Reducing the physical burden when handling containers at KLM's apron service

Julius van der Veldt
4234154
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Introduction

This report describes a graduation project of the master Integrated Product Design at the faculty of Industrial Design Engineering at the Delft University of Technology.
This project was commissioned by the KLM (Royal Dutch Airlines) Apron Services. KLM Apron Services is responsible for loading aircraft at Schiphol Airport.

The apron services noticed that in the last twenty years aviation has been has been under the influence of many innovations. KLM, which has been at the top of Dutch aviation for more than hundred years, always striving to get the latest innovations or develop them by themselves. Those innovations have always been focussed on improving the efficiency of their fleet(KLM, 2019).
As the innovations above the wing were booming, the innovation of their ground operations below the wing has been little to nothing in the last thirty years. The same applies for the Apron Services, there has been no innovation for the past 30 years. (M. Rügebregt, personal communication 11-02-2020).
The lack of innovation means that a lot of the ground processes are still done by hand. Even a very repetitive process, the handling of containers, is done by hand. The manual labour required to handle containers causes a lot of injuries all around the ground crews of KLM at Schiphol. Especially the Apron service which is responsible for loading aircraft has to deal with a lot of injuries and therefore suffers a lot of absenteeism among their personnel.

Rotating a container by hand

Pushing a container by hand

The aim of this project was to design a solution for the apron services of KLM that will relieve the ground crew from their physical burden and makes the handling of containers safer. Both with the goal to reduce the chance of getting injured while handling containers. Next to the reduction of injuries, the goal is to improve the efficiency of the handling of containers on the platform.

The report is build up out of different chapters that all represent a stage in the design process. In chapter 1,2, 3 and 4 the process of handling containers is described. After the description an elaborate evaluation of the process is made in chapter 5 and 6 to show all the parts of the problem. Chapter 7 and 8 discover the possibilities in solving the problem. Chapter 9 will discuss the future on rotating containers. From chapter 10 it is all about finalizing the concept.

Glossary

AKE	The code on the containers: A=certified ULD K=dimensions E=no forklift holes
Apron	A defined area on an airport intended to accommodate aircraft for purposes of loading or unloading passengers or cargo, refuelling, parking, or maintenance.(FAA, 1996)
Apron service	Department of KLM responsible for (un)loading aircraft
Below the wing	All the movement on the platform that concerns the belly of the aircraft.
Above the wing	All passenger related business
CLD	Container loaded dolly
Dolly	A cart with a rotating top deck, which is used to transport containers across the airport
ICA	Intercontinental, Flights between the continents
Load tool	An application designed by KLM to help apron services with determining the loading and unloading sequences
ULD	Unit Load Device, A container or pallet that contains

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1. Problem definition

When a container arrives at the platform it can not be unloaded immediately. The top bed of the dolly with the container have to be rotated by hand, with the purpose that the container can be unloaded from the side of the dolly. Unloading the container has to be done manually as well. The same steps have to be performed in reversed order when a container is loaded onto a dolly. These steps have to be done 14 to 16 times per aircraft by one employee. These repetitive and physically demanding actions cause a lot of injuries.

Some containers are bended, dented or cracked and also some dollies do not move as smooth as they should due to years of harsh handling. These abnormalities can trouble the movement of a container. If personnel has problems with movement of the container their response is to put more effort into it. The more effort they provide the more strain the personnel will put on their bodies, resulting in more injuries. Another response is to misuse the brute force of the machines. A machine can cause even more injuries when personnel stands too close to the machine, they can get hit by the machine or pinched between the machine and dolly.

Schiphol is growing every year. More aircraft are processed and even more cargo, baggage and mail is passing through. With the current situation lacking efficiency, the pressure on the ground personnel is increased, resulting in an increased physical workload.

figure 1.1 Personnel putting a lot of effort into getting a container onto a dolly

figure 1.2. Getting too close to a moving machine when handling a container

The growth of Schiphol also makes the platform more crowed, as bigger aircraft have to be handled in lesser time. Due to less time more actions are happening at the same time causing a bad overview on the platform, resulting in more dangerous situations.

At last, KLM struggles to find new personnel for the apron service. On the other hand, most personnel has been in service for a lot of years. The combination of long enlisted staff and not enough new personnel , results in the average age of the ground personnel to be high. The high average age makes the problem more urgent as the personnel is more vulnerable to injuries.

figure 1.3. Unlocking and loading containers while there are baggegetrains arriving and leaving

2. KLM Apron Service ICA unit

KLM Apron Services is a department of KLM which is responsible for loading aircraft at Schiphol. Their domain is defined to the platform where aircraft are stationed. Everything within the red lines(figure 2.1) and below the wings of the aircraft is their responsibility. This project will focus on the Apron Service at intercontinental flights at Schiphol. The difference in Apron Intercontinental and Apron Europe is that the intercontinental flights are mostly wide body aircraft. That means that an aircraft is wide enough to fit two Containers next to each other in the cargo hold(Wikipedia, 2020).

figure 2.0.The boeing 747 is considered a wide body aircraft

The Apron Service will receive the dead load(baggage, cargo and mail) from other departments of KLM. The containers are already prepared and are transported from all over Schiphol to the aircraft. Apron Service will have the specifics of the load prior to arrival of an aircraft. The specifics are used to make scheme's for loading the aircraft to make sure that the aircraft is loaded in a balanced way. To make the process of loading and making loading schemes more structured KLM has developed an application. This application is called the load tool, that combines all the information of load, aircraft and flight plan into a loading scheme. The load tool tells the apron personnel when to load which container.
The Apron service is also responsible for unloading aircraft. They have to make sure that all the load is taken away by the right departments or is transferred to the right transfer flight.

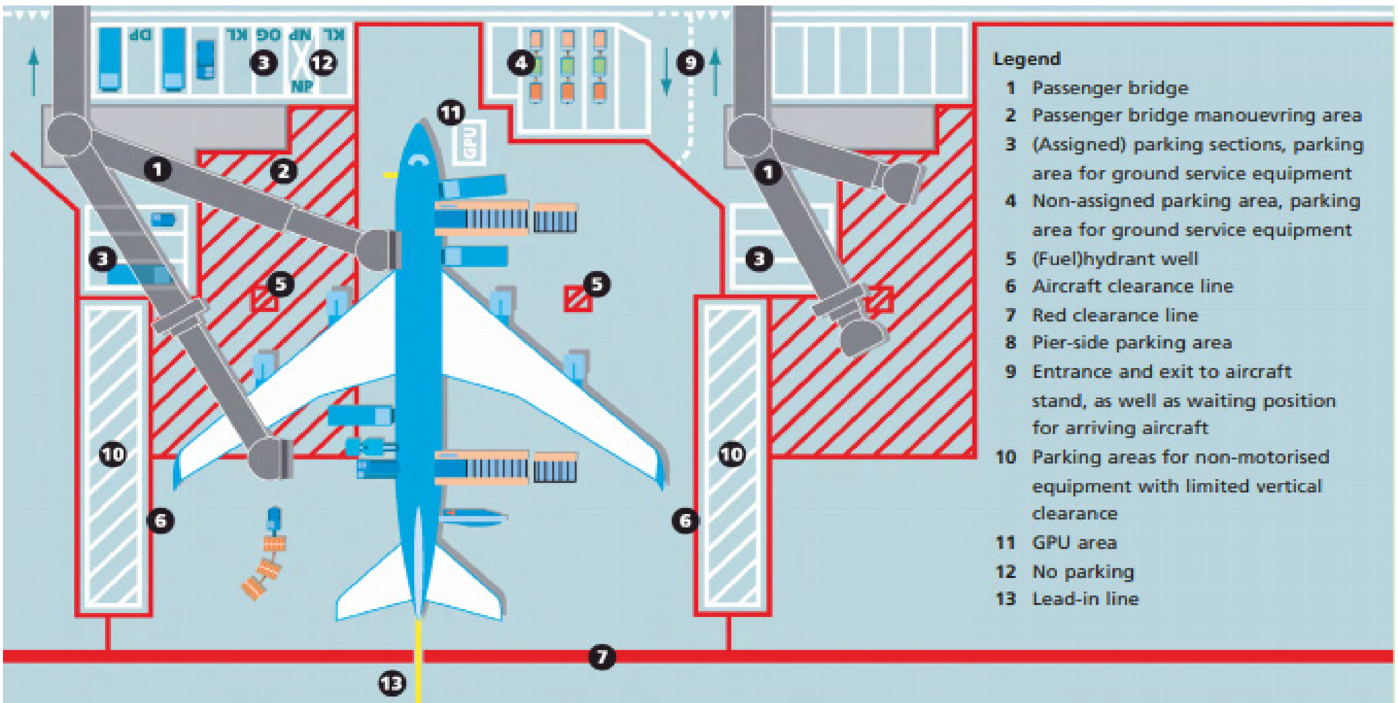


figure 2.1. Domain of the apron service.

3. Apron equipment

Various pieces of equipment are used when handling containers. This chapter will go into detail about dimensions, manufacturers, systems, etc. An icon is designed for every piece of equipment to use in the rest of the report.

Container/ULD LD-3(infinite pcs)

Containers are used for carrying dead load in wide body aircraft. A container can have a maximum weight of 1500 kilos. Containers are often referred to as ULD's(unit load device) or AKE's.

The containers(figure 3.1) are made of an aluminium frame with composite walls and are produced by Driessen-Zodiac Aerospace(J. Versleijen, 2014). The containers can not be altered in this project as they are a world wide used product and the container of KLM should also work on other airports. Containers can come in different conditions from brand new to badly damaged. KLM's Containers are in a relatively good condition but containers of other airlines can be in a very bad state. KLM also does the apron service of those airliners and get those badly conditioned containers too.

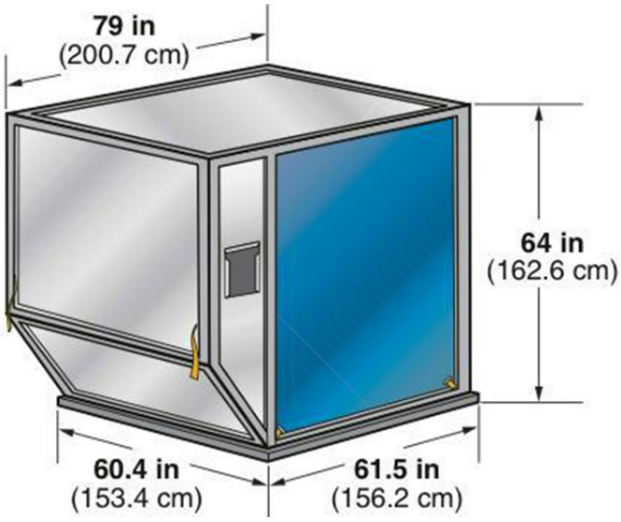


fig 3.1 LD-3 ULD container dimensions (Incdocs, 2019)

Fig 3.2. Top view container

Fig 3.3. Front view container

Fig 3.4 Side view closed container

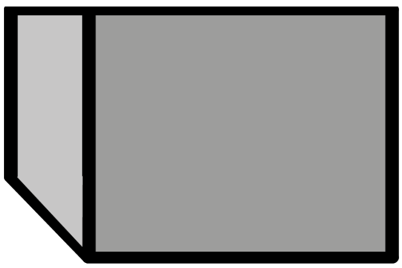


Fig 3.5 Side view open container

Fig 3.6. Containers stored at Schiphol. Some airline companies use different materials in their containers, but the dimensions are the same.

dolly(1350pcs)

The 5ft dolly is used to transport containers around the airport. The dolly has a turning table which can rotate 360 degrees. The turning table can be fixed with a lock on the bottom part of the dolly to keep it from rotating while driving with the dolly. The turning table is fitted with rollers to make loading and unloading of the container possible. A container is fixed on the turning table by locks. On the side of the turning table are handles to release the rotation and container locks. The rotation lock has a spring which puts it back into position when the handle is released, as a result the turning table locks every 90 degrees. The handles for the container locks have to be pulled outwards before pushing them down, after pushing down they will stay in place.
At this moment the manufacturer, S-P-S, is developing a new version of the dolly(fig 3.8). The difference is the removal of the single roller on the rear, there are less rollers and less supporting members in the middle. The new container is used in this project.

Fig 3.7. 5ft dolly with container

Fig 3.8. The new version of the 5ft dolly has 20 rollers in total and less structural members

Fig 3.9. The current version of the 5ft dolly has 25 rollers in total. For the new dolly the single roller on the back will be removed and the rollers will be placed further apart that only 20 rollers are needed

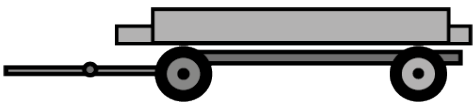


Fig 3.10 Side view container dolly

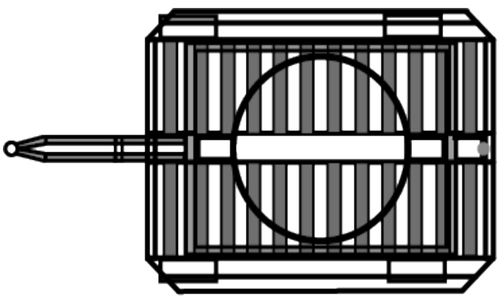


Fig 3.11. Top view container dolly

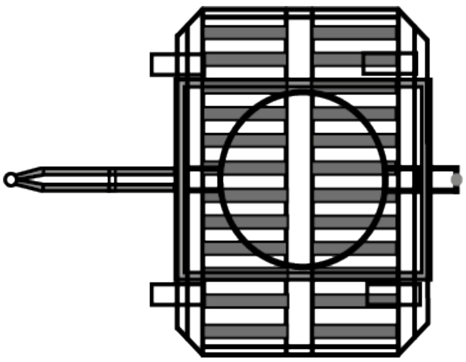


Fig 3.12. Top view rotated container dolly

Tractor(34pcs)

Dollies are pulled by a tractor to transport them at the airport. The tractors belong to the baggage or cargo department of KLM. The tractor will deliver or pick up dollies and leave the platform as fast as possible.
The new tractor(Figure 3.15), manufactured by Volk is fully electric and can go up to 30 kph (15kph when towing dollies). The maximum towing capacity is around 25.000kgThe tractor is 3.2m long, 1,3m wide and 2.2m tall(Volk, 2019).

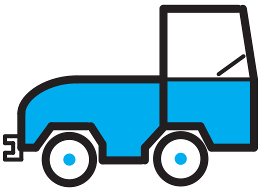


Fig 3.13. Side view tractor

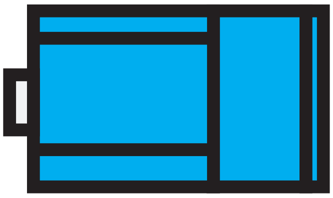


Fig 3.14. Top view tractor

Figure 3.15. On the right the new Volk electric tractor and on the left the old Volk diesel tractors

Transporter(28pcs)

Transporters are used to transport the containers at the platform, between the dollies and the aircraft. Containers are pushed from the dolly onto the transporter until the first roller of the transporter gets a grip on the container, then the transporter pulls the container further. When loading onto the dolly the transporter pushes the container as far as possible, only the last push has to be done by hand.
The transporter can load at the front, the rear and sideways. It is equipped with 2 sections of rollers, each with a different direction, one for sideways loading and one for front and rear loading. The pulsar 7SL transporter is produced by Mulag and the TF10-FTC is produced by TLD(Figure 3.18). The TLD transporters will replace the Mulag transporters over time.

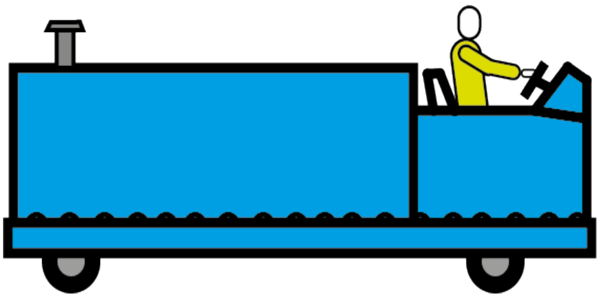


Fig 3.16. Side view transporter

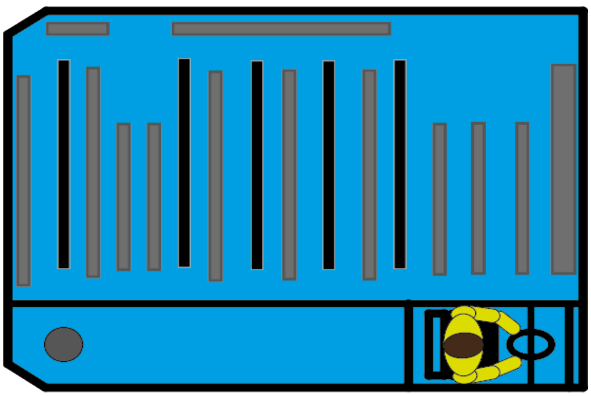


Fig 3.17. Top view transporter

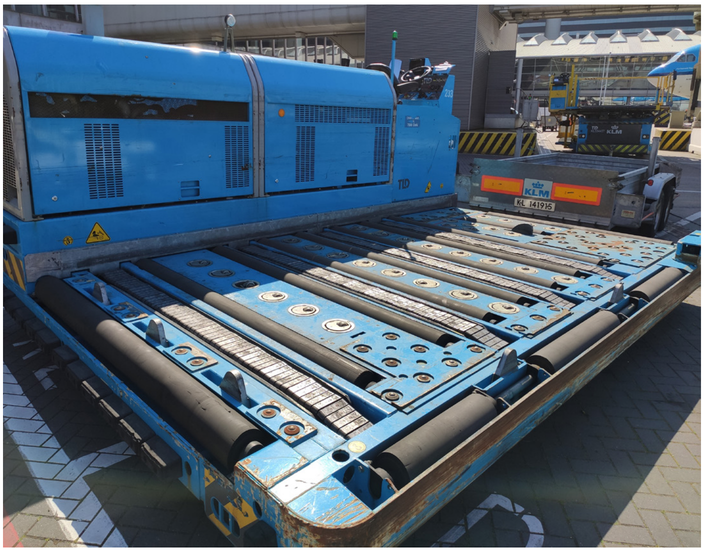
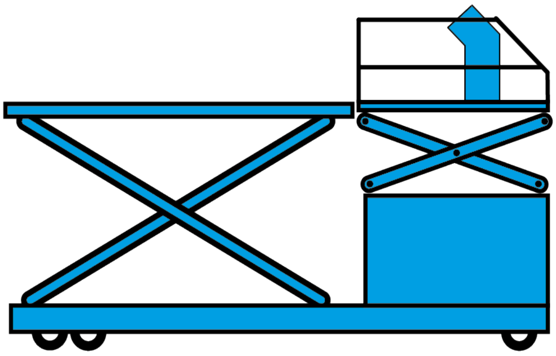


Figure 3.18. TLD TF10-FTC transporter

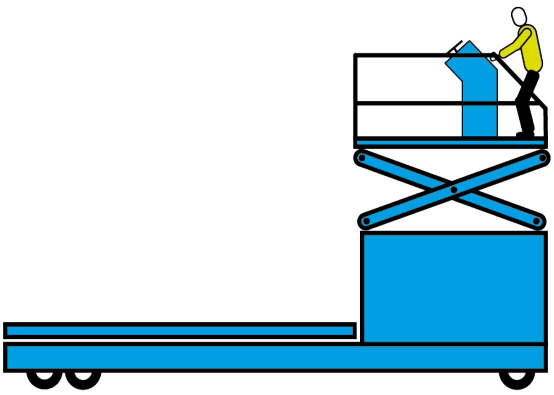
Loader(46 pcs)

Loader are used to lift the containers into the aircraft. The transporter will push the containers onto the loader, which then lifts them up. When unloading, the loader will lower the containers and push them onto the transporter.
The TLD TXL-838-reGen loader(figure 3.20) is a new electric loader that can load up to 250 containers before needing to recharge. The loader is designed to recharge when used, for instance when the rear platform goes down the loader recharges. Next to the reGen is the TXL-838 diesel version used. The diesel version will slowly be replaced by the reGen to achieve the goal towards a CO2-neutral ground operation(KLM, 2019[3])

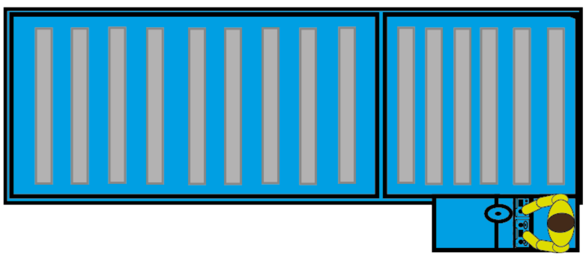


3.19. Side view loader up

Figure 3.20. TLD TXL-838-reGen loading containers into an aircraft



3.21. Side view loader down



3.22 Top view loader

Aircraft floor(infinite psc)

The floor of the cargo hold of aircraft is fitted with motorized rollers to help load and unload containers. Whenever the loader has pushed the container far enough the aircraft floor will take over the movement of the container. To power the rollers the aircraft is connected to a power supply from the airport.

Figure 3.23. Cross section of an aircraft with the cargo door open.

Figure 3.24. Cargo hold of a Boeing 777(B. Leibowitz, 2016)

Platform

The platform is also a tool for the apron service and a considerable piece of equipment/workspace. The platform(figure 3.26) is designed with a slope so water will be directed towards a gutter in the middle. The slope of the platform is often used to make it easier to unload containers from the dollies. But the slope can also force the container down against the lock(Figure 3.25). The weight of the containers causes too much friction in the lock which makes it hard to open.

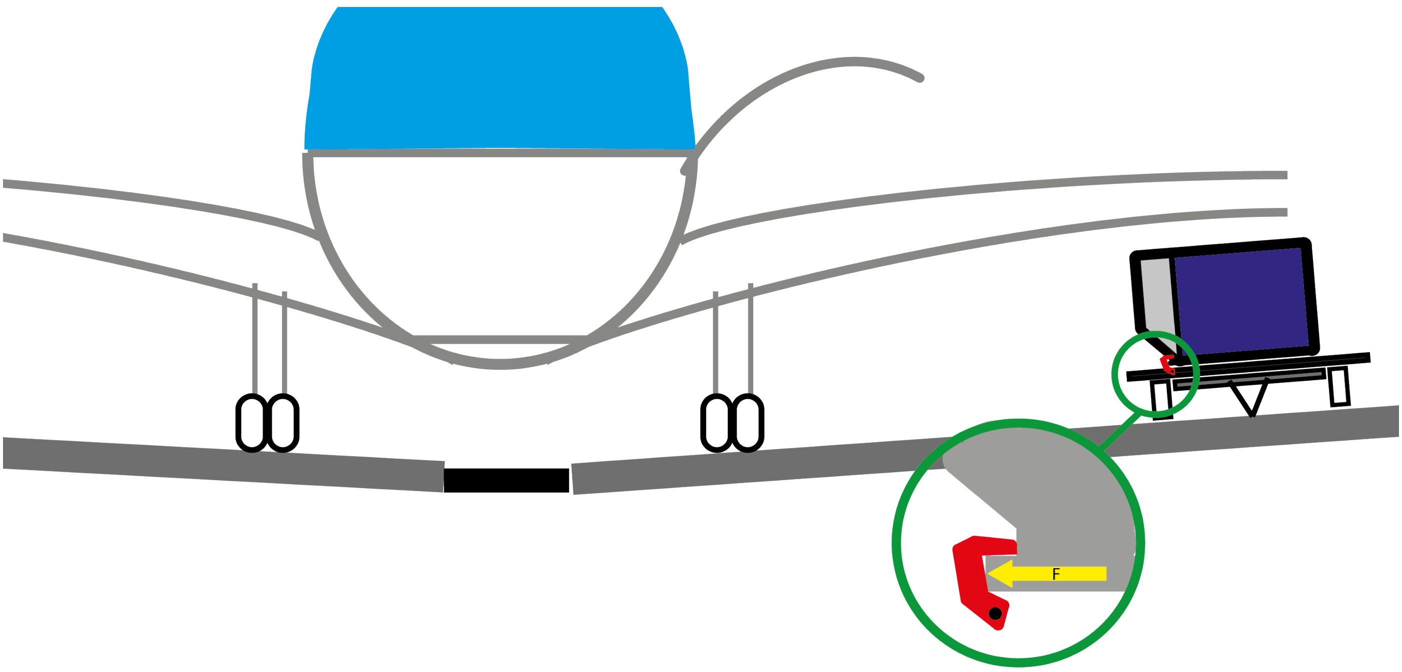


Figure 3.25. Cross section of the platform with an aircraft and a dolly with container. It shows that the container is pushing against the lock.

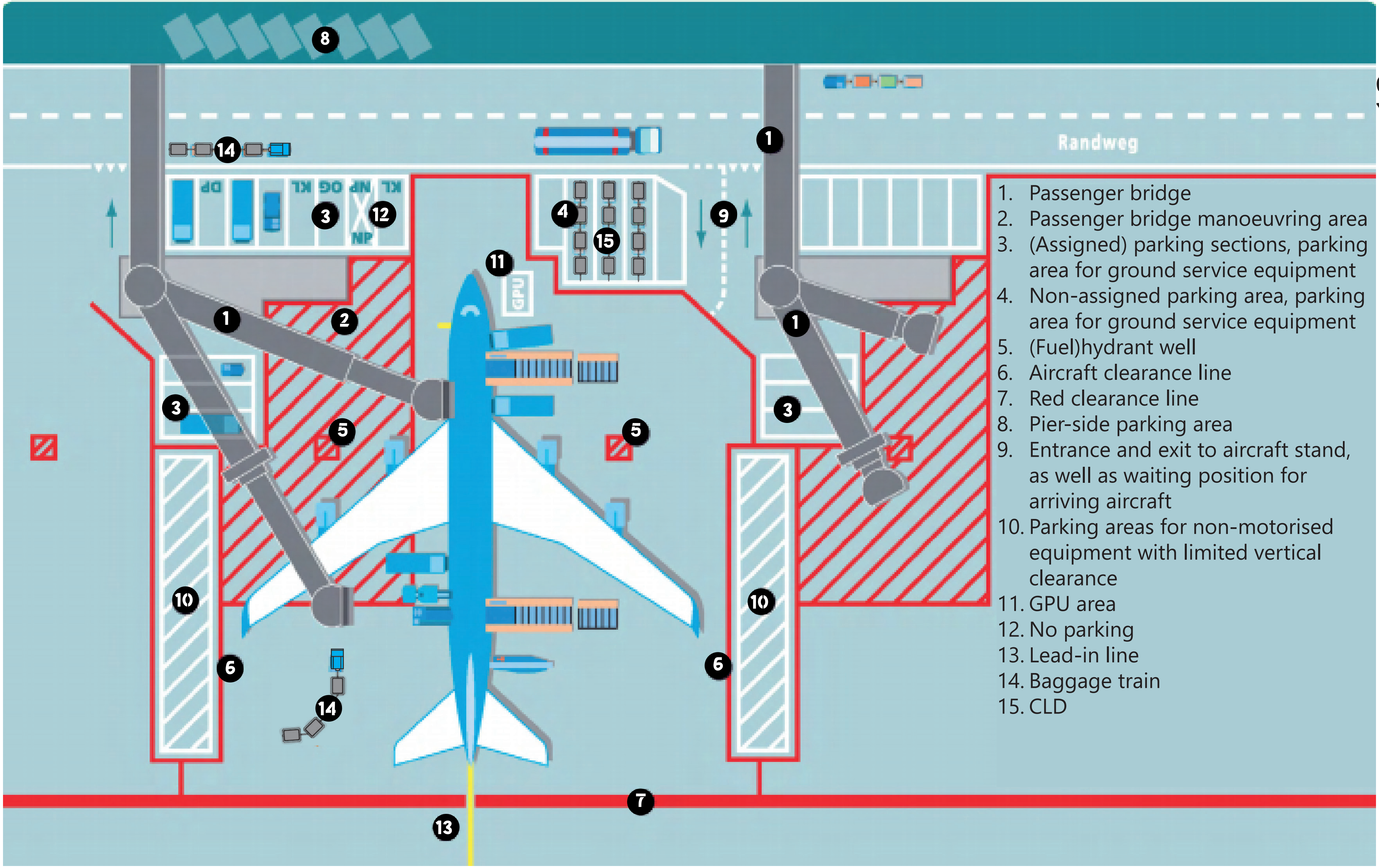


Figure 3.26. An Apron(or VOP(vliegtuigopstelplaats as the Dutch call it)consist of multiple areas and lines. There are two sorts of red lines on the apron, a thin red(6) and a wide red line(7). The thin red line defines the aprons and the wide red line indicates the border between the apron and aircraft taxiways. The thin red line can be crossed when someone needs to work in the adjoining apron. It is prohibited to cross the wide red line, with the exception of the push back service. Everything within the red lines is considered the responsibility of apron service.

Push assist(17pcs)

KLM developed a push assist to help personnel with pushing heavy containers. The push assist is a simple rod with a wheel mounted on a cart. Despite the effort, the push assist is not used as often as KLM expected. The problem is that personnel wants to load an aircraft fast and therefore decide to put their body to work. Another problem is that the push assist is often too far away. At last the macho culture makes personnel to show their strength, using the push assist is considered to be weak.

Figure 3.27. Push assist in action

Figure 3.28. Push assist created by KLM and produced by Spijkstaal (Spijkstaal, 2018)

4. Loading containers in an aircraft

This chapter will explain the steps containers go through from the moment it is put on a dolly/ filled till it is in the aircraft. The titles will also show the equipment that is affecting the process at that stage. A piece of equipment can be present in a stage but is not necessarily involved.

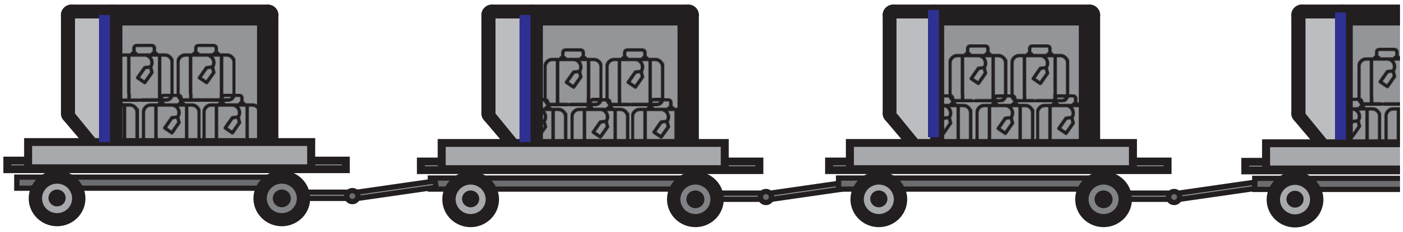


Fig 4.1. CLD(container loaded dolly)

Container onto dolly (container+dolly)

The process of the containers starts at the baggage centre in the basement of Schiphol. Containers are stationed at conveyor belts where the baggage is presented on. The straight end of the baggage belt is called the lateral(see fig 4.2). The containers are already on dollies with the chamfered side facing backward. In this orientations the opening of the container points towards the lateral. If the containers are fully loaded the blue canvas is closed. This combination of dollies and containers is called container-loaded dolly(CLD)(figure 4.1) combination.

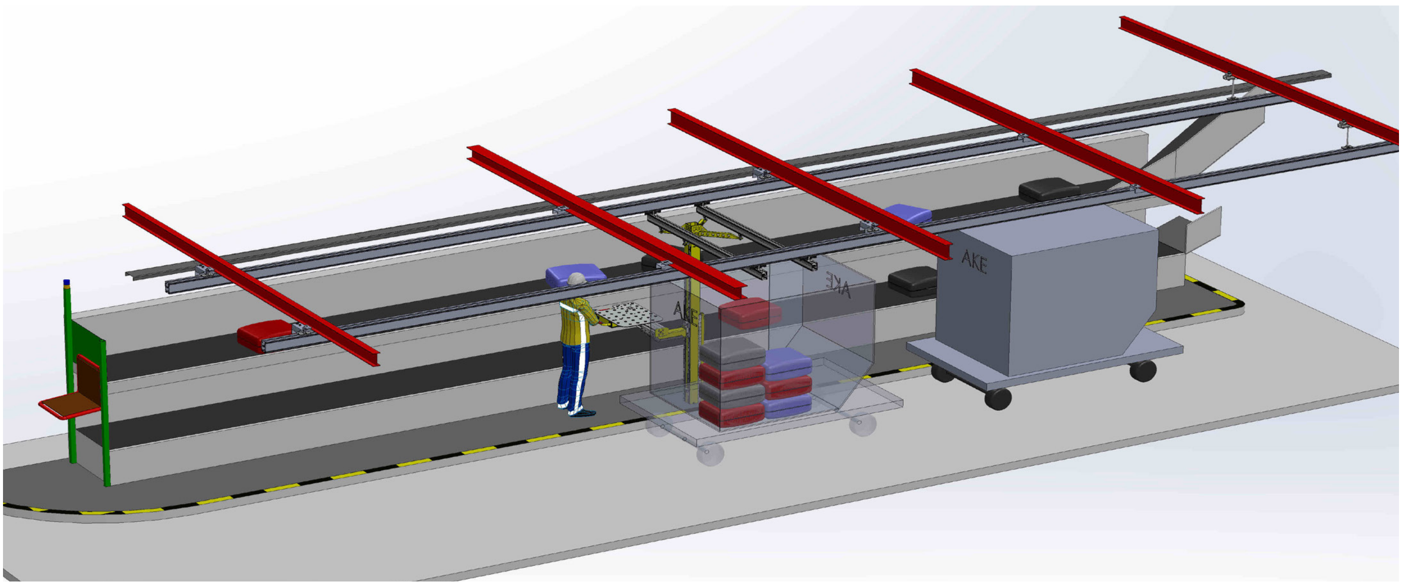


Fig 4.2. CLD combination at the lateral in the baggage basement(Liftsall, 2013)

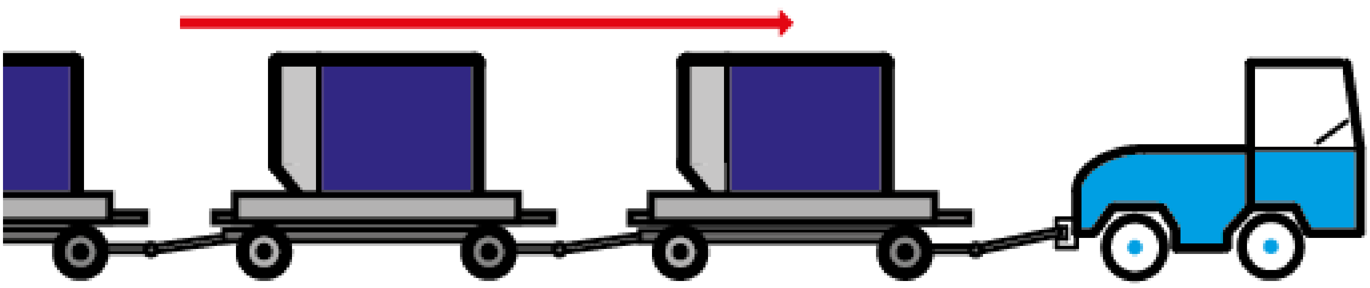


Fig 4.3.Baggagetrain

Container to platform (dolly+tractor)

The CLD combination is then picked up by a tractor that will transport them to the platform. When the tractor is linked it is called a baggage train(Figure 4.3). A baggage train can consist of a maximum of 6 CLD's, but often consists of less CLD's.

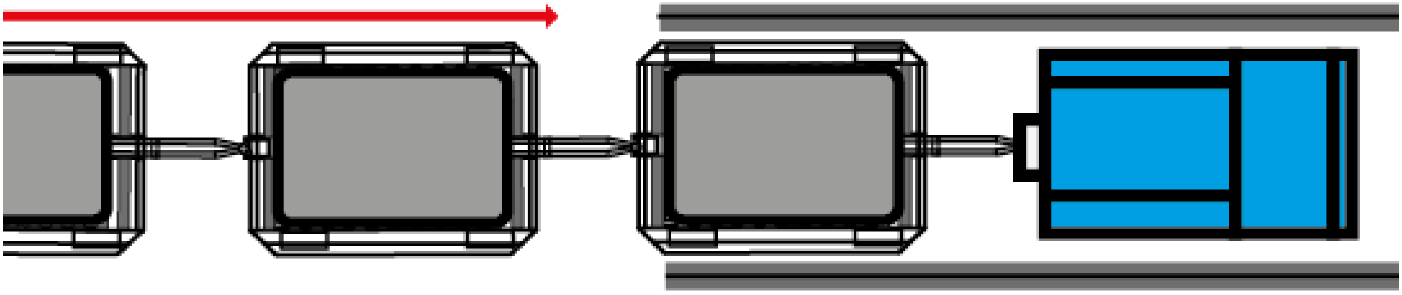


Fig 4.4. Baggagetrain maneuvering through the a basement corridor.

