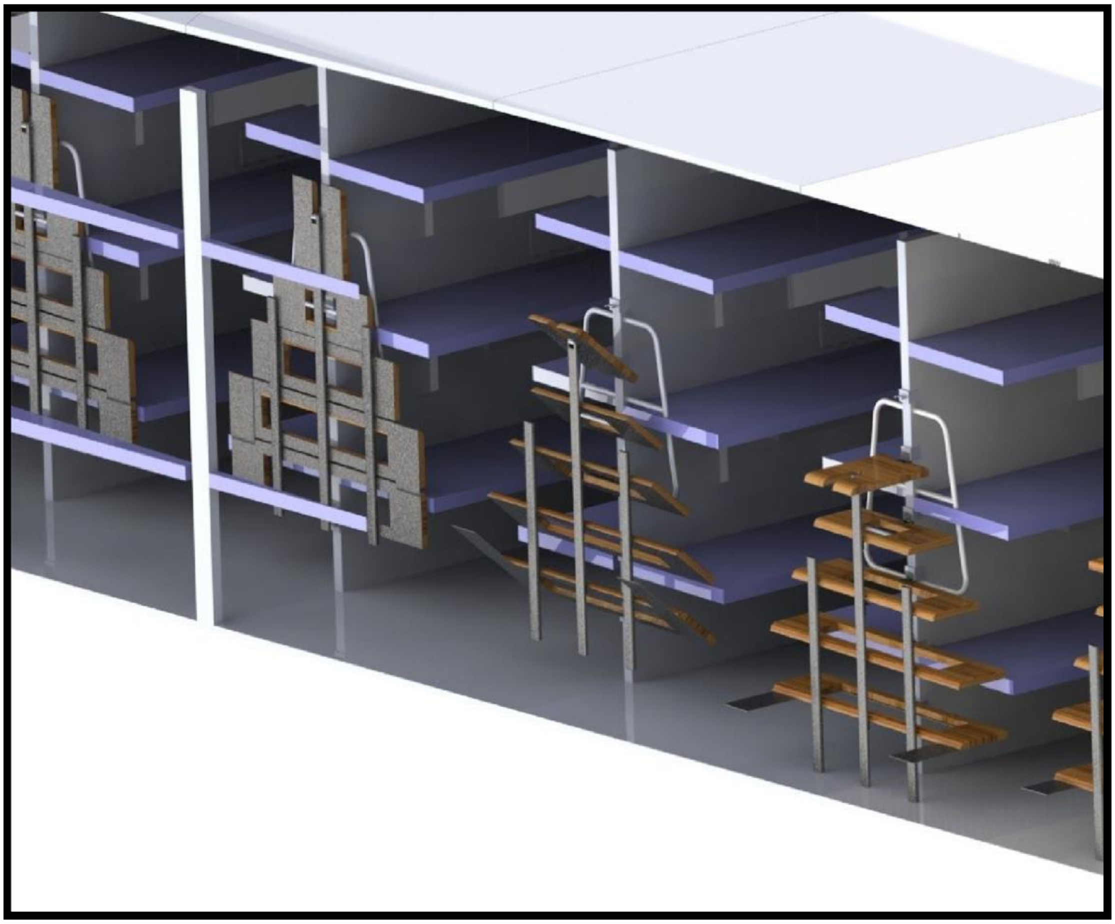
ReBAM

(Retractable Berth Accessibility Mechanism)



Unravelling Transportation

Vishnu MH (UT-69887768)

Kulkarni Atharva Kumar

S M Deepsikha

Burhanuddin Shirose

Sudarsana Jayandan J

Jayendran R

Table of Contents

1. Abstract:

1.1 Objective: The primary objective of the following project is to assist the passengers to comfortably climb onto the main as well as side upper and middle berths of the sleeper, 2 and 3 tier A/C coaches in the train.

1.2 Beneficiaries**:** The beneficiaries of the project are passengers who commute for longer times by train. This includes primarily old and middle-aged people (more than 40 years old), people with feeble bones and muscles, differently-abled or physically injured people and pregnant women. Briefly, the people who find it generally difficult to climb up or down the middle or upper berth of railway coaches are beneficiaries of this project.

1.3 Value of results: The staircase system designed by the team can be easily installed and deployed in almost every existing railway coaches with minimum modifications and without the requirement of completely dismantling and modifying the structure of existing or upcoming railway coaches, in turn making the manufacturers more sustainable in practice. The mechanism helps the passengers to resort to the designated berth without discomfort. The project also gives passengers the self-reliance to comfortably climb up without expecting help from others. This also eliminates the dilemma of switching the berths and rearranging within themselves according to their ease.

2. Background:

The Indian Railways System has different classes of seats available for varying price ranges and journey distances. There are about 8 different classes but not all of them are available on all trains. The most common classes are AC first class, AC 2 tier, AC 3 tier and sleeper. The issue that we have decided to address in the railway system is the difficulty of climbing onto the upper berths. Apart from the AC first class which has stairs for the upper berth, the rest have a ladder-like structure to climb on to the upper/middle berth. In some cases, the ladder exists only on the main berth side.

In 2015, the Indian Railways decided to address this issue and decided to invest 20k per coach to make user-friendly stairs/ladders. The task of climbing onto the upper berth is mostly achievable by an average adult, but it becomes strenuous for the physically unfit.

While ticket booking, reservations for lower berth are provided for senior citizens, pregnant women and the physically challenged. Each coach has 3 lower berths (in AC) and 6 lower berths (in Sleeper) reserved for the elderly. As there are only a small number of lower berth seats for senior citizens, only a single lower berth is allocated against a booking form, no matter how many senior citizens are mentioned in it. This is a limitation on the reservation system. Apart from senior citizens, individuals with health conditions and physical limitations find it very challenging to use the existing ladder system.

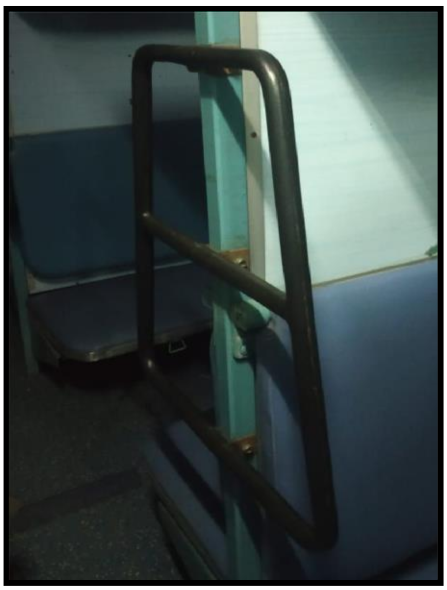
Most of the time people have to switch seats with their fellow passengers if they find it cumbersome or uncomfortable in climbing onto the upper berths in trains.

3. Statement of Problem

Our goal in this project is to design, ergonomically suitable for the elderly and easily accessible mechanism that can be used to climb every type of berth which will also be retractable, detachable, compact and will be easy to manufacture at the same time.

4. Research:

The existing ladder structure to climb onto the upper berth varies with the train. Some of the existing structures are:



The Existing methods to tackle this problem:

a. **Reservations-** There are trains which offer a reservation for 'Senior citizen, women over the age of 40 years, pregnant women and physically challenged'. In all trains having reserved sleeping accommodation, a combined quota of six lower berths per coach in sleeper class and three lower berths per coach each in A/C 3 and A/C 2 tier classes have been earmarked for above stated passengers. Due to the low number of reserved lower berths, only one is allotted for each booking form, no matter how many senior citizens are mentioned. Example: you are booking tickets for three people (72-year old male, 65-year old female and again another 61-year old male) using a single form, you will be allocated only one lower berth seat, where ideally the first senior citizen will get the lower berth. The rest will be allocated to middle or upper berths.

b. First Class A/C- There are three Brick-stairs built into the First Class A/C coaches. Although, these stairs are a steeper version of the normal staircases and the height of each stair is also more than the desired 20 to 25 cm. Still, this is a better option than the ladder-like structure available in the second and third-tier and sleeper coaches. This solution takes up a lot of space and thus making it impossible to implement in A/C 2 and 3 tier as well as sleeper coaches.

c. Swedish Railway Design- In Swedish 'Arctic Circle Train', there is a ladder attached to one of the walls of the compartment. This ladder can be accessed when needed. Although this design is compact, cheap and easy to access; but ergonomically this design does not provide comfort to the user. Also, this design is rendered useless if a person wants to climb to side berth.

d. Beijing Railway Design- Similarly, in 'Beijing Railway', there are two foldable steps built into the walls of the compartment itself. This design is also very simple and easy to use but lacks flexibility while positioning the design. Also, this design is used in trains which are comparable to luxury trains in India.

Proposed Solution:

Our solution to this issue is a foldable staircase that is easily retractable when needed. The staircase will be a symmetric structure to provide access to both compartments' upper and middle berth as well as the side upper berth. The mechanism will be stored in a folded position along the aisle. The push button to open the staircase will be situated along the edge of the compartment wall between the upper berth and middle berth, so that people from upper/middle berths can access it when required. This structure won't come in anybody's way when not in use and makes access to the higher berths much easier. Closing the ladder back just requires an extra push to lock it in place. This product will end any further discomfort involved in climbing up the stairs and make the train journey a lot easier.

Alternate Approaches:

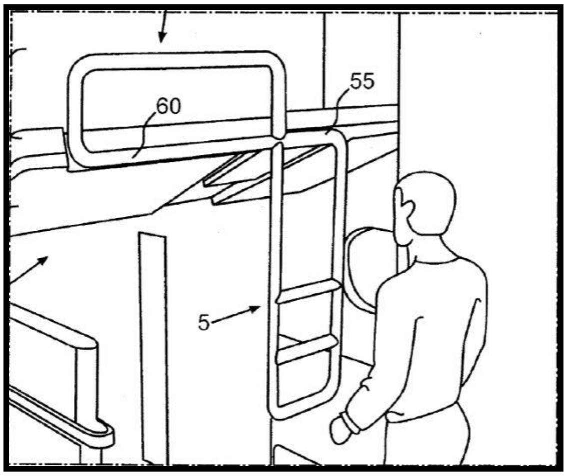
As of now, if a person is unable to climb the existing ladders, or is uncomfortable doing so, he/she would have to ask a fellow traveller to switch the seats. This leads to unnecessary arguments and makes the person dependent on his/her fellow travellers.

Research on patents for retractable ladders:

We went through around 40 patents and most of them made use of a telescopic mechanism to function. This made the solutions expensive to manufacture. And in the cases where the system is affordable, they tend to take up more space. The Indian railways coaches not only have space constraints but also need it to be affordable.

A few of the possible solutions:

1. https://patentimages.storage.googleapis.com/61/7b/d0/3a7e92e60f20f7/US2840290.pdf
   Features:



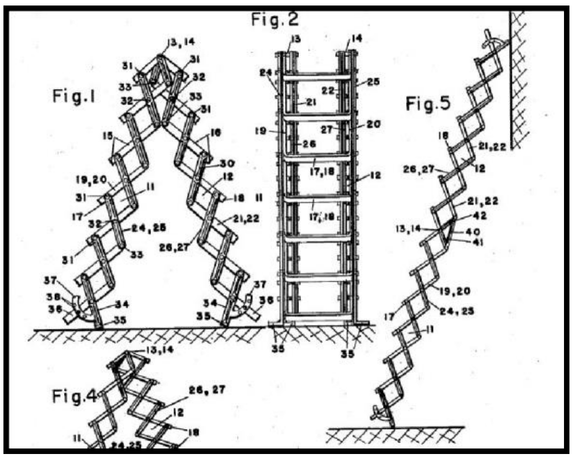
Adaptive with every ordinary coach (no need to change the coach). Folds into a compact form.

Easily accessible from the upper berth.

Cons:

It cannot take much load. Costlier since it's a telescopic mechanism. Need separate units for all the upper berths

2. https://patentimages.storage.googleapis.com/7c/78/44/591fcfd2a6213c/US2567302.pdf



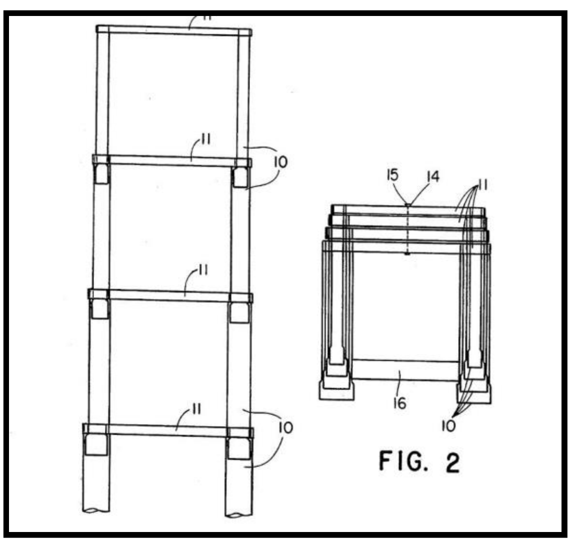
Features:

This is similar to the scissor mechanism staircase. There's a locking mechanism at the bottom which is used to lock the stairs in place.

Con:

The mechanism can't be unlocked once the person has climbed up the ladder. Therefore it is not a one-person use system and isn't accessible to all.

3. https://patentimages.storage.googleapis.com/1a/df/21/c3e38309c37a4c/US5495915.pdf



Features:

A step ladder with telescopically collapsible stiles. The rungs of this ladder have on their under-side latch mechanisms including resiliently biased pins which engage in holes in the stiles to lock the stiles in an extended position. A cord connected to the pins is also engaged by a button centrally mounted on the rung. When the button is depressed, it pulls on the cords and retracts the pins from the holes in the stiles, to allow the sections to be collapsed into one another.

Pros: The ladder occupies very little space. And it can be collapsed for ease of storage.

Cons: Climbing a ladder isn't a comfortable task for the elderly, people with disabilities and pregnant women. These ladders can only be used when it has to be suspended from the top. Also, the button on each rung, in turn, must be depressed to allow the sections to be collapsed one at a time, thus making the collapsing of the ladder a time-consuming process.

4. http://gyti.techpedia.in/project-detail/ergonomic-retractable-novel-stair-design-to-provideease-in-climbing/14795

Figure 1: Isometric view of the retractable stair design in open condition (3D rendered CAD model) S1 indicates lower or first step, S2 indicates middle or second step and S3 indicates upper or third step H1 indicates the handle which fold and unfold the steps and works as a normal handle as well while climbing up and down. S4 indicates a foot rest to aid climbing to the upper berth.

Features:

There are three retractable steps, one in lower berth, one in between lower and middle berth and one in middle berth such that the thickness of plate decreases gradually as we go up. The three steps are placed in a zig-zag manner rather than straight because to ease the movement of passengers and provide enough space to climb in a cramped up corridor.

In a normal staircase, there will be an inclination angle for the person to climb up. Since you can't have that due to limited space, they have made the steps decrease gradually in thickness such that it resembles a staircase with inclination.

The steps are retractable and can be unfolded by pressing the upper knob, present at the upper berth or the lower knob, present at the lower berth and then pulling the handle present at the edge of the sideways. A spring-loaded bolt is used to hold the steps in vertical positions.

Cons:

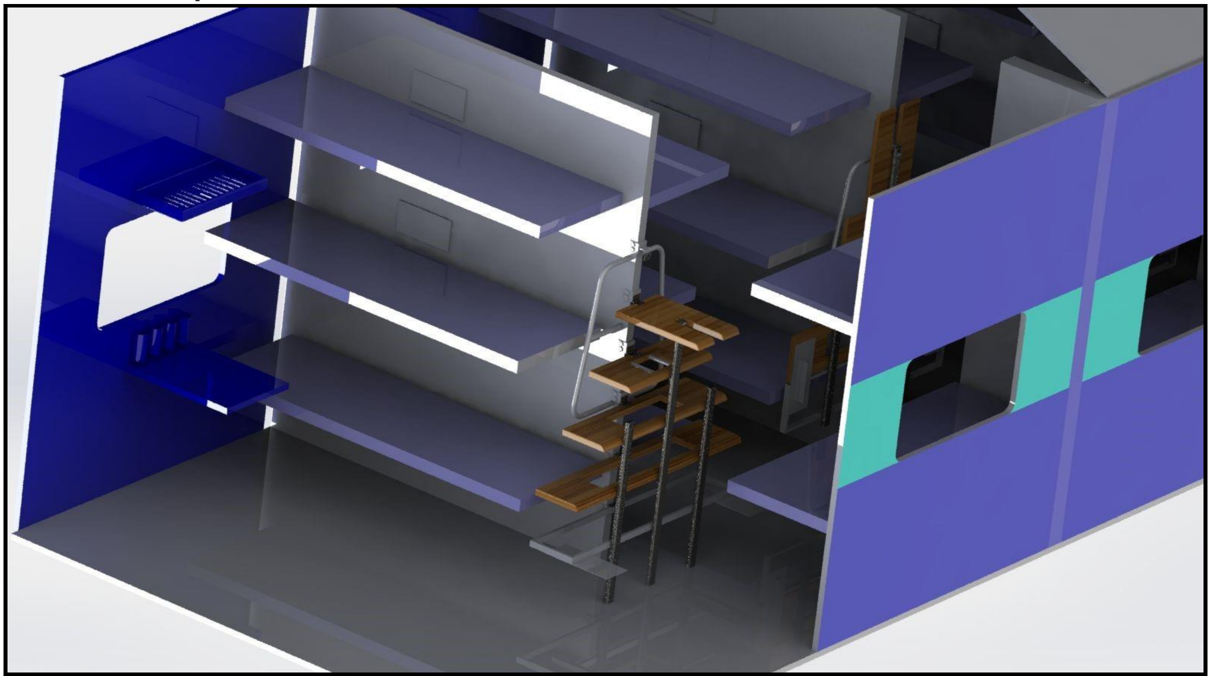
The major inconvenience comes when a person tries to climb up the topmost berth. As the thickness of the plate decreases, the person might feel uncomfortable to place his/her feet on the plate. The zig-zag nature of the step, though ideal for the space available, might be a little uncomfortable for older people to move along.

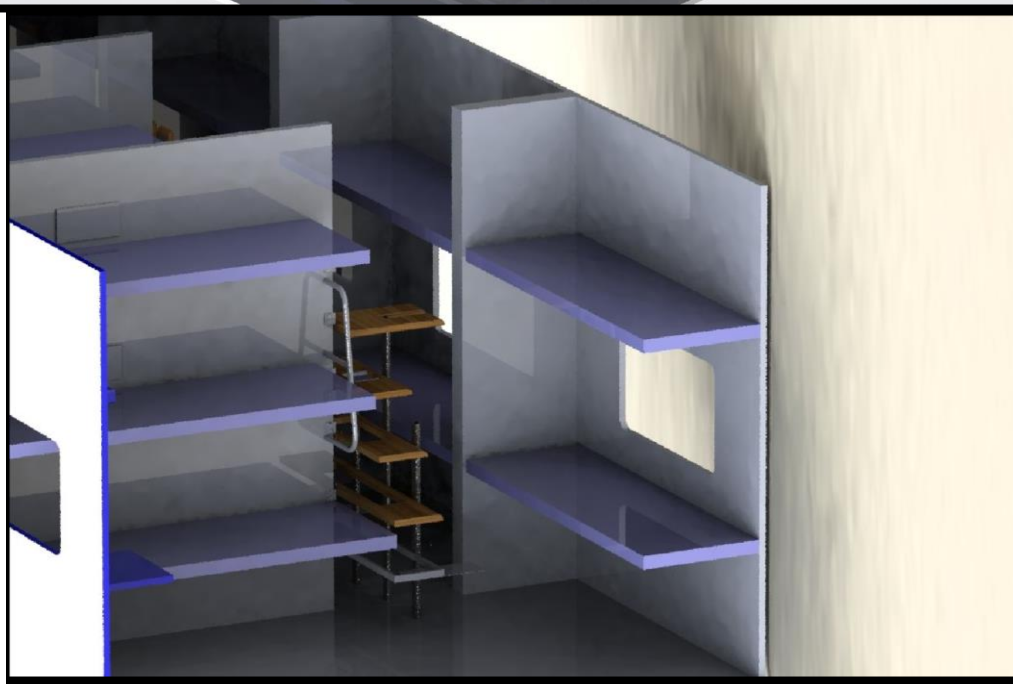
Novelty of Approach:

Our solution is compact ergonomic and affordable. Very few compromises have been made without affecting the overall usability and comfort of the product. Further out mechanism solves the problem efficiently without compromising any other vital factor.

Unlike other solutions which either give up, ease of use, compactibility or ergonomics. The solution is basically novel in combining the best of all the major factors and giving the best possible solution.

5. Technical Report:





Ergonomics involved in step dimensioning:

For comfort of the user, the important concern was choosing the right distance between two steps. According to the 'International Residential Code (IRC)', 25 cm height of stairs is comfortable for individual use. The proposed solution replaces the existing bars with a set of 5 steps each wide and reasonably spaced apart to enable the elderly to climb up the top berth.

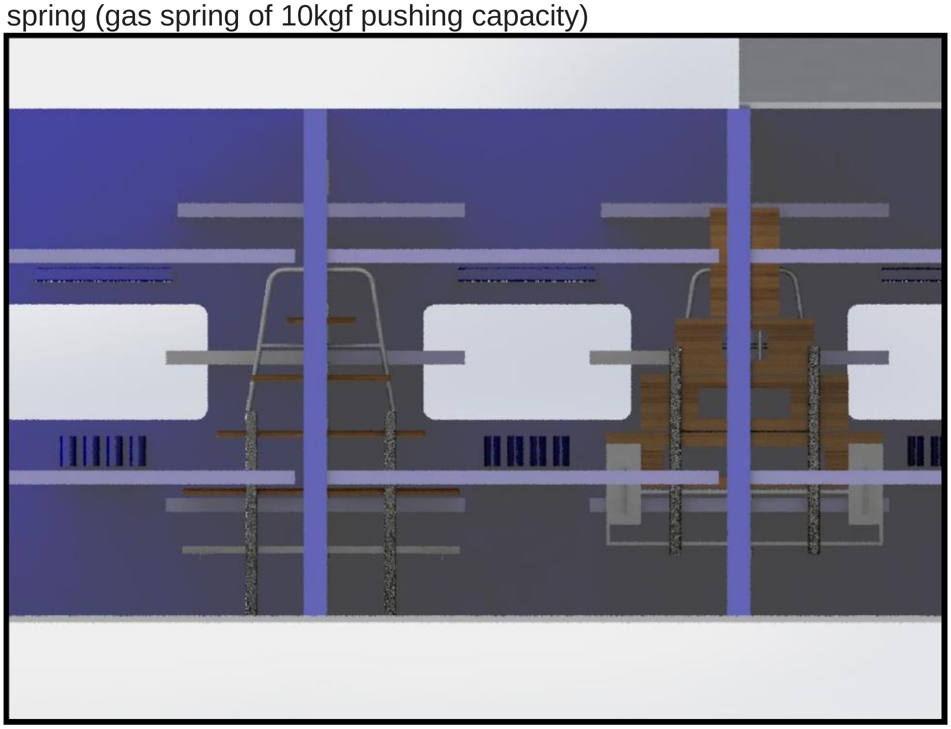
While standing upright an adult's feet need about 25cm*20cm area. Every aspect of our design is catered to serve each of the anthropomorphic limits.

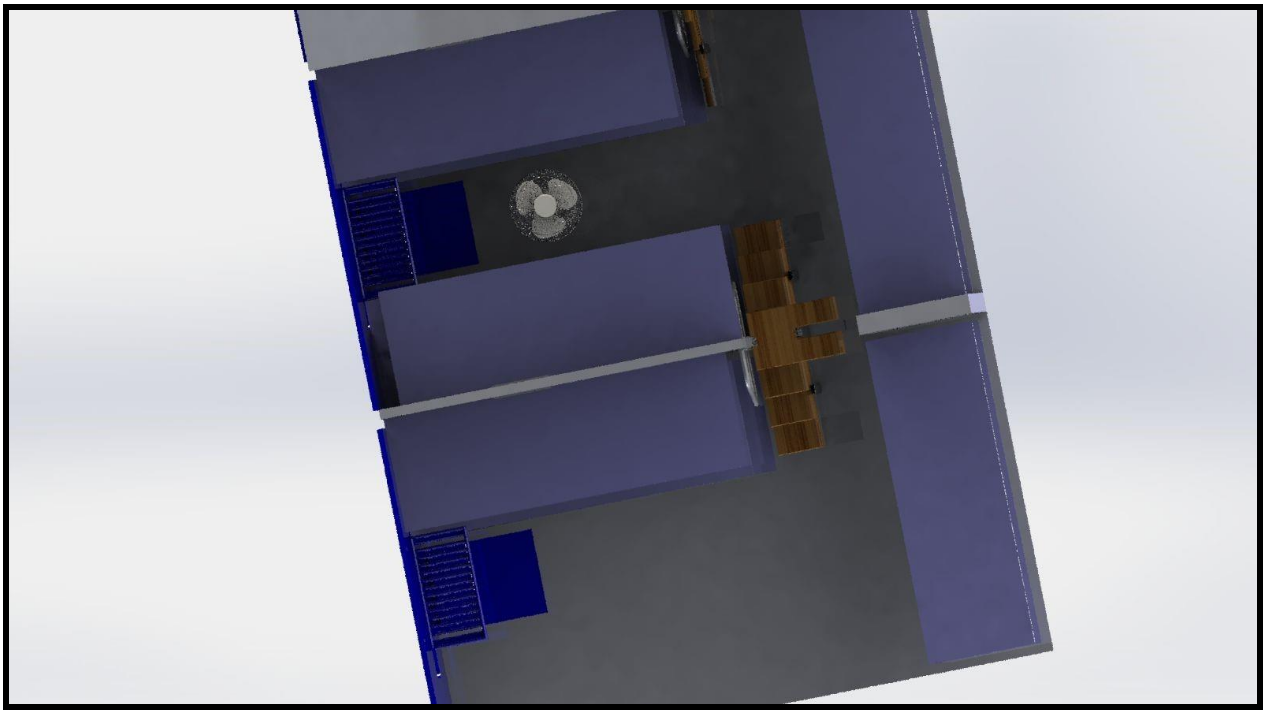
Approach

We followed *Ulrich approach* in designing our solution. First was market analysis. This consists of finding out the existing solutions either implemented in other country railways or looking up patents. Over 40 different google patents were looked into to draw inspiration and ideas. This was followed by making a priority list of desired features that our product should have. This list had factors as ergonomics, compactness accessibility and sturdiness. Then keeping this list, existing ideas and ergonomic comforts in mind, ideation started. Each idea, each change made was based on these factors. After this ideation session the proposed solution, it was designed in SolidWorks. This showed us the weight of the product exceeded what an adult could lift, this brought us to the idea of cutting slots in the steps to save weight. After this each step was put through ANSYS testing and checked for the load-bearing capacity for the modelled dimensions, this leads us to find the optimum balance between weight and load-bearing capacity. Also, our product was tested using Vive Ergo Lab software for checking the reachability of our product and to check the ease of use of the passengers while climbing the stairs.