To leave the basement the baggage train has to go through narrow corridors(figure 4.5). The corridors are built in such a way that only containers, dollies and tractors can fit through. Containers should have the small side perpendicular to the drive direction to fit through the corridor.

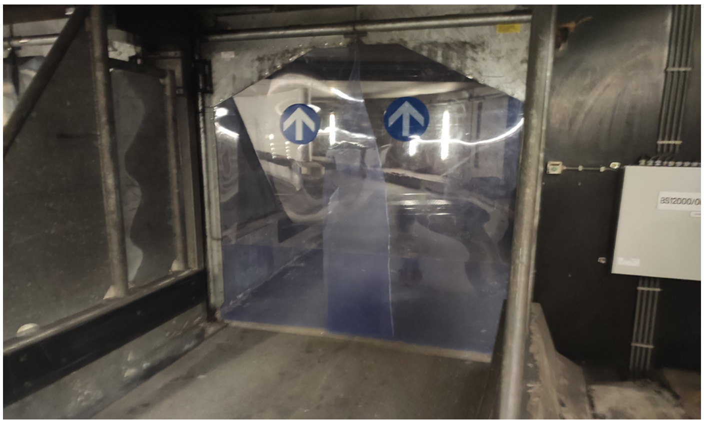


Fig 4.5 The exits at the baggage basement on basement level are very small

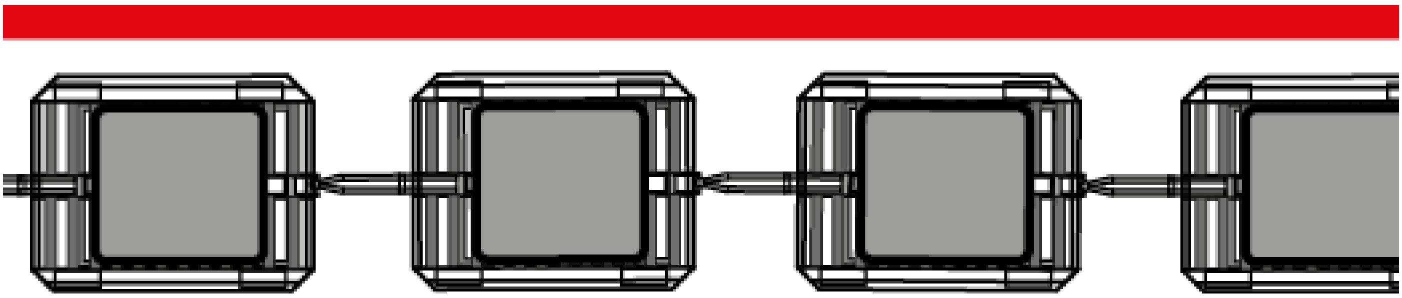


Fig 4.6 CLD's parked close to the big red line

Parking container at platform(dolly+tractor)

A CLD combination is commonly placed as close as possible to the red clearance line. This is done to keep as much space as possible around the aircraft, however leaving a tight space behind the CLD combination where no equipment can come. As seen in figure 4.7 there is only enough place for a person.

The moment the baggage tractor detaches the CLD becomes the responsibility of the apron service. Apron service will now start the process of loading containers

Fig 4.7. CLD parked close to the red clearance line

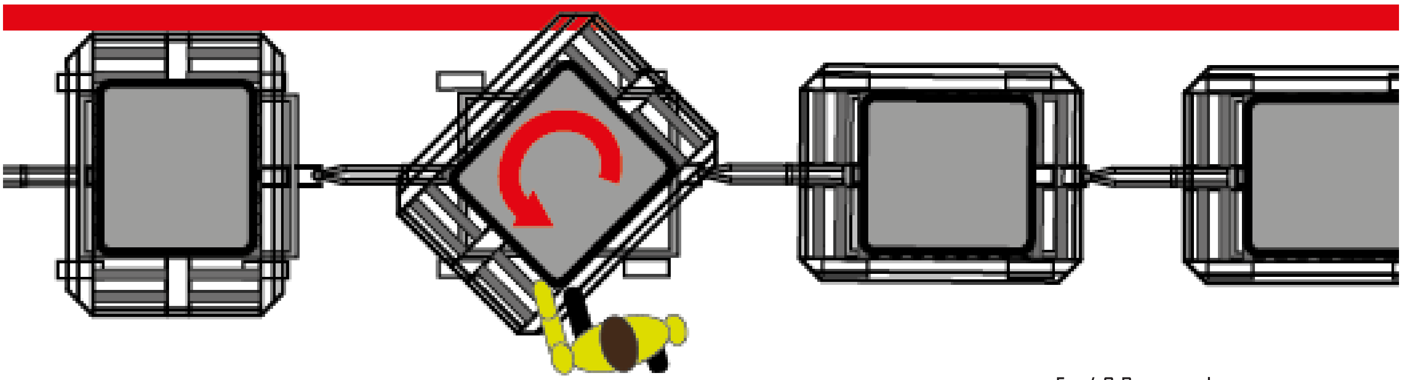


Fig 4.8 Personnel rotation a container

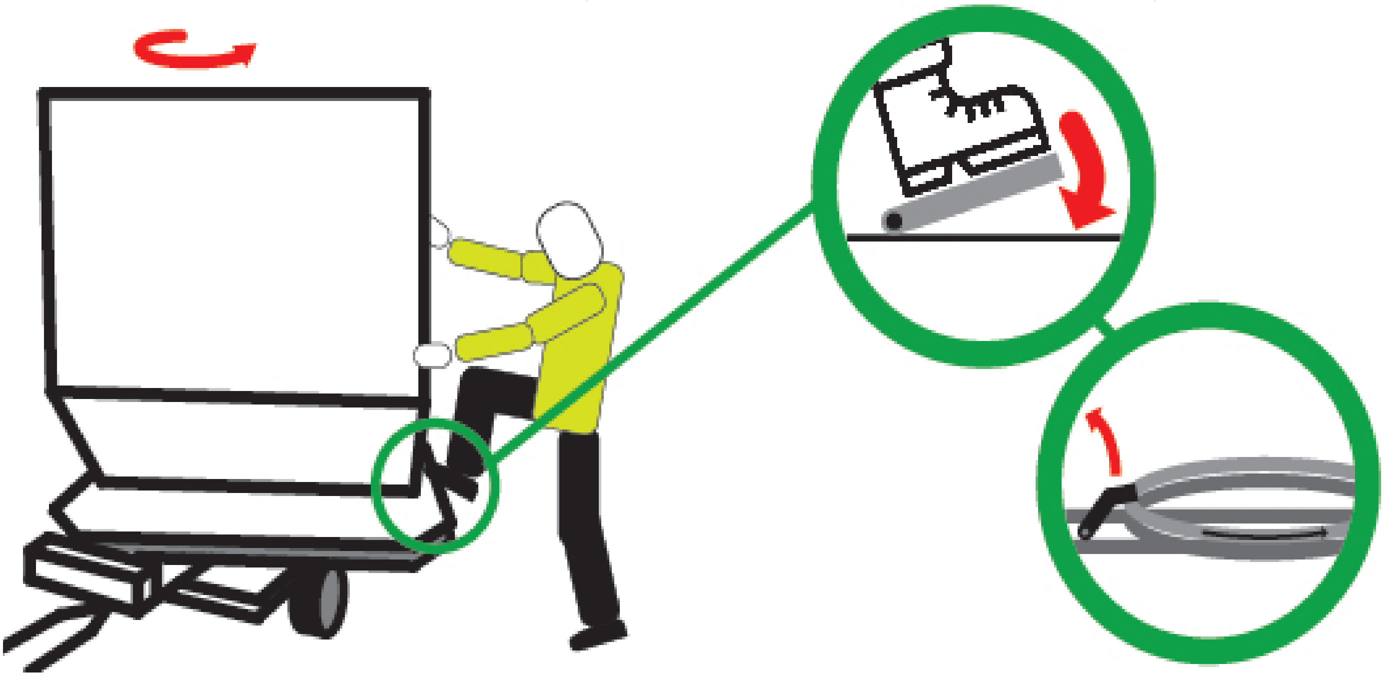


Fig 4.9 The rotation lock is opened with the foot

Rotate container on the dolly (container+dolly)

Personnel will rotate the containers by pushing against the turning table of the dolly. This is done in advance to the loading process with the transporter. Simultaneously the employees pushes with his foot to release the lock of the turning table so the top bed and container can turn. The handle is connected to a clamp, when the handle is pushed down the clamp folds away and releases the turning table.

Fig 4.9. Rotated containers, ready to be picked up by the transporter

Fig 4.10 Transporter approaching the dolly with container

Move container from dolly onto transporter(container+dolly+transporter)

Containers are always rotated per two, as they go side by side in the plane. If two containers have the right orientation they are ready to be picked up by the transporter(Figure 4.9).

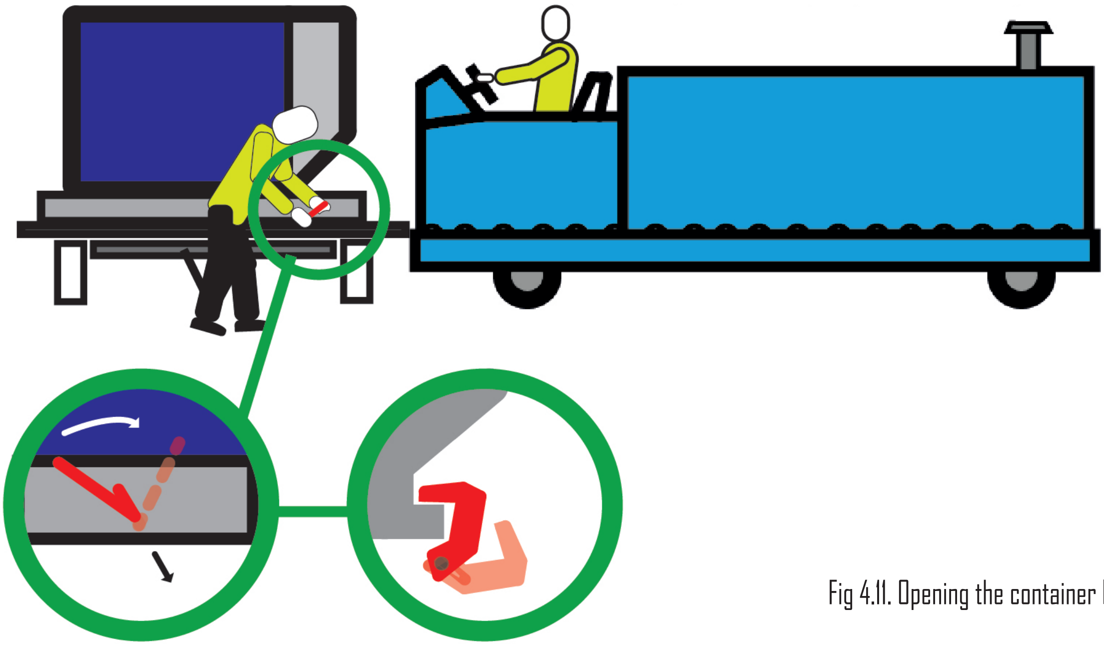


Fig 4.11. Opening the container lock

Another lock has to be released before the container can be unloaded from the dolly. Again this lock is opened manually. The handle has to be pulled outwards first before it can be turned.

Fig 4.12. Pushing the container onto the transporter.

The container can now be pushed off. Personnel has to push until the container reaches the rollers of the transporter. The rollers of the transporter will pull the container further onto the bed of the transporter.

To reach the second container the transporter has to make some tight turns in limited space on the apron. It is not always that two containers next to each other are going simultaneous into the plane. The load tool decides which container can go into the plane. It could also be containers of a different bagaggetrain.

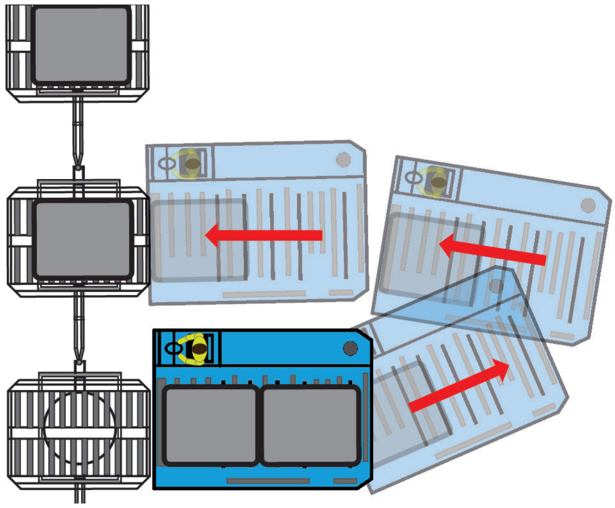


Fig 4.13. Transporter turning to get the second container

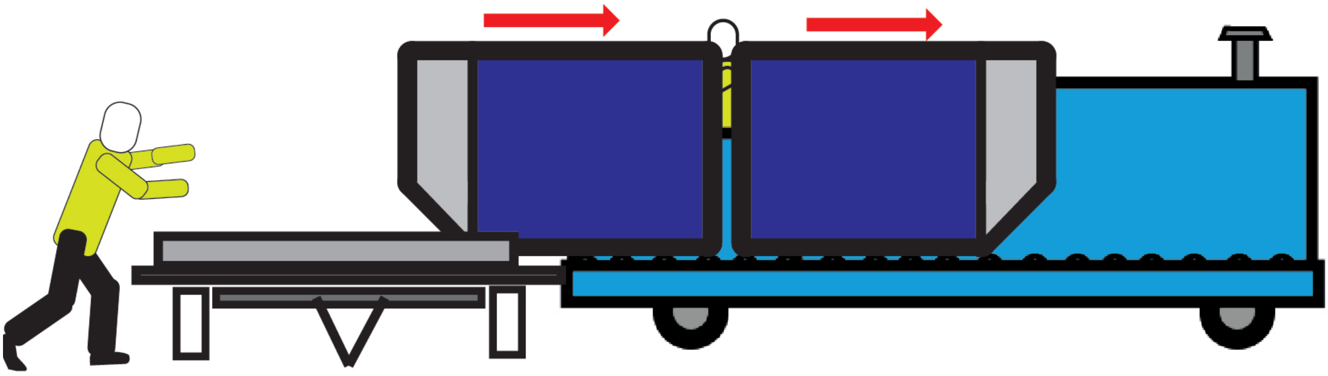


Fig 4.14. Pushing the second container onto the transporter

To load the second container the process happens again(fig 4.15). The second container always has to mirror the first container to cope with the shape of the cargo hold(figure 3.29).

Fig 4.15. Pushing the second container onto the transporter

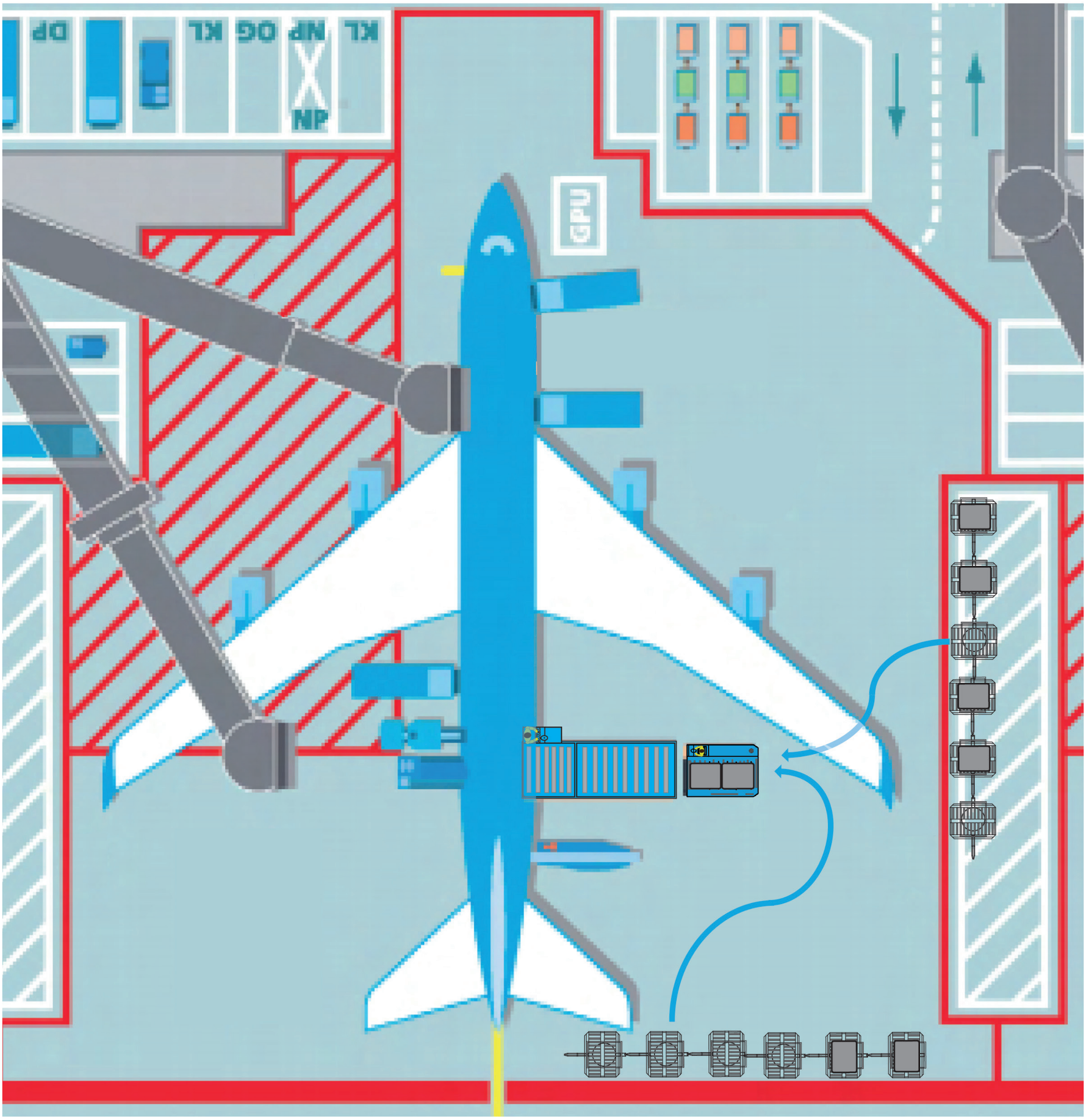


Fig 4.16. Transporter route during loading sequence

Transporting container from dolly to loader(transporter)

The loading process is often done with one loader and one transporter. However if an aircraft is in a hurry or if there is enough personnel and equipment available it is done with two transporters and two loaders. The transporter is constantly moving between the CLD combination and the loader during the loading process.

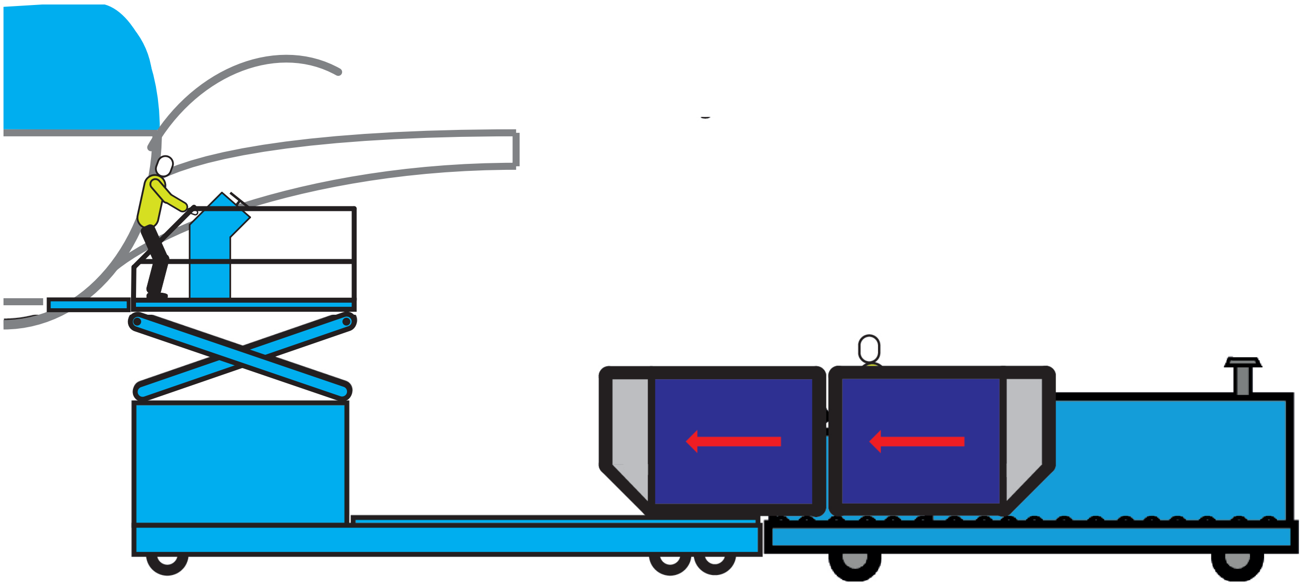


Fig 4.17. Loading containers onto the loader

Container from loader into aircraft(Loader+transporter+aircraft floor)

At the start of the loading process the loader is parked at the aircraft and the front lifting section is lifted up to the cargo hold floor and stays there . A couple of times during the loading process the loader will switch between the front cargo door and the rear cargo door. The amount of switching is determined by what kind of cargo is presented at the platform. The front is often filled first, otherwise the aircraft will tilt backwards.
The transporter parks the front against the loader. Then pushes the containers onto the lifting bed of the loader(figure 4.17). In the case of loading the aircraft the transporter will push the containers onto the loader. When unloading the aircraft the loader will push the containers onto the transporter. The loader will lift the lifting bed and the containers up to the level of the cargo hold.(figure 4.18) Unloading means the loader will lower the containers from the cargo hold.

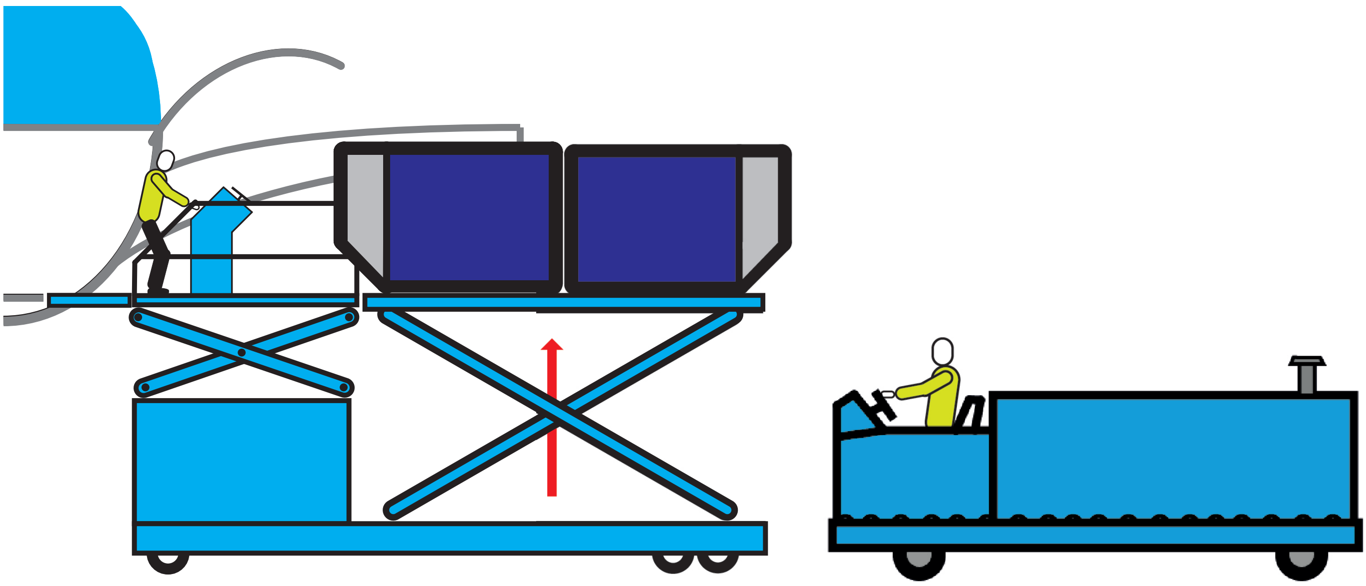


Fig 4.18. Lifting container up to the cargo hold floor

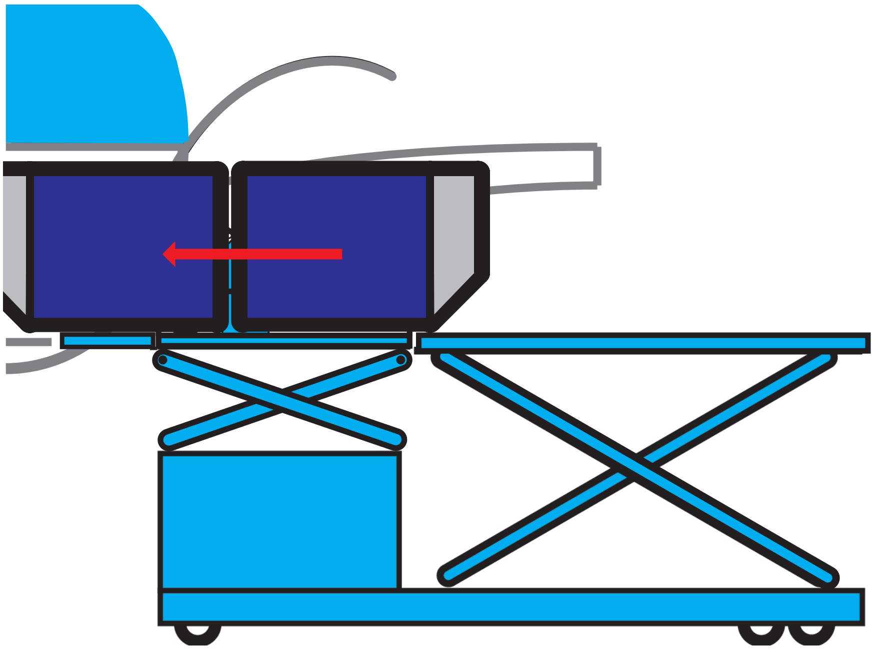


Fig 4.19. Pushing containers into the cargo hold

The rollers the loader will push the containers into the aircraft. The floor of the aircraft takes over and moves the container further into the cargo hold. This is the end of the loading sequence of a container.
It can happen that a container has to be taken out during the loading process due to a passenger that is not on board or a change in the unloading sequence on the arrival destination. In both cases a container is lowered from the aircraft and put on the nearest dolly to be emptied or to be loaded later.

Fig 4.20. The platform can look like a real mess. Especially when an aircraft has a little delay and a lot of transfer passengers

5. Analysis on the loading sequence

An analysis is performed on the loading sequence of containers. This chapter will state the causes and consequences found by the analysis in each step of the route of an container.

CLD at the lateral

A container only has one opening, consequently they s should always have the same orientation at the lateral otherwise loading becomes impossible. It is given by KLM that the containers can not be altered as they are used world wide and the whole aviation industry is geared to this type of containers. This means the solution should be found somewhere else.
Containers can not be turned at the lateral already for an easier use later on as the opening. The rotated containers would not fit through the corridors. Also they can not face the front or the back of the CLD. If the opening would face the front or the back it means that the person loading the baggage needs to be moving between the dollies. Being or moving between the dollies is forbidden(schiphol airport, 2016)

Fig 5.1. Moving between to containers is forbidden at Schiphol

Baggage train leaving basement

As the previous chapter told, the baggage train leaves the basement through a very narrow corridor. The reason this corridor is so narrow is because of the building costs. A bigger corridor means more costs, so they build it the exact size they needed. They used special concrete to make walls of a meter thick to keep groundwater out(Schiphol, 2016) as the basement is more than 10 meters below sea level(luchtvaartnieuws, 2004). At this depth brackish seawater is forced up, which required the special measures to keep the basement from flooding. In conclusion it would be too expensive to change the baggage basement corridors.

Fig 5.2 Exit and entrance of the baggage basement at ground level

Fig 5.3. Exit of the baggage basement at ground level, on the right is the entrance

Placing CLD combinations at the platform.

There should be as much space around the aircraft as possible. This space is needed for fuelling trucks, catering trucks, loaders, transporters, stairs, etc. This space has shrunk over the past decades as aircraft became bigger, but the platform stayed the same size. Another reason for the shrunken space is that the platform is more crowded. The turn around time of aircraft has been decreased a lot over the years but the same or even more load goes into the aircraft. To keep as much space as possible the CLD combinations are placed as close as possible to the red clearance line. This results in a limited space behind the CLD where no equipment can come because nobody is allowed to pass the red clearance line.

Fig 5.4. Personnel has to stand on the red clearance line to be able to push a container

Rotating containers

There are different ways to load a container into the plane. But the most efficient way, according to KLM, is to rotate the containers on the dollies and then transport them to the loader with the use of a transporter. This way the apron personnel does not have to keep to the order in which the containers are standing on the CLD combination. This flexibility allows the apron personnel to use the load tool. The load tool helps the personnel loading an aircraft by showing which container or pallet should be loaded. The load tool sets all the baggage container on their total number of luggage that it contains, let's say in this case 30, and links them to the passenger. A connection is made by the load tool on the platform and the check in counter in the terminal. If a passenger checks in the load tool links that to the container in which the corresponding luggage is. The load tool then lowers the number, in this case to 29. When the counter hits zero the container is ready to be loaded. For the load tool to be efficient the apron personnel needs to be flexible in their way of loading and rotating containers.

Fig 5.5. The load tool is an application the team captain can access on a tablet.(KLM 2018)

Transporting containers between dolly and loader

If two containers go to the loader they need to have the chamfered side facing outwards(figure 5.6).

Fig 5.6. Right orientation for containers on the transporter

To make sure the containers have this orientation they are rotated on the dollies. The orientation is dependant on the sequence they have to be loaded. The rotation should be possible at the last moment before the transporter picks up the containers. The transporter picks up the containers with the front and has to make multiple turns to put the front against another dolly for the second container. In this way so the driver is always looking forward as it is the most obvious and safest way to do it. Two other ways are possible to load containers on the transporter. One is backing up against the second container, but this is not possible as was said by the apron personnel(Test on April 16, 2020, appendix A). Backing up against the second container means that the transporter has to make too much tuns which makes it very unsafe plus the driver of the transporter is learned to keep it's movements at a minimal. Another advantage of front loading is that the transporter is limited in reverse, so driving forward is simply faster.

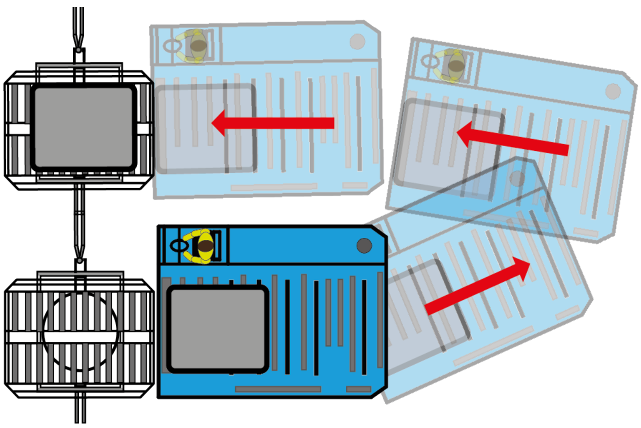


Fig 5.7. Loading with the front

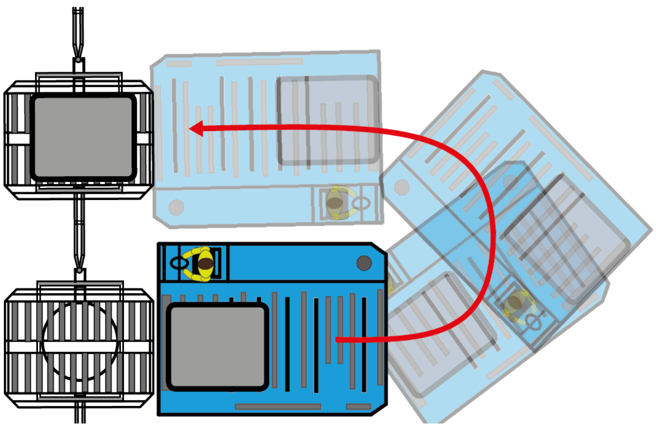


Fig 5.8. Backing up for second container

The second possibility is to load containers from the side of the transporter. If the containers are loaded in the normal way they will have the wrong orientation to go into the plane. However if the containers are not rotated they can have the right orientation on the transporter. This means the dollies have to be adapted.

Loading containers with the loader

The loader needs to be going up and down continuously. The loader is said to be the bottleneck in the process (M. Heikens, personal communication, 12 March, 2020). However R. Potemans says that has to do with the fact that the loader is used too late in the process and that they are never using the loader continuously throughout the process (personal communication, 9 April). The next chapter explains if the loader is used the whole time and whether the statements are true.
The loader is capable of rotating one container. Due to limited space on the loader it is not possible to rotate two containers simultaneously or one by one when they are both on the loader. That means the transporter has to wait with loading the second container onto the loader until the first is rotated. Research will find out how much time it will cost to rotate a container on the loader and how much longer the transporter needs to stay at the loader. A comparison can be made

between rotating on the dolly and rotating on the loader.

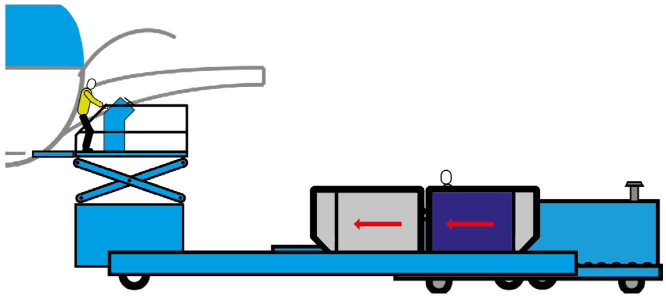


Fig 5.10. Current process; loading containers both in opposite orientation

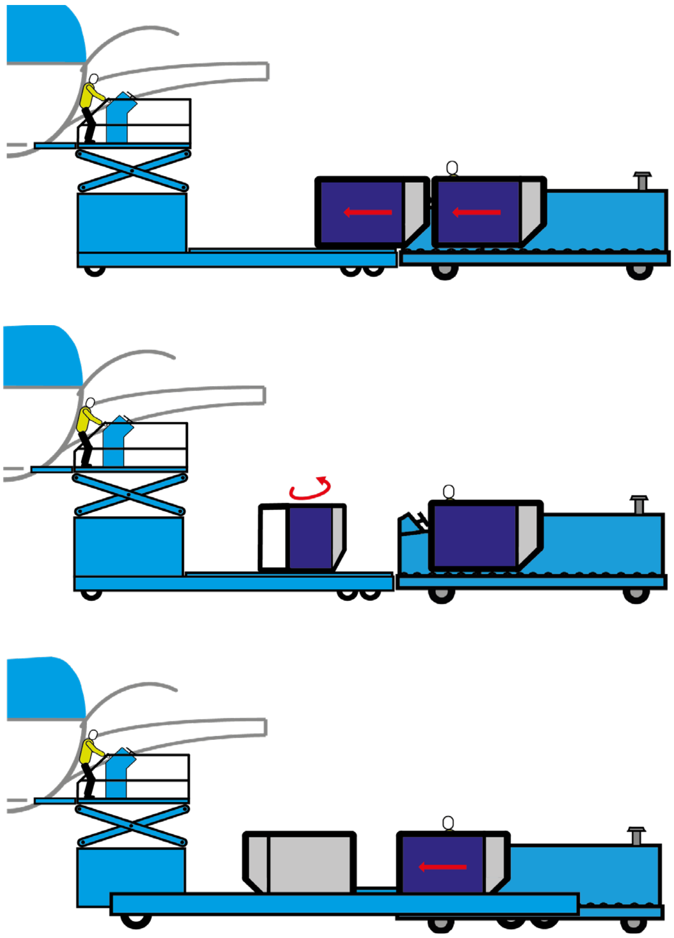


Fig 5.9. Loader lifting containers

Fig 5.11. Variation; loading one container first, rotate it and then load a second container

6. Duration of apron processes

This chapter shows the results of a research that was done to measure the duration of different steps in the loading process. The research can be found in appendix A

Loading containers on transporter

Turning containers and pushing them up the transporter is one of the most repetitive processes on the platform. It takes an average of 15.2 seconds to load the first container on the transporter. That means from the moment of releasing the lock until the transporter drives away with the first container. The duration of this step is totally dependant on the speed of the person pushing and unlocking the container.

Fig 6.1. Start of loading the first container

Fig 6.2. End of loading the first container and start of loading a second container

It takes an average of 26 seconds to load the second container on the transporter. That is from driving away at the first dolly to driving away at the second dolly. The duration is dependant on the person who is pushing the container, but even more on the turning time of the transporter. Every time the employee had to wait at the second dolly for the transporter to reach it before he could take action. The reason is that the transporter has to make some turns to reach the second dolly.

Fig 6.3 End of loading second container

Fig 6.4. The pusher has to wait for the transporter to reach the second contantainer

Loading containers on the loader.

Loading both containers on the loader takes an average of 31,2 seconds. That is from the moment the transporter left the second dolly to the moment the loader has both containers on top. This duration depends on the distance of the drive from the dolly to the loader. The transporter can even be slowed by other equipment obstructing the route.

Fig 6.5. The start of the loader sequece

Rotating containers on loader

There are two statements about rotating containers on the loader. One being that the loader has no time to rotate containers. The argument is that the loader has to be going up and down continuously as it is the bottleneck in the loading process. The other statement says that the loader is never used throughout the whole loading process.
A test compared two scenarios, one in which the transporter loads the containers on the loader in the same orientation as they go into the aircraft. In the other scenario the transporter will load the containers both in the same orientation from the dolly so the loader has to turn the first one before it can lift both containers.

Fig 6.6. Rotating a container on the loader .

The transporter has to wait 27 seconds on average when the loader is rotating the first container. However the operator said that he had a bad view on the situation and therefore had to guess if the container was placed right for the rotation. The poor view(fig 6.7) makes the process of rotating on the loader very hard. It is not standard procedure, therefore the personnel is not used to it. If this would become a standard procedure the personnel will be getting faster in rotating containers on the loader due to experience.

Fig 6.7. Sightlines of the operator of the loader

7. Concepts

Multiple concepts have been developed that can lower the large psychical burden. The concepts are shown in this chapter as they all helped designing the final solution. Some features of these concepts are used (in an adapted version) in the final concept. Background of the concepts can be seen in appendix B. The design process and evaluation on the premature concepts updated the concepts (see appendices D and E). All of these concepts were designed with the knowledge that there would be an automatic lock(Appendix C). The automatic lock made it possible for the transporter to load containers on dolly's without the help of a pusher. The automatic lock gave a certain freedom to the design, that opened up some ideas. In a later stage of the project the development of that automatic lock was stopped by S-P-S.

Transporter arm

The transporter is fitted with an hydraulic arm, that will reach for the containers. The arm is fitted with a clamp that can hold containers and rotate them.
The transporter drives to the dolly with the clamp aligned to the driving direction of the transporter. This orientation is needed to get the arm between the containers. When the clamp is in the right position the arm rotates to a position where the clamp is centred above the container. The clamp rotates until the vertical rods align with the handles of the rotation lock.

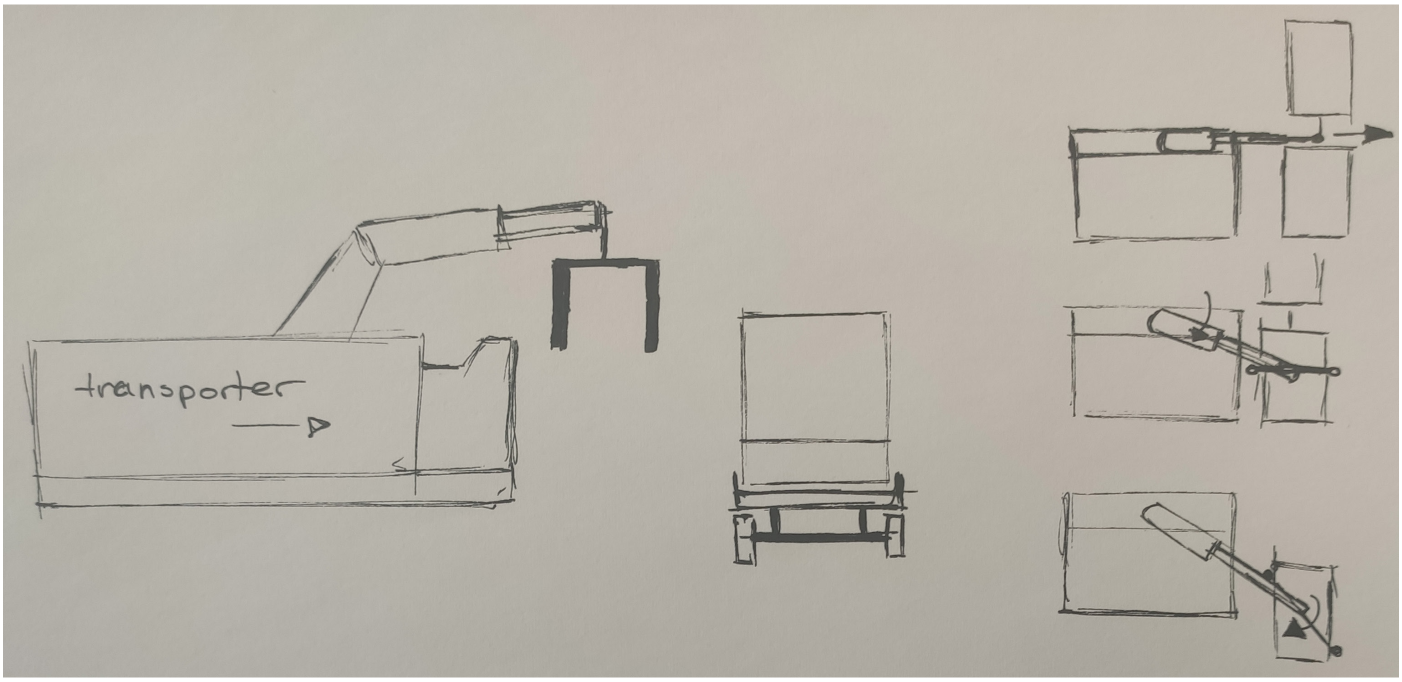


Figure 7.1 - Approaching the containers and positioning the clamp.

When the position of the clamp is right, the vertical rods extend to push down the handles of the lock to unlock the rotational motion of the dolly.

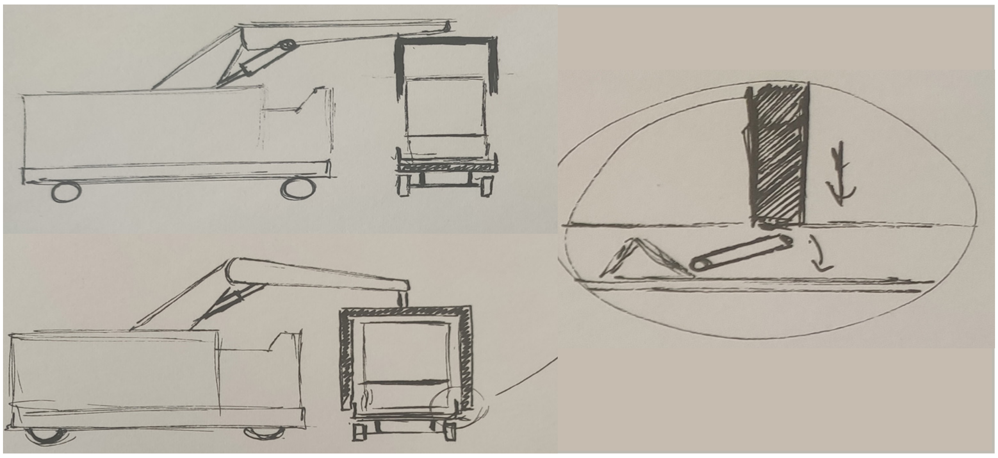


Figure 7.2 -Moving the clamp over the container and pushing down the rods

When the container is rotated, the clamp rotates back, perpendicular to the container. In this perpendicular position the clamp closes. The vertical rods pushes on the other lock handles, this time to release the horizontal movement lock. If the lock is open the clamp can fully grab the container and pull it onto the transporter.

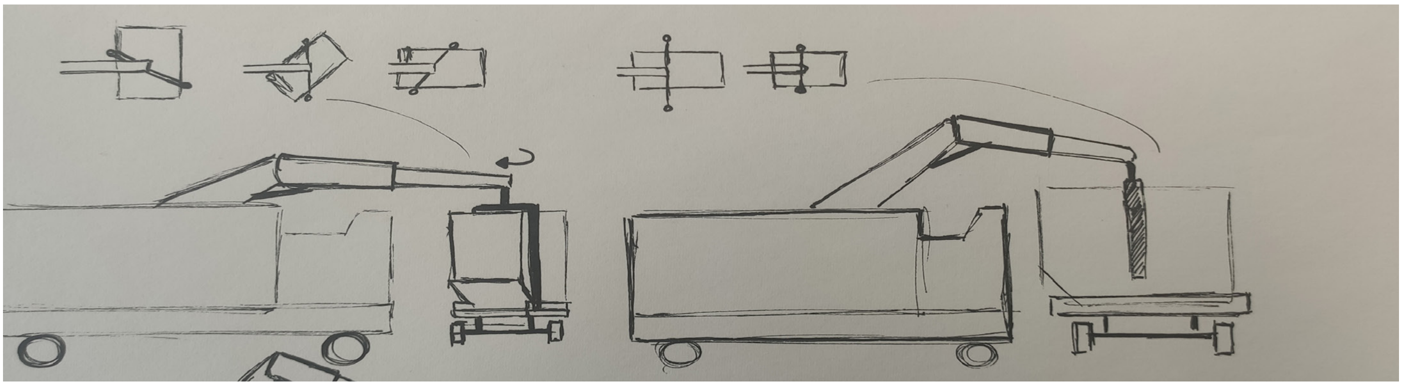


Figure 7.3 - Rotating container and rotating clamp back to perpendicular.

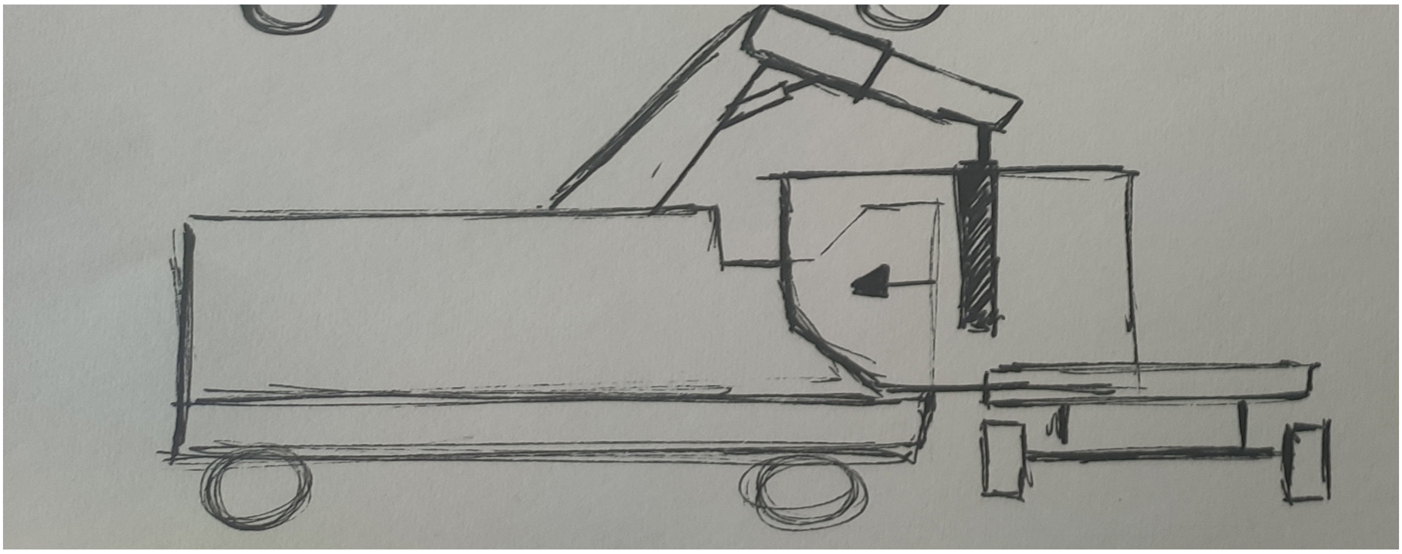


Fig 7.4. - Pulling the containers onto the transporter.

Sideways dolly's

The dollies are changed in a way that they can unload containers from the side without rotating They still have the same dimension as the current dollies as they still have to fit through the basement corridors.

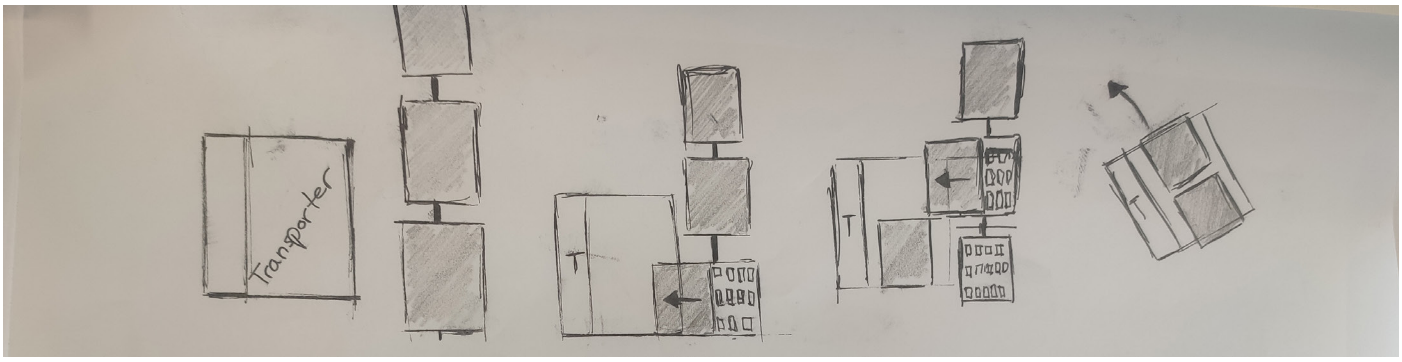


Figure 7.5. A Top view of loading containers from sideways dollies. The transporter drives alongside the dollies and loads them sideways.

To load containers on the transporter, the transporter drives alongside the dollies. There are two kind of dollies that can be used, one that rotates and one that can not. If the dollies are not rotating, the containers will get on the transporter with both the same orientation. In that case the containers have to be rotated later on. If the dollies could rotate, a container needs to make a rotation of 180 degrees before loaded on the transporter.

Figure 7.6. - On the left if the dolly can not rotate and is put on the transporter. On the right if the dolly can rotate.

Powered dollies (battery)

In this concept the dollies are powered by a motor that rotates the turning table of the dolly. The rotation can either be activated by hand or a remote control.
The motor is fitted on the chassis of the dolly and the rotational part is attached to the turning table. The rotation lock is also opened by a simple motor that lifts the lock. Both motors work synchronized. With one press on the button both motors start to work.
The button can be placed on the dolly itself or on a remote control. It will probably start by placing the button on the dolly to prove the principle. Later on the dolly will be remotely controlled, for instance by the operator of the transporter.
The motors need to be powered, therefore the dolly will be fitted with a battery. The battery does not need much capacity because a dolly usually makes two rotations on the platform. Even with additional charges for emergencies the total required capacity stays low. The battery still needs to be charged. Luckily the dollies on Schiphol have a standard route in which charging can be done, for instance in the baggage basement. Another option could be a dynamo.

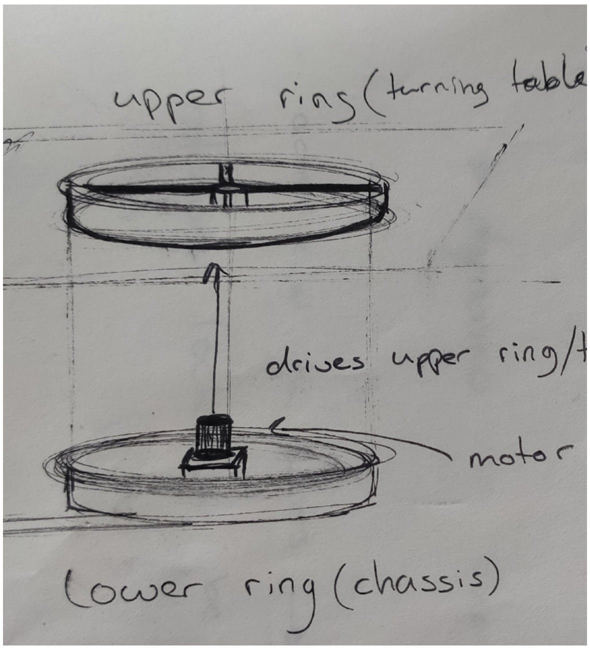


Fig 7.7. A motor drives the upper ring of the turntable.

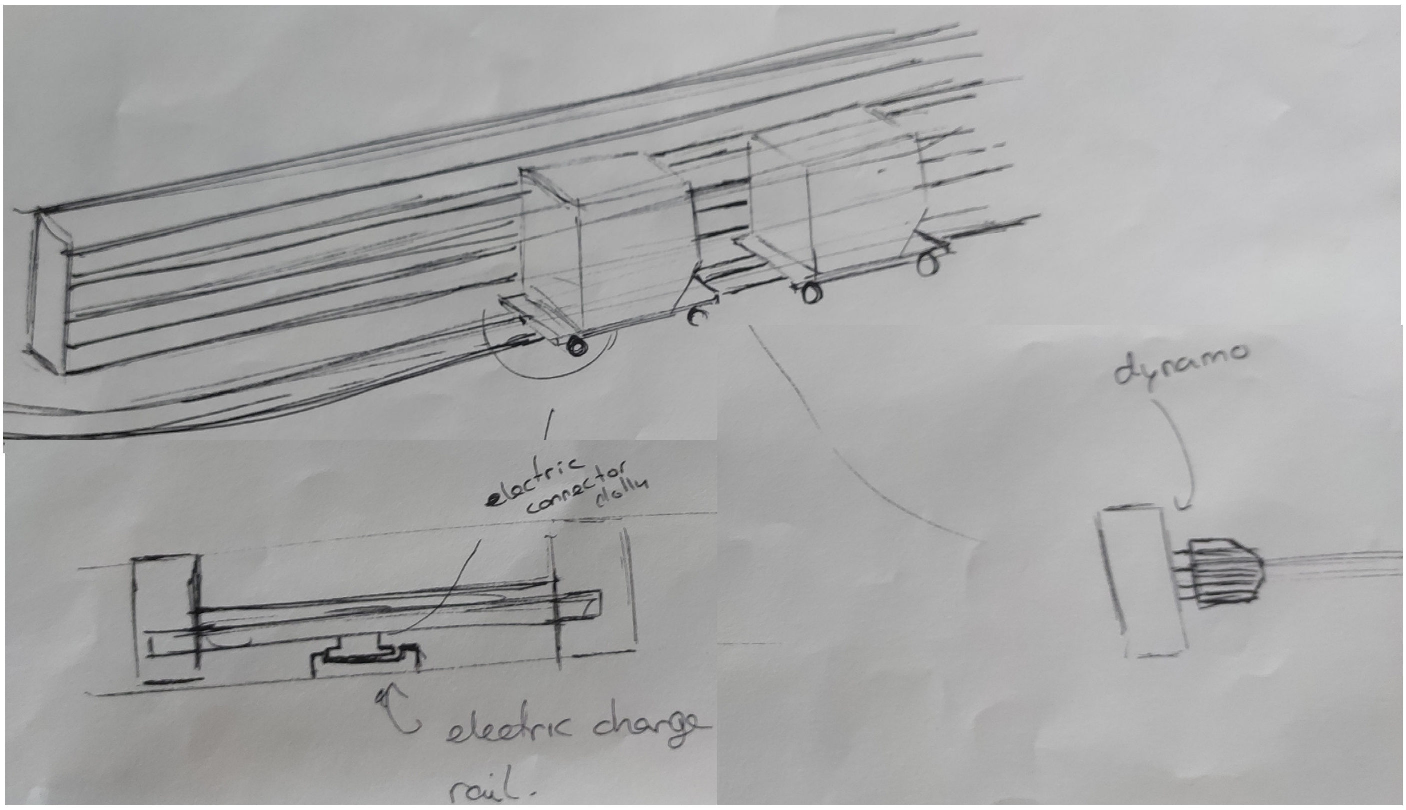


Figure 7.8 The battery can be charged through a rail at the baggage loading bays or through a dynamo.

Powered dollies(equipment)

This concept is almost the same as the previous concept, but here the dollies are powered by the equipment. The powering is done through an external axle on the transporter. The axle connects with a connector on the dolly. The connector drives the rotation of the turning table. The lock opens when the transporter connects to the dolly. The force of the transporter pushes the lock open. The transporter is in total control of everything happening to the container in this concept.

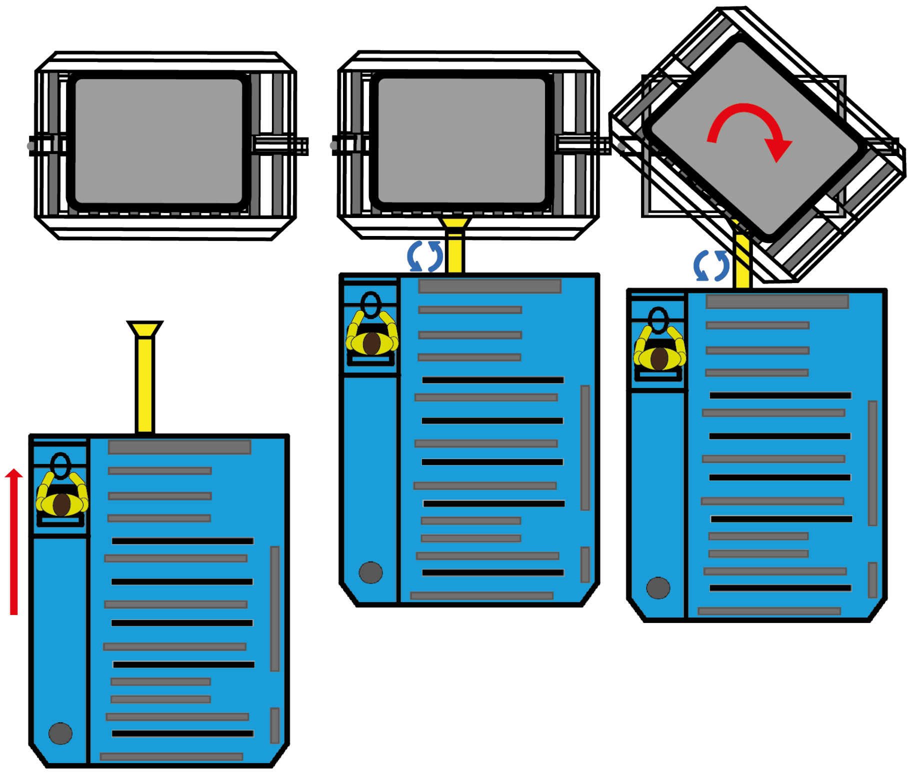


Fig 7.9 . Top view of linking the transporter to the dolly and rotating it.

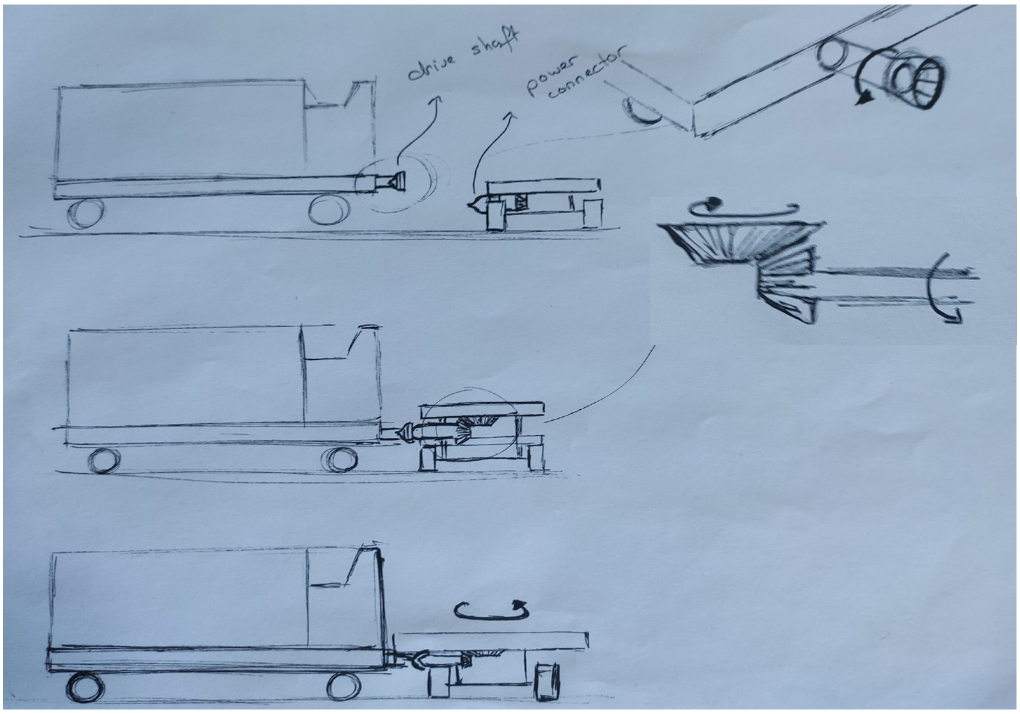


Fig 7.10. Detail of the gears from the transporter rod connecting to the gears of the dolly. On the left a side view of the transporter connecting to the dolly.

Push bar

Dollies are equipped with a system that can push off a container and at the same time open the locks. By driving the transporter against a bumper on the head or the rear of the turning bed a hook pulls the container. In this case it is assumed that the dolly is already rotated.

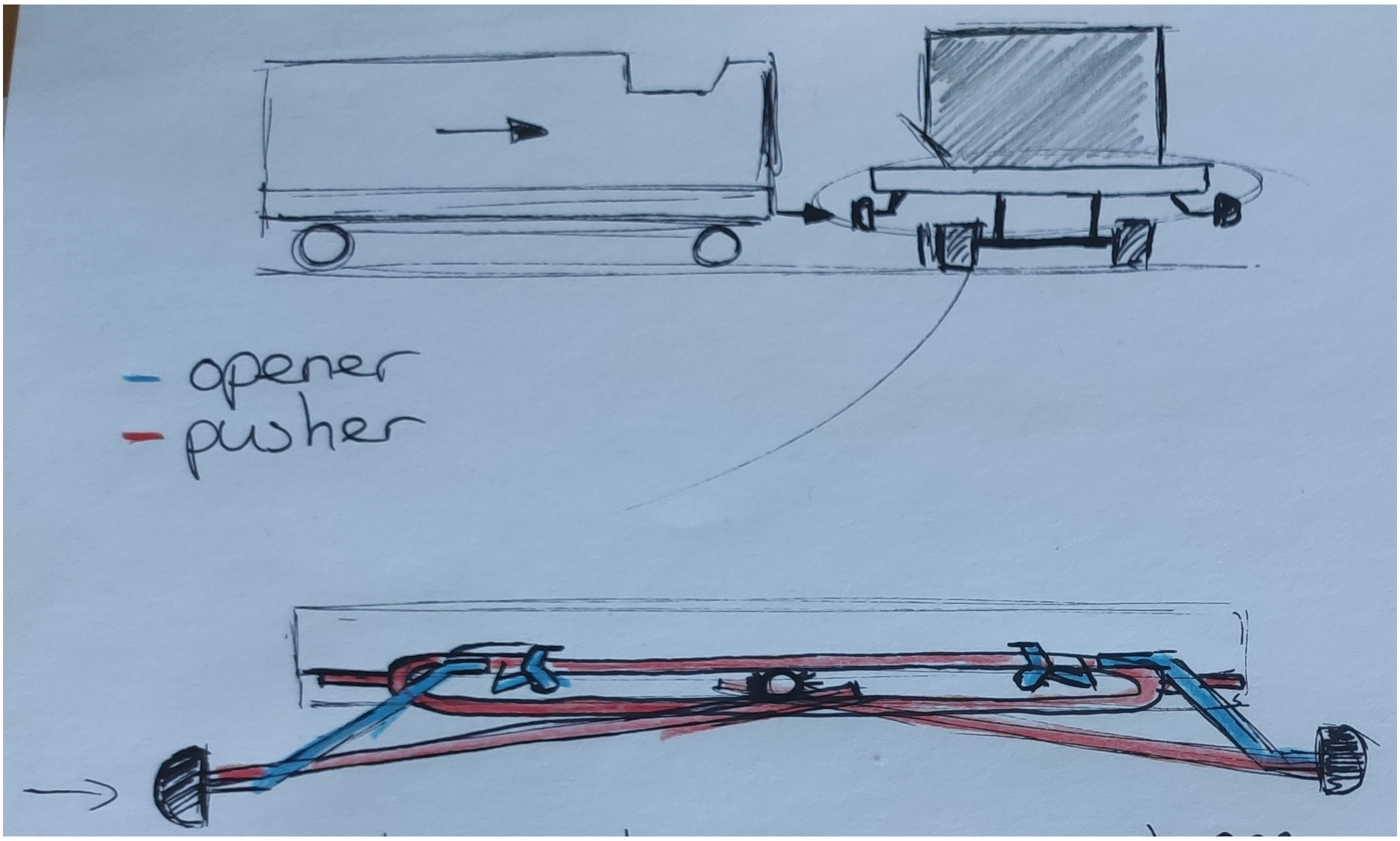


Fig 7.11 The push bar is fitted on both sides of the dolly . Multiple rods make it possible to open the lock and activate the push mechanism. The locks open and the pin pushes on the back of the container when the transporter drives against the bumper

When the transporter drives against the bumper on the dolly, a rod moves further into the dolly. That rod is connected to the lock (the automatic one described in Appendix C) and pushes the lock open.

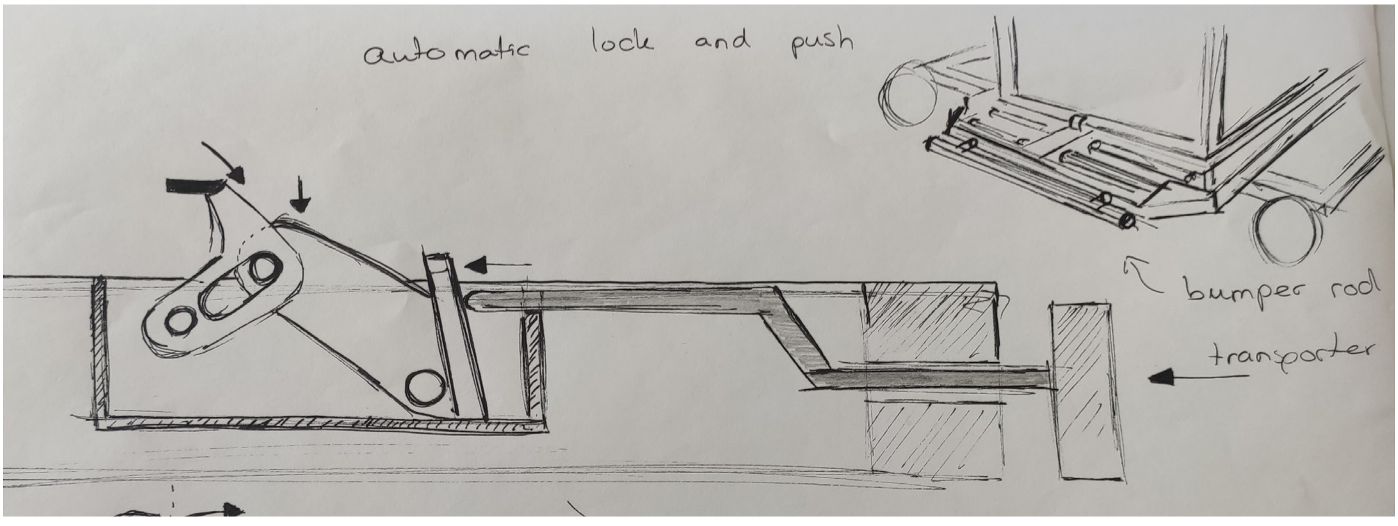


Fig 7.12 The push bar connects to a rod that pushes the lock open.

When the transporter drives further another rod starts moving. This rod is connected to a gear inside the dolly. When the rod moves, the gear turns. The gear drives a chain with two pins on both sides of the dolly. When the chain is in neutral position the pins are down, in that way they do not obstruct the container. When the chain starts moving, the pin on the back of the container comes up and start pushing the container towards the transporter. The container only has to be moved 30 centimetres, after that the rollers of the transporter can get a grip on the container.

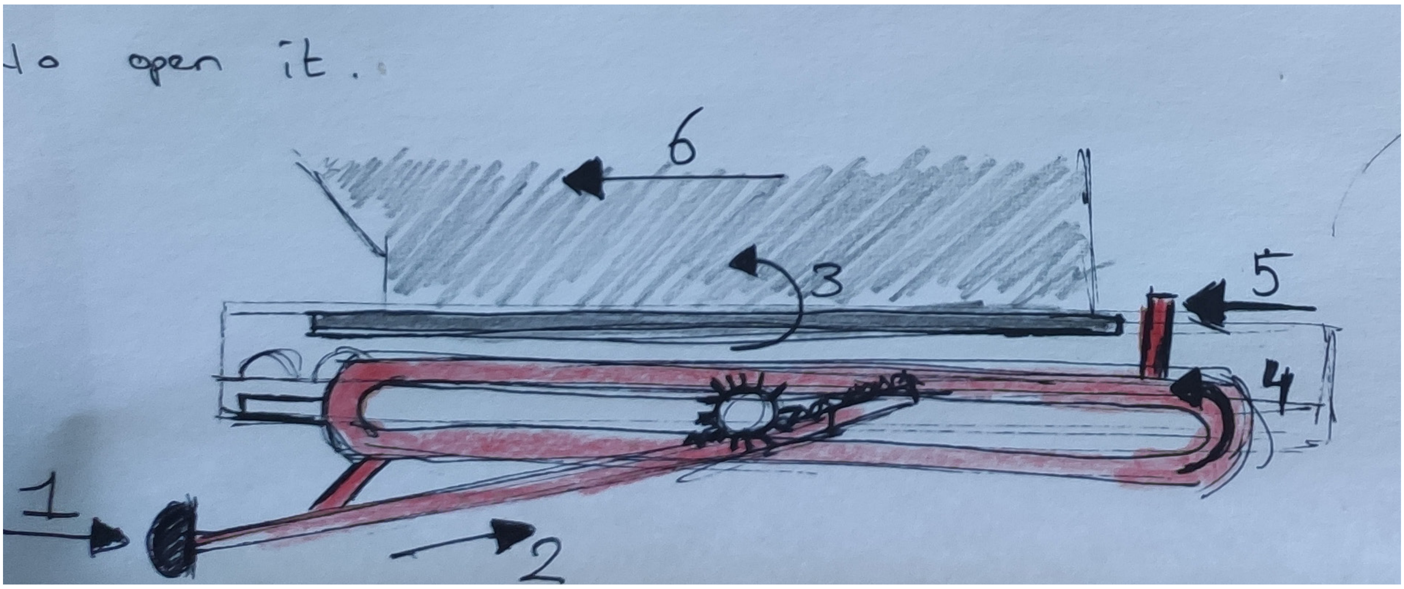


Fig7.13 When the transporter drives against the bar far enough the push mechanism starts to move. The rod drive a gear that drives a chain with a pin. That pin pushes against the container.