Component list

- Steps (Plywood 25mm)
- Cutouts and Retraction Handle
- Connecting rods (stainless steel)
- U-clamps (stainless steel)
- Locking mechanism
- Top spring (gas spring of 10kgf pushing capacity)

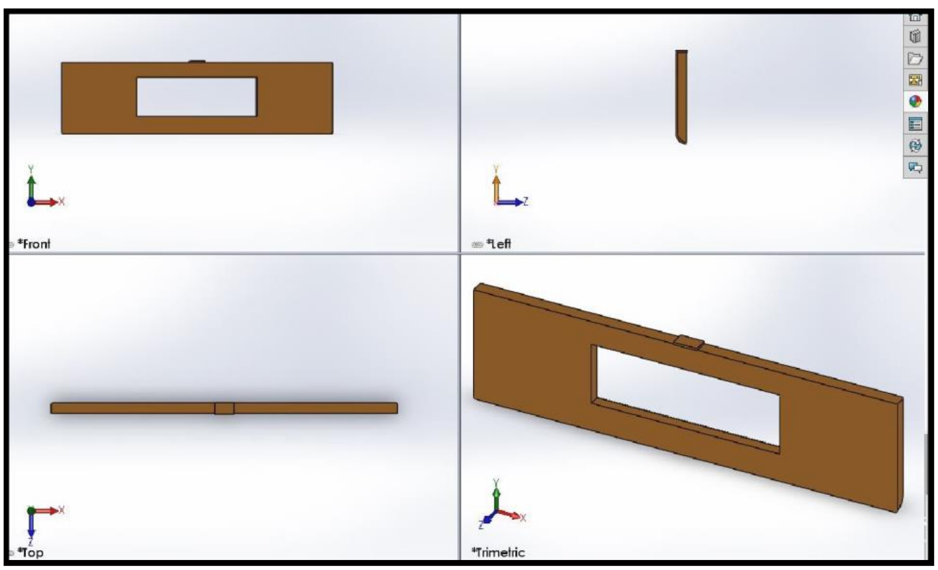




- **Steps (Plywood)**

  These are the actual steps of the staircase on which the users would be climbing in order to get to the required berth. These steps are made of Plywood which not only reduces the weight of the mechanism.

Dimensions of each step:



Step 2: Area= 120*24 cm sq some part of the system is cut out to reduce the weight of the system. So the cut out parts area is 80*24 cm sq.

Step 3: Area=90*24cm sq area cut out is 50*24 cm sq

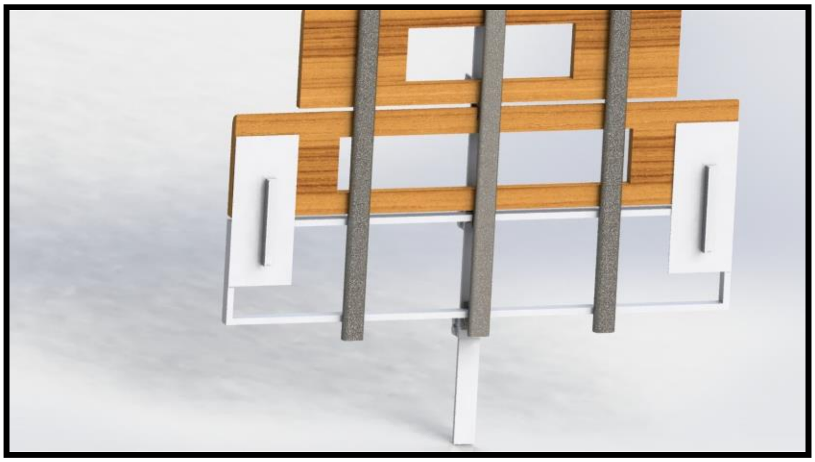
Step 4: Area=60*24 cm sq, cut out area is 20*24 cm sq

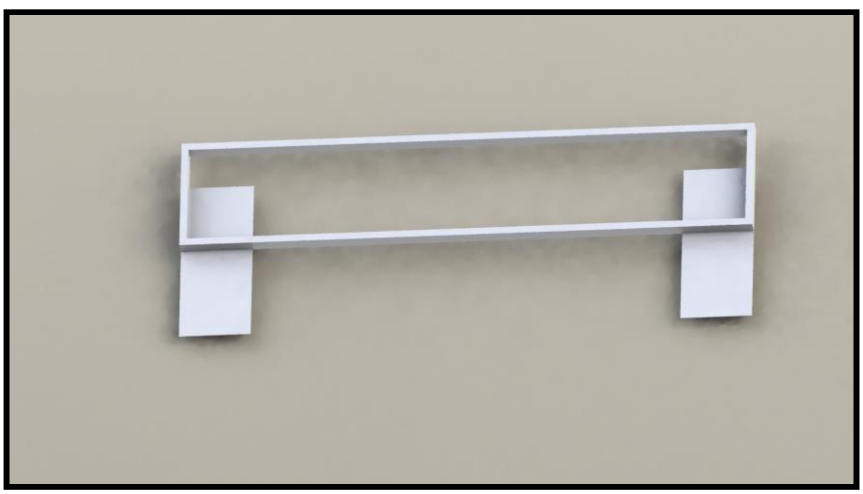
Step 5: Area= (30*24 + 30*23) cm sq. Extension is given towards the side to make it easier to move on to the side berth. Area cut out to allow the main rod movement is 6*25 cm sq.

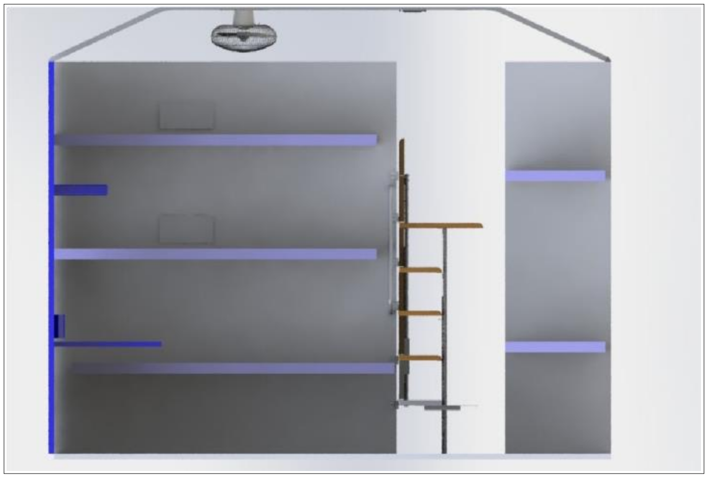
The thickness of each step is 25mm.

First step

with regards to the first step, the user has to step on the extended part of the step therefore to reduce the weight of the structure, the step is made of a metal frame with two metal plates welded on either side to user to step upon. The metal structure is lighter to a comparable wood structure and at the same time cheaper too. The two metal plates are 3mm thick with an L column welded underneath them for further strength. The dimensions of L column are 2.5 width of each arm of L and the thickness is 3mm.

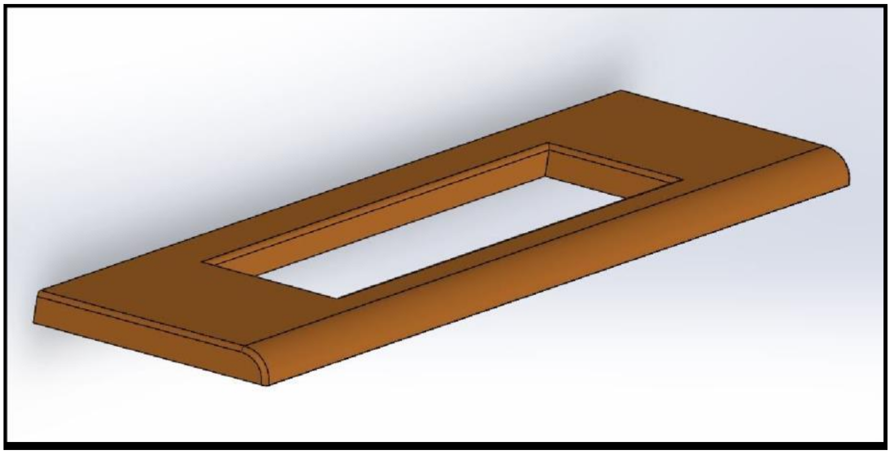






Placement of each step:

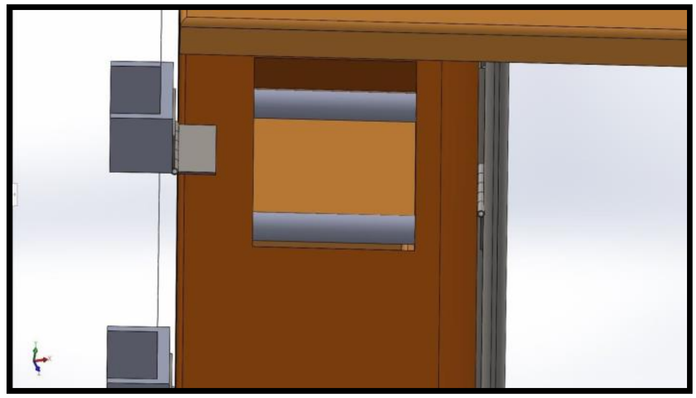
As stated earlier the distance between two steps cannot be more than 30cm, keeping this in mind our steps are placed as the respective heights
1st step at 30cm above ground
2nd step at 55cm above the ground
3rd step at 80cm above the ground
4th step at 105cm above the ground
5th step at 130cm above the ground
The middle berth is at 113cm above ground so that the person can get onto it from the 3rd step. The topmost berth is at 173cm above the ground so after stepping onto the 5th step, the person can just sit onto the berth and pull their legs within.
The last step is kept 47cm wide so as to enable the user to climb onto the side upper berth. The side upper berth is at 147cm and the corridor is 63cm wide so the person has to step over a gap of 16 cm (which is close to the length of a normal step) to get to the side upper berth.

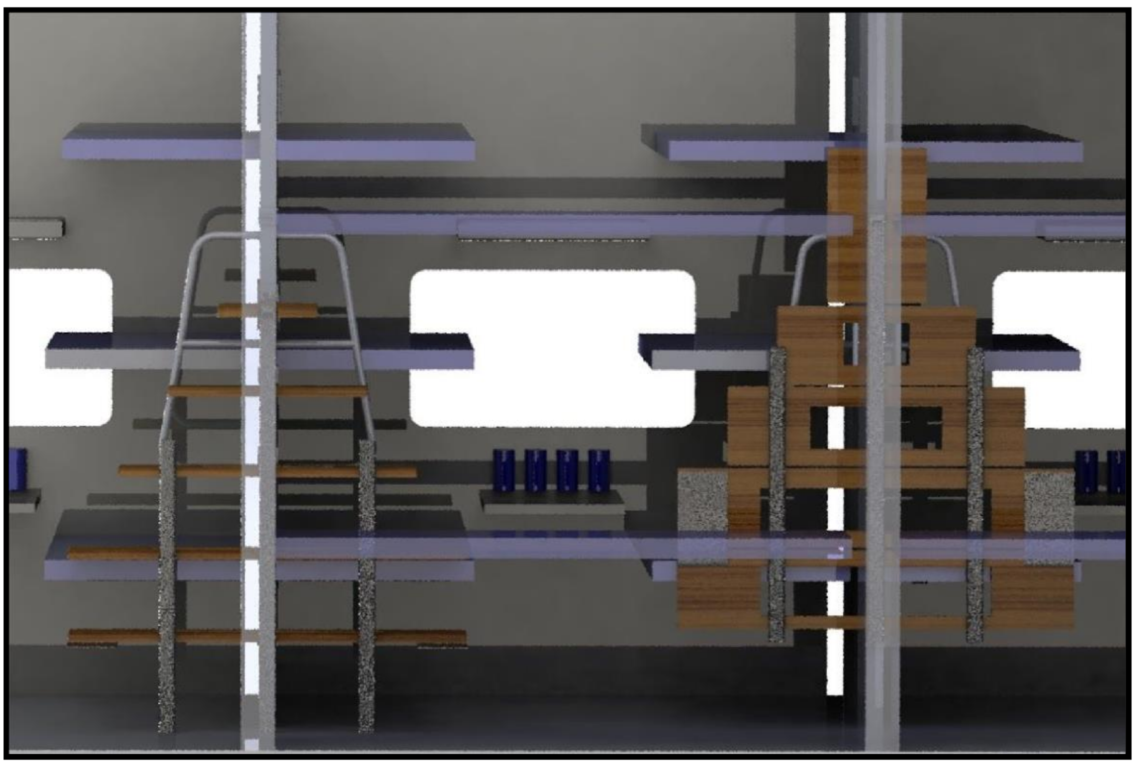


Cutouts and retraction handle:

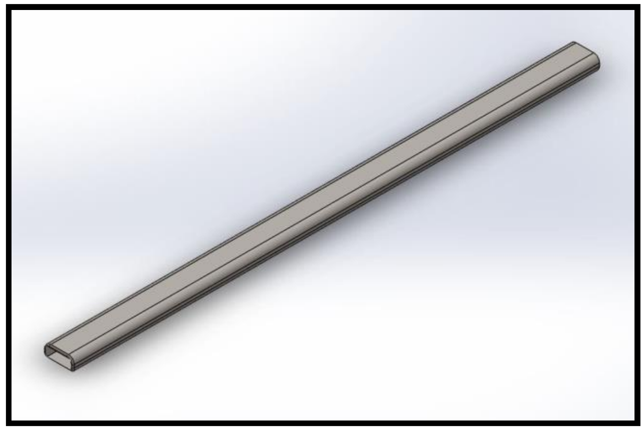
First 4 steps have a rectangular cut out in the middle. This is done to reduce the weight and cost of the entire mechanism. After making these cutouts analysis done again and data shows the necessary factor of safety is achieved.

In the cutout of the 4th step two rods are fixed. These rods are to assist the user of the middle berth to close the mechanism once he sits onto the berth. After climbing onto the middle berth these rods will act as a handle to grab onto so that that person could close it.





Connecting rods:



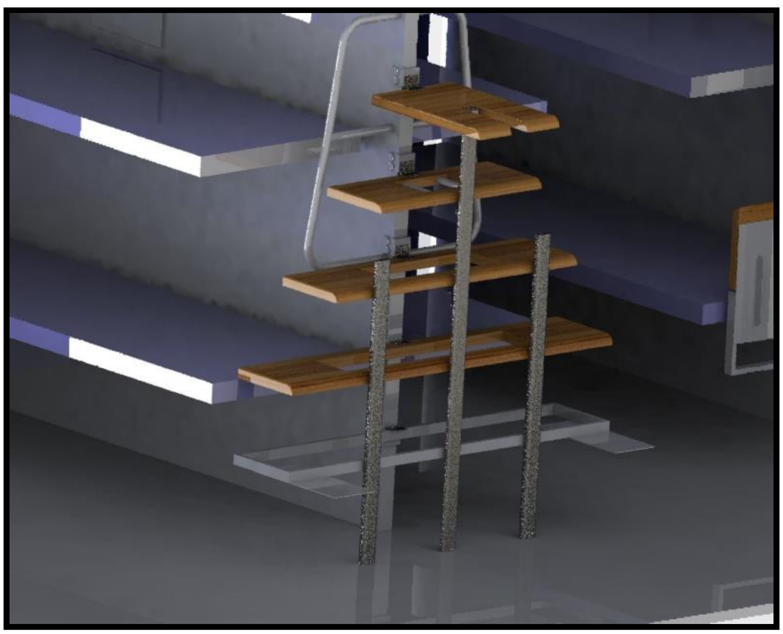
There are 3 side rods in our proposed solution. All three rest on the ground in the deployed position so as to provide support to each step on either end. Three rods consist of one central rod that connects all the steps and two addition rods connecting the first three steps for support. The first three steps extend more than 40cm away from the central support, this would make them a cantilever, thus unsturdy and susceptible to failure. So additional two rods connect these three steps and rest on the ground.