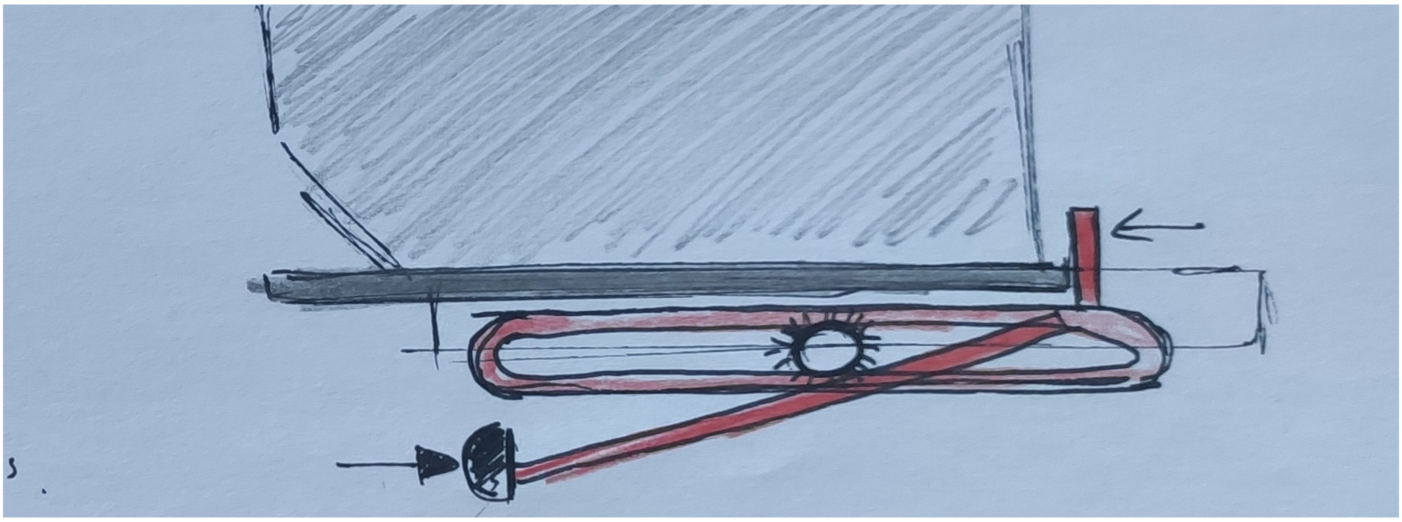


Figure 7.14- The pin rises from the dolly. This way it won't be obstructing the movement of the container when the containers moves in the other direction.

Rotation gate

Gates are placed around Schiphol to rotate dollies. These gates are placed at points where every bagaggetrain has to go through, for instance the exits of the basement.

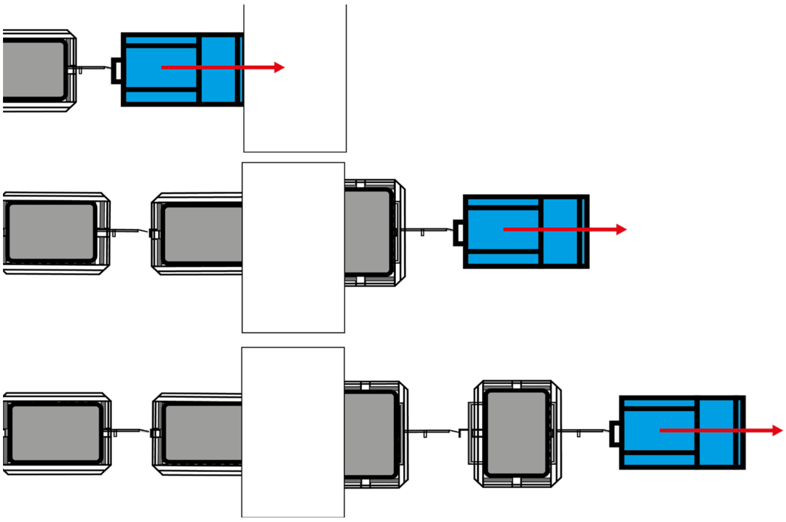


Fig 7.15. The bagaggetrain drives through the gate. The gate registers if there is a container and rotates it.

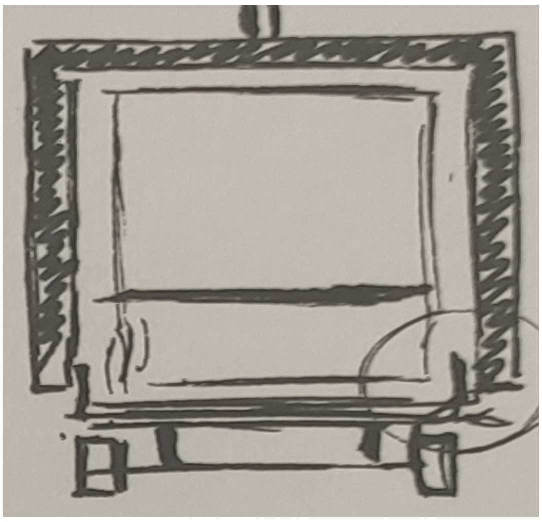


Fig 7.16- The front of the gate. The vertical rods push on the locks to unlock the rotational movement.

When the dolly drives into the gate the locks have to be unlocked for the rotational motion. This unlocking is done by letting the vertical bars of the gate push down onto the handles of the locks. To make sure only the rotation lock is opened a latch is made on top of the handle as seen in figure 7.17. This latch is higher than the handles of the other locks, as a result the vertical bars can only activate the rotation lock and will not be able to open the other locks.

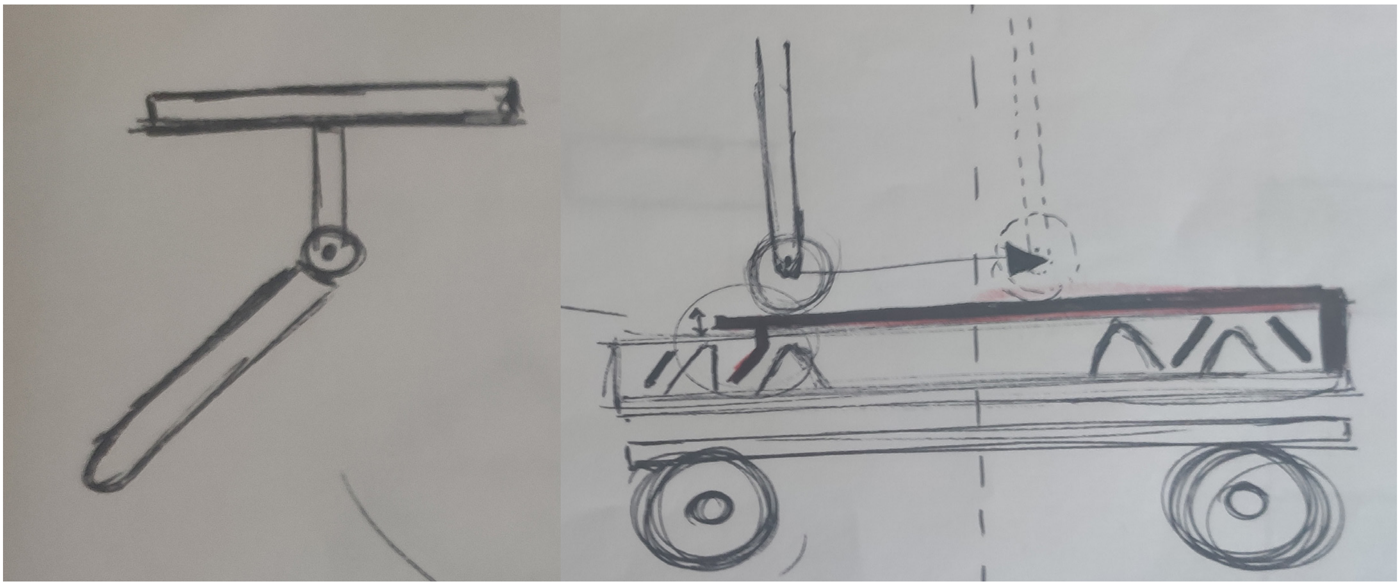


Fig 7.17. Side view of the gate. In the left an addition to the lock handle to make it easier to open by the gate. With that addition a wheel can roll over it to keep the lock open.

The containers rotate when the train drives through the gate. The gate detects that a container is inserted far enough, then the yellow bar starts to turn. The bar rotates the container 90 degrees and then the vertical bars on the yellow beam separate to make room for the container to leave the gate. The other container can enter and the yellow bar can turn the other way. With this sequence the containers get alternated in their orientation. An alternated line of containers is better for the process as the chance is high that containers already have the right orientation. If a container has the wrong orientation it can be rotated by backing up the transporter to it, the container loads at the back, with a mirrored orientation to the first loaded container. The containers can also be rotated at the loader or transporter.

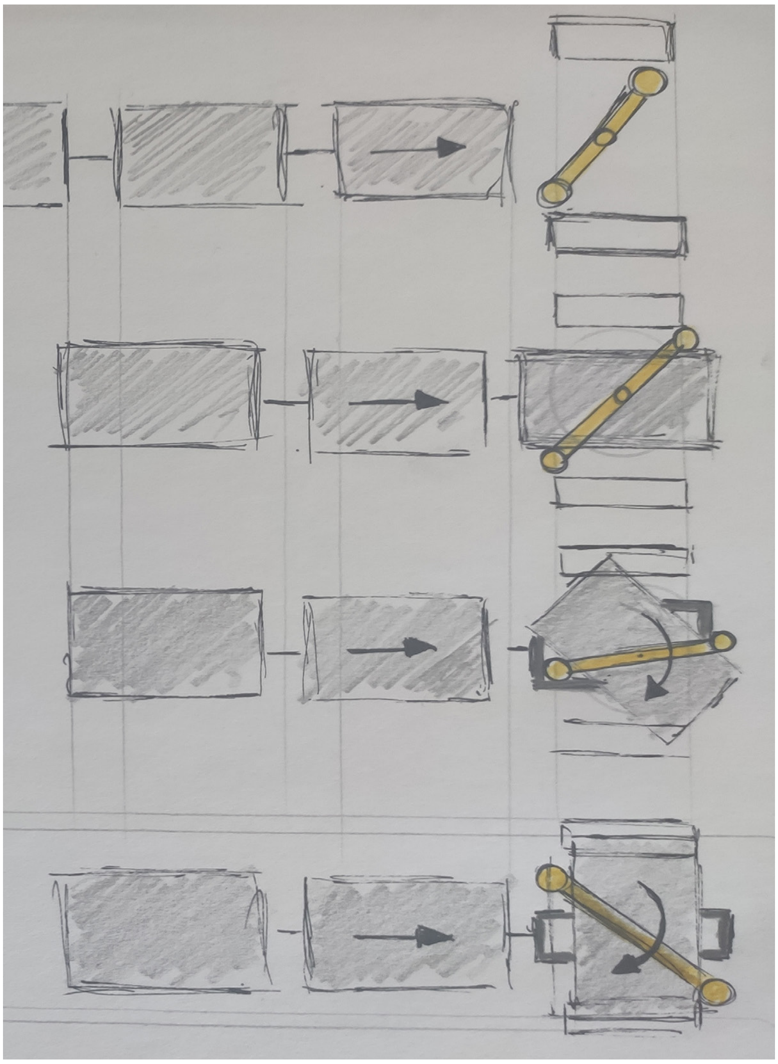


Fig 7.18 A top view of what happens inside the gate. The yellow rod rotates the containers.

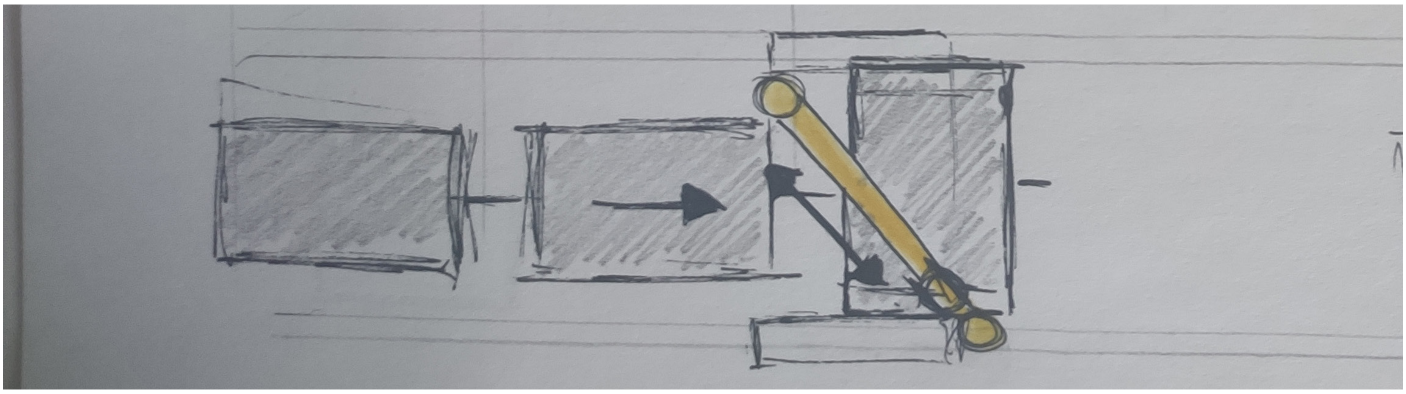
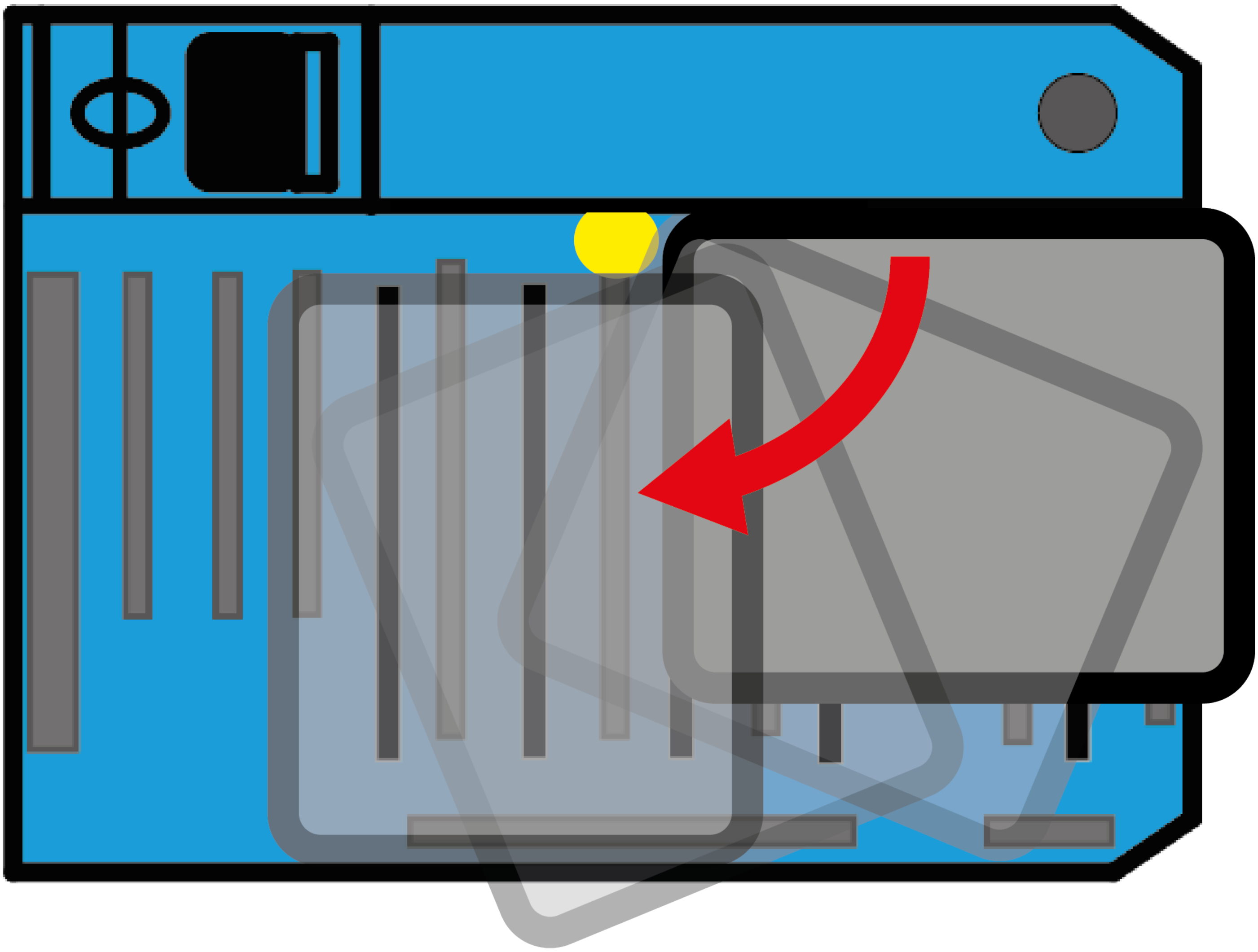


Fig 7.19. the rod has to open to let the container through.

Transporter rotates containers.

This concept works when the containers are already on the transporter, but in the wrong orientation. This concept can be used as an extension to other concepts where a second turn is needed after unloading from the dollies.
The concept works with a little bump on the transporter which rotates the containers. The transporter just has to move the container against the bump and keep pushing it, then the



container will make a turn of 90 degrees.

Figure 7.20- A simple bump is also used in factories on conveyor belt to re-orientate products. The transporter only has to push the container against the bump to rotate it.

8. Evaluation of concepts

The concepts will be evaluated to choose between the concepts and start working towards a final direction. The evaluation will happen by testing the concepts on criteria and wishes. These criteria and wishes were set by KLM or emerged from the research. Notion should be taken that for the push off of containers all the concepts are combined with the push-off bar, only the transporter arm is combined with the transporter arm for pushing container off(see appendix F for explanation on these combinations)

criteria	weight	transporter arm(pull and rotate	loader rotates	side dollies	powered dollies(battery)	powered dollies(equipment)	Push/rotation tool	rotation gate	transporter rotates	Push bar
compatability with load tool	5	5	2	2	5	5	5	3	3	5
Safety	5	5	4	3	4	5	2	4	4	5
Efficiency	5	2	3	2	3	2	2	2	2	5
Implementation time	1	3	4	5	3	1	5	2	4	4
radicality of change	2	2	3	1	3	2	3	2	2	4
ease of use	4	2	3	4	4	3	2	3	3	4
maintenance	1	3	5	5	3	2	5	4	5	4
size	1	3	5	5	5	4	4	2	4	5
future perspective	3	5	3	5	5	5	1	5	4	5
Stand alone	2	5	2	2	4	3	3	2	4	3
total		106	90	87	116	104	82	88	94	133

The figure above shows the scores per concept on every point. The concepts are ranked on a score from 1 to 5, with 5 being the best score. Below is a quick description of every criteria.

- Efficiency: the amount the concept will increase the efficiency of the process
- Implementation time: the time it will take to implement the solution, lower score means a bigger downtime of equipment or operation
- Radicality of change: The amount the process of handling containers is changed
- Ease of use: How easy is the concept to use and how much time will it cost to learn the machine
- Costs: How much will the product cost
- Maintenance: Will the concept need a lot of maintenance, mostly due to mechanical moving parts
- Compatibility with load tool: Is it possible to change container orientation at the last moment
- Size: How much space will the concept take on the platform
- Future perspective: Is the concept fit to be adapted to the future perspective of an autonomous platform
- Stand alone: Can the concept work on it own or does it need additional machines to be able to function on the platform

The transporter arm and the powered dolly came at as the best concepts. The rest of this chapter will explain the score.

Reduction of physical burden

The most important criteria is: the solution should reduce the physical burden when rotating and pushing containers on the platform. All the concepts meet this criteria in such a way that either the pushing does not have to be performed by human power or the rotation have to be performed by human power. Some concept can make sure both rotation and pushing does not have to be performed anymore. The only concept that will not exclude the human from any action is the push/rotation tool. The tool is a loose piece of equipment that should be carried around and needs a lot of human interaction to operate. Therefore the push/rotation tool will not be developed further.

Load tool compatibility

criteria	weight	transporter arm(pull and rotate	loader rotates	side dollies	powered dollies(battery)	powered dollies(equipment)	rotation gate	transporter rotates	Push bar
compatability with load tool	5	5	2	2	5	5	3	3	5

The solution should not interfere with the load tool. That means that the containers should be able to change to the correct orientation at the latest moment.
The side dollies do not work well with the load tool because all the containers would have the same orientation and would need a 180 degree turn if they have to change orientation or the transporter has to make more turns to get the containers in the right orientation. Because the side dollies have such a bad score on one of the most important criteria they are not further discussed.

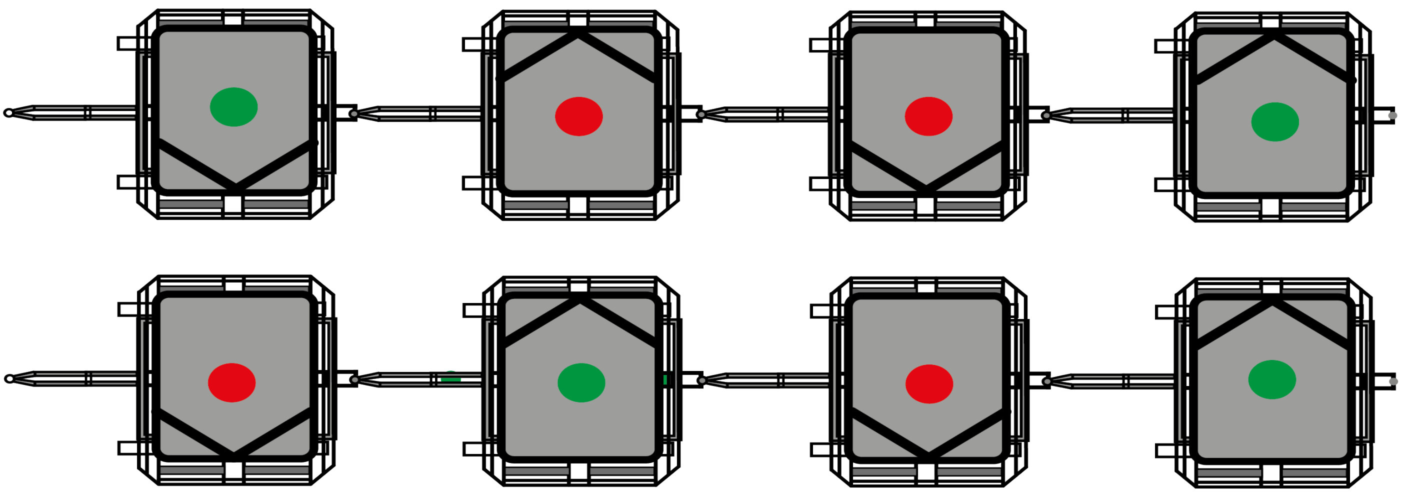


Fig 8.1. Combinations of containers that can be loaded. The top combination gives no problems as there are two containers with a mirrored orientation. The combination on the bottom, however, give problem as two containers with the same orientation have to be loaded.

Rotation on the loader seems the best solution as the loader is the latest step in the process. However, the problem that ocurs when the loader rotates is that the transporter has to wait every time for the loader to rotate the first container(see p.28 'rotation on loader"), therefore rotation on the loader will not be discussed anymore.
The rotation gates turns the containers alternating in order that combinations can be made that can be loaded on the aircraft. However some containers will have to be turned extra on the platform to make combinations that are in the right orientation(fig8.1). It can be solved by rotating one of the containers 180 degrees on the dolly. Therefore the rotation gate is capable of working with the load tool, but does not make it easier.

Safety

criteria	weight	transporter arm(pull and rotate	powered dollies(battery)	powered dollies(equipment)	rotation gate	transporter rotates	Push bar
Safety	5	5	4	5	4	4	5

Safety is a big pillar in the strategy of KLM. More safety means less injuries and that leads to less absenteeism. Most accidents happen around the rotation and unloading of containers onto the transporter. Employees have to get close to the moving transporter to open locks(fig 8.2) or are waiting behind a container to push it when the transporter lines up. Especially when the transporter is used to force locks or containers to move it gets dangerous.

Fig 8.2. The employee has to stand close to a moving transporter to open the locks.

To increase safety the employees should be able to leave the red circles(fig 8.3) when a container is rotating or when the transporter is approaching a dolly.

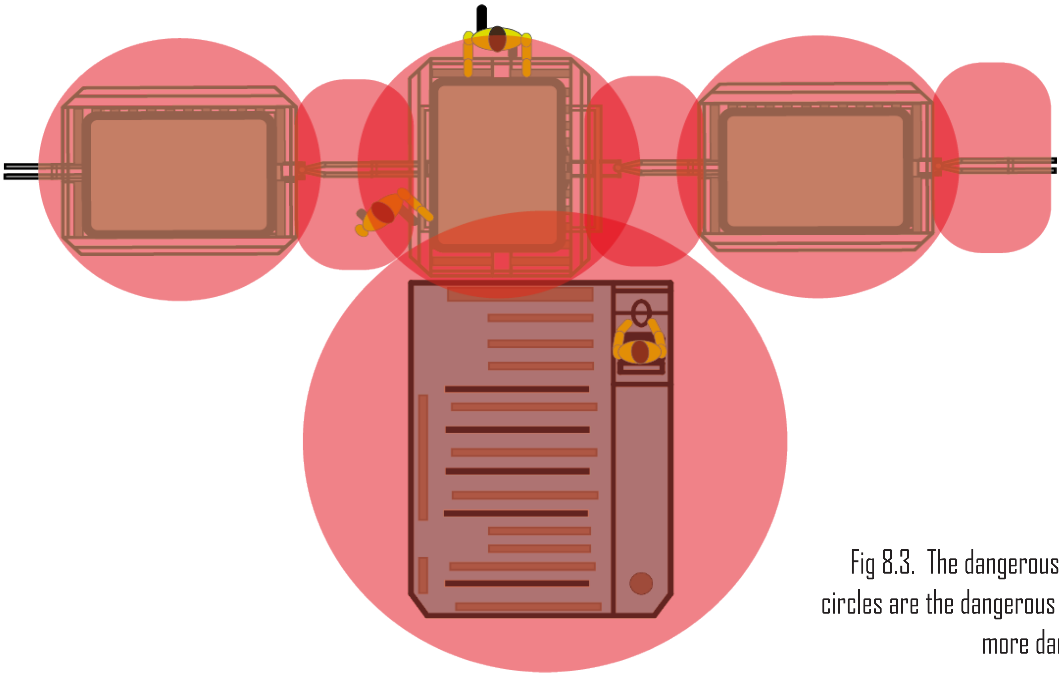


Fig 8.3. The dangerous areas around the dollies. The red circles are the dangerous zones, darker red zones are even more dangerous due to multiple variables.

The rotation gate is far away from the platform, but with pushing of containers the employee still has to come close. Moreover, if a container is rotated on the dolly, the 180 degree turn has a high chance of causing injuries. For that reason, when using the rotation gate the manual rotation is not possible.
The powered dolly has a change of hitting an employee when it is operated with a button on the dolly, but when it gets remotely controlled in the future that problem is solved.
Although the rotating on the transporter relocates the rotation away from the employees, there have to be adaptations to reduce the chance of containers falling off.

Efficiency

criteria	weight	transporter arm(pull and rotate	powered dollies(battery)	powered dollies(equipment)	rotation gate	transporter rotates	Push bar
Efficiency	5	2	3	2	2	2	5

Alongside solving the problem is the ambition to make the process more efficient. The push bar makes the process more efficient by making it possible to rotate containers before arrival of the transporter(fig 8.4). The employee does not have to wait at every container for the transporter and the transporter never has to wait at the dolly.
The rotation gate makes the process slightly more efficient as containers can be unloaded immediately. However the double rotation or rearrangement slows down the process.
The transporter arm rotates the container and therefore the container can not be rotated in advance. In that case the transporter has more waiting time where it is not transporting(figure 8.5). On top of this the arm has to retract constantly when driving with the transporter which will take time. The extra time positioning, retracting and extending the arm are not even taken into considering in figure 8.5, which could add even more steps. Conclusively, the transporter arm will slow down the process, but saves human labour in costs.
Rotation on the transporter will slow the process down as the machines has to stop to rotate a container.

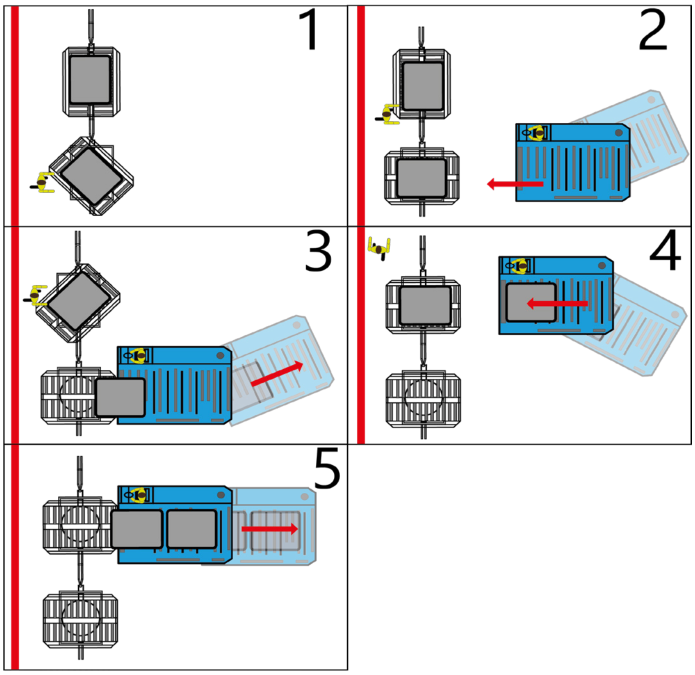


Fig 8.4. The sequence when using the push bar. The employee can stay a step ahead of the transporter.

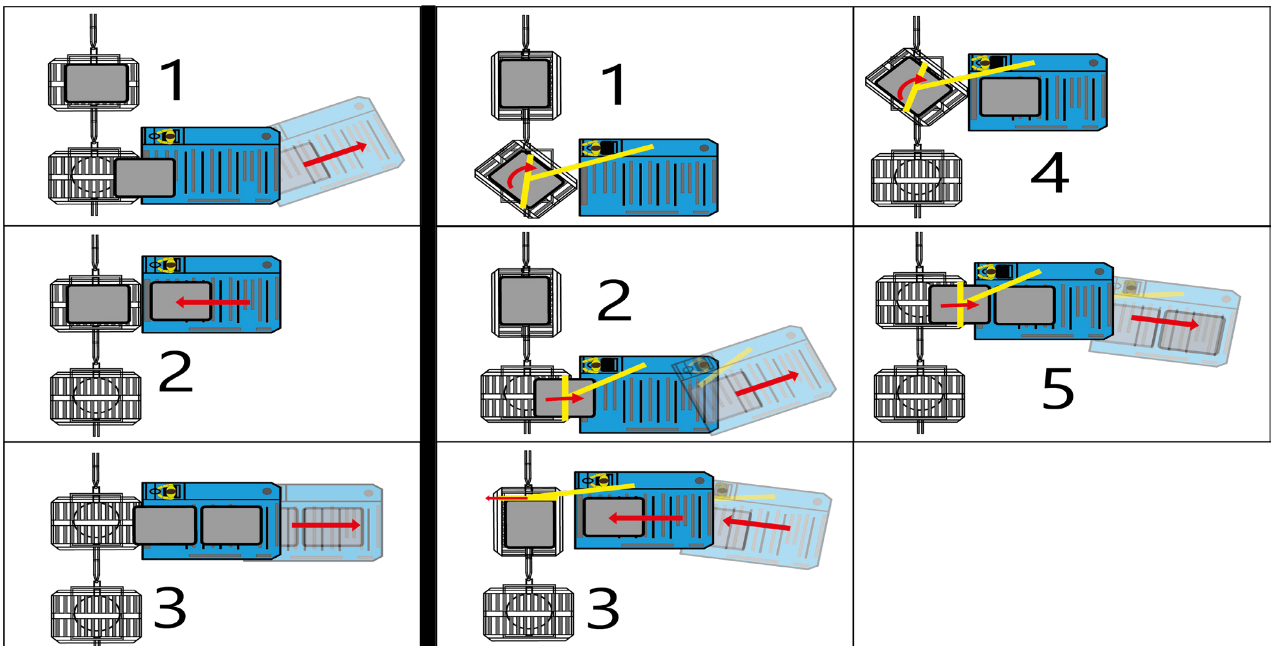


Fig 8.5. There are two steps extra needed from the transporter with the transporter arm.

Training and routines

criteria	weight	transporter arm(pull and rotate	powered dollies(battery)	powered dollies(equipment)	rotation gate	transporter rotates	Push bar
Implementation time	1	3	3	1	2	4	4
radicality of change	2	2	3	2	2	2	4
ease of use	4	2	4	3	3	3	4

"Training and routines" is the same as "implantation time", "radicality of change" and "ease of use" in the table.
The personnel of KLM is not very eager to change their routines, that was confirmed by the push assist that worked fine but was never used. In conversations the personnel confirmed it themselves that they do not like change. They say that they do this work for a long time, and change is not easy. It is not only the change but also their attitude in which they rather choose to do heavy work than to take an extra step to make it easier or lighter. Therefore the remaining solution are not possible to bypass.
The radicality of the change determines weather the personnel will accept the idea or not, if it changes there process too much they will not like it. The push bar has a good score, as it only takes a step out of the process. The rest of the concepts all add steps to the process, which makes it feel as a radical change to the personnel.
In the order of learning, the push bar is the most easy as the personnel only has to drive against it to work.
The transporter arm will require the most training and adaptation as the personnel needs to learn how to use a totally new tool and get acquainted with the aiming of the clamp on the arm.

Maintenance

criteria	weight	transporter arm(pull and rotate	powered dollies(battery)	powered dollies(equipment)	rotation gate	transporter rotates	Push bar
maintenance	1	3	3	2	4	5	4

The concepts all need maintenance, one more then the other. More maintenance on a product means more money spent, therefore it is important to take into consideration. Since everything of the apron service will be outside and exposed to harsh conditions, products will already need more maintenance.
The "transporter rotates" has a good score on maintenance because it already exists on the platform and do not require more maintenance than there is now. The powered dolly(equipment) get a low score because both the transporter and the dolly will have an extra mechanism with a lot of moving parts. That means regular greasing of gears and cleaning of critical parts. The rotation gate gets a pretty good score as it is the only concept that will not be moving around and could also be placed under a roof where the weather has less influence on the concept.

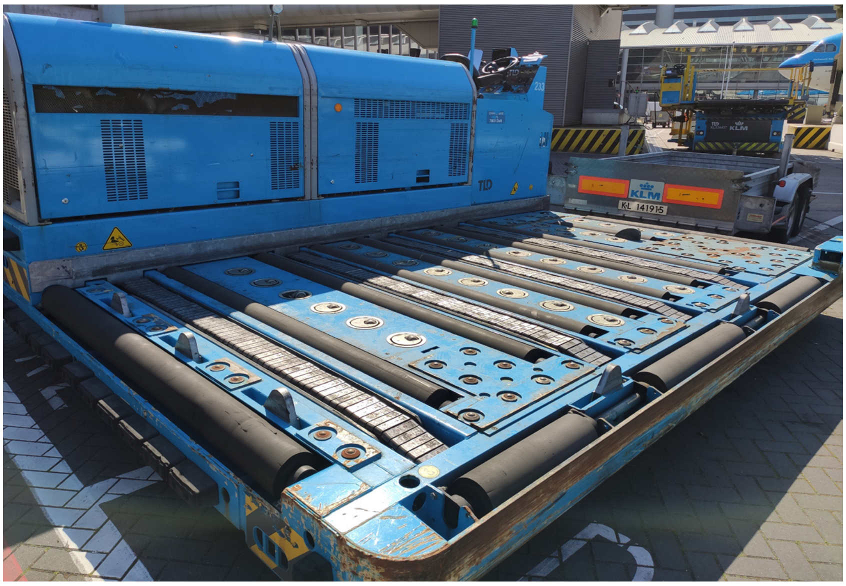


Figure 8.6 - Machines of the apron service work in harsh conditions as can be seen by the scratches and rust on this transporter

Size

criteria	weight	transporter arm(pull and rotate	powered dollies(battery)	powered dollies(equipment)	rotation gate	transporter rotates	Push bar
size	1	3	5	4	2	4	5

The platform is a busy place at all times and every meter of space is used. The space is needed to make the process as efficient as possible. Vehicles that have more space to make turns can make those turns faster or can do actions with one turn. More space also means a better overview and a safer workspace. Therefore, a solution that takes more space is not preferable.

The rotation gate takes space direct and indirectly. The gates will take up more space and should be suitable for other vehicles to pass, otherwise the gate takes even more space. If the gates are placed at the exits of the basement they would not take space on the platform which is better for the process on the platform. However that means that baggage trains will drive around with rotated dollies. Those rotated dollies are not very handy when driving around Schiphol, because most of the time the bagaggetrains have to make tight turns. Figure 8.7 shows that if a train with rotated dollies would drive the same line as the train with non rotated dollies that the rotated dollies will hit the wall. Concluding that when driving with rotated dollies the train need more room to drive and that employees have to adapt to driving with rotated dollies. Furthermore, driving with rotated dollies means that there has to be more space reserved on the platform as they need more room to pass between objects. The saving of space on the platform was exactly what was tried to prevent by placing the gates at the basement exits. As there is not really a place to put the rotation gates and the other negative points, the rotation gate will not be discussed anymore.

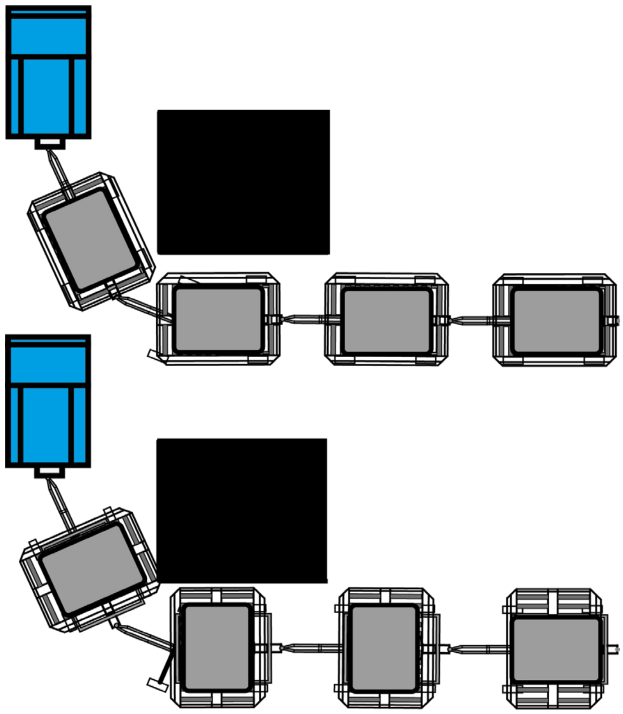


Figure 8.7 - Normal dollies cornering versus rotated dollies cornering.

The transporter arm will make the transporter bigger, even when folded. However this space is above the transporter, that does not matter for the space on the platform.

Figure 8.8. The platform is a crowded place, where a lot of machinery is driving around

Pallets

The physical burden on the platform does not only applies to containers, pushing pallets is part of the problem too. The only thing with pallets is that they do not have to be rotated to unload them from the dollies. Still, pallets have to be pushed off the dollies to get them onto the transporter(fig 8.9). Therefore, the solution should be able to work with pallets or has to be able to be changed into a version that can work with pallets.
Because only the transporter arm and the push bar could possibly interact with pallets it is not put in the table.

Figure 8.9- Pallets also have to be pushed manually onto the transporter

The transporter arm could work with pallets, as the clamp on the arm could hook behind the pallet and pull it off the dolly. This means the arm should be long enough to be able to lift the clamp over the pallet.
An issue with the arm is that pallets are often loaded with boxes that can be damaged when the arm pushes against it. Those boxes also lead to pallets with irregular shape of the load, which could make it hard to get a hold on. The arm could also be used in a way where it gets a hold on the front of the pallet, however that is a small piece of pallet to grab, plus overloaded pallets or nets can make it impossible to grab.

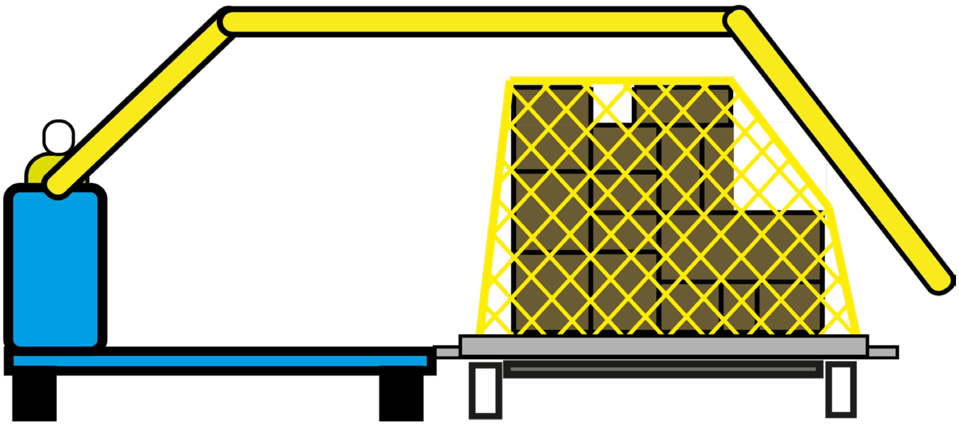


Figure 8.10 - The transporter arm pulling a pallet onto the transporter.

The push bar should be able to push pallets, but the transporter load pallets on the side and has to drive parallel to the dollies to load. Therefore to work with pallets the push bar should be rotated 90 degrees and the system will need some adaptations. However, the principle would stay the same.

Autonomous

criteria	weight	transporter arm(pull and rotate	powered dollies(battery)	powered dollies(equipment)	transporter rotates	Push bar
future perspective	3	5	5	5	4	5
Stand alone	2	5	4	3	4	3

Last wish of KLM is to make a solution that fits their ambition to make the platform totally autonomous in the future, meaning that more stand alone solutions better fits with the autonomous ambition. An advantage of a fully autonomous platform is that there are no employees and thus a transporter can make more turns to solve the problem of wrongly orientated containers. The transporter arm and the powered dolly can be made into autonomous working machines. Therefore, both concept will get a high score. Unfortunately KLM does not have the beliefs to make the full change within a year. The automation will therefore be done gradually and in the most safest way. In this case the transporter will be the last thing that will be automated, it is already one of the dangerous pieces of equipment on the platform right now. Making the transporter running autonomous on the platform will make it very unsafe. The transporter also has a driver, therefore it would not make sense automating it gradually. With the driver still on the transporter it makes more sense to let the driver do everything instead of only driving for instance. For that reason the transporter with the transporter arm has to become autonomous totally at once.
The powered dollies do not have to move on their own, which makes it safer and easier to automate their actions. The automation could go very gradually, first buttons, than a remote and in the end the load tool that communicates with the dollies directly when they have to rotate and which orientation.
The push bar is already autonomous in a way as the transporter only has to drive against the dolly, like pushing a button.
Concluding that the powered dolly and push bar are the best concepts considering autonomous platforms.

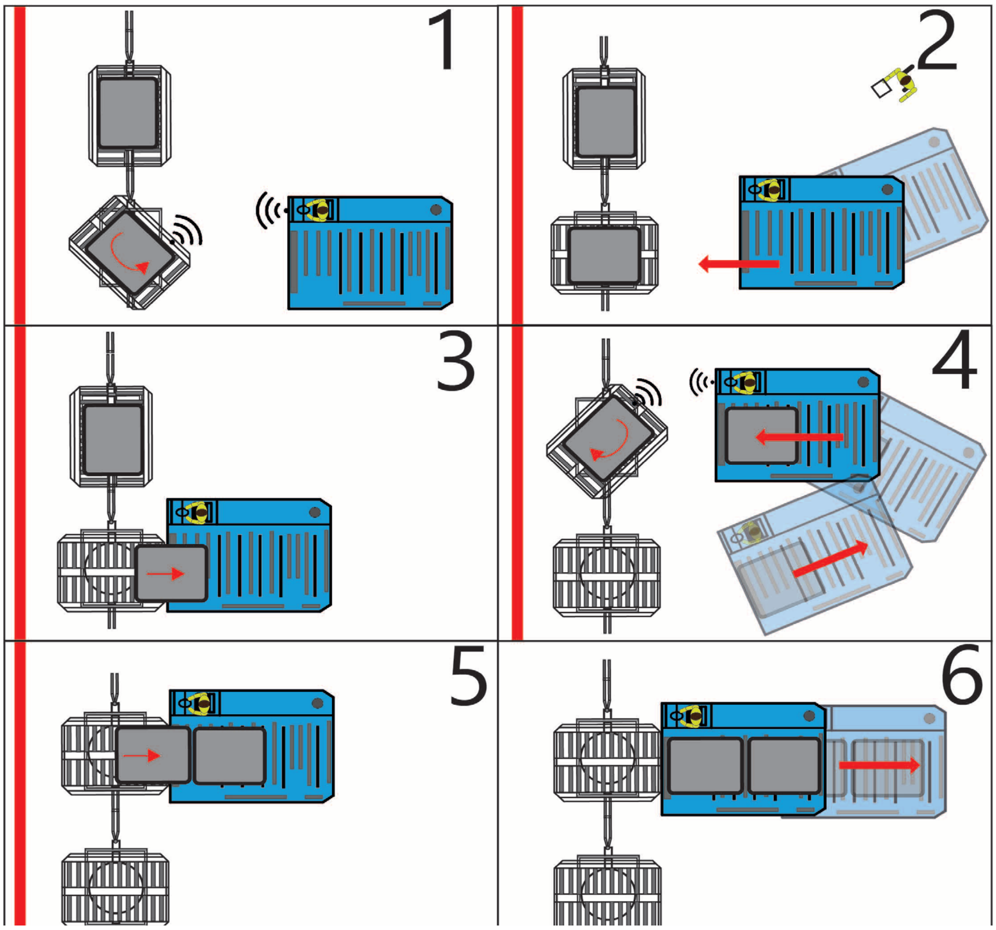


Figure 8.11 - A combination of the powered dolly and the push bar could make all the human labour concerning handling containers obsolete. In this scenario the transporter is in total control of the whole process.

Conclusion

criteria	weight	transporter arm(pull and rotate	powered dollies(battery)	powered dollies(equipment)	transporter rotates	Push bar
total		106	116	104	94	133

The transporter arm and powered dolly-push bar combination came out as best. Both concepts, The transporter arm and push off, greatly improve safety on the platform as there has to be no employee close to the dolly when the transporter is there.

Converging all the 37 transporters will take less time to implement and also less money compared to converging all 1350 dollies. However the investment on the dollies can be spread out over a larger period of time due to various steps in the transformation that can be done one at a time.

The powered dolly and the push bar are more efficient than the transporter arm. The powered dolly-push bar combination decreases the time it takes the grab and rotate a container. The transporter arm will not decrease the time, because the transporter has to do everything and the speed of the process is dependant on the speed of the transporter.

Both the transporter arm and the push bar make the employee who pushes containers on the platform redundant Therefore both save costs in terms off less personnel. However, the push bar and powered dolly are more efficient, therefore they have an even bigger economic advantage.

Looking at the future perspective of both concepts the conclusion can be made that a combination of the push bar and the powered dolly is the best. But also stand alone they are better then the transporter arm in solving either the rotation or the pushing.

9. Decision on the design process for the rotation

The solution for the rotation of container will not be elaborated at the same extend of the push off mechanism. The reason for terminating the design process for the rotation has to do with two things. One is the financial condition of KLM at this moment. The only projects that can pass the board are the projects with a significant financial advantage(internal communication, E. van der Jagt, 15-07-2020). The problem with the rotation solution is that the financial advantage only lies in the reduction of injuries of the personnel. The cost reduction will only be significant after a long period of time, when all the injuries are healed and absenteeism is lowered. There is no direct financial advantage because the rotation still needs a person standing at the dolly to push the button, which makes it financially less attractive. After the button is pushed the person has to wait at the dolly for the transporter to arrive and then push the container.

A remote control would solve that there has to be an employee at the dolly, but would make the investment significantly bigger and would be a whole project on it's own. To clarify, the remote needs software that should be written in such a way that every dolly could be controlled on every platform by every team captain. All the tablets of the team captains should be able to communicate with every dolly on Schiphol, but should also make a difference between the dollies on the intended platform and the dollies on the adjacent platform. Otherwise the team captain of one platform could rotate containers on the other platform by accident. That would mean that every platform should have it's own closed network that could only be accessed by the tablet of the team captain who is working on that platform. In this setup also the driver of the transporter could rotate the dollies by himself, and then the whole situation becomes interesting, especially when combined with the push bar.

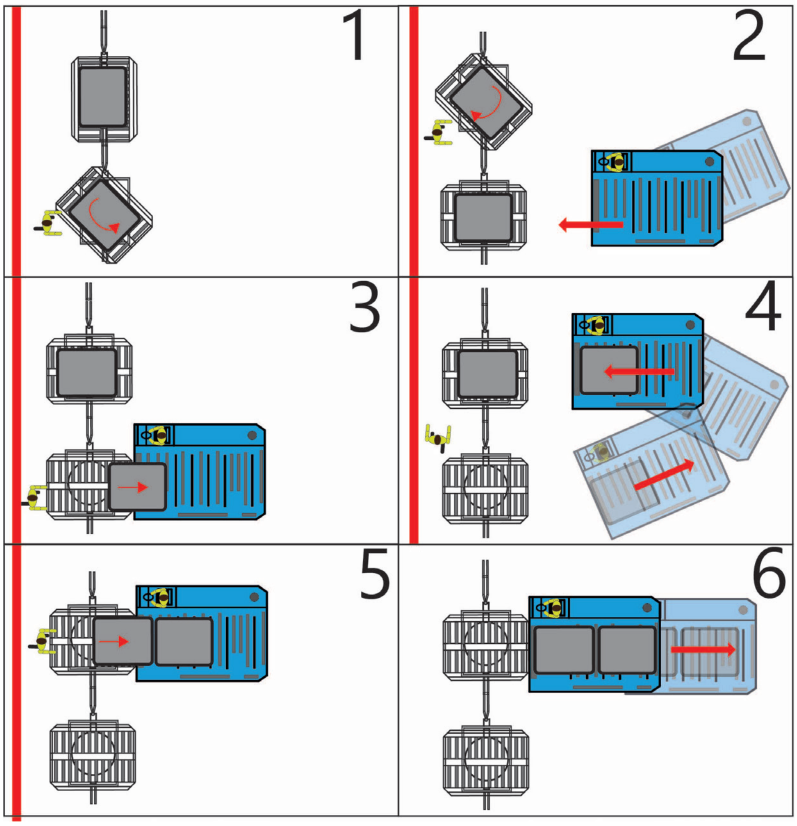


Fig9.1. An employee can at a maximum turn two containers before pushing them, but should always be waiting near those two dollies for the transporter.

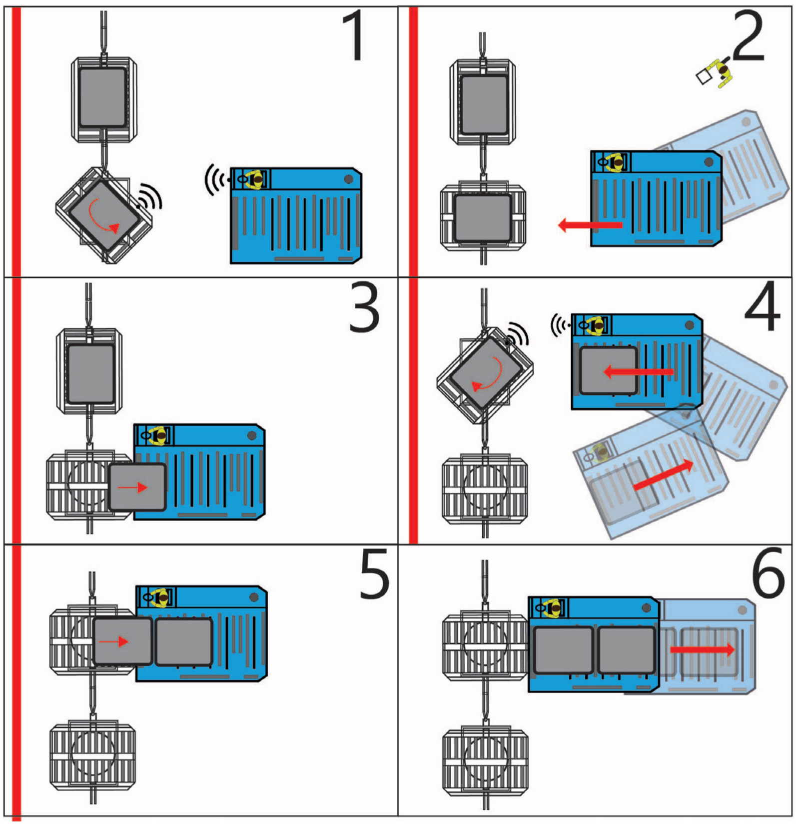


Fig92. When the tranporter would have a remote and the dollies the push bar, then the powered dollies become financially attractive

The second reason the rotation will not be elaborated is the opinion of S-P-S. The push-bar took their interest, but the rotation mechanism received a lot of criticism. They would not implement the electrical parts in the dolly because they thought it would be too fragile and they did not had faith in the durability of the electrical parts within the harsh environment of the platform.
Another argument was that their dolly should be altered to much, just at the moment that they are at the final stage of the development of a new dolly. The specifics of this dolly are not available yet, only certain dimensions of the top bed are known.(personal communication with Paul Schmitz(head of S-P-S) and Michiel Heikens(Contract manager and Account manager Ground Support Equipment KLM)).

The rotation of containers still forms a hazard to the health of the personnel of KLM. Because of that hazard a relatively simple concept will be described for future purposes. The forces concerning rotation can be found in appendix H and the concept can be found in appendix I.

10. Final design

The push bar will relieve the apron personnel from pushing containers. The task will be taken over by a mechanism in the dolly which is powered by the transporter. The personnel is relieved from an repetitive force exertion of 500 Newton, which is the force required for moving an average 900kg container filled with baggage. The personnel is also saved from pushing 900 newton to move a maximum filled 1500kg containers. Appendix J and G will show where these forces came from.

Figure 10.1 - In the current situation a push from the personnel is needed to move a container

Figure 10.2 - The current situation also requires the opening of the lock manually

In the new situation the transporter will open the locks. In the current situation the personnel has to open the lock by hand. With the push bar the locks open automatically when the bar is pushed. This does not only relieve the personnel from the action of opening the lock, but also gives the personnel the opportunity to keep a distance from the transporter.

Figure 10.3- In the new situation the transporter pushes to move a container without the need to open the lock

11. The working principle of the Push bar.

The Push bar uses the power of the transporter to get containers on and off the dollies, without any human force needed. The push bar consist of two bumpers on both sides of the dolly. the bumpers are attached to their own pulley mechanism, that will make sure a10 centimetre push on the bumper results in a 40 centimetre movement of the container. To exclude the human force from the process when loading container onto the dollies, the dollies are fitted with springs. These springs will pull the container onto the dolly. The working principle is presented in this chapter.

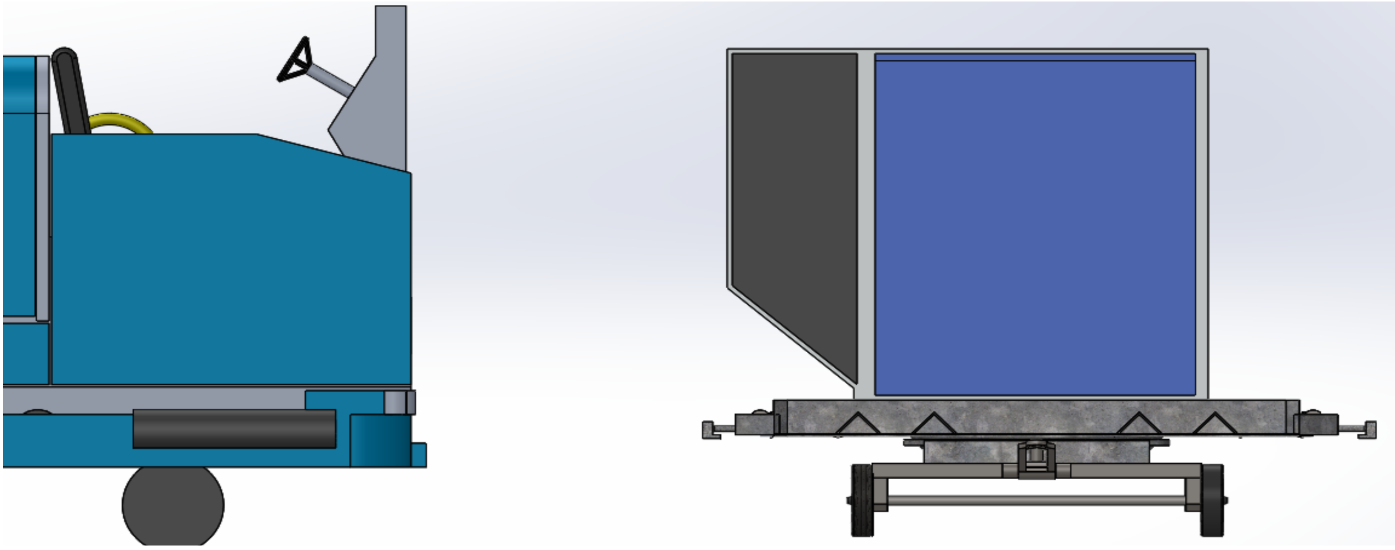


Figure 11.1- The transporter approaches the dolly

The transporter will approach a rotated dolly. The dolly has a container on top that has to be loaded. The container is already rotated by an employee in advance of the transporters arrival.

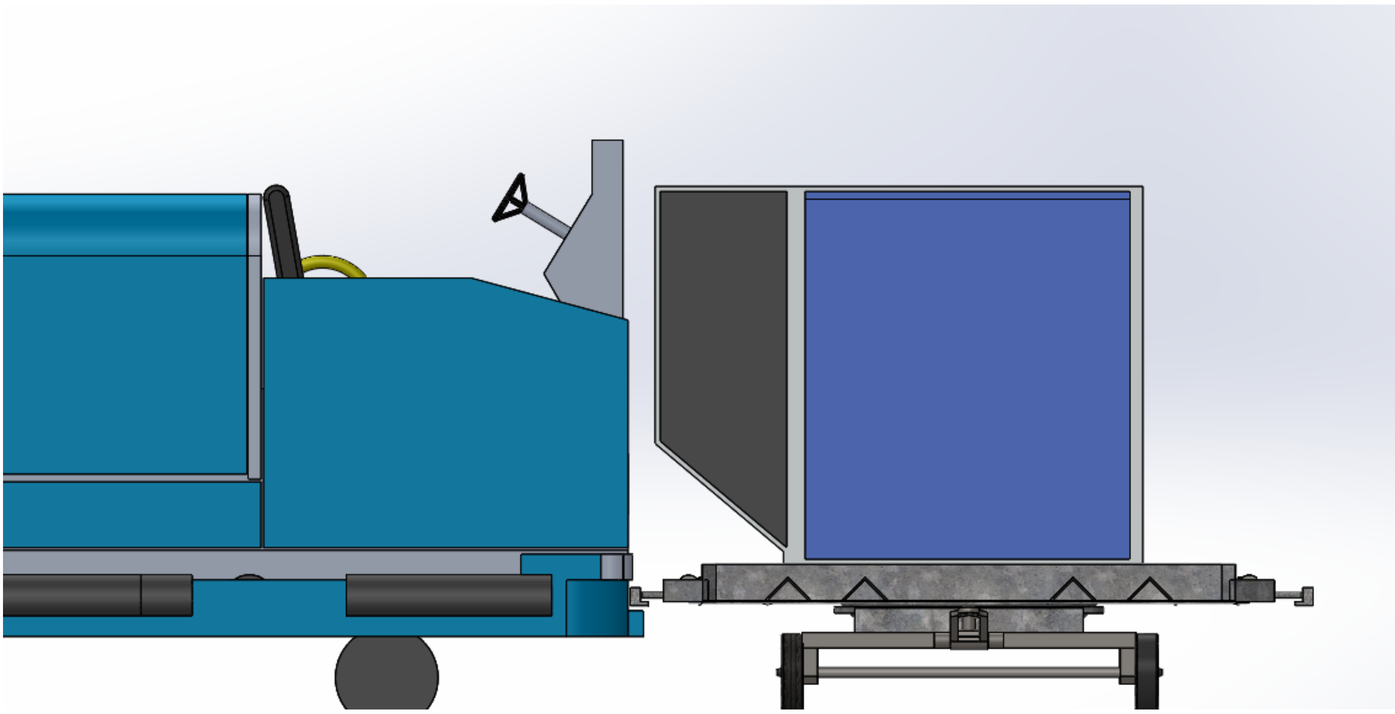


Figure 11.2- The transporter hits the push bar

The transporter positions itself in front of the dolly and drives against the push bar. The transporter can hit the push bar when driving because the push bar is designed to cope with the force of the transporter.

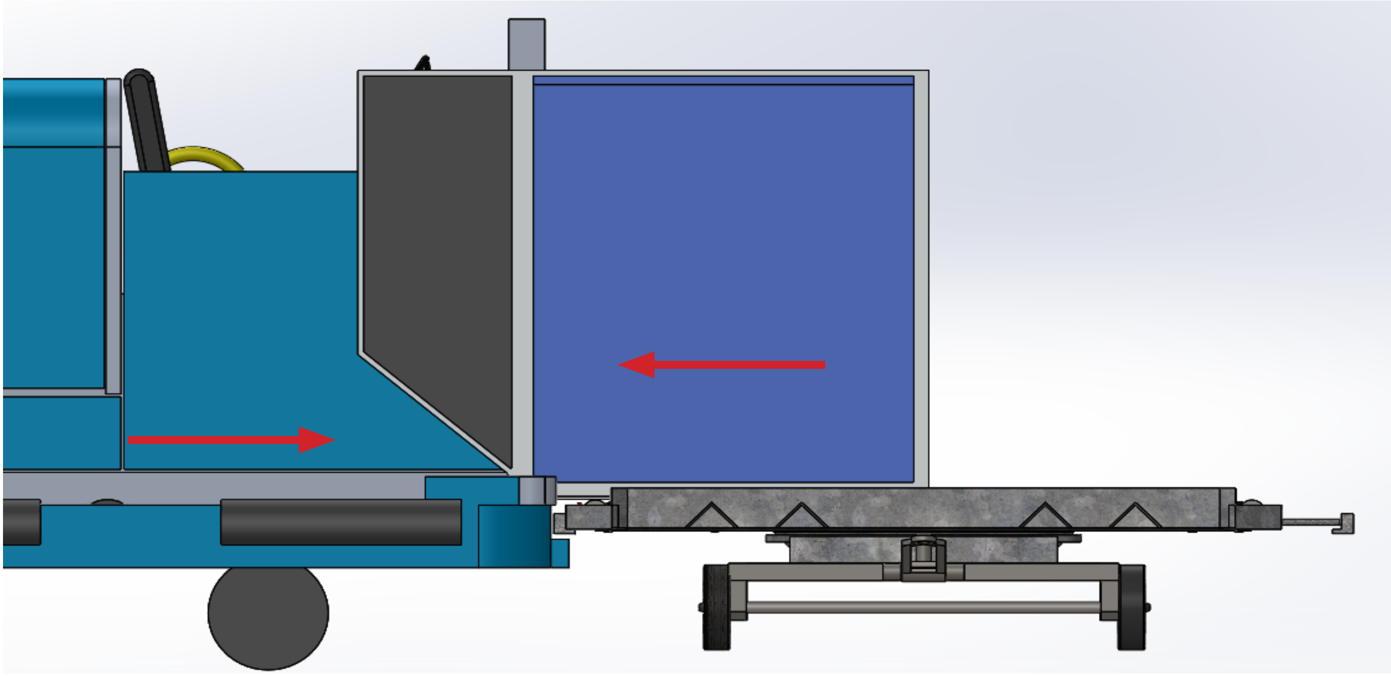


Figure 11.3- The transporter pushes the push bar and the container starts to move

The transporter drives further and pushes the bumper fully into the dolly. The movement of the bumper drives a pulley inside the dolly that will move the container towards the transporter

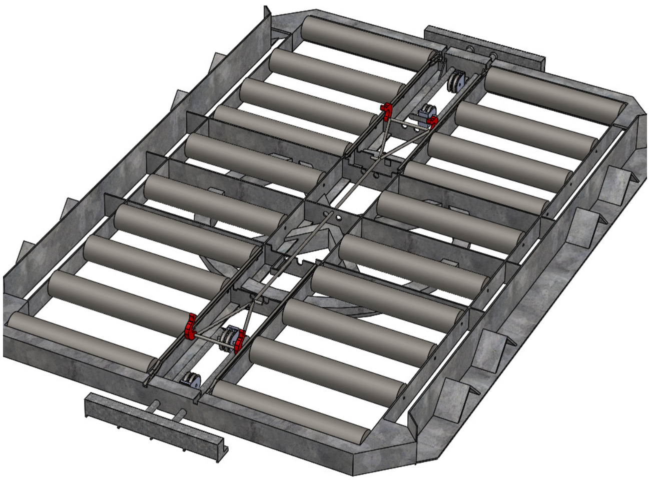


Figure 11.4- neutral position of the push bar

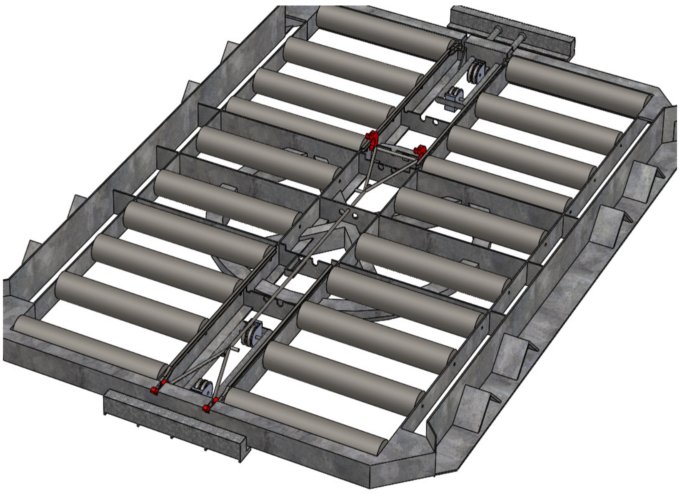


Figure 11.5-the push bar when fully pushes

Inside the dolly, a rod is connected to the bumper through a pulley system. Because of the pulleys the rod will move 4 times as much as the bumper. The hooks will grab the rim of the bottom plate of the container and transfer the force to the container.

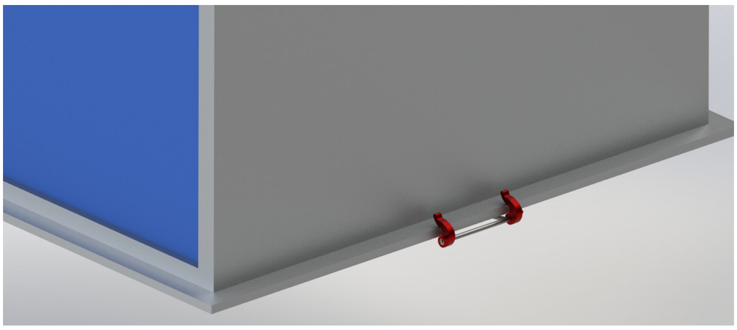


Figure 11.6- the hooks grab the bottom plate of the container

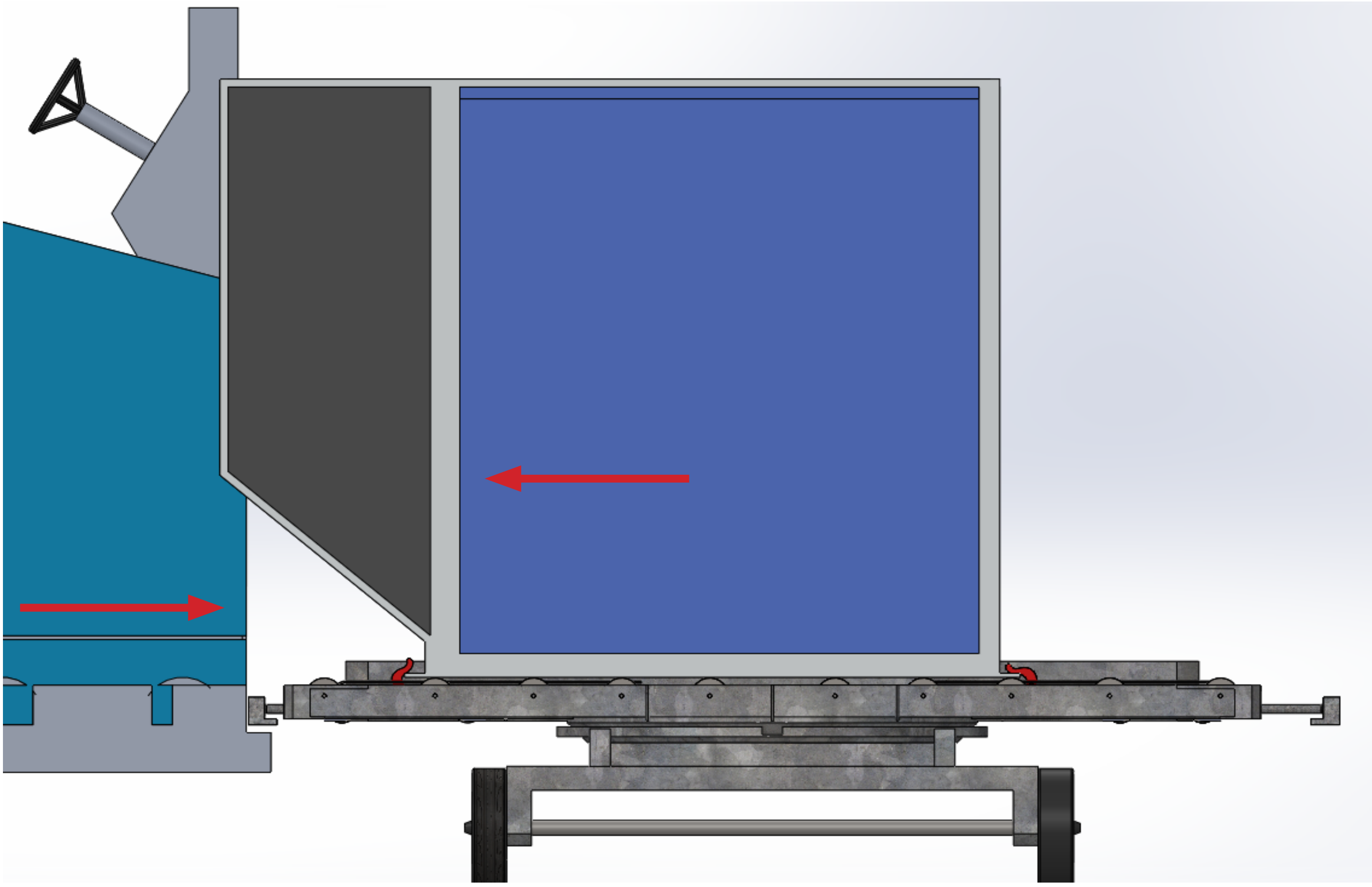


Figure 11.7- The transporter activates the mechanism inside the dolly

When the bumper is pushed the hook on the back of the container will push the container towards the transporter.

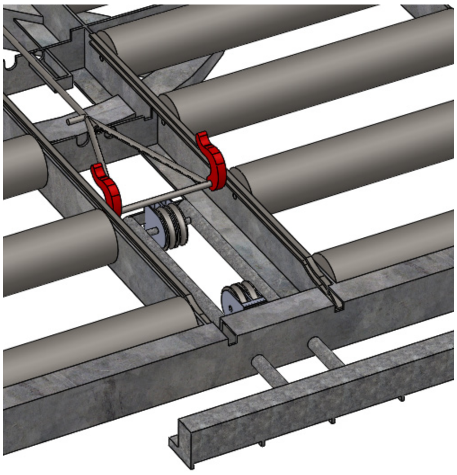


Figure 11.8- begin position

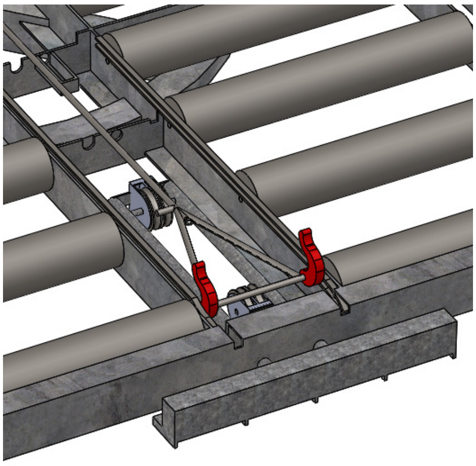


Figure 11.9- push bar half way

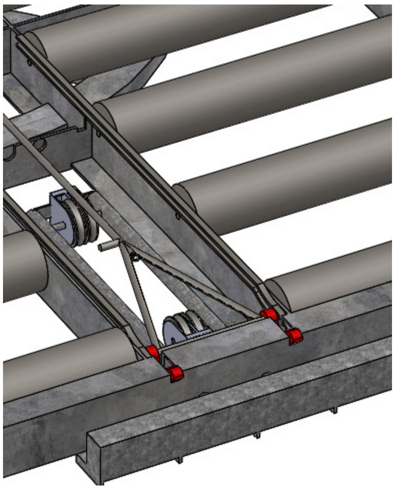


Figure 11.10- end position

At the last moment, at the end of the dolly, the front hooks will fold away to let the container off the dolly.