Dimension of the support rods are:

Length = 100 cm

Face cross sections = 4*2cm^2

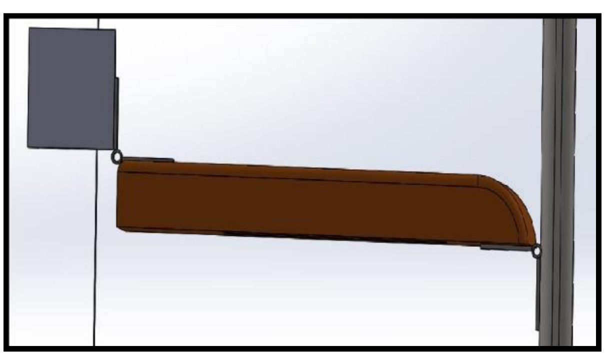
Hollow cross sections = 3.6*1.6 cm^2

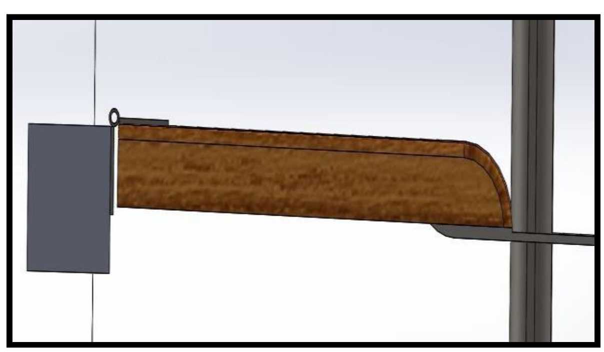


U clamp:

The U-clamps are used to attach the mechanism onto the 5 cm thick compartment wall edge. These U-clamps are bolted onto the wall and the hinges are welded on to the clamps.
The presence of these U-Clamps makes the whole staircase mechanism detachable and easier to install.

We are using 5 square U-clamps in order to attach our mechanism on to the compartment wall. Dimensions of U-clamp are: length= 5 cm, width= 5 cm, depth= 5 cm and thickness= 5mm. The U-clamps will be fastened to the steps(by bolting on wood or welding on metal) and will be bolted to the compartment wall. By using U-clamps, we can attach and detach this mechanism at will as well as this design gains flexibility so that it can be accommodated in coaches with different ladder arrangements in the following way: The position where we can bolt the U-clamp can be altered according to our need. In the following images, we demonstrate two extreme positions for fixing hinges on the U-clamp. Similarly, we can fix U-clamp to hinge at any point between these two extremes ranging about 5 cm, since the ladder rods are only 3cm thick this flexibility of 5cm should enable it to fit into every existing ladder position.





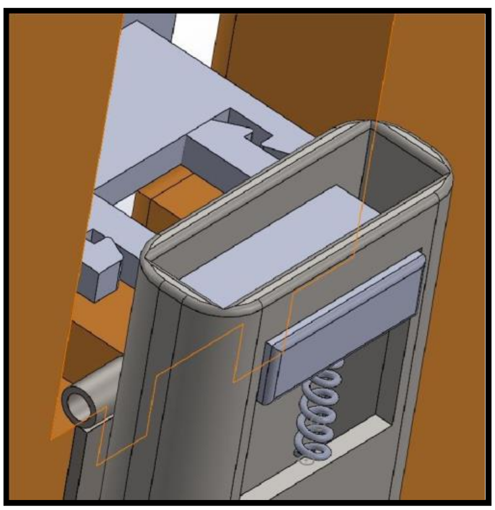
Locking Mechanism:

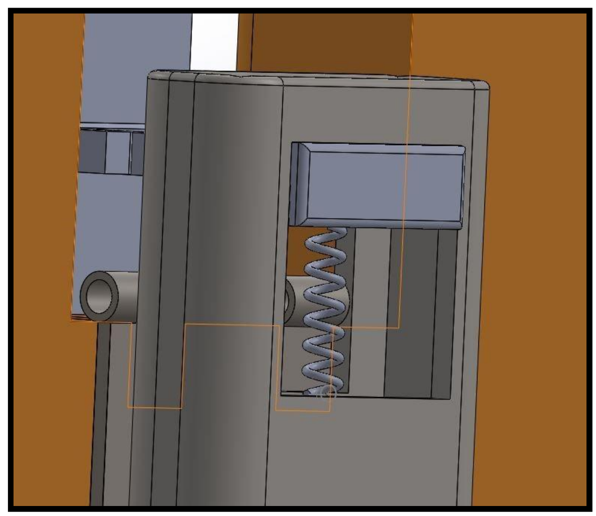
The locking mechanism in the design consists of 2 parts, one attached to the compartment wall and the other to the top of the central rod. The part connected to the central rod consists of 2 plastic hooks that get interlocked with the other two

tic hooks fixed to the compartment wall. As the user pushes the rod against the wall, all four of the hooks bend a little and snap in place. This is the locked position. The user presses the push button to unlock the hooks from each other. The push-button is spring-loaded to bring the hook back to its original position once it is released.

This mechanism is well suited for this use as it only requires one action to unlock it, the locking part is achieved automatically by the pressing force of the central rod by the user thus making this easy to use.

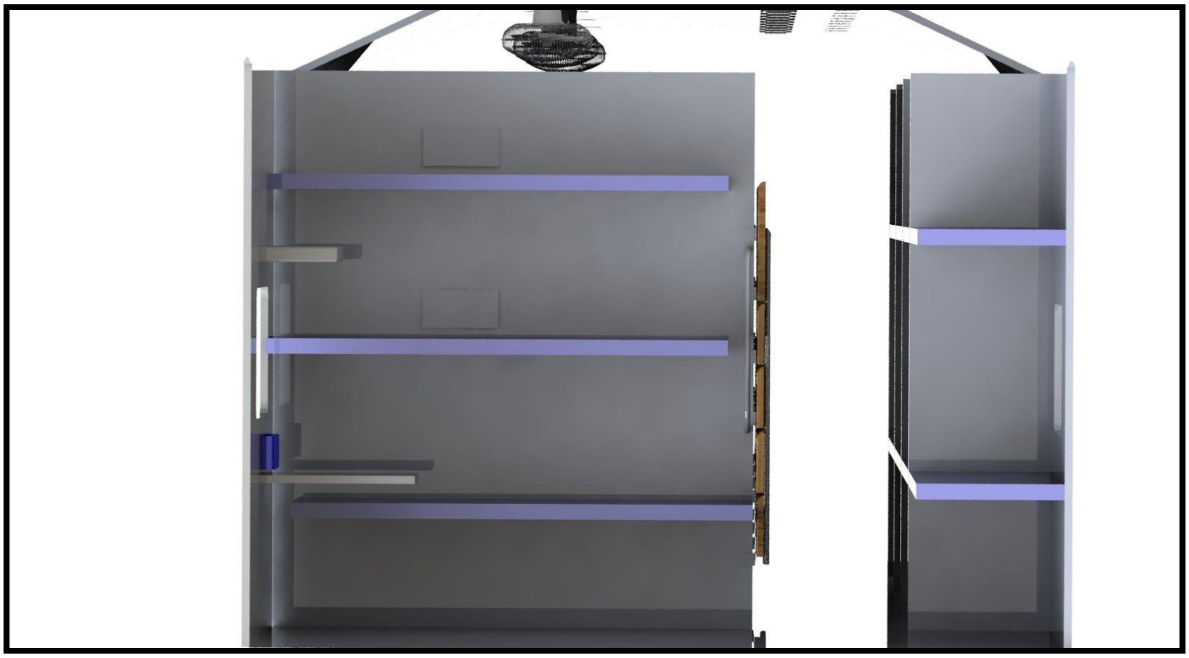
It is placed on top of the central rod which in its closed position will be 155 cms above the ground. This is the eye-level height for an average adult. For the person sitting on the middle berth, it's right in the middle of the top and middle berth so it's easy for him to push. The side berth is about 150cm above ground and corridor width is 63cm so person sitting on the side upper berth can too easily reach this. For the person sitting on the top berth its below his berth so while sitting on it he can push it using his leg. So to conclude it is within comfortable reach of every person.

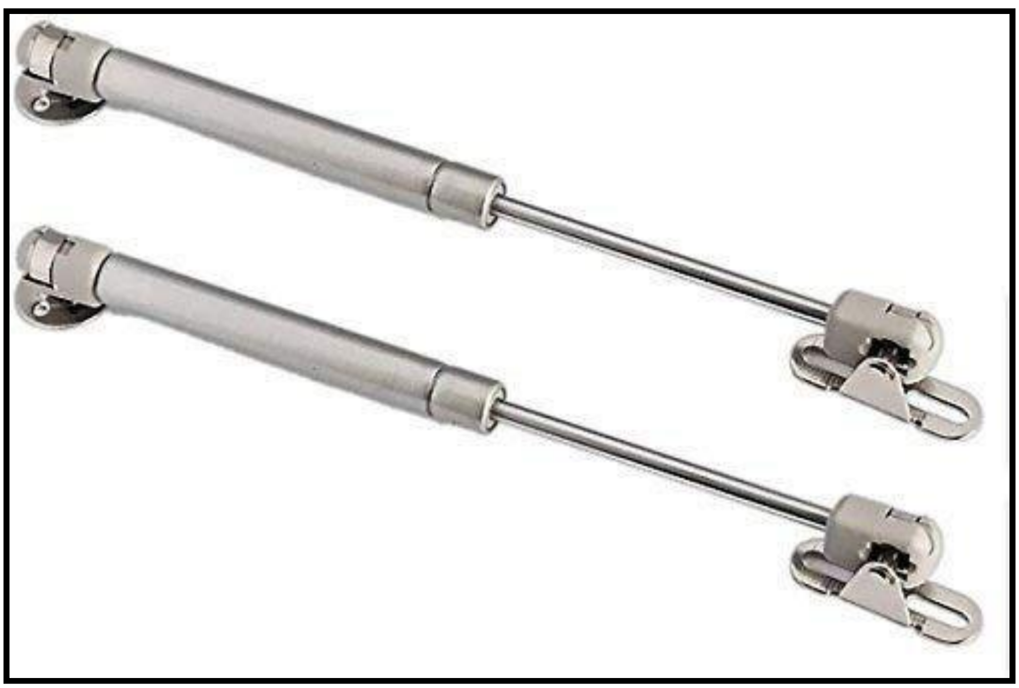




Closed position of our solution:

In the closed position, ReBAM takes up the bare minimum of step thickness of corridor width which is about 3cm. The existing solution consists of a few rods attached to the compartment wall which are 3cm in diameter. One set of these rods are also attached to the other end side of the compartment wall for the person to get to the side upper berth. This in total would eat 6cm of corridor space compared to our 3cm. The first and second step which are the largest of the bunch only extend 60cm from the compartment wall thus will be in line with lower berth thus limiting the whole product to the boundary of the berths and thereby not eating any space form the legroom.





Gas spring:

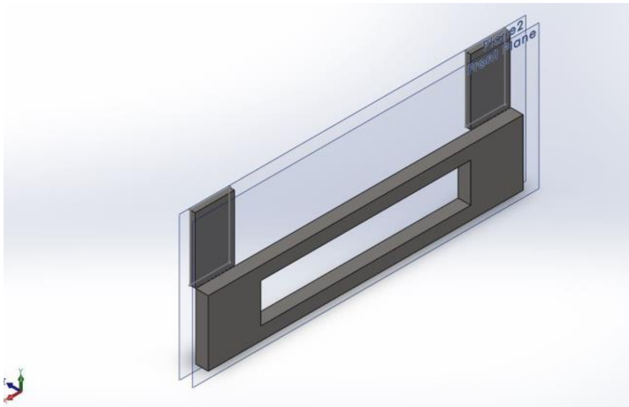
As per our weight analysis, the total weight of the structure comes up to be around 20 kg which would require the require to apply a force of around 10kgf on the central rod to push the whole mechanism. This might be uncomfortable for an elderly user.

To solve this we have provided two gas spring each capable of providing a force of 100N on full compression. We have attached these gas springs at places such that it compresses when the steps are opened and assists in closing by expanding when needs to be closed.

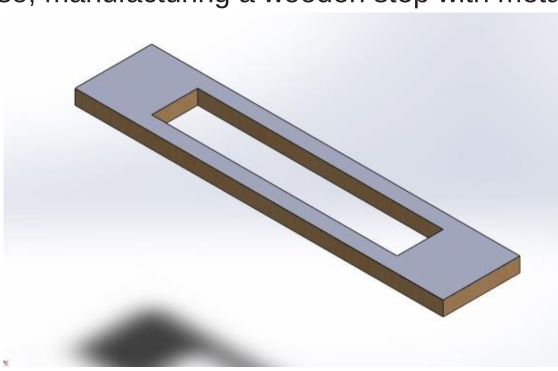
Materials Analysis:

All steps are made with a 25mmm thick plywood sheet of density 0.6g percm^3 . These steps attain the necessary balance between structural rigidity, weight and cost. The bottom step has a 3mm thick steel plate at its bottom which protrudes out and is the one on which the person steps.