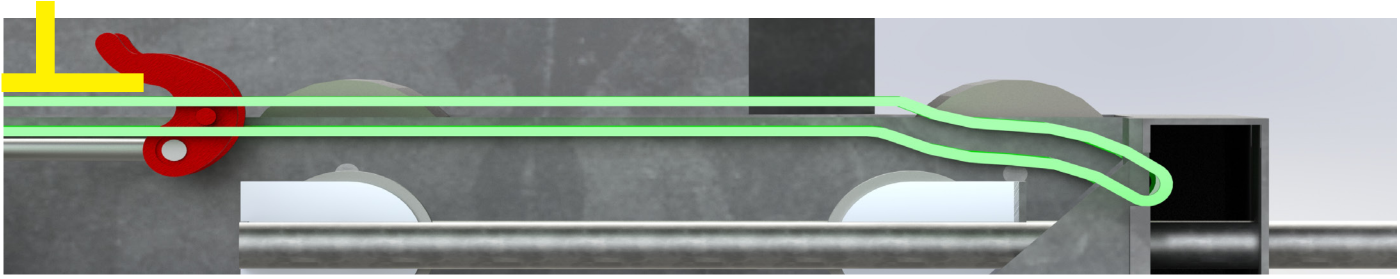


Figure 11.11- begin position

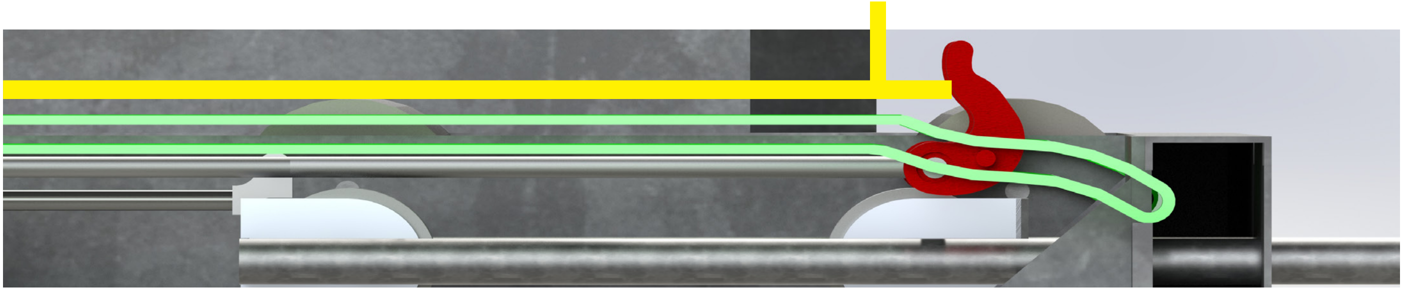


Figure 11.12- push bar half way

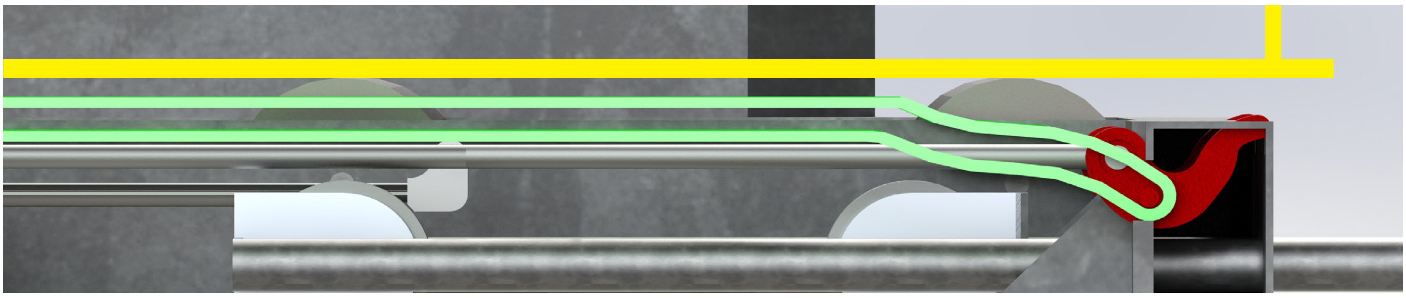


Figure 11.13- end position

The hooks are forced down as their pin moves through a slot that dips at the end of the dolly. The yellow lines represent the container.

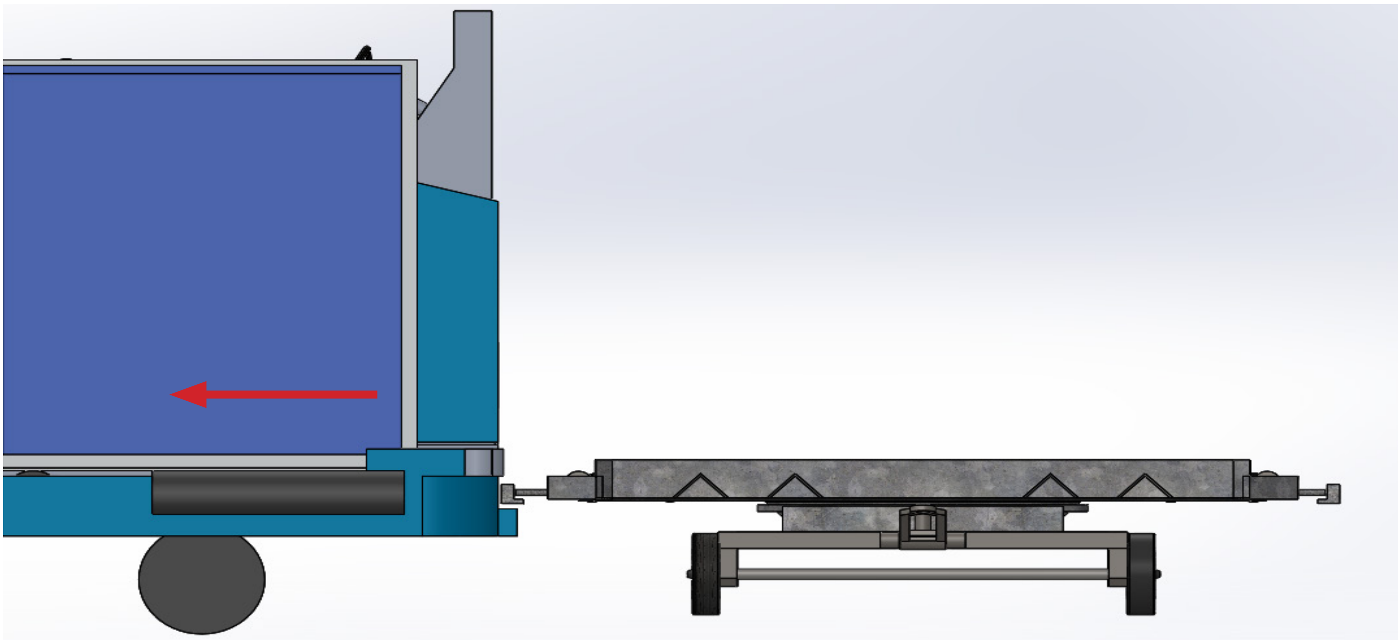


Figure 11.14- The transporter drives away

When the transporter drives away, the bumper is pushed outward. The bumper is pushed outwards because a spring inside the system pushes the rod back to the middle en therefore moves the bumper outwards. This resets the mechanism to its neutral position.

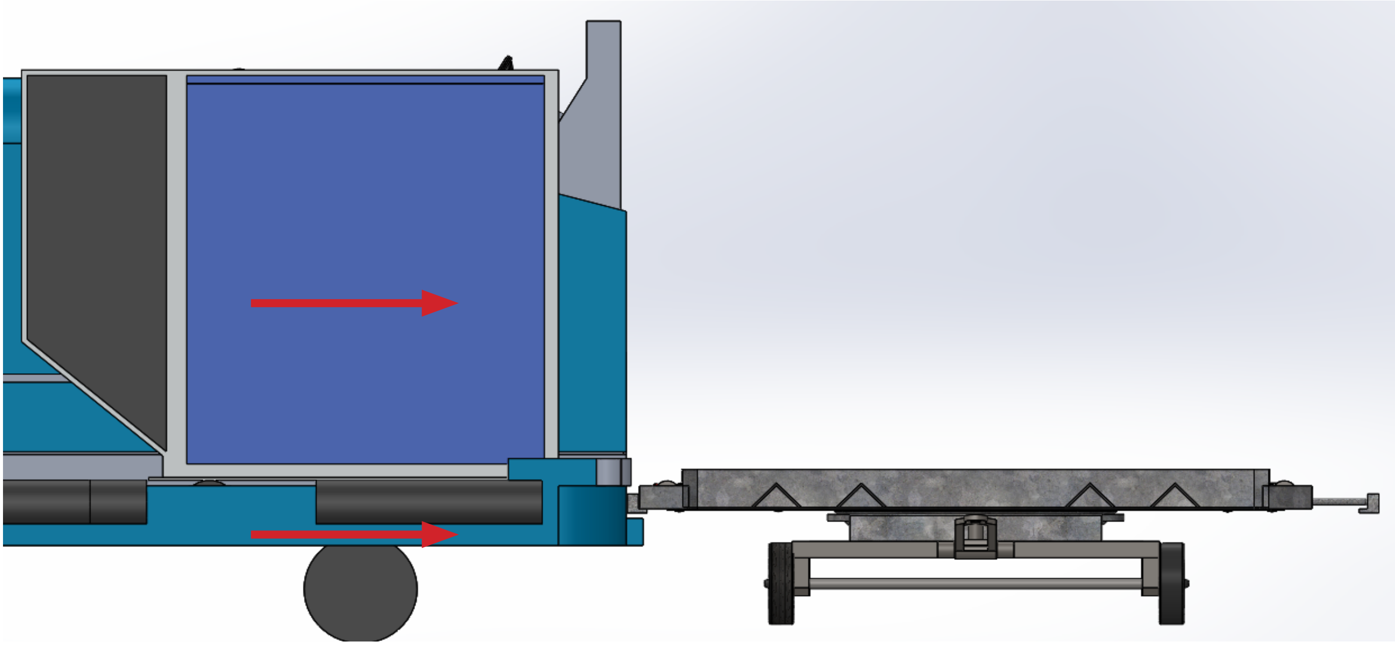


Figure 11.15- The transporter transports a container to a dolly

When a container needs to be loaded onto a dolly the process is just in reverse. The transporter drives against the bumper to move the system towards the transporter and open the hooks.

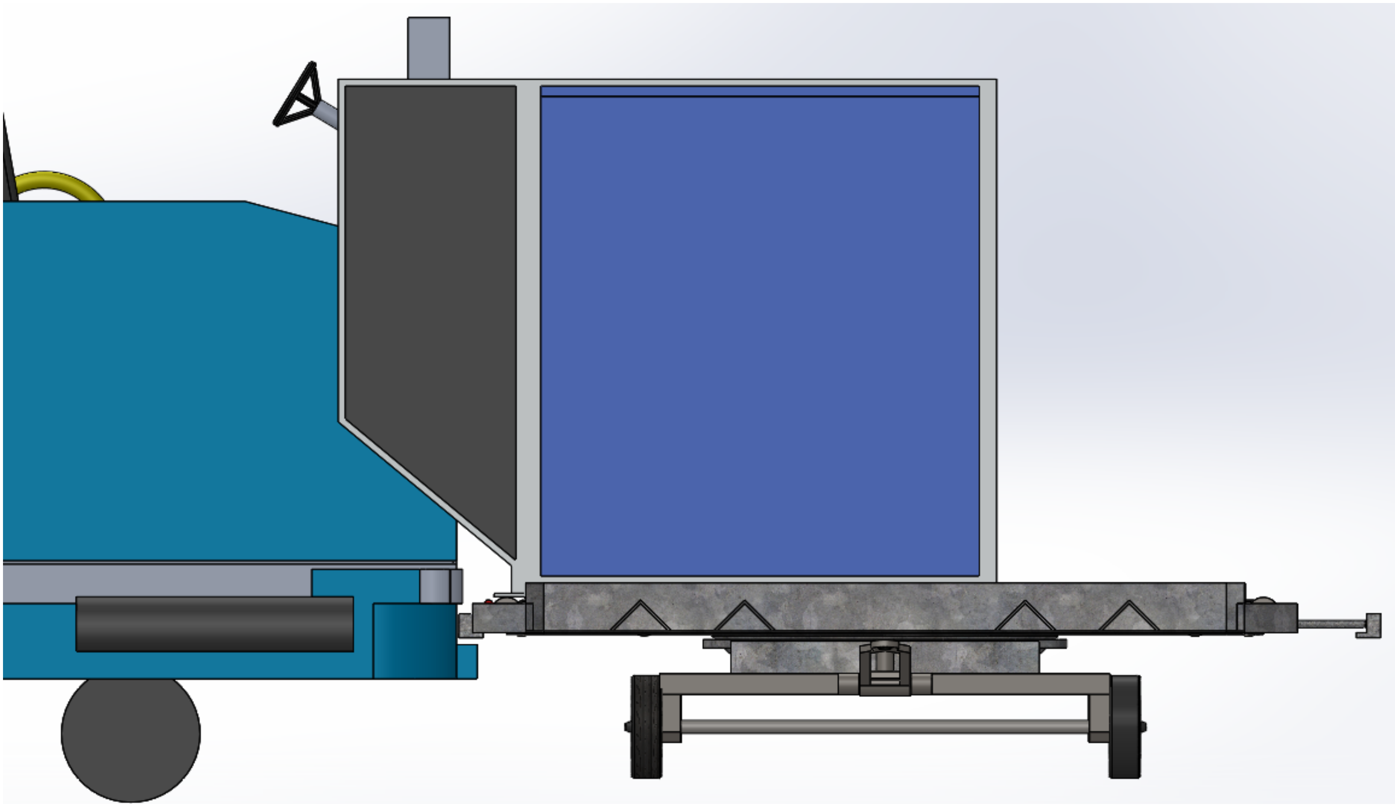


Figure 11.16- The transporter pushes the container onto the dolly

The rollers of the transporter pushes the container onto the dolly. The container has to pass all the way over the bumper to let the hooks grab the bottom plate of the container

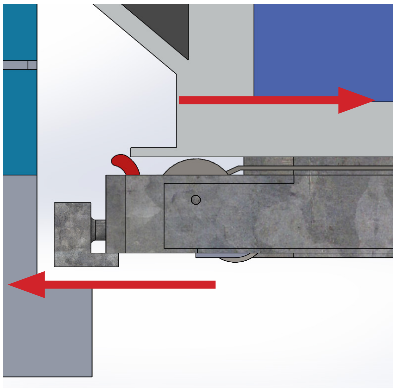


Figure 11.17-The hook is forced up

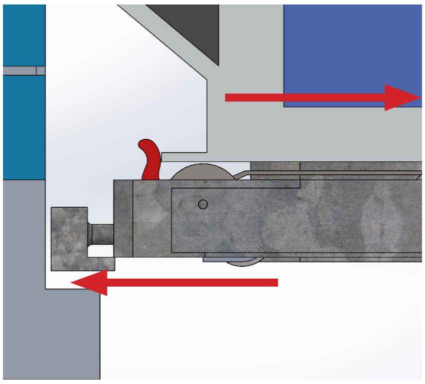


Figure 11.18- The hook pushes the container

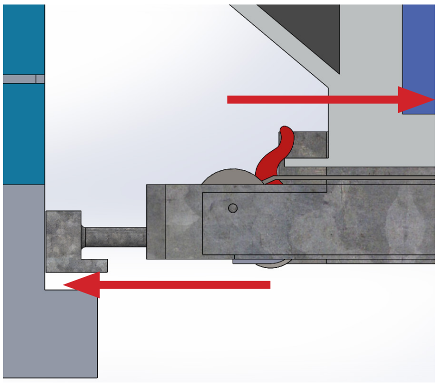


Figure 11.19- The hook fold over the bottom plate

A gas spring will make sure the system will return. The spring is strong enough to pull a fully loaded container onto the dolly. The hook has such a shape that it will first push the container into the other hook and than will hook itself over the rim of the bottom plate.

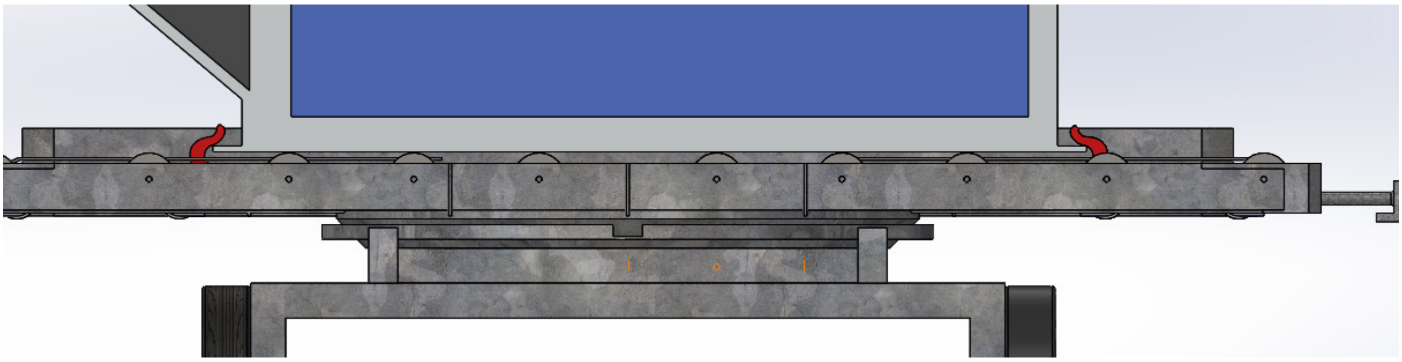


Figure 11.20- The hooks lock the container onto the dolly

The hooks will lock the container onto the dolly when the system is fully returned. Because the hooks are in the slots they can not move. The springs inside the system keep the system in its place horizontally. Both systems make sure the container is locked horizontally and vertically

12. Parts of the Push bar

This chapter will show every part with its requirements. For the exact calculations see appendix I and for the force simulations see appendix .J

Sled

The sled is the part that slides over the dolly and is the connection between the pulley system and the hooks. Also the spring system is connected to the sled. The sled is often revered as cradle but officially that is when the hooks are attached to the sled.

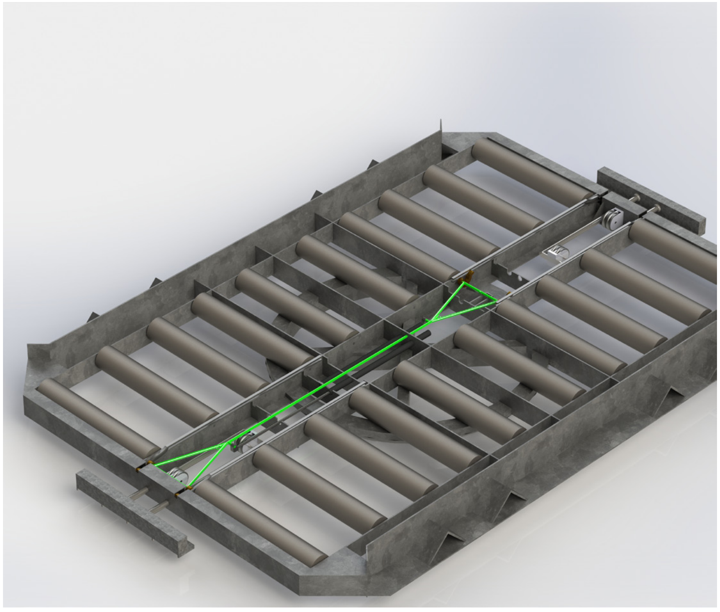


Fig12.1 Position of the sled within the dolly

Requirements

- Strain of 1348N
- Maximum elongation of 0,1mm
- Attachments for hooks and cable
- Less then 0,5 mm tolerance in sideways and vertical direction
- Contain a AKE container, 1562mmx1534mm

The strain

The most durable material to use in dolly's is metal, because is can cope with axial stress.
A metal rod of 10mm is use, to not make it to wobbly. A rod is chosen because the chance to get stuck, like in the prototype, is smaller than with a square beam. A rod also give the option to use relatively simple linear ball bearings, which will minimize the movement in the sideways and vertical direction
The minimum Yield strength required for the sled when handling the heaviest container possible is 0,015MPa. That value is achievable with almost every metal. The maximum elongation of 0,1 mm is also achievable with any metal rod because the Young's modulus only has to be higher then 2.8*10-4GPa, most metals start at a value of 10GPa(CES Edupack).
The material should be able to cope with the harsh surroundings of a platform(read: rough handling from personnel) it has to have a certain hardness on the Vickers scale. The material that comes forward is low carbon steel, which is often used in construction and mechanical engineering and is easy to process as well as in shaping and assembly(welding).
The price of carbon steel is relatively low at 0.67€/kg. Conclusively the Sled will consist one metal rod of 10mm in diameter and made of annealed AISI 1010 carbon steel. To protect it from corrosion it should be galvanized, something S-P-S does with most of their metal parts.

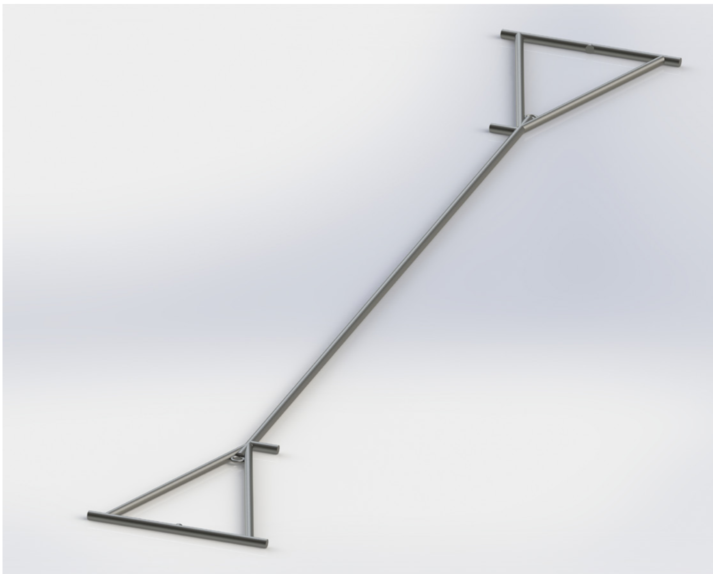
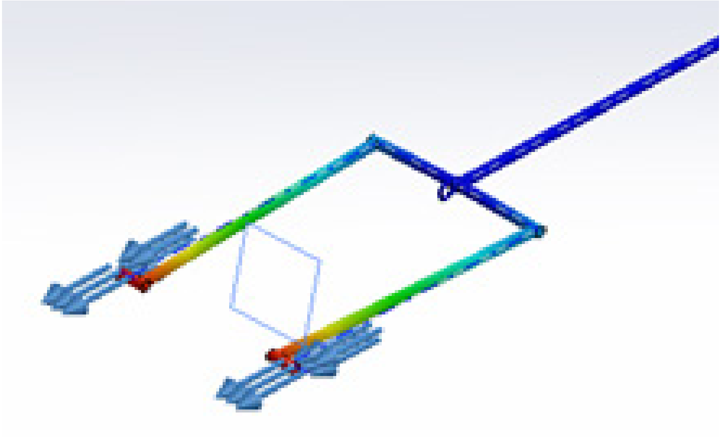


Fig12.2 The sled consist of a carbon steel rod with triangles on both sides

The sled is made out of one rod because it turned out that one simple rod was strong enough. Having only one rod also saves costs and is easier to implement in the dolly as less holes have to be drilled.

The square setup of the rods deformed to much at the end. The rods warped to the inside when a force was applied on the axles of the hooks. The warping could cause the clamping force on the container to increase, which could result in the hooks not opening when a container is pushed off. To counter the warping, the end is changed to a triangular one. The triangle distributes the forces better, and as a result the sled will have less warping.



The sled is fitted with a ring to attach the cable, the ring will be welded into place. Behind the split is a small rod to attach the head of the spring. At the end of the triangle are two small ends to attach the hooks to. In the end all rods and accessories will be welded together.

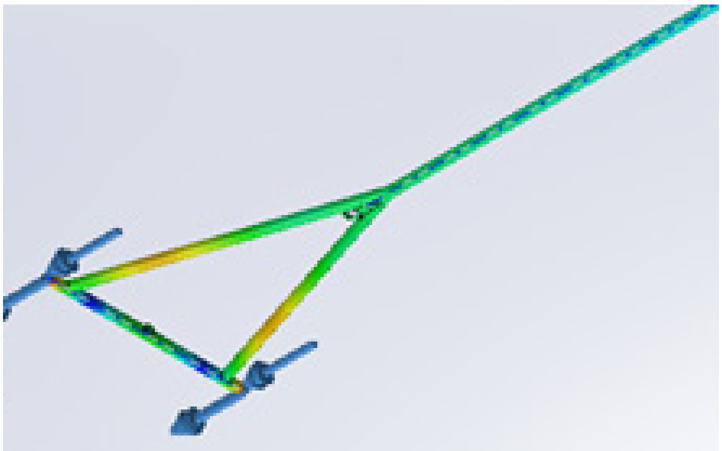


Fig12.3 Difference in deformation of the different sled heads. The colors show where the most stress is occuring. Note that the bottom sled is almost totaaly green. that means that the stress in the whole sled is the same

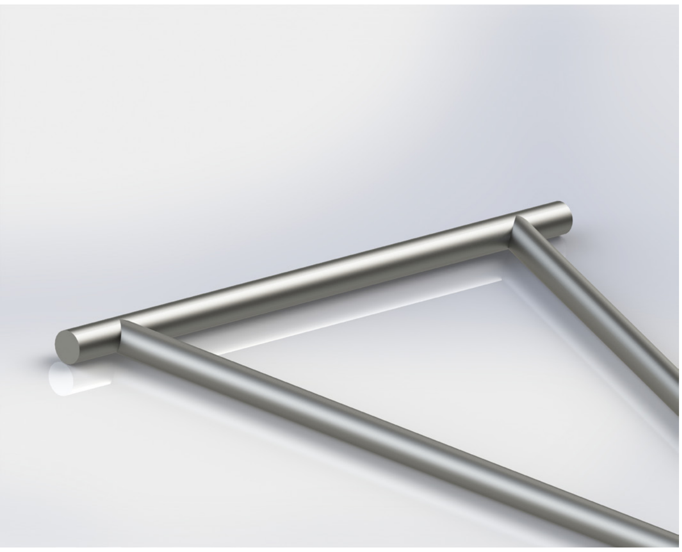


Fig12.4 The head of the sled, with the axles for the hooks

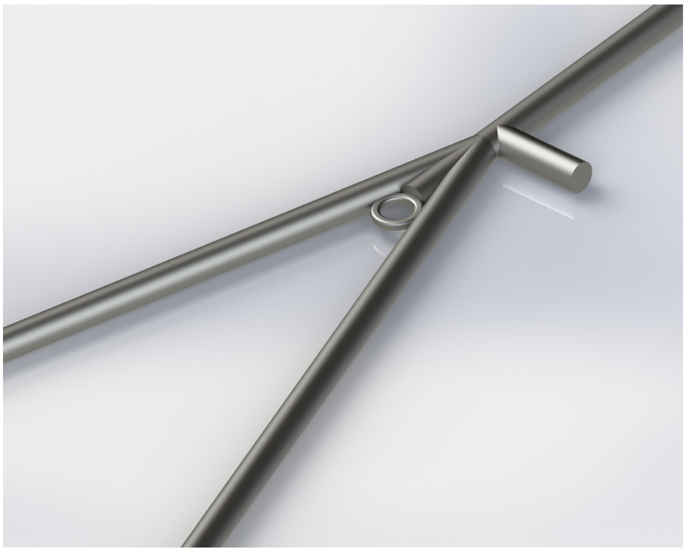


Fig13.5. The sled has a ring to attach the steel cable to and an axle to attach the gas spring .

Bumper

The bumper sticks out of the dolly on both sides. The transporter drives against the bumper to activate the system. The bumper is connected to a part of the pulley system inside the dolly.

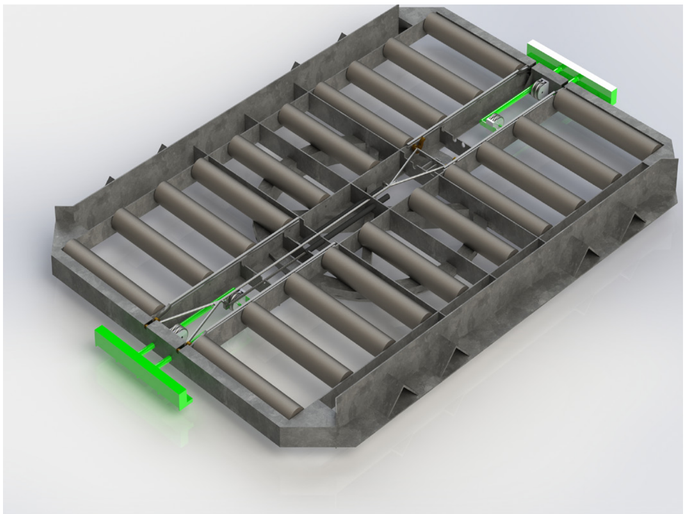


Fig12.6. The position of the bumpers on the dolly

Requirements

- A shear force of 7680N on the external part
- Deformation of the external part of maximum 2mm
- Pressure force of 70000N on the external part
- A impact force of 70000N on the external part
- Axial load of 7680N on the internal structure
- Attachment for the pulley
- Minimal range of motion of 100mm
- Maximum buckling deformation of 0.5mm

Buckling

A disadvantage on the prototype was that a straight rectangular member for the bumper rods were getting jammed in the frame of the dolly. Bearings can prevent the jam from happening. However circular bearings are cheaper plus a rod on is own is already less vulnerable to getting jammed. When the transporter is driving against the bumper the rods will receive an axial load and therefore can buckle under that load. Calculating with a carbon steel rod it will result in rods with a diameter of at least 12mm.

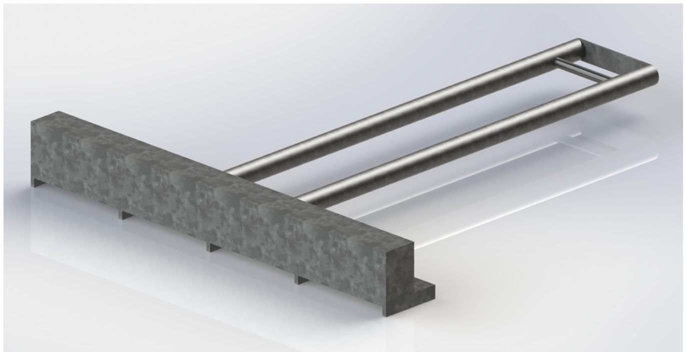


Fig12.7. The bumper

Bending 1

It can happen that the transporter hits the bumper at an angle. The biggest angle will be 18 degrees, when the bumper is at 100mm of the dolly, as otherwise the transporter will hit the side of the dolly. If the transporter hits the bumper at an angle it will result in a perpendicular force on the rods of 2194N. Two rods of 16,4mm will suffice for a maximum deflection of 0,5mm The deflection decreases exponentially. When the bumper is pushed more into the dolly the length of the rod decreases and the angle the transporter can push also decreases. For example if the bumper is at 75mm from the dolly the deflection is already decreased to 0,37mm.

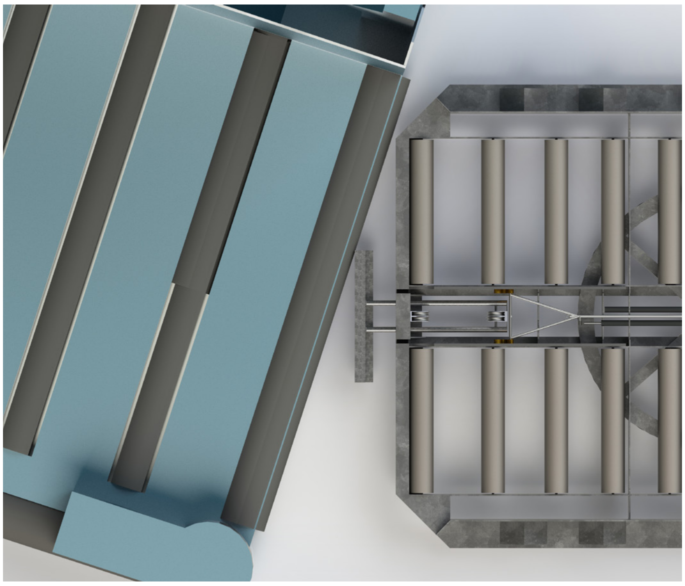


Fig12.8. The transporter hitting the bumper with an angle

Shear force

The shear force on the bumper is a result of a maximum loaded container and the spring that both have to be pushed, in total that will be a shear force of 6920N. The transporter can push more but then the mechanism will be moving until the bumper hits the frame of the dolly. When the bumper is against the frame the shear force will disappear and only a pressure will remain. The bumper will be made of the same steel as the sled. A bumper with a wall thickness of 0,2 mm would be enough to counter the shear stress. However with that thickness the bumper will be deforming to much. The thickness will be determined by the amount the bumper will bend.

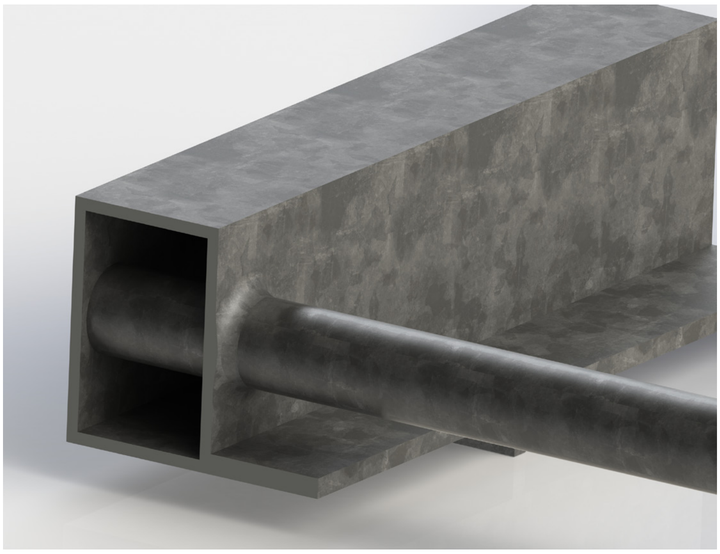


Fig12.9. Section view of the bumper

Bending 2

Work on the platform happens fast, therefore the bumper will not always be pushed right at the centre of it. To give the bumper more strength on the critical part in the middle, the rods are moved through the bumper. It is not bad if the bumper bend a little, as long as it is not permanent or too much. Maximum bending at the end of the bumper can only by 10mm otherwise the mechanism will not work anymore. The beam can be 60mm high to leave enough space for the hooks to fold down. It is preferable to have a beam that is higher then it is wide, because the transporter has to lift the dolly by the beam. The lifting is heavier than the pushing, therefore more height in the beam is preferable. The assumption is made that the transporter pushes on the furthest end of the bumper which is 200mm from the centre of the bumper. A standard beam with a height of 60mm, a width of 40mm and a wall thickness of 1.5mm(Structuralsteel, 2020) will be enough to stay within the10mm deformation.

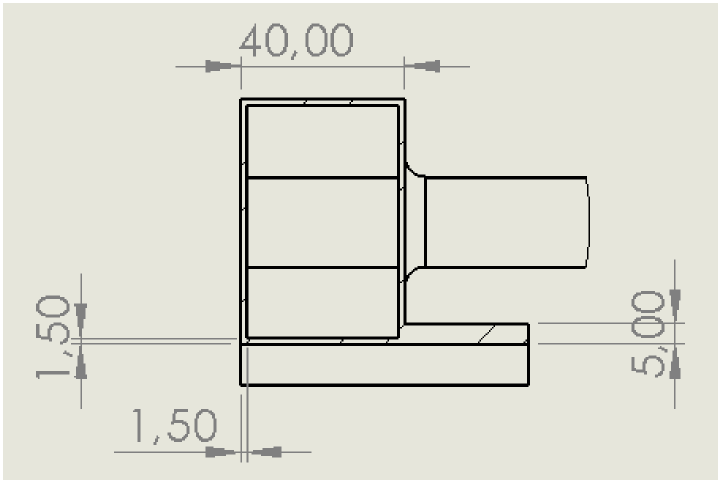


Fig12.10.dimensions of the bumper

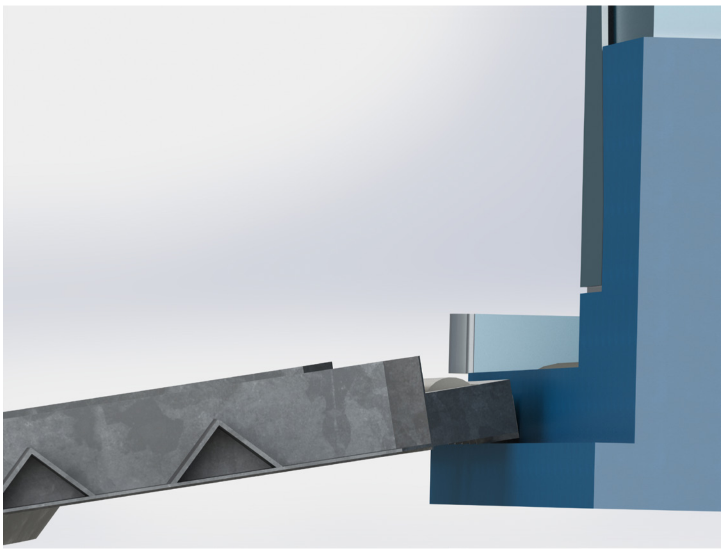


Fig12.11. The transporter uses the rim to lift the dolly

Shear 2

Not every dolly works as smooth as it should and not every container has the flat bottom it should have. Plus every dolly is placed on the edges of the platform where the slope always descends towards the aircraft. What the driver of the transporter does now to overcome both problems is to lift the dolly a bit and let gravity do the job to load the container on the dolly. With the mechanism those problems can still occur. To give the driver the possibility to lend a hand to the mechanism the bumper has to be designed to be strong enough to lift the dolly with a fully loaded container. However the rods will deform too much under the weight, therefore a plate is welded to the bumper. The plate goes under the dolly when the bumper is fully pressed. A single plate seemed not enough to cope with the weight, to solve that, 5mm thick and 10mm high plates are welded perpendicular under the bumper(fig 13.12&13.13).

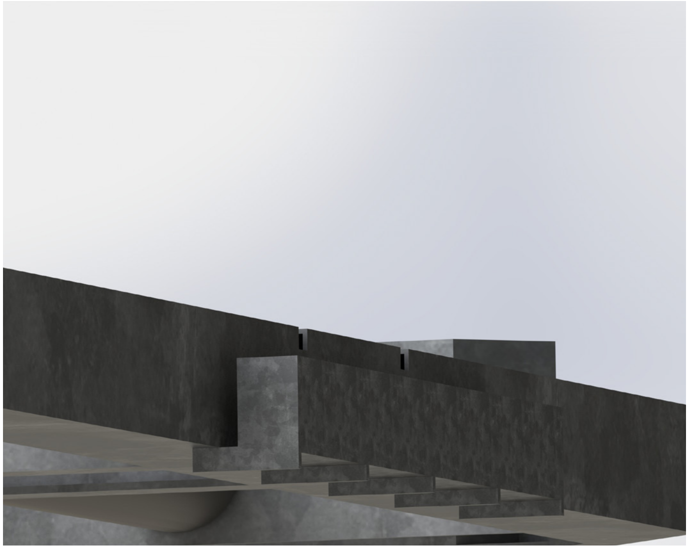


Fig12.12.The bumper has to be fitted with structural plates to prevent it from bending to much.

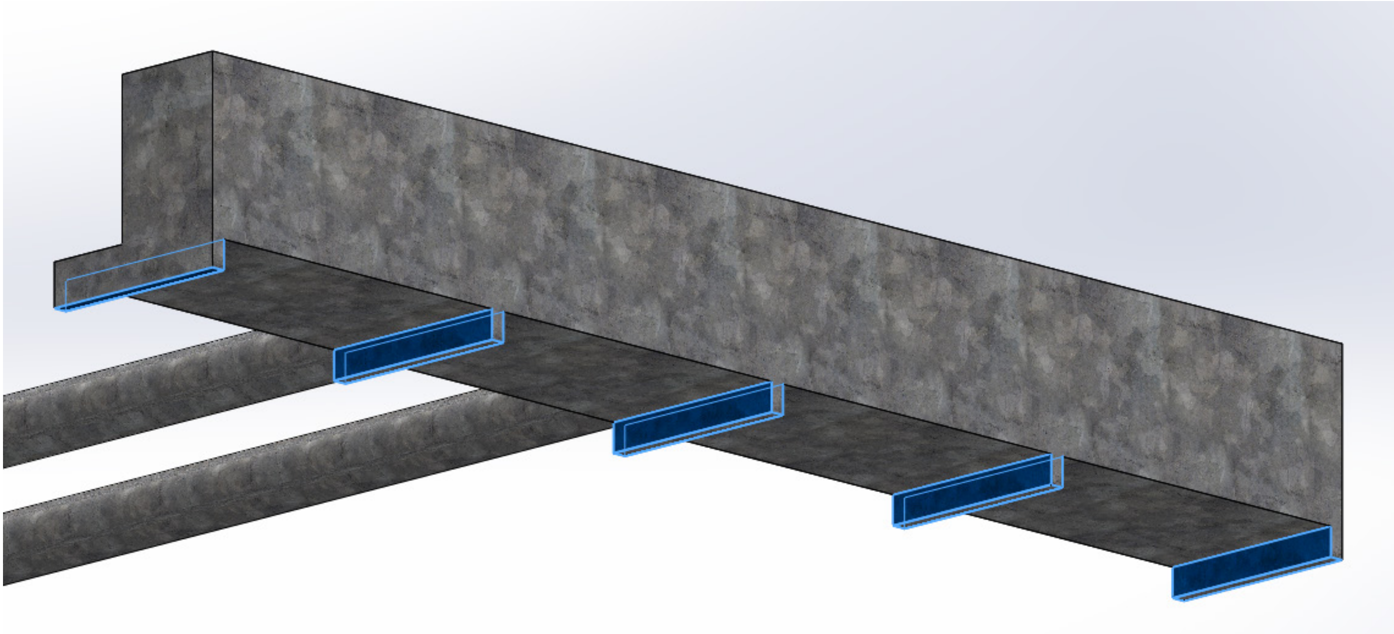


Fig12.13.The structural plates are highlighted blue in this image

Pulley

The pulley translates the motion of the bumper into a bigger motion of the sled. The pulley is attached to the dolly, bumper and sled. The change to a pulley system instead of a gear system has to do with the cost and complexity of the system. A pulley system is much cheaper then a gear system,because pulley systems can be bought in standard versions and a gear system has to be custom made, especially the rack and pinion parts. The gears also gave a problem of switching the gears rotation direction, which was solvable with a switch. The pulley system does not need a switch to change the direction of motion.

Requirements

- Shear force of 1920N on the axles
- Steel cable capable of pulling 1920

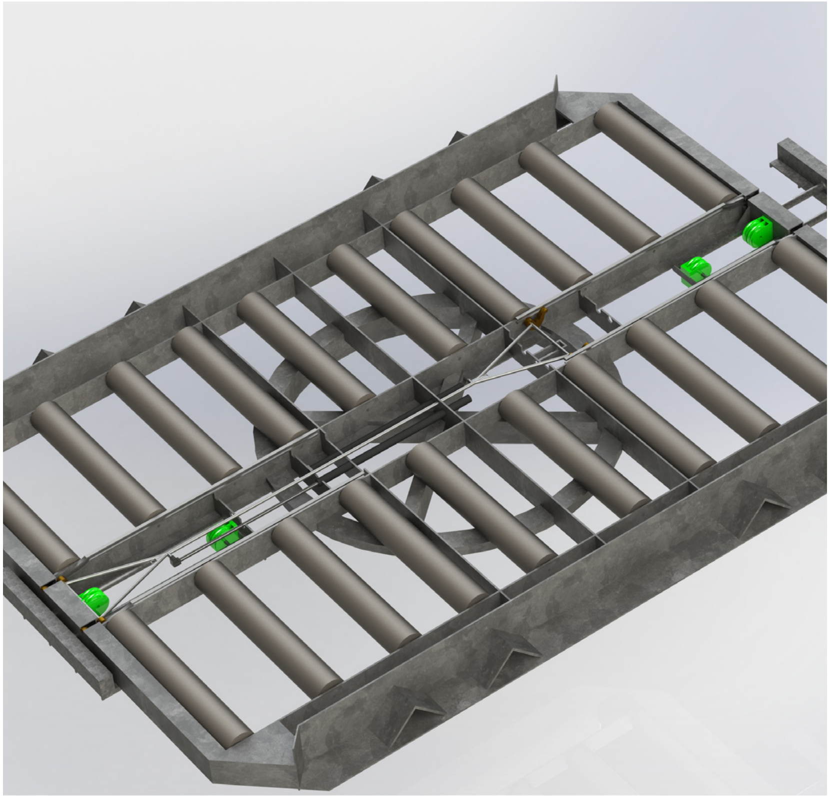


Fig12.14.location of the pulley's on the dolly

The pulley should be suitable for a cable that is 6mm thick. A steel cable of 6mm thick can hold the force of 8220N, which is more then enough to work with the maximum force of 3460N that will be on the rope.

The pulley's themselves are standard pulley's that can work with a maximum load of 6800N per wheel(Farmtec, 2020). The sheaves of the pulley are made of Lubra-Tuf™. Lubra Tuf, also callled Ultra-high-molecular-weight polyethylene (UHMWPE, UHMW), is a self-lubricating plastic which is very wear resistant(Trademark, 2016).

Fig12.15.Standard pulley(Farmtec, 2020)

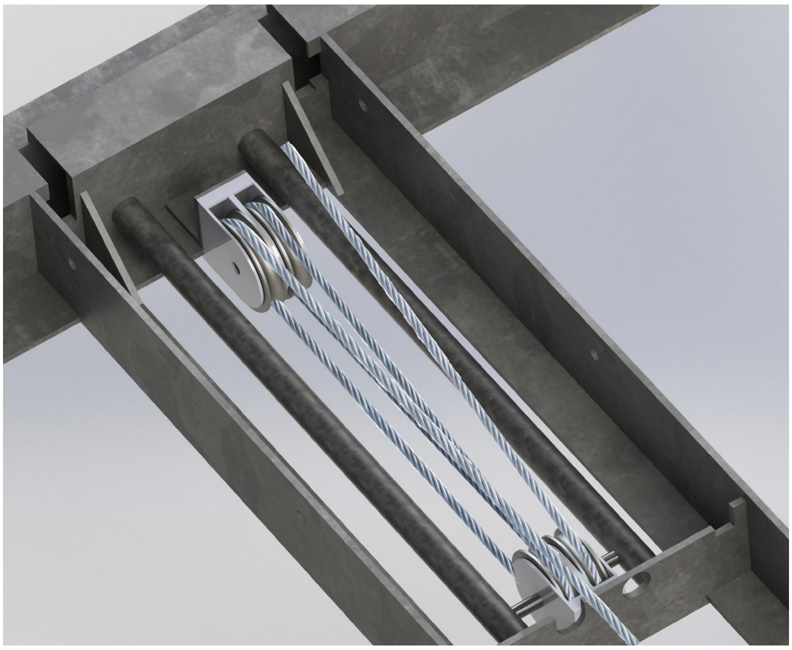


Fig12.16.Pulley with the 6mm cable

Hooks

The hooks grab the container behind the bottom ledge when the container is pushed off the dolly or pulled onto. The hooks also push the container enough of the sled so the transporter can get a grip on the container. At last the hooks lock the container onto the dolly in a horizontal position and vertical position.

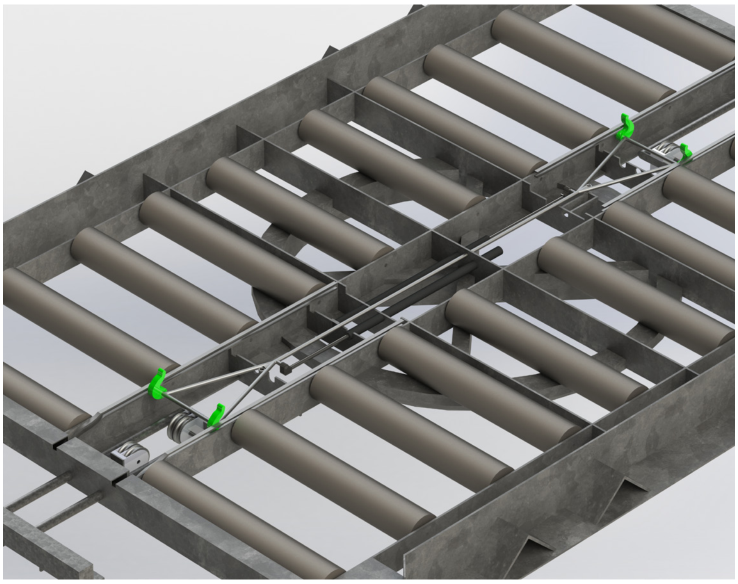


Fig12.17.Position of the hooks

Before beginning on calculations a study was done on the shape of the hook. A rough cardboard version of the same hook that is used on containers right now, got jammed on the container edge too many times in the test. The second hook was made round to see if a smoother opening would help. That helped a lot, but the hook got stuck on the last point.
Different variations on the second hook were made out of plastic, but each one got stuck on the last edge. The last version has a little arch on the end, which prevents the hook from getting jammed. The arch also helps to load a container on the dolly as it makes sure the hook get on top of the rim of the container. Smaller and bigger hooks were also compared, smaller hook were better because they locked the container better. A smaller hook also mean a smaller slot in the dolly for the hook to fall into.

Fig12.18. The evolution of the hook.

Requirements

- Shear force of 1348N
- Maximum deformation 0f 0,5mm
- Always open and close

Fig12.19.Hooks on the end of the sled

The Hooks have to be at least 15mm thick and 10mm wide to cope with the shear stress and to make sure they do not bend more then 0,5mm. The best way to make the hook is by casting it. That is the cheapest way to do it and is also common when producing crane hooks(Iron Foundry 2020 & Sunlightforging 2020). The tip of the hook became 5 mm thicker in the end as simulations showed there was too much stress in the tip

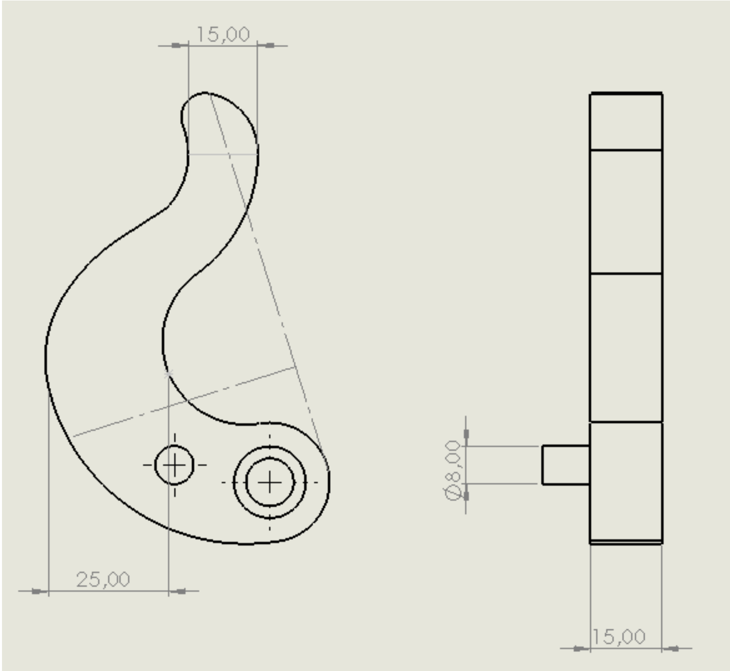


Fig12.20.The final measurements of the hook(do not scale)

Spring

The springs have to make sure a container can get onto the dolly from the transporter. The springs also make sure the container stays locked during transport. The choice for gas springs was needed because a normal spring(coil spring or elastic rope) in the prototype was increasing in force over distance, that means that at the end the spring is very powerful, but in the beginning very weak. The variation in force of the spring can cause the container to be catapulted onto the dolly or not make it to the middle of the dolly. A gas spring however, has an equal force distribution, it stays the same, no matter the position.

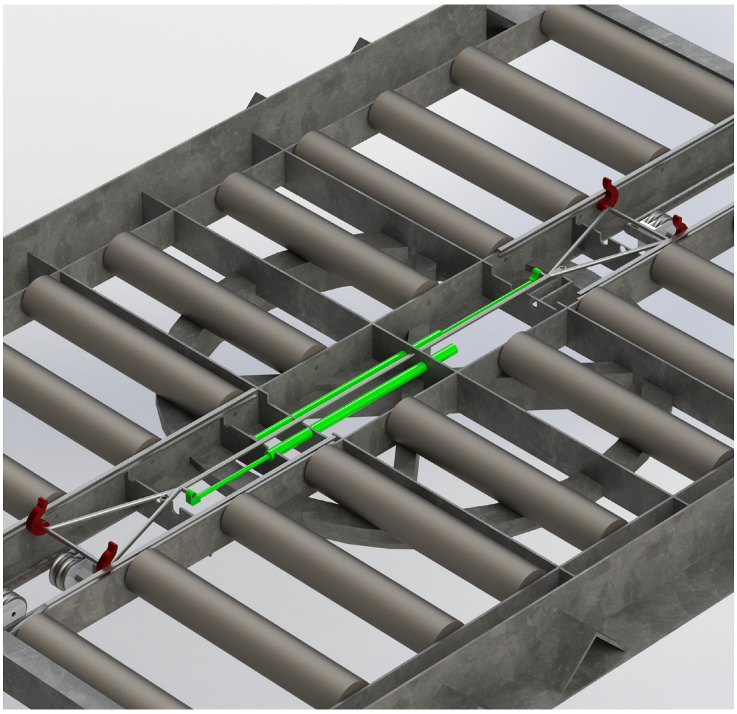


Fig12.21.The hook will grab the rim at the bottom of the container

Requirements

- Maximum force of 900Newton
- Range of motion of 400mm

Fig12.23. Standard 1000N gas spring (Rewald, 2020)

A standard gas spring will be used with a stroke of 400mm and an a force of 1000N(Rewald, 2020). The force is close to the required force, as a result the container will be pulled gently on the dolly instead of being catapulted.

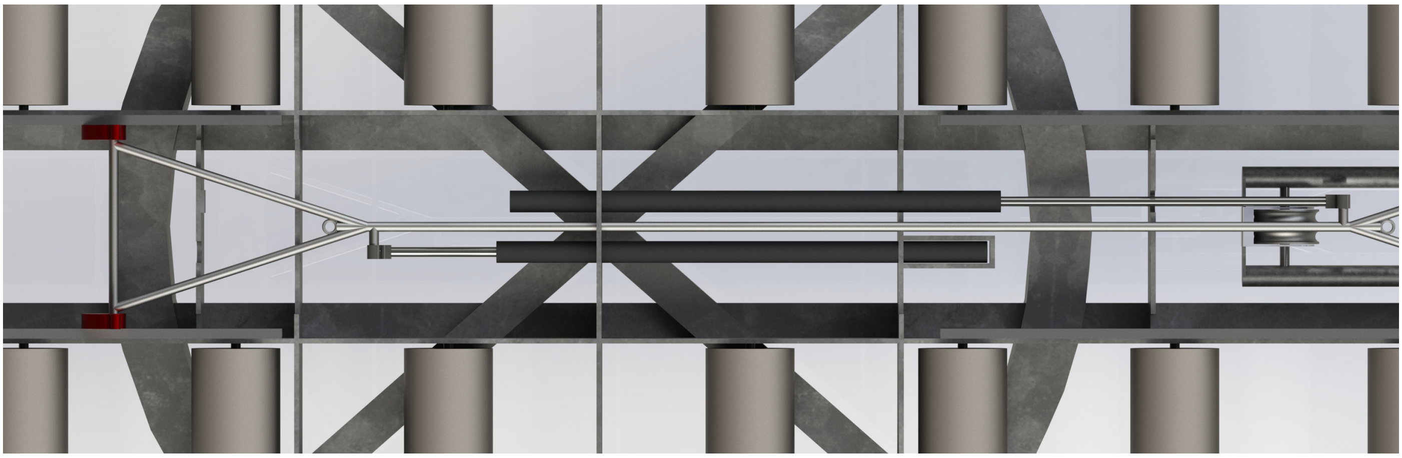


Fig12.24. Top view on the gas springs

By attaching the spring to the cradle instead of the bumper the force is kept to a minimal, otherwise a spring was needed with a force of 5 times as big. A spring with 5 times more power is almost twice as expensive, therefore attaching to the cradle is cheaper(Tevema, 2020).

If the springs would be fixed into position they would work against each other and the container would not get on the dolly. Therefore the springs can slide through the dolly. When the transporter starts pushing(fig 12.24), the spring on the other side is compressed while the other just slides through the dolly without giving any resistance.

Hook slots

The hooks can fail to open as gravity is not enough to pull them open. If the hook were jammed in the test it took just a small tap to open them. However that tap should not be needed and also could lowers the reliability of the mechanism. Small slots force the hook to open and close. Furthermore, the slots give a more secure lock when the container is on the dolly.

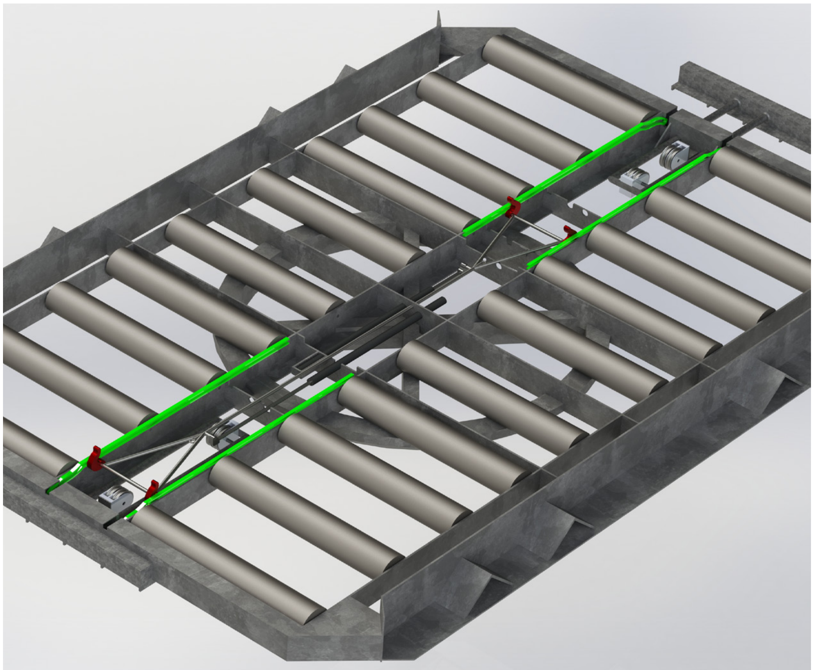


Fig12.25. position of the hook slots

The slots will be made of standard carbon steel U-profiles(Bouwmaat, 2020). That profiles only need to be bended at the ends. A tolerance has to be into the slot because the bends will tighten the profile.
The slot consist of two bends at the end. The first bend(left) is to release the clamping force on the container. That has to be done otherwise the container will keep pressure on the hook. If the pressure will stay on the hook, the wear on both container and hook will be too big. The second bend is to let the hook fold away into the dolly to let the container off. Two bends also have a function when loading a container onto the dolly. The first bend(The right bend this time) makes sure the hook can grab the container, but still keep some space. That space is needed as test showed that when the hook got up immediately, it would get stuck on the container. Therefore the first bend would only let the hook grab the container, but would not pound the container into the other hook. The second bend is to lock the container tight onto the dolly.

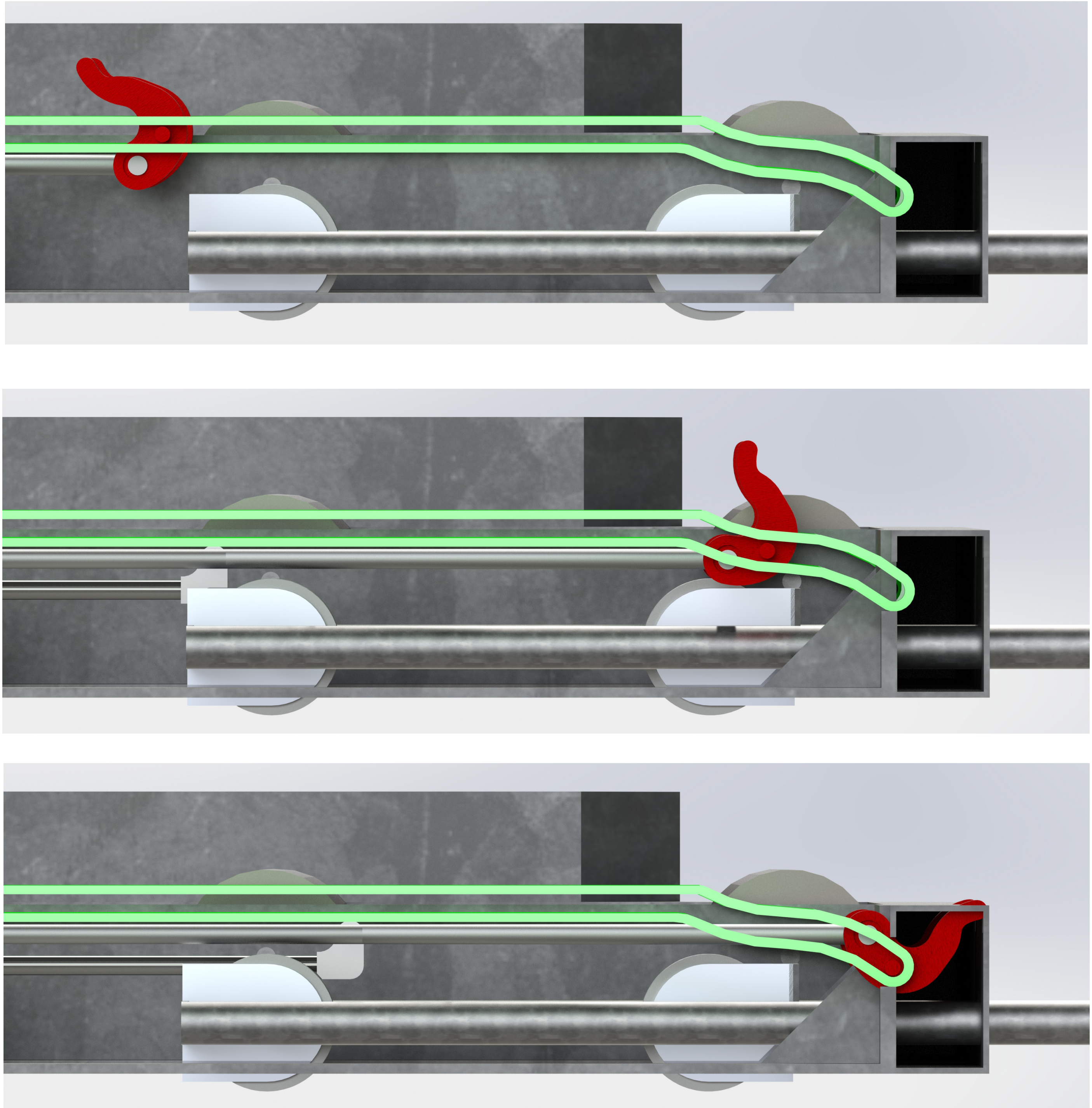


Fig12.25. Movement of the hook forced by the hook slot

Costs

The total costs of the mechanism with the implementation onto the dolly wil be around €400,-. This price is build up out of the material cost, adjustments on the dolly and the man hours made to create the mechanism and adjust the dolly. The total build up of the cost can be found in appendix L. These cost are made when considering an existing dolly is used and adjusted. The cost can be lowered when the adjustments are taken into the manufacturing process of dollies. Furthermore, calculation have been made on an amount of 1350 dollies. When producing more of these dollies with the mechanism the parts and materials can be bought in bulk, which could safe more money.

Profit

The profit of the dollies is dependable on the amount of injuries that is reduced and the fact that an aircraft can be loaded with one less person. The profit of the reduced injuries and therefore absenteeism is hard to calculate. It is also not only profit in the way of money, but also a profit in a mental and moral way.
The savings of having one person less on the platform is easy to calculate. Apron service needs 50 minutes for an aircraft, from an empty aircraft to departure. In that time there is a full apron crew for 40 minutes on the platform. From that 40 minutes a persons is pushing containers for 20 minutes. An apron worker costs €28,- per hour(Adecco, 2020)(Ondernemenmetpersoneel, 2020), that means per aircraft KLM can safe about €9,-. That does not seem much, but KLM does around 166 flights a day(personal communication R. Rugebregt & R. Potemans), that means they save €1500 per day, which comes down to just a bit more then half a million a year. In the raw case of a saving half a million, the investment will be returned within a year. Calculating the other flights,

freight and the healthcare savings with it the return of investment will be much sooner.

Conclusion

The initial assignment of KLM was to reduce the physical burden of their personnel on the platforms. As the project progressed it became known that an increase in safety on the platform was almost equally important in this project.
An evaluation on the process showed that the biggest problems were caused by the rotation and the pushing of containers. A detailed overview of all the processes lead to the discovery of the importance of the load tool. The load tool requires that containers are able to rotate at the latest moment. Two solutions were found for both the rotation and pushing of containers. Unfortunately the mechanism for rotation had to be put on hold, because it was not profitable enough in the current economical climate of KLM.

The Push bar on its own tackles a lot of problems concerning the physical burden and safety issues. The physical burden, which was caused by the repetitive movements, is reduced because the personnel does not have to push containers anymore. The safety issues concerning close encounters with the transporter are solved because nobody has to be close to a dolly at the same time as the transporter. The advantages of the push bar do not only extent to the physical burden and safety. Making the process more efficient gives the push bar also an economic advantage. The efficiency is a result of a transporter that does not have to wait at the dollies anymore.

To finalize the design focus was placed on making the push bar fool proof. It was found that any piece of equipment on the platform has to withstand harsh conditions imposed by the weather and the personnel. An extended calculation and computer simulation was made to give the push bar the required safety standards

Discussion

KLM is not the builder of dollies or apron equipment, but their years of experience of loading and unloading aircraft gave this project the knowledge it needed to come to a solution fitted or the apron personnel. However the efforts have led to some interesting insights and challenges that are discussed hereafter.
Firstly, the concept was never tested in real life, making it hard to determine how the personnel will handle it. The same as the push assist, which was also developed with the best intentions, but failed when personnel ignored to use it.
Secondly the prototype is build of wood. A model made of wood reacts very different then a model made of steel. The biggest difference will be that the wooden model will get jammed more easily. Another note on the model is that the model has not changed after calculations and gained knowledge in the last part. So the principle is never really tested to it's full extend.
The Push bar is not tested in the real harsh environment of the platform, so it is not sure if it will hold. Moreover it is hard to determine how long the mechanism will survive and how much maintenance is needed on the mechanism. In the end the other possibilities and causes of the injuries should be researched more to see what all the factors are. After research the possibilities to combine different solutions should be developed.
For the price calculations numbers and prices were found on the internet. Probably if S-P-S will build the push bar the prices will differ from the prices that are mentioned in this report. The difference in prices has to do with contracts S-P-S has with its suppliers and the bulk they probably can buy.
The outbreak of the coronavirus kept a lot of planes on the ground for several months, meaning that there was not a lot of apron activity needed. The low amount of apron activity led to more time for processing aircraft, resulting in very relax loading of aircraft. This relax version of the process made that the process was never seen in it's full glory. This could have shined light on some important matters that only occur when a platform is in full chaos and Schiphol is on it's maximum capacity.

Recommendation

Since this project ended with a computer model and a wooden prototype instead of a full scale working model, I aim to extend this result with valuable recommendations.

Safety is very important in this project and not only when the push bar is working. While a dolly is pulled around Schiphol by a tractor a lot can happen. By fitting the dolly with a clamp to hold the push bar while a dolly is moving, noting can happen. The push bar just slides into the clamp when the top bed of the dolly is rotated into the driving orientation and is given free when rotated into the perpendicular position.

Furthermore it is important that the push bar will always work, and more importantly is always able to release a container. An aircraft can not wait for a container that can not get of a dolly. By assembling the sled and the gas springs to the system with emergency releases the container should always be able to get of the dolly. The safety release could be something as a pin that is pulled out to release a structural pin.

At last, the physical burden does not only concerns containers, pallets can also give a heavy load. When an aircraft is loaded with cargo it often stands on a pallet. These pallets are transported on dollies that are twice as big as container dollies and can only unload from the side. To make the push bar work on these pallets it should be able to function when a transporter is driving alongside it. Simply said the push bar should be rotated 90 degrees.

Reflection

My role as a designer in this project really opened up the way KLM looked at their process. It looked like a very simple but researching it showed the complexity of it. That unseen complexity is probably also the reason that handling container stayed the same for the past 30 years. I feel that as a designer I opened the whole problem and not only discovered problems that were known, but also discovered the reason why the process is like it is

I do not have the experience in hardcore mechanical engineering, therefore calculation can be simplistic. But, I am not trained as a mechanical engineer and it would therefore be better to use the experience of S-P-S for the final calculations of the push bar. On the other side the calculations are a good started to get something of dimensions for the push bar.

Looking back at this project, which was the first big project which was totally done by my own from the beginning, I am proud of what I achieved. At the beginning I was afraid of working all by myself and did not had full trust in my own design skills. But taking a look back, I was never all alone. I got a lot of help and intense and extended feedback from my two TU Delft mentors. Next to that the people at KLM were always willing to help, Especially Rob Potemans and Miel Rügebregt helped me a lot and their enthusiasm gave me the motivation to keep designing and bringing this project to a good end.