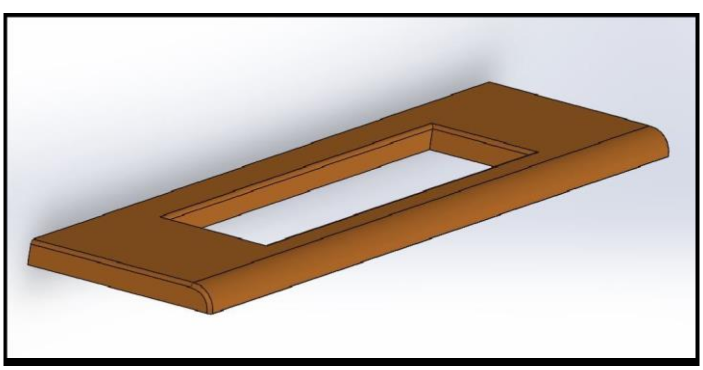
Three cases were considered for the steps: I.Metal II.Wood with metal plate and III.Wood.
The metal steps are stronger but made the whole setup heavier, making it harder to close.



Later, wooden steps with a supporting metal sheet at its lower end were considered but it also made the mechanism very heavy and extra support wasn't needed as the Ansys analysis shows the 3cm wooden plate is strong enough to support the weight with a required factor of safety. Also, manufacturing a wooden step with metal plate ideally was not possible.

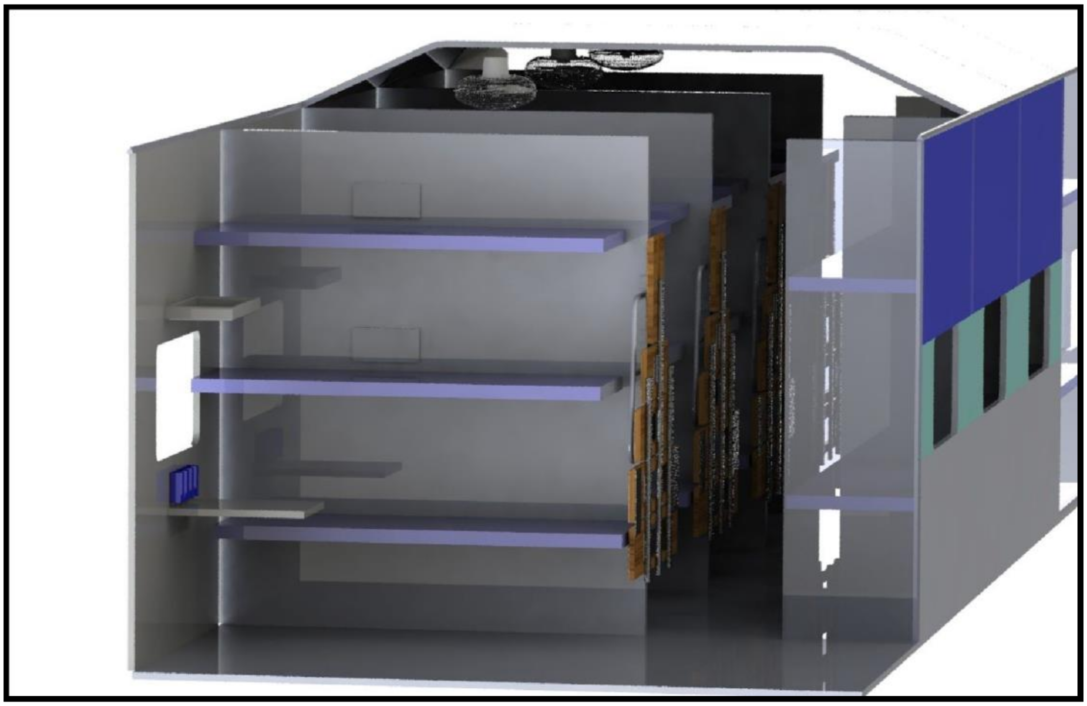


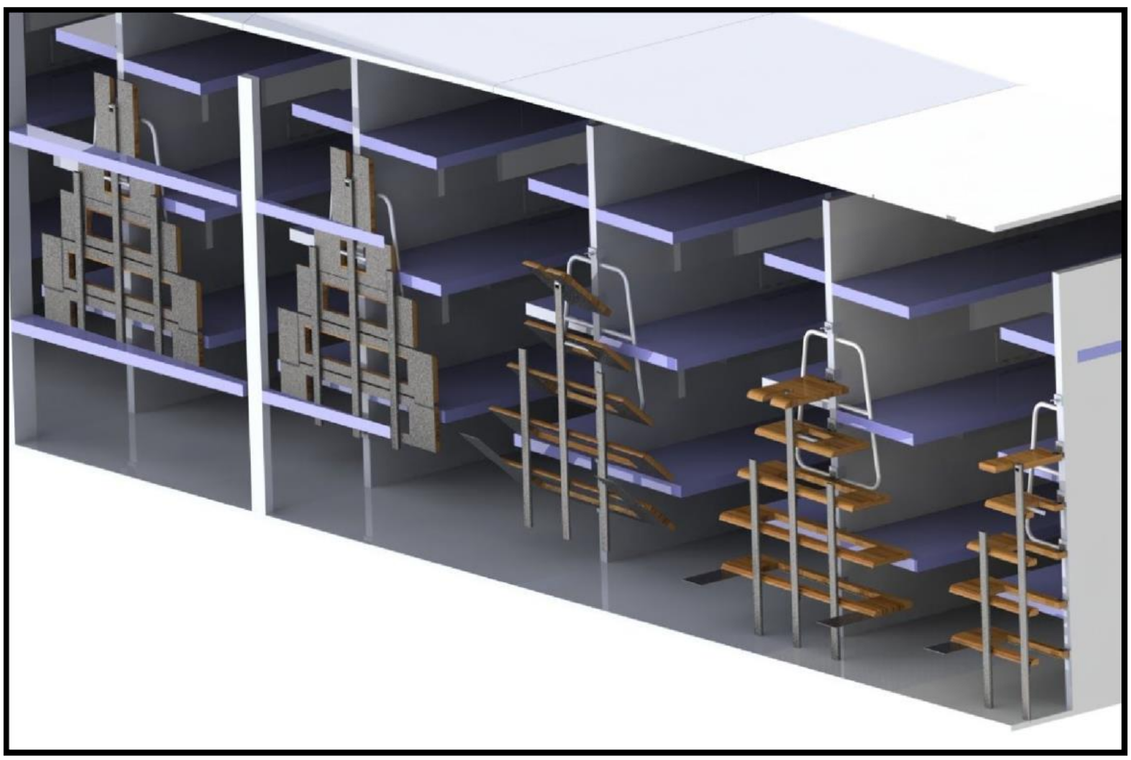
The top four steps were wooden and Ansys analysis shows the wooden step to be strong enough. However, for the bottommost step, sheet metal plates were employed to climb up as there will be a huge load on a step which is given a smaller thickness, so that the whole setup remains compact when closed.



The support bars are made of stainless steel. They are hollow rectangular bars of standard sections.

The hinges and U-clamps are also made of stainless steel. The U-clamp and the hinges are welded together.





Process of usage of our solution:

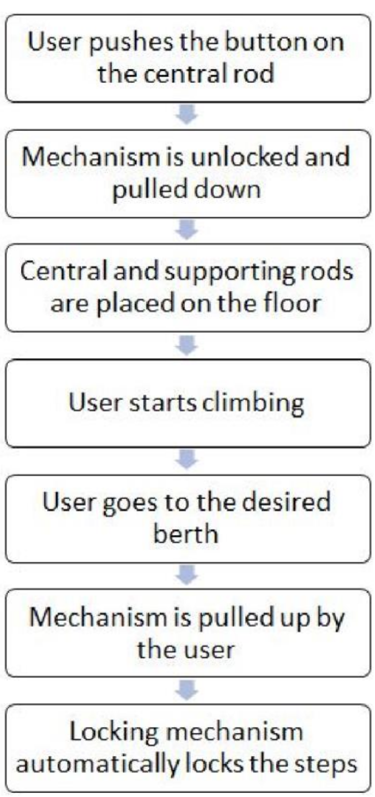
Climbing up:
The user would step next to the lower berth and press the push button situated on top of the central supporting rod. The whole mechanism would be released and now can be pulled down. All the steps and the 3 side rods unfold in a single synchronised motion. The three supporting rods touch the ground and the mechanism is now ready to be used. The user would step onto the protruding part of the last step and turn to step on the second step. The user would then climb on the next two or three steps depending on which berth he needs to go to. Standing on the step in front of the berth the user has an option to either enter the berth by climbing onto it head-on or by turning his/her back on the berth and sitting on it. As the user climbs into the berth he/she would pull the whole mechanism towards himself/herself in order to close it. Connecting every step to central rods enables the user to just pull the one step in place will others automatically get in place. The locking mechanism would automatically close it when the steps fold back completely. For the person stepping onto the middle berth, rods are provided on the fourth step thus providing him with a handle to grab onto for closing the mechanism.

Climbing down:
The user would press the push button and the steps would unfold. The user would step onto the topmost step and climbs down. After stepping on the ground, the user would grab any of the supporting rods comfortable for him/her and push the mechanism back to its retracted position. Again the lock automatically locks the mechanism in its place.

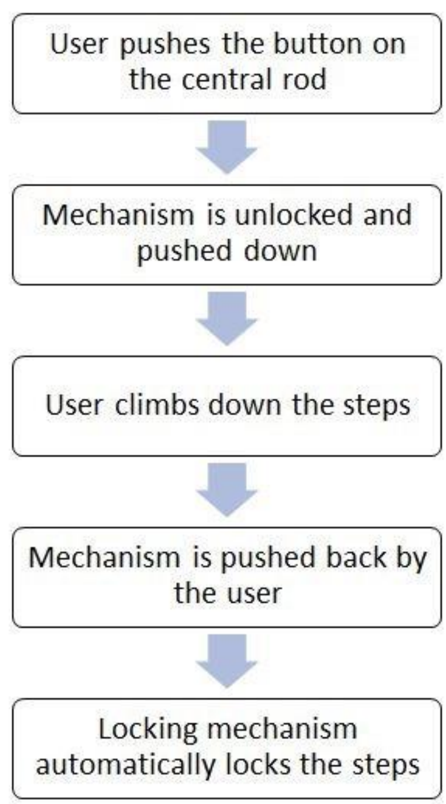
Detailed block diagram is given below.

Block Diagram:

User Climbing up the Stairs



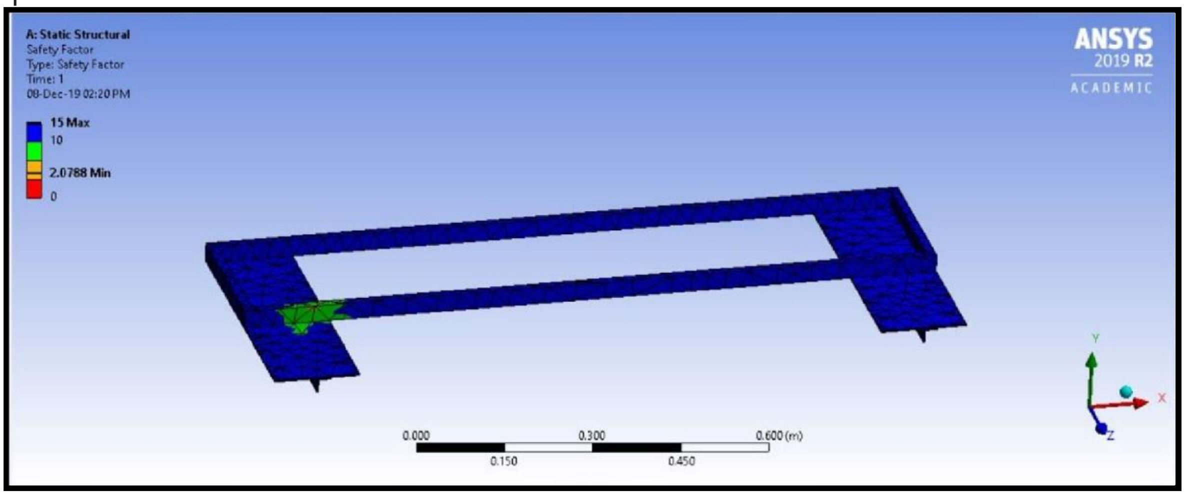
User Climbing up the Stairs



6. Results:

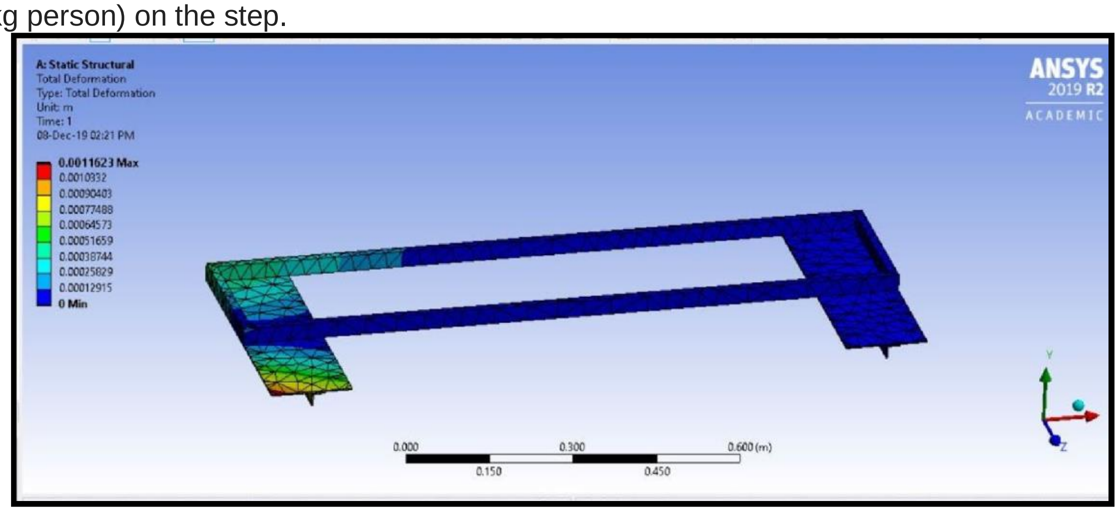
Actual Findings and Analysis:
A major point of consideration was how thin we could make our whole system so as it could bear the weight of an adult with the necessary factor of safety. So the following Ansys analysis was done for each step.

Step 1:



Factor of safety:

As it is seen in the analysis the minimum factor of safety is 4.25 when given a 1000N force (roughly 100kg person) on the step.



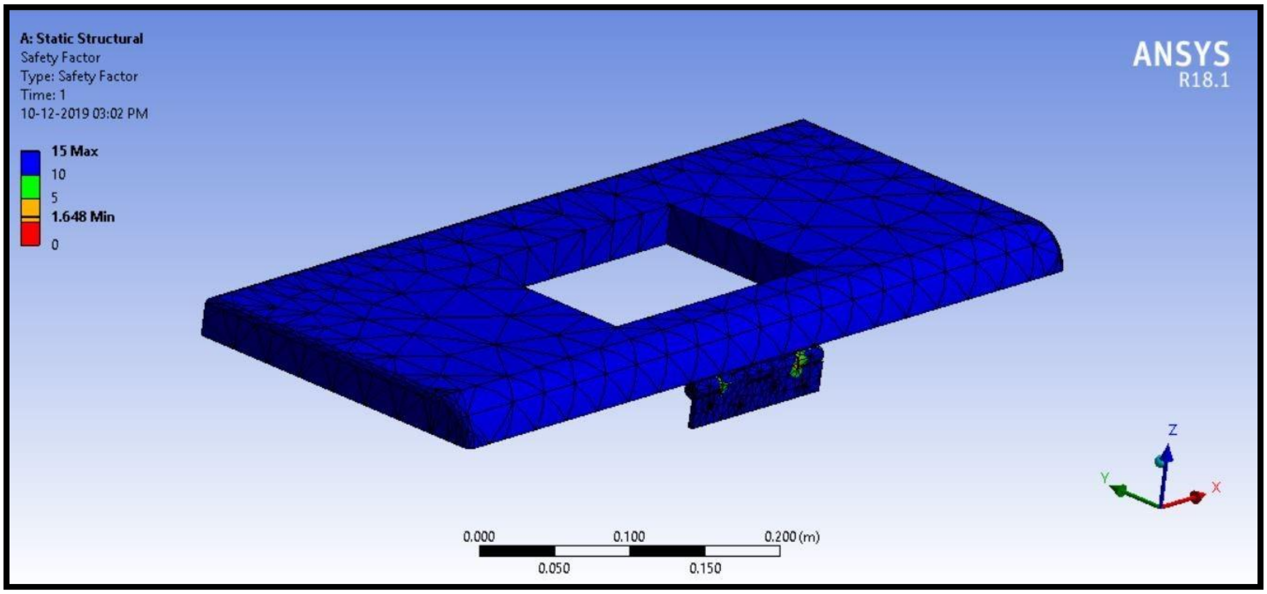
This analysis shows the deformation taken by the step under that load. It is 3mm at the extremes of the step.

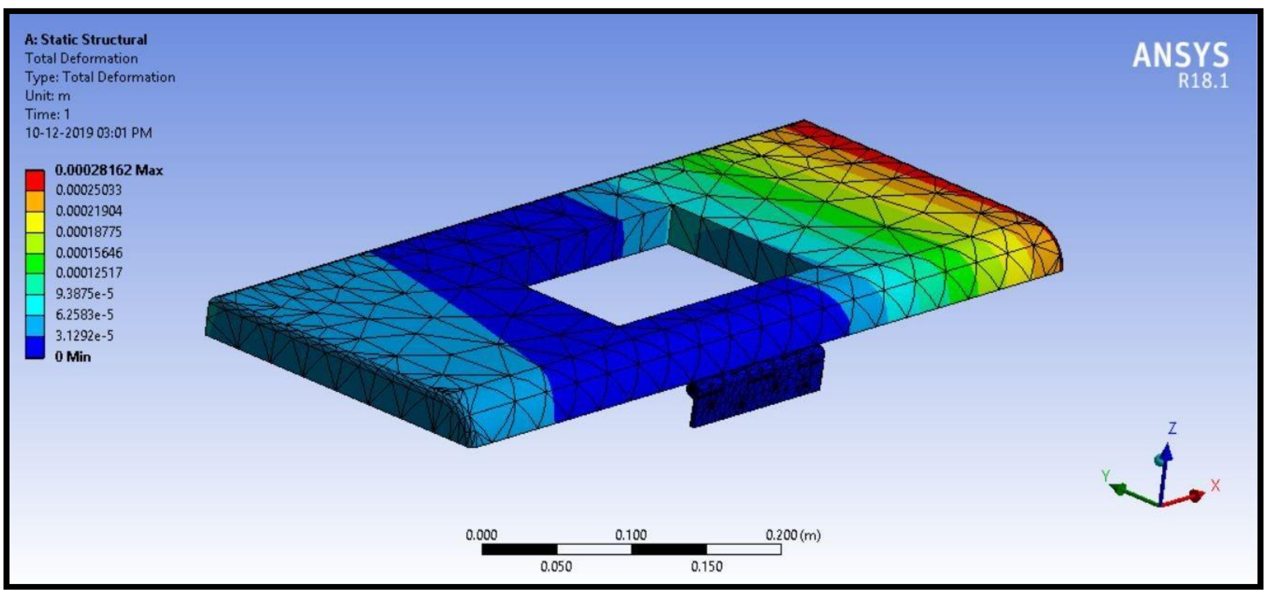
Step 2:

Step 2 has the same dimensions and railing as that of step 1 and when applied a force of 1000N (weight of 100Kg) on one side of step, it shows the minimum Factor of Safety as 4.25 and minimum deformation as 3 mm.

Step 3

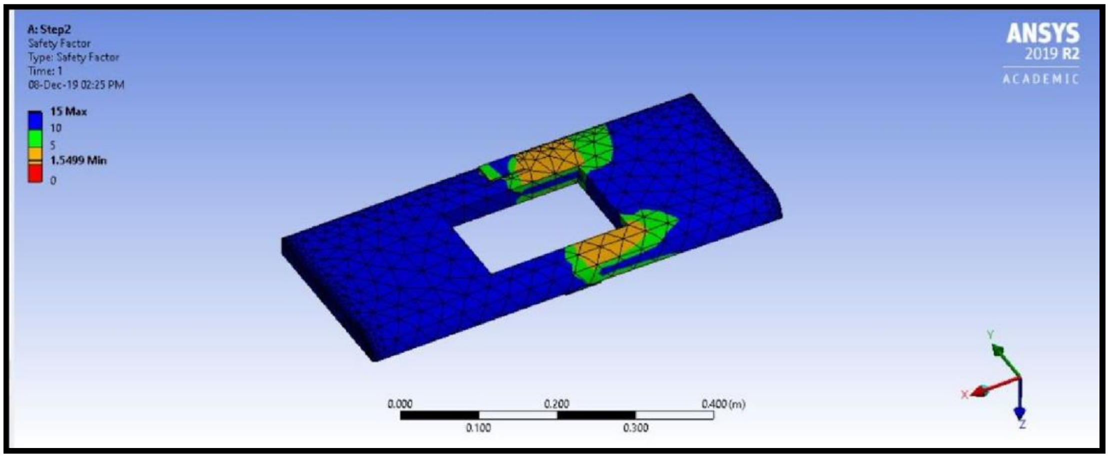
The factor of safety for step 3 is 1.64 for a 1000N of force applied at the edge and the maximum deformation the step undergoes is 2.8mm.



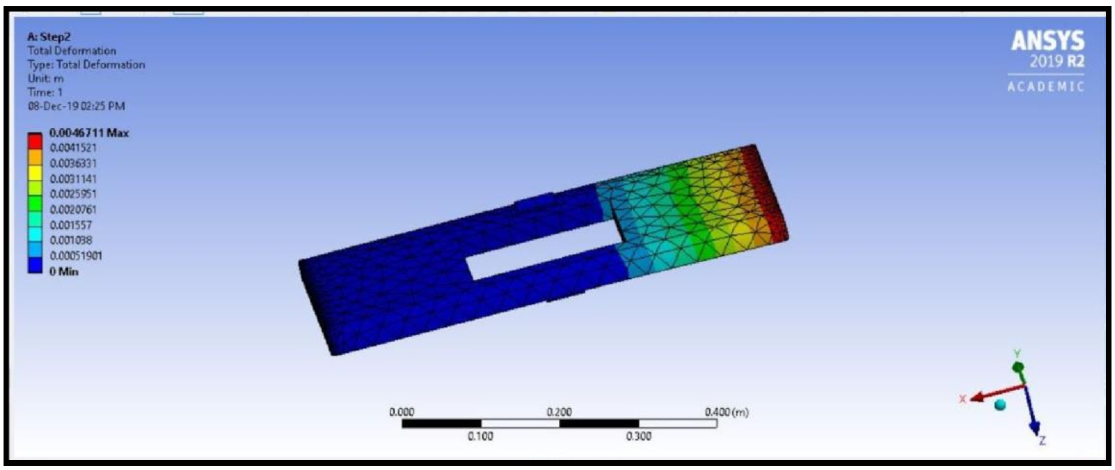


Step 4:

The minimum Factor of Safety is 1.59 for the second topmost step when given a force of 1000N (weight of 100Kg) on one side of the step.

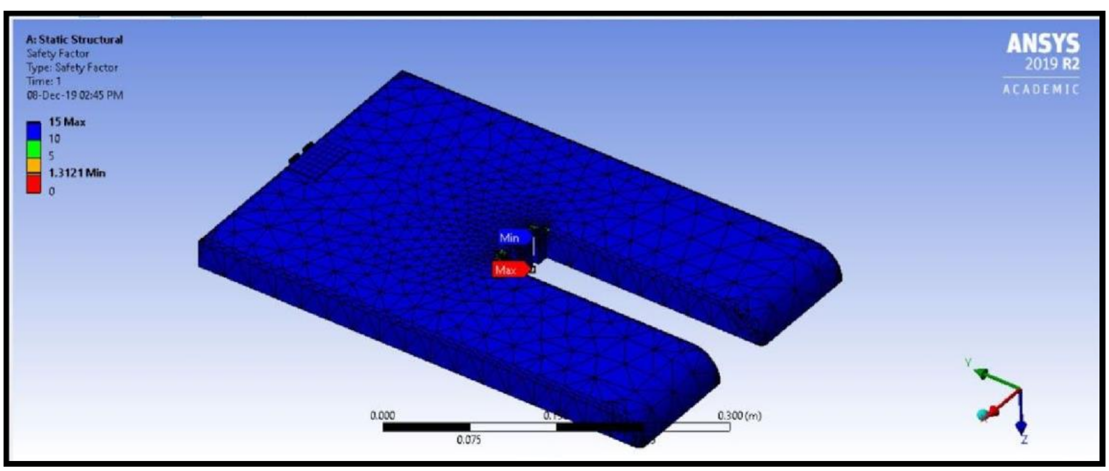


The total deformation is 4.6 mm at maximum.

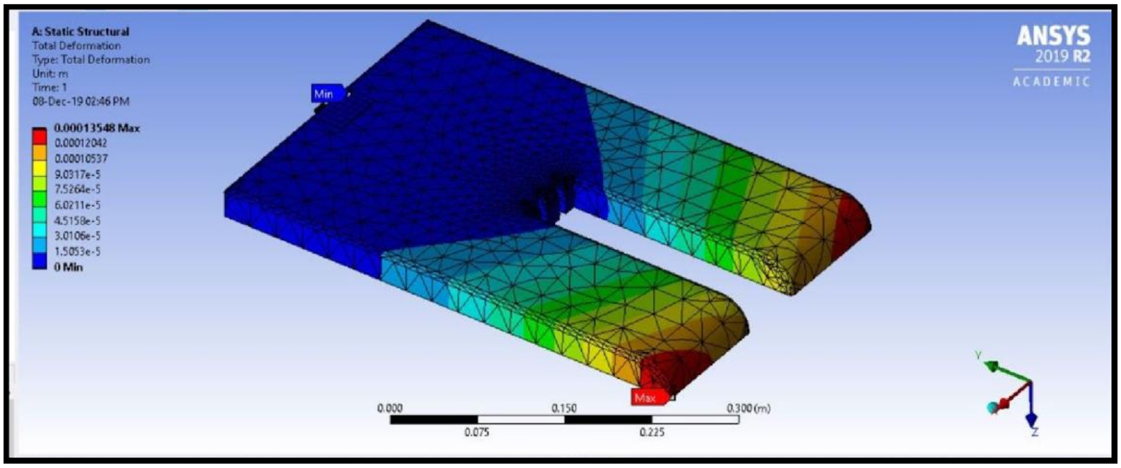


Step 5:

The minimum Factor of Safety is 2.26 for the topmost step, when given a force of 1000N (weight of 100Kg) on the edges.

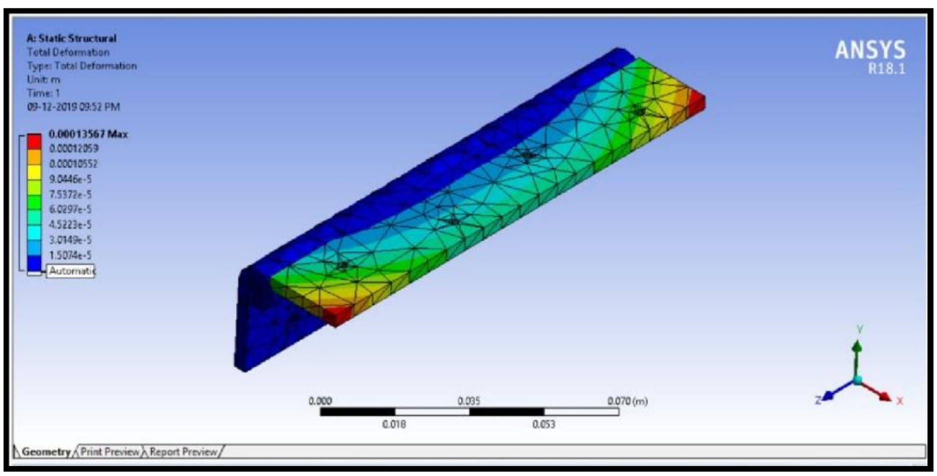


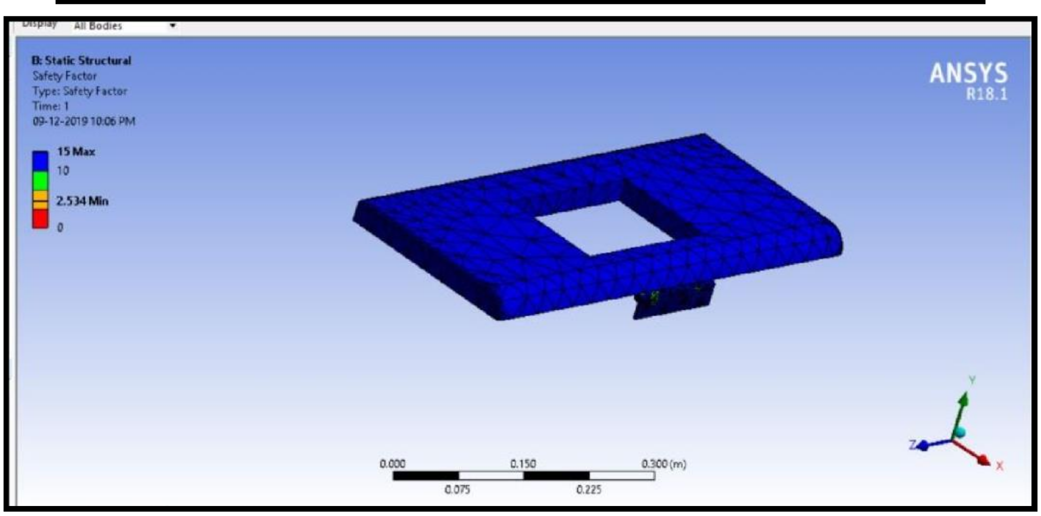
The total deformation of the step for the above analysis is 13mm at max



Hinge analysis

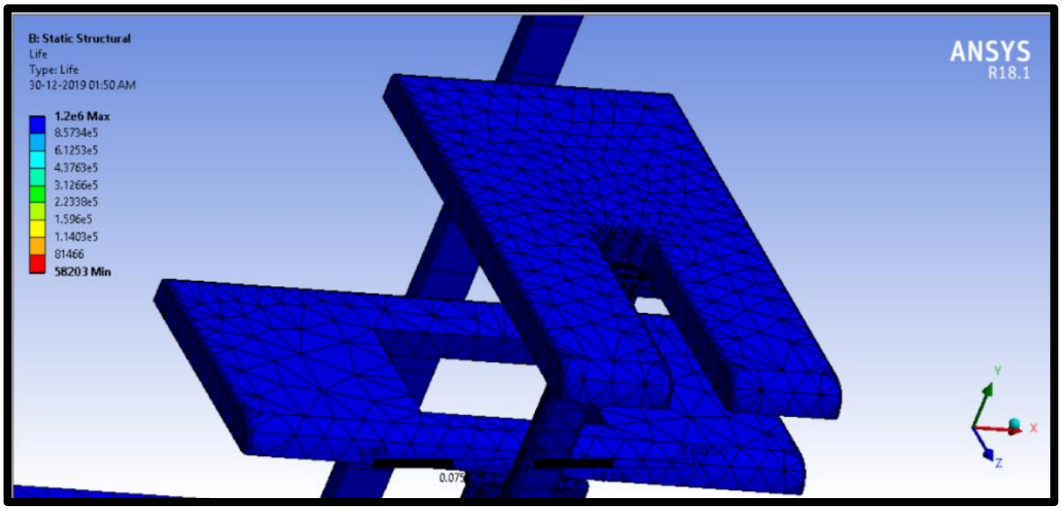
In the mechanism the whole load is taken up by the hinges thus it is very important to do the load analysis of the hinges. As per the analysis, we would require a 3.5mm thick hinge plate to bear the load of the 100kgf with the required factor of safety.

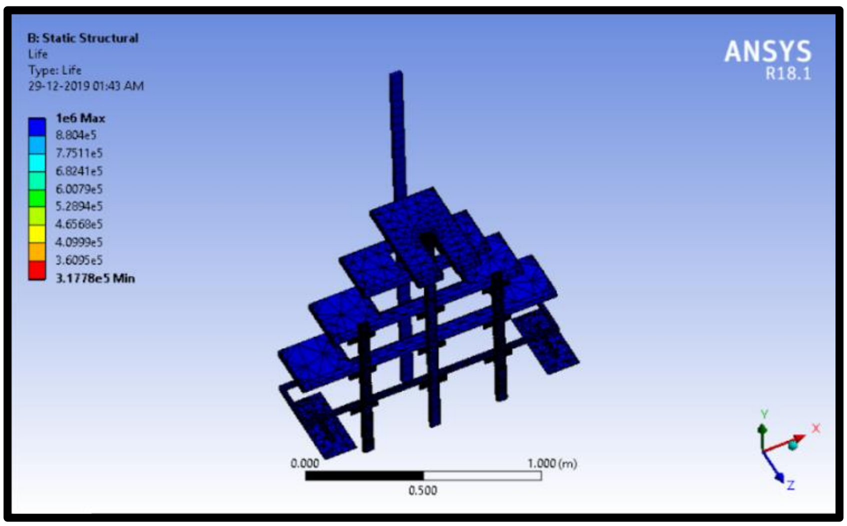




Fatigue Analysis:

Fatigue load analysis was done on the steps for the load of the human weight is being applied on the steps each time a person steps on it. The results showed us that the top step can with stand a total of 58,203 cycles and the bottom step can withstand 3.17 e5 cycles.





Weight Analysis:

Steps:

There are 4 steps made of wood. (density = .6g/cm^3)

The first step alone has a metal protrusion along with a metal frame. (stainless steel density = 7.9 g/cm^3)

Volume of Plywood required for the steps:

Step 1 (bottom most step) is made of a metal frame.

Step 2 = 8640 cm^3

Step 3 = 6480 cm^3

Step 4 = 4320 cm^3
Step 5 = 4320 cm^3

Volume of cut outs in the respective steps:

Step 1 (bottom most step) has no cut outs.
Step 2 = 2940 cm^3
Step 3 = 1680cm^3
Step 4 = 840 cm^3
Step 5 = 288 cm^3

Therefore,total required volume = (8640+6480+4320+4320) - (2940+1680+840+288)
= 18,012 cm^3

Weight of the steps = density x volume
= 0.6 x 18,012
= 10,807.2 g
= 10.81 Kg
Weight of the metal plate under the lowermost step is 2.4kg. And the weight of the metal frame is 594 cm^3 * (7.9 g/cm^3) = 4689.44 g
= 4.7 kg
Dimensions of this metal plate are 15*35 cm^2 .

Supporting rods:
Main and side rods= (vol)*(density) = ((4*2-3.6*1.6)*(130+100+100)cm^3*(7.9g/cm^3) = 5.8kg

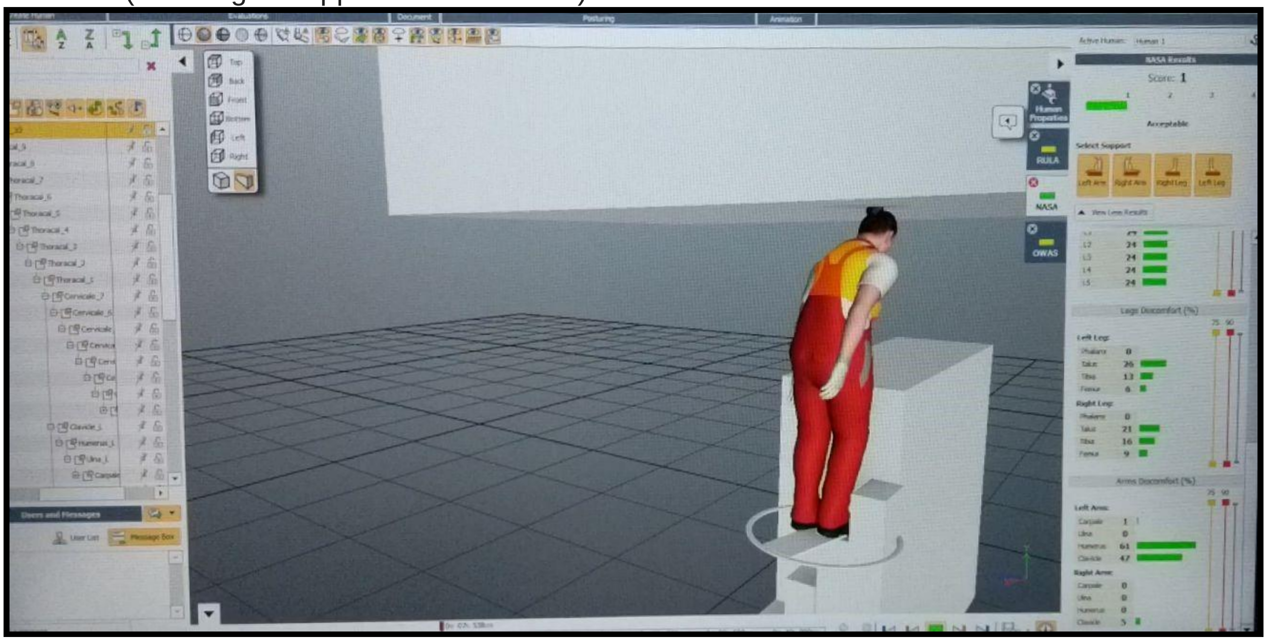
Specifications: Rectangular sections.

Size	kgs /m	Size	kgs / m
30 x 20 x 1.2 mm	0.93	80 x 40 x 2.0 mm	3.71
30 x 20 x 1.5 mm	1.15	80 x 40 x 3.0 mm	5.49
30 x 20 x 2.0 mm	1.50	80 x 40 x 4.0 mm	7.22
40 x 10 x 1.5 mm	1.15	80 x 40 x 5.0 mm	8.90
40 x 10 x 2.0 mm	1.50	80 x 50 x 1.5 mm	2.96
40 x 20 x 1.2 mm	1.11	80 x 50 x 2.0 mm	4.06
40 x 20 x 1.5 mm	1.37	80 x 50 x 3.0 mm	5.93
40 x 20 x 2.0 mm	1.84	80 x 50 x 4.0 mm	7.81

TOTAL WEIGHT : 22.308 kg

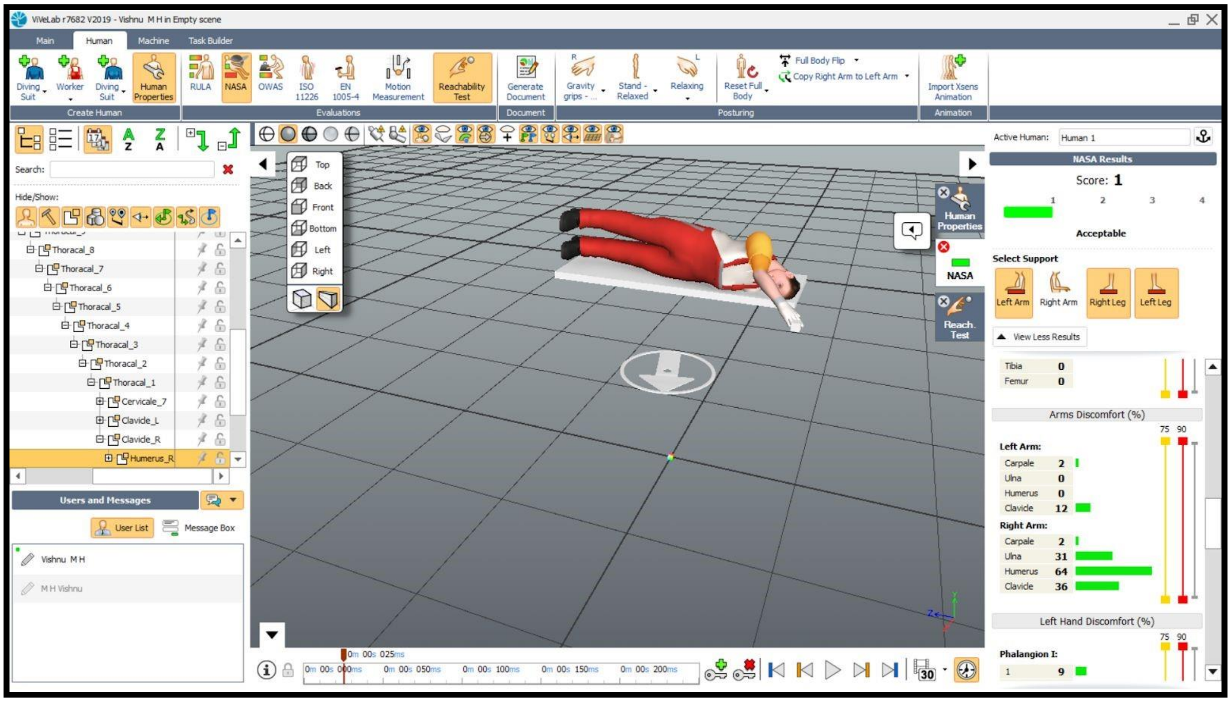
Ergonomics:

Our whole solution is centered about providing an ergonomic solution for the elderly to climb onto the middle and the top berth. To test the ergonomics of our product we ran simulations on **ViveLabs 3D visual ergonomic simulation** and checked for stresses on major bones of legs and spines of elderly as per NASA scale and the results suggests that stresses on bones are well below 65 (75 being the upper limit of comfort).

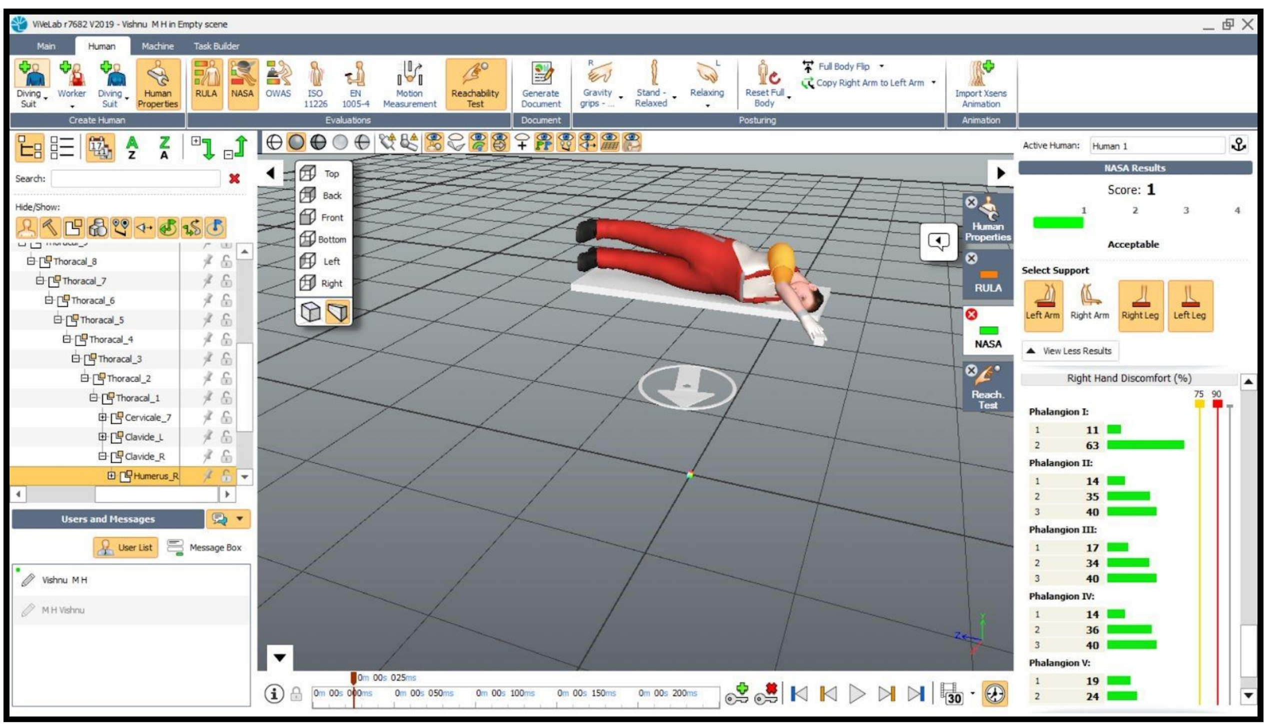


Here’s a snapshot of a person going onto the topmost berth from the first and the second step. The sidebar shows all bones are in a comfortable position.

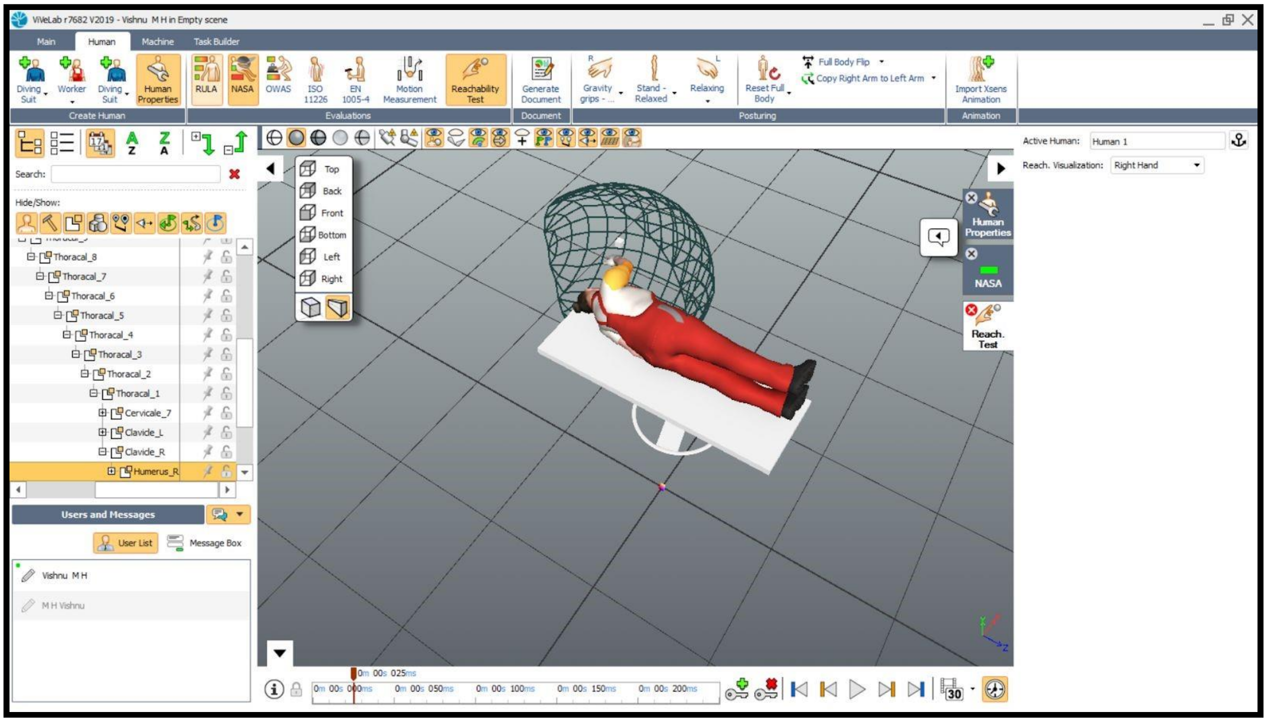
Here’s a video simulation of the person getting into the top berth with real-time discomfort values displayed on the right.



This snapshot of the ergonomics of reachability of the lock from the side upper berth. The lady is lying down on the side upper berth and is stretching her hand so as to reach the lock to open the steps. In the sidebar, the stress on her each arm bone can be seen. Everything green shows that it is in her comfort zone.



This is the position of her grabbing the lock. In the sidebar stresses on her each hand bone can be seen.

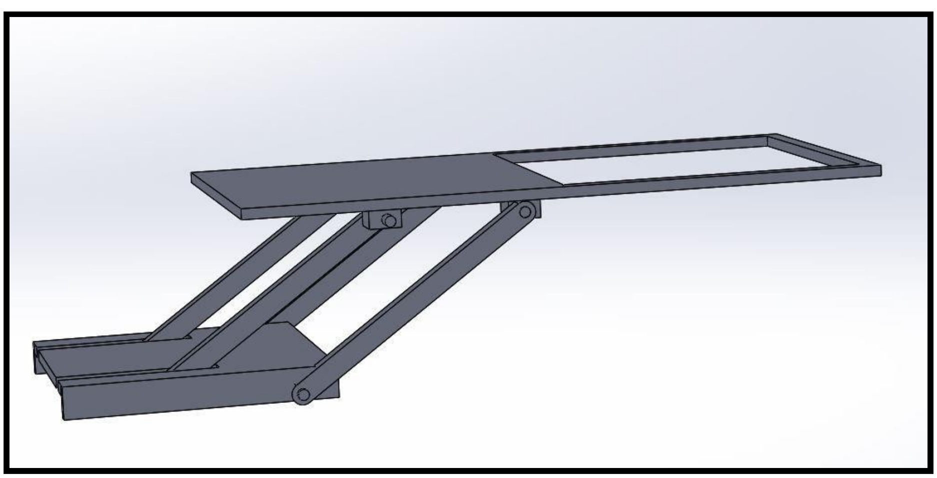


In this image the reachability test of her hand is shown. As seen the lock of our product is reachable

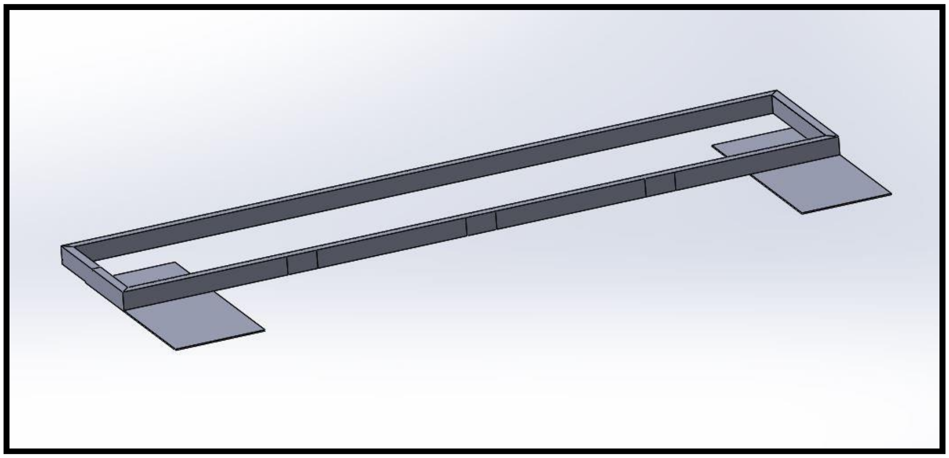
2. Include problems encountered , credibility of results, accuracy estimates:

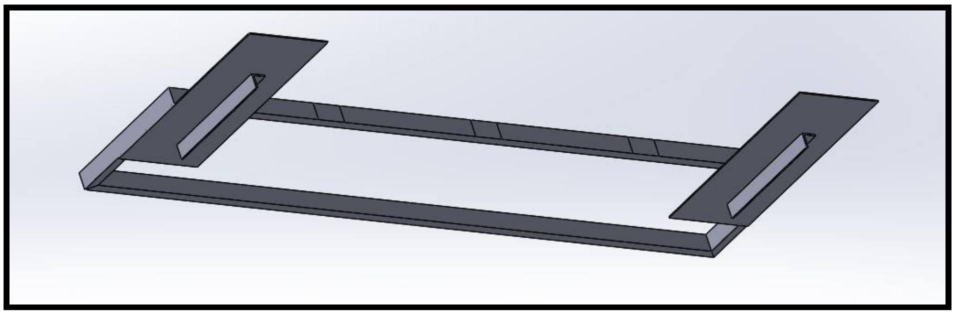
The compactness of the mechanism proposed has to be looked after in the design due to the minimal space present in the cabin. This also provided the challenge of designing the steps within the constrained space. Also, the existing structures in cabin has to be considered, with the choice of removing it completely or utilising it within the design.

A major problem we faced was in the bottommost step of the mechanism, whose positioning had to be made in such a way the aisle shouldn't be blocked. An extensive folding mechanism was initially considered, but due to the complexity and difficulty to retract and operate, it was discarded.



A final solution was reached where the last step was made with a protrusion that folds onto the second bottommost step. This provided to be a far simpler and ergonomic step to climb up.





Other problems encountered include the material used for manufacturing steps, rods and clamps, which needed to be lightweight enough to fold and sturdy enough to carry a heavy person. Various factors of locking mechanism were also looked after, such as retractability, positioning and effort required, so that the mechanism can be unfolded and folded by anyone from any berth.

ANSYS Software was used to analyse the model and the results were examined to bring further improvements in the design and arrive at the current final model. In addition to that, a cloud-based ergonomic simulation software called ViveLabs was used to find the ease of climbing for persons of various backgrounds. The model was tested on the data available to examine the relative impact of the body in correspondence to the action.

The measurements of the railway cabin were taken from railway website and then was cross-checked by an actual reading taken in two different compartments of a stationed express train. Cost analysis was made by taking the value of materials in the market as of November 1. The dimensions of the mechanism such as size, weight, et cetera., are verified and calculated as per data are given in trusted websites.

Utility of result:
The results obtained from analysis and simulations done in Ansys and ViveLabs were utilised to improve the model. Few improvements include replacing metal with Plywood and keeping protrusion in last step. Extension to side upper berth was made with careful consideration of stress analysis made.

Costs:

Material	Rate	Amount of material	Total cost
Plywood	1600 per 4x8 sq feet sheet	area=(120x24+90x24 +60x24+30x47) sq.cm = 7890 cm^2 = 8.49ft^2	Rs.425
Stainless steel bars	Rs.45 per kg	40mmx20mm & thickness is 2mm Height of central rod = 130cm Height of side rods = 100cm First step frame = 290cm Weight = 10.5 kg	Rs. 472.5
ABS Plastic	Rs. 95/kg	250 g	Rs. 25
Steel plate	Rs. 160/kg	2.4 kg	Rs384
Gas Springs	Rs.200/piece	1	Rs.200
Hinges	Rs. 24/piece	16	Rs.384
U clamp	Rs. 65/piece	5 (one for each step)	Rs. 325
Machining and labour	Rs. 1000	For one individual product	Rs.500
Total Cost (Estimated)		For an individual mechanism	Rs 2780

The above price is for the production of one individual part and the price per piece would go down significantly if the mechanism is mass manufactured for the India Railways. The estimated cost per piece if mass manufactured = Rs 1250 (approx.)

Working model:
A working prototype has been made and tested out.


In closed position.


In open position.

For testing video please check the drive link given below

Pros:
The pros of the results include that

- The staircase setup is compact and takes minimum space in the railway coach.
- It is accessible and ergonomically comfortable for the user.
- Saves a lot of time and manual labour into its manufacturing due to simple design.
- It is easily replaceable.
- primary and secondary railings to support and provide sturdiness while climbing
- Accessibility of solution from all berths
- Ease of operating by a simple push button to unfold and fold the retractable machine ● Prevention of probable accidents of falling while berth climbing

Scope of improvement:

- It takes up 4-5cm of the aisle space.
- The spring system can be made more compact by using torsional hinge springs
- Manual labour required skilled enough to customize the machine according to berth specifications

7. Google Drive Folder Link:

The video for testing of our prototype along with detailed pictures of design, analysis and fabrication are given in the following Google Drive folder link.
https://drive.google.com/drive/folders/1y1j6wSIHdJsBhwbFU9VBylFod7g94CxC

8. Application:

Our idea as a solution to the problem:

This is an apt solution to the existing discomfort of climbing onto the upper berth. All the steps are aligned such that they are in line with the berth, this makes the transfer from the step to the berth easier.

Additional applications:

Can be used as a fixed ladder in places with space constraint.
A similar mechanism is used in foldable bunk beds.
Can be used in Sleeper coach buses.

Benefits to users:

- Easy to operate mechanism.
- Makes the user self-reliant and doesn't require any assistance to climb up and down the berths.
- Avoids possible accidents while climbing up the berth.
- The angle of the ladder is a comfortable inclination of 60 degrees, instead of normal 90 degrees.
- Footspace has been increased to 25*15 cm^2, which is more convenient than a bar.
- Accessible mechanism irrespective of the berth position.