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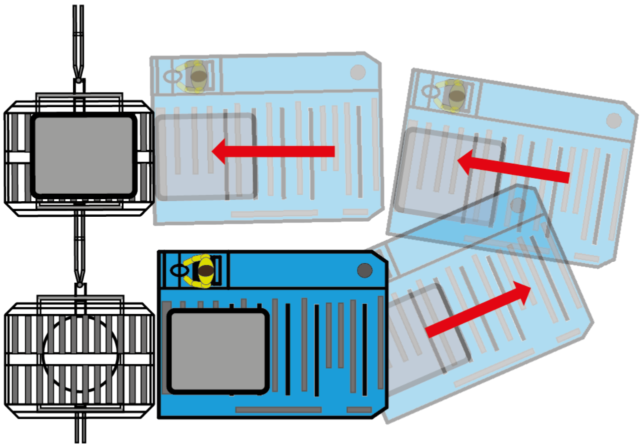
Appendix A: Duration apron processes

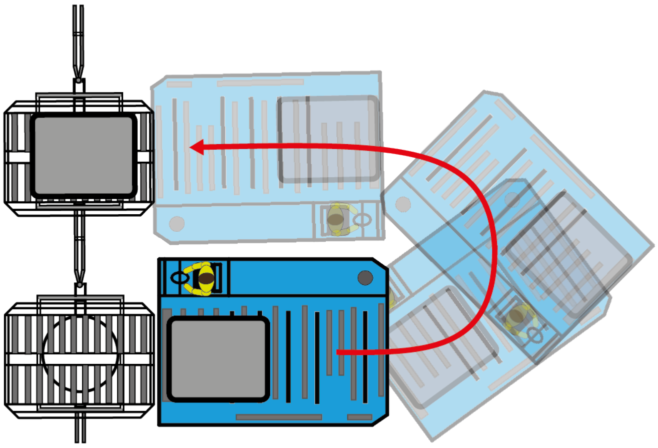
To get an understanding of the duration of the processes on the platform a study was performed. The study measured the different steps in the process of loading containers into a plane

Loading containers on transporter

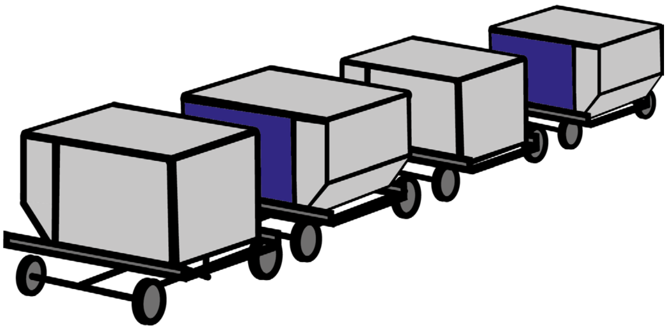
The current process means that containers on dollies are turned in different directions so the transporter can take them of the dollies with the front of the transporter. On top of that thy can't rotate the containers on forehand as the load tool will determine the loading sequence of the containers. So turning all containers on forehand can be very beneficial for the effectiveness of the loading process. However if this happens the transporter has to back up to get the second container. These test will see whether it is beneficial to load in this way. The image below show the two variation in loading a container on the transporter



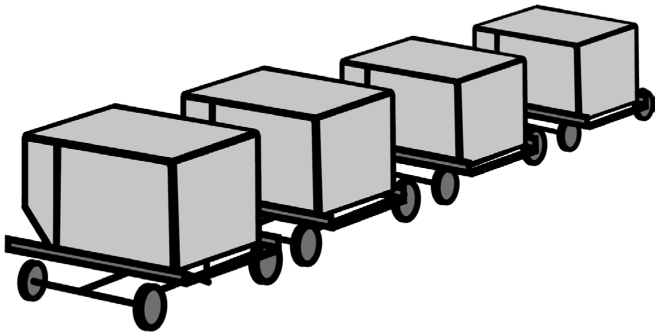
Loading with the front



Backing up for second container



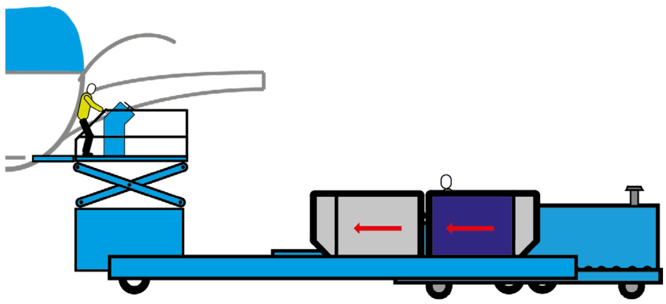
Container orientation for front loading



Container orientation for backward loading

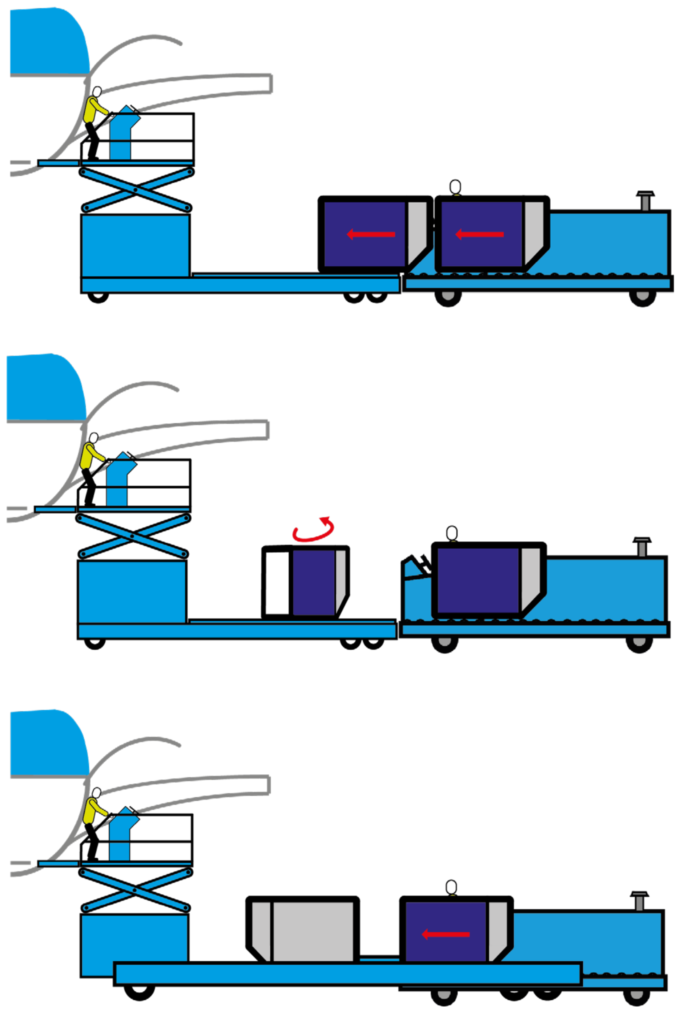
Rotating containers on loader

There are two contradicting statements about rotating containers on the loader. One statement being that the loader has no time to rotate containers as it has to be going up and down continuously as it is the bottleneck in the loading process. The other statement contradicts this because it says that the loader is never used throughout the whole loading process. These test should bring clarification on the extra time it will cost when containers are rotated on the loader en whether it is possible.
This test will compare two scenarios, one in which the transporter loads the containers on the loader in the same orientation as they go into the plane. In the other scenario the transporter will load the containers both in the same orientation from the dolly so the loader has to turn the first one before it can lift both containers.



Current process; loading containers both in opposite orientation

This test will not show that the second part is faster, but that is not goal. The goal of this research is to see how much extra time it will cost to rotate a container on a loader. Than that extra time can be compared to rotating containers at other stages of the process.



Variation; loading one container first, rotate it and then load second container

Start of the test

First AKE on transporter

Second AKE on transporter

First AKE on loader

Second AKE on loader

Loader lifted

	driving the transporter backwards up to the loader				
	1st AKE on transporter	2nd AKE on transporter	1st AKE on loader	2nd AKE on loader	loader lifted
1	00:16	00:37(21s)	01:23(46s)	01:28(5s)	01:48(20s)
2	00:13	00:42(29s)	01:18(36s)	01:22(4s)	01:43(21s)
3	00:15	00:44(29s)	01:20(36s)	01:25(5s)	01:45(20s)
4	00:19	00:45(26s)	01:19(34s)	01:24(5s)	01:44(20s)
5	00:14	00:43(29s)	01:21(38s)	01:27(6s)	01:47(20s)
6	00:14	00:39(25s)	01:21(42s)	01:26(5s)	01:47(21s)
avg duration	15,2s	26,5s	38,7s	5s	20,3s

The second test the transporter will be driving forward against the loader

	driving the transporter forwards up to the loader				
	1e AKE on transporter	2e AKE on transporter	1e AKE on loader	2e AKE on loader	loader lifted
1	00:11	00:40(29s)	01:06(26s)	01:12(6s)	01:32(20s)
2	00:14	00:35(21s)	01:00(25s)	~~01:10(10s)~~	01:30(20s)
3	00:11	00:36(25s)	01:02(26s)	01:07(5s)	01:27(20s)
avg duration	12s	25s	25,7s	5,5s	20s
	* empty container droped between transporter and loader				

First AKE on loader

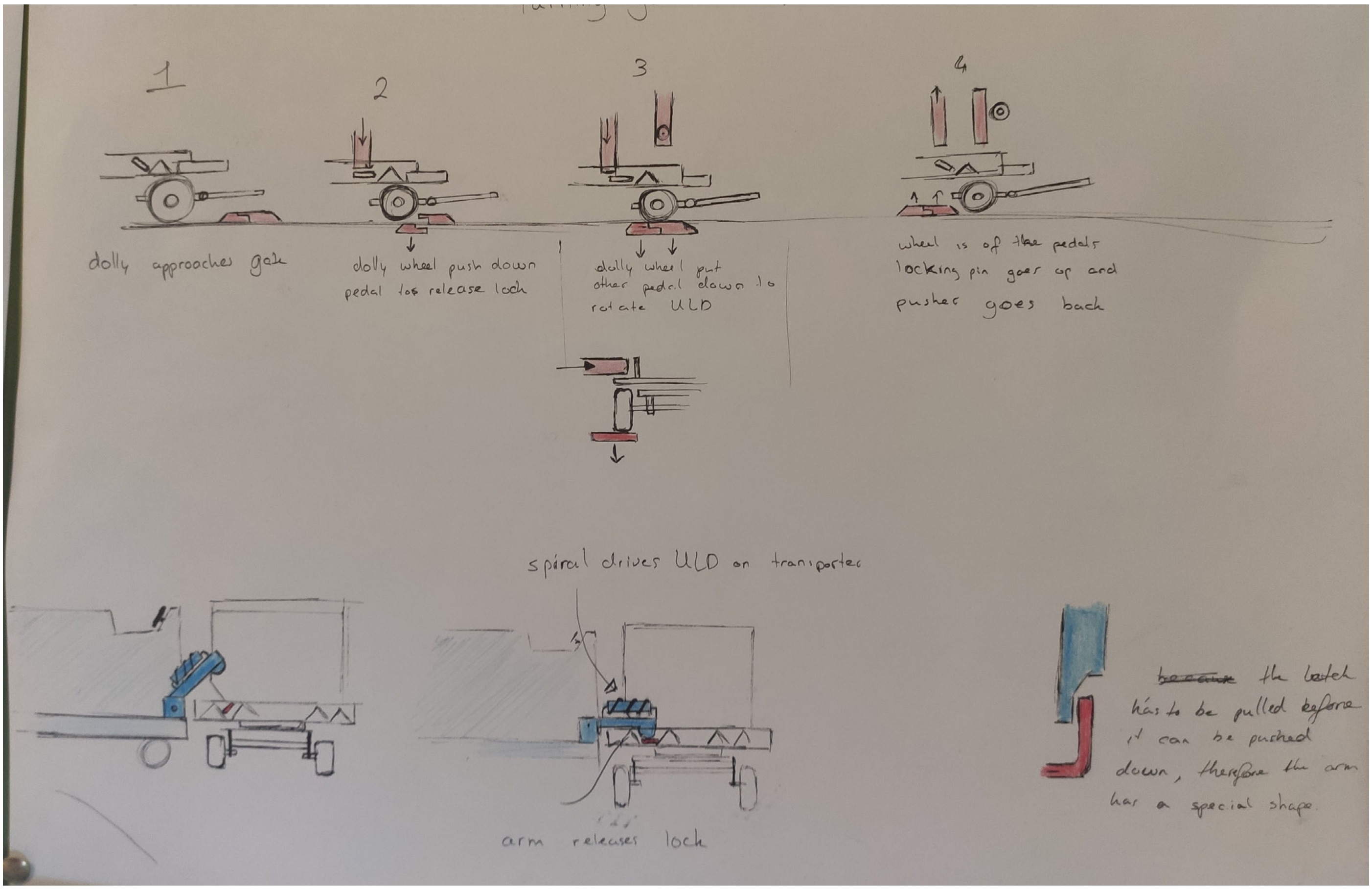
First AKE rotated

	rotating AKE on loader			
	1st AKE on loader	1st AKE rotated	2nd AKE on loader	Loader boven
avg duration	00:09s	00:28(19s)	00:37(9s)	00:57(20s)

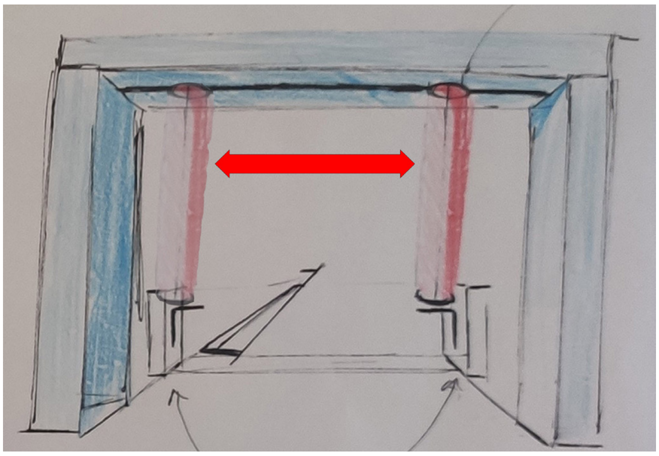
Appendix B: first stage Concepts

This chapter will elaborate on the combination of solutions which were made with the morphological chart. These concepts as they are called are more in a state of principles than really a definitive solution. Some concepts are transformed after the combination as sketching learned that some things were not possible or could be done better

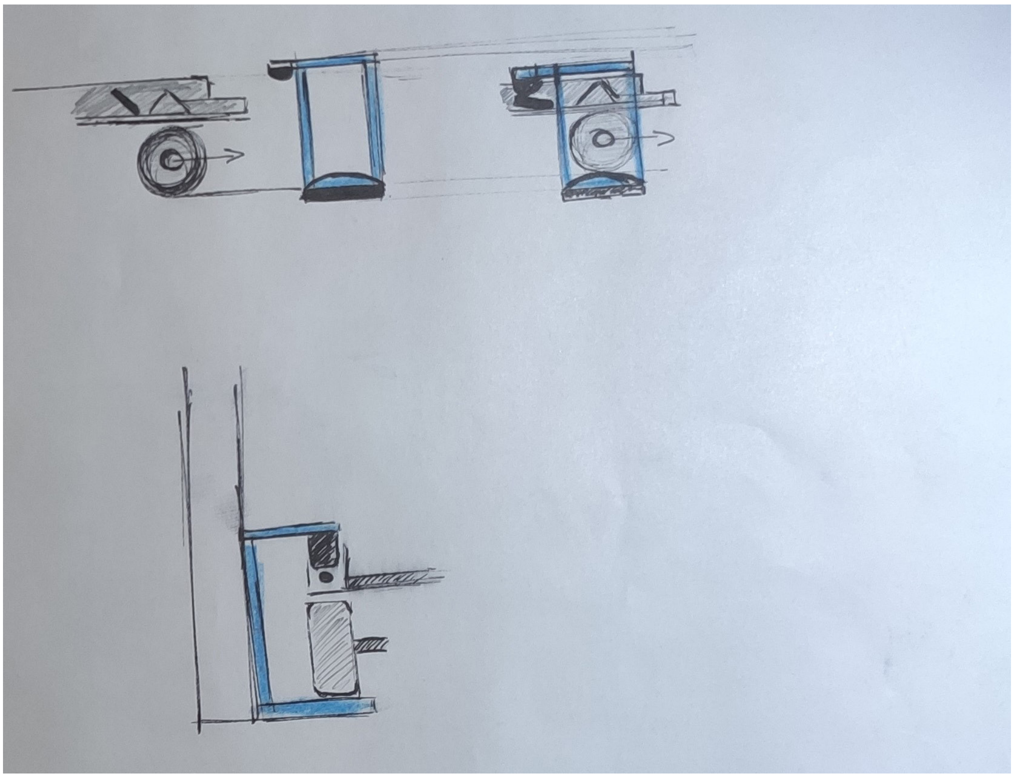
Concept A: turning gate



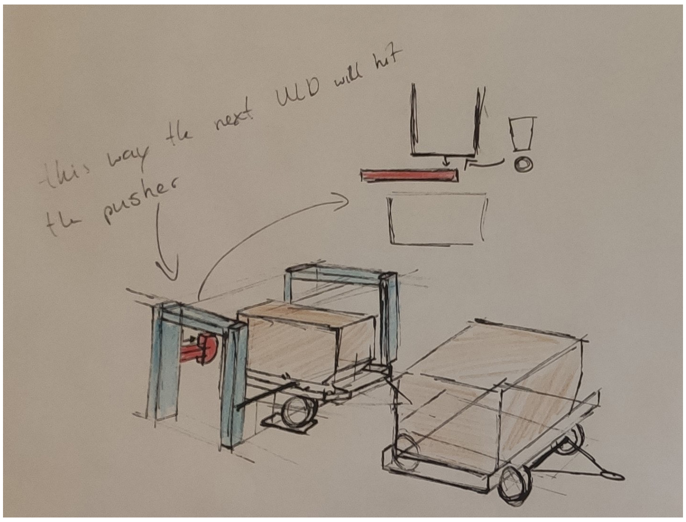
Concept A is a two step concept in which the rotation of the container and the unloading of the container are separated. A gate is placed at the edge of the platform. The baggage train will drive through the gate when entering the platform. When going through the gate the weight of the dollies will push down on pads that will activate the mechanisms. The gate releases the rotation lock after which the gate will rotate the container. Because the containers need to alternate in orientation the gate has to be able to rotate the container both sides. In the figure above this is done by a push rod from the side, but it can also be done with a rod that moves from left to right(sketch on the right). In both sketches the movement of the gate is initiated by the weight of the dolly(see next page). After the gate the dollies will be stationed at the platform. The transporter can now pick up the containers. To pick up a container the transporter makes use of an arm that will push down on the handle of the lock to release the lock. The sketches show that a feeder screw will move the container onto the transporter. However after doing research it became clear that a will not work as it will not have enough grip on the container neither will a wheel have because of the flexible walls of container. Therefore a hook or pin that can grab a rim of the container will be much better in this case.



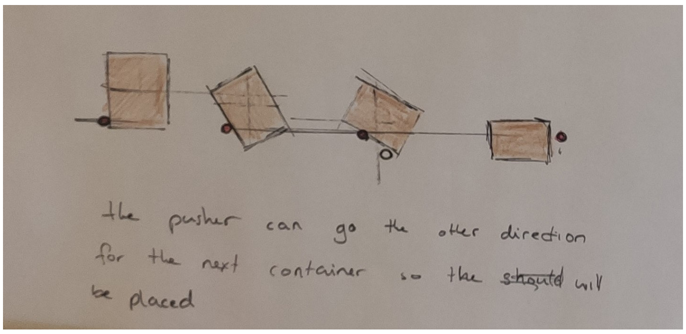
The push bar will move left and right to alternate between container orientation



To release the lock the dolly has to drive over a pad. This pad is attached to a rod that is positioned above the handle of the lock. When the pad is pushed down buy the dolly the rod is also going down and will press on the handle to release the lock.

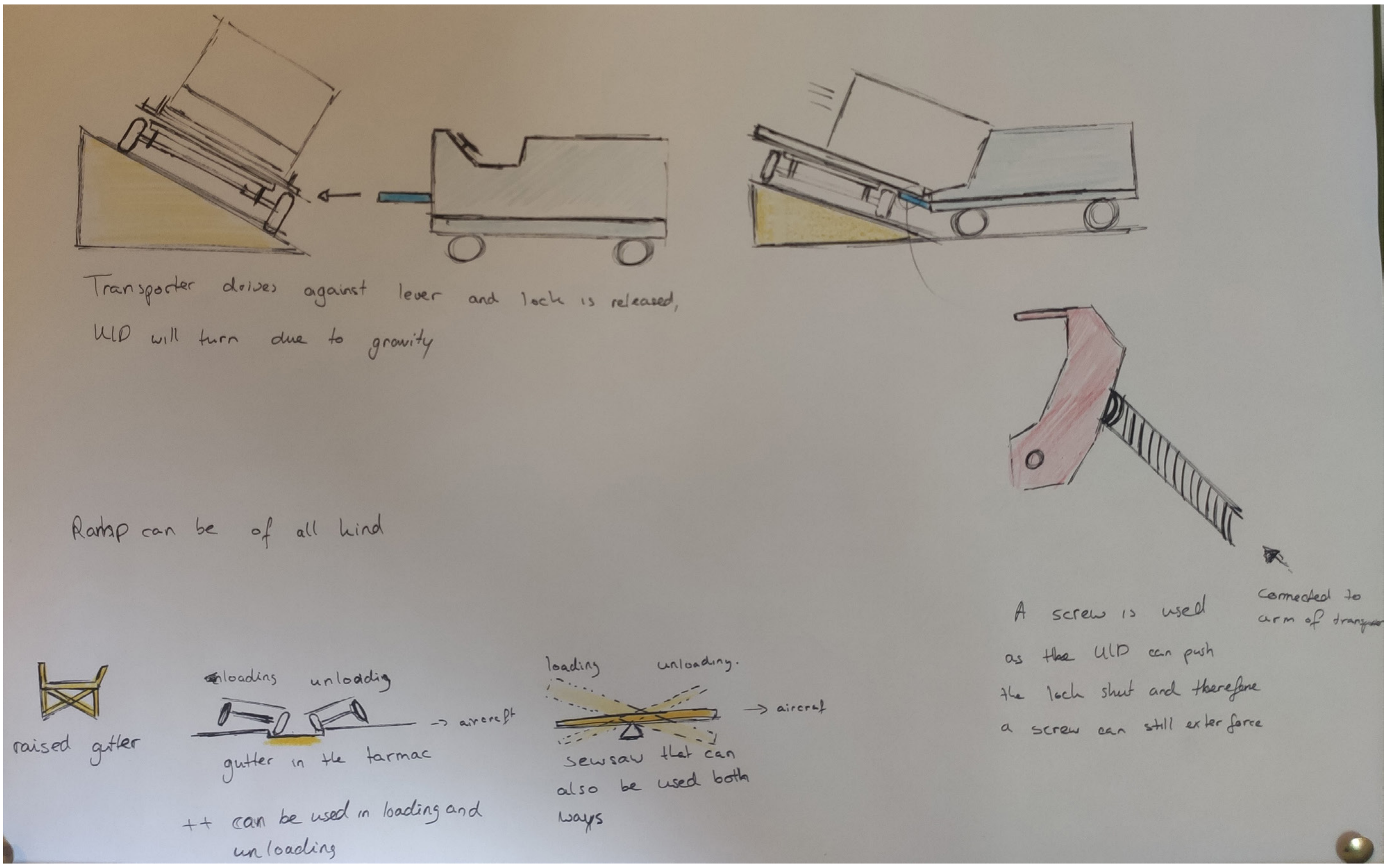


A rod that pushes from one side is possible but it will need to retract fast as otherwise it will be hit by the next dolly. Also a rod that does not move all the way can cause dollies to not turn all the way.

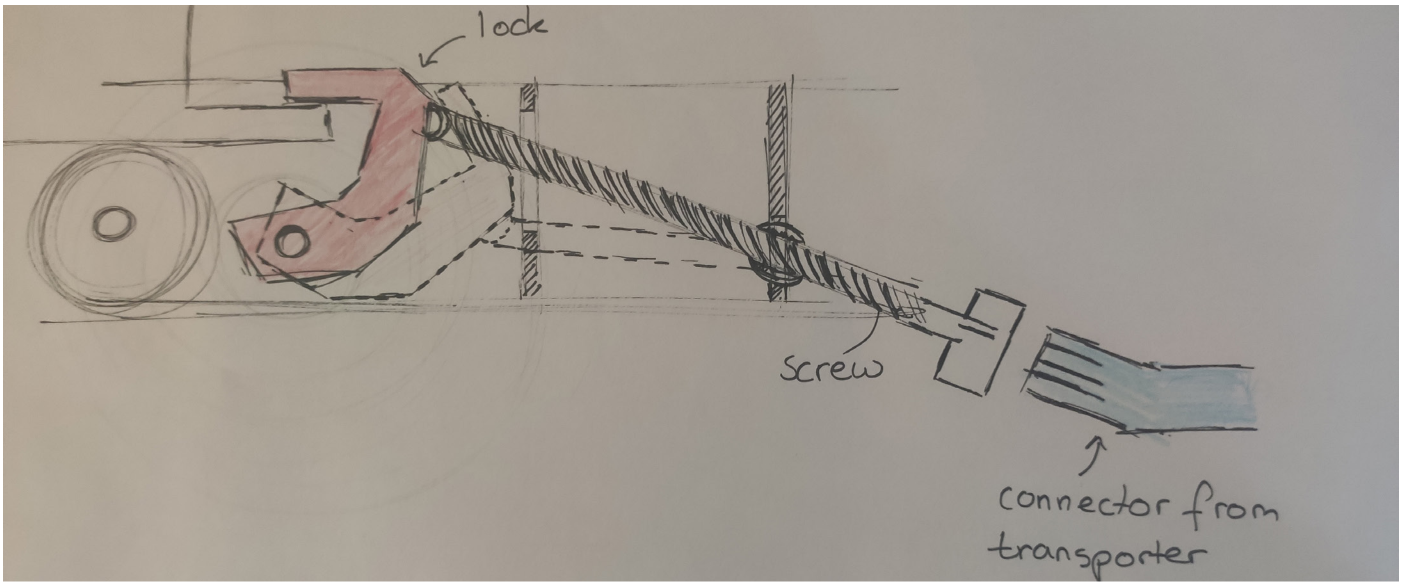


The principle of the turning gate. The dolly with container moves down(in the image) and the rod moves to the right

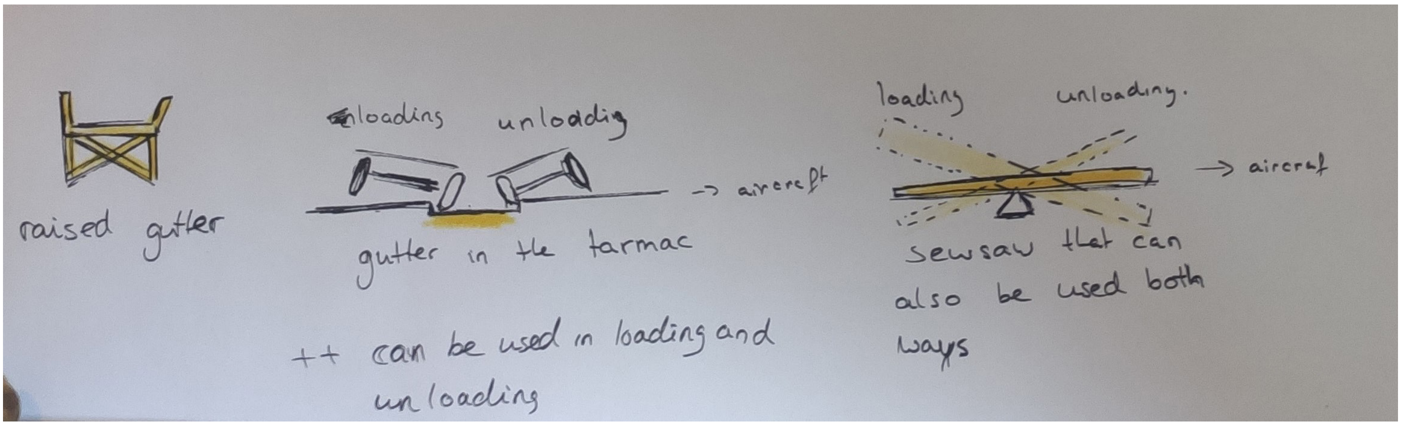
Concept B tilting the dolly



Concept B consist of a ramp and an arm on the transporter. This concept mostly makes use of gravity. A ramp is created on the platform, this can be either a raised piece of platform or a gutter either way it should create an angle that is enough to make the container roll of the dolly. But first the angle is used to rotate the dolly. The transporter will drive up to the dolly, connect with handle to release the rotation lock. The transporter can either push or pull against the dolly to determine the orientation of the container the gravity will do the rest. The container is now pushing against the lock and therefore the lock is hard to open. A screw however is able to open the lock under tension. The arm of the transporter will connect to this screw to unlock it. If the lock is opened the container will roll onto the transporter.

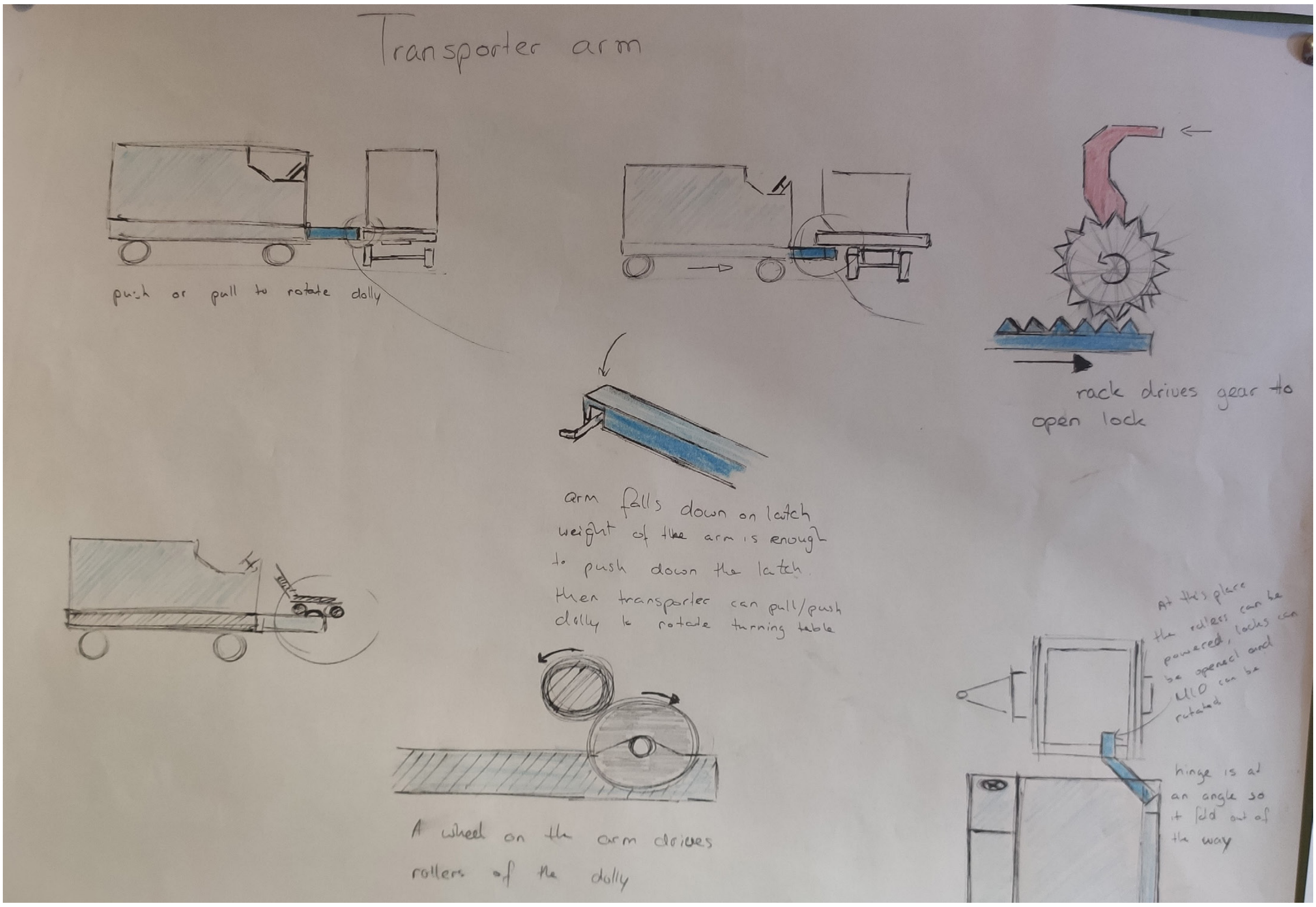


Screw unlocking mechanism. The connector from the transport arm will make the screw turn. if the screw turns it will retract and pull the lock down. To make sure the angles can be made the screw is attached to the lock and frame with a ball joints.

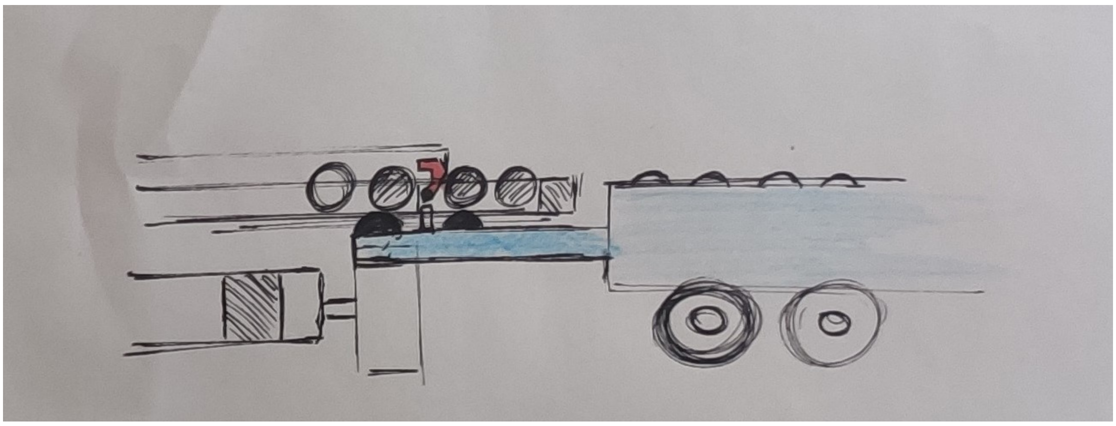


There are different options in tilting the dolly. All three can also be used to when unloading an aircraft as the incline can be the other way when the wheels on the other side are placed on it. However it should be considered that vehicles on the platform should be able to drive it, also aircraft. As aircraft need to drive over it a raised structure needs to be very though, therefore a gutter in the concrete is a simple yet strong solution to make the dolly tilt.

Concept C Transporter arm

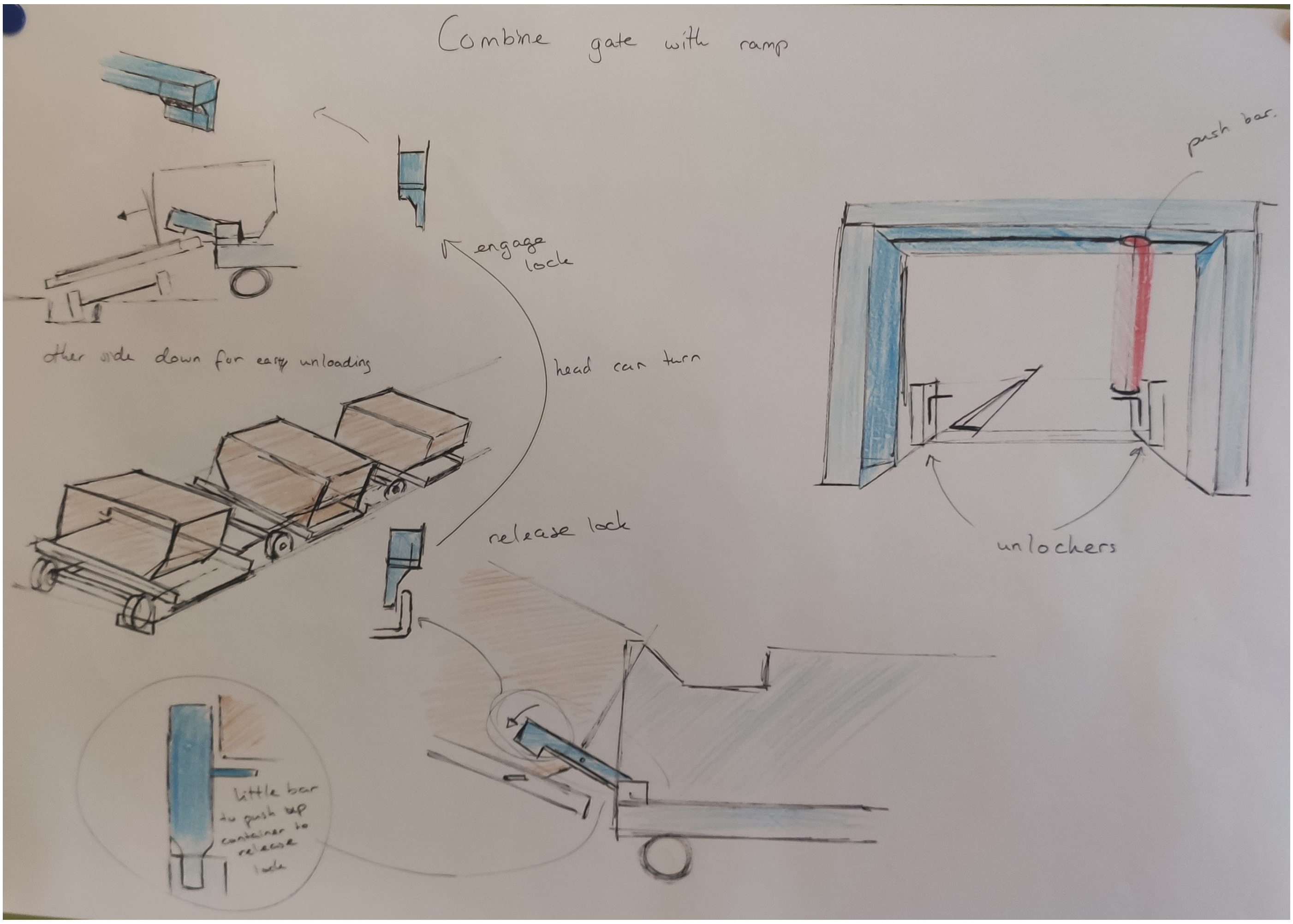


Concept C is a combination of the brown and blue solutions. The tool was let out of the blue solution as it is another tool the crew has to use, which was exactly the problem why the push assist nowadays. The threshold for using a tool should be very low. However the tool is now integrated in the arm that will be on the transporter. In this concept the transporter will hook onto the handle to release the rotation lock. When this lock is released, the transporter can turn the container, either by pushing or pulling. When the container is in the right position the arm will go under the turning table. Under the turning table the arms rack will drive a gear which opens release the lock. A wheel is attached to the arm to drive the rollers of the dolly which will then push off the container.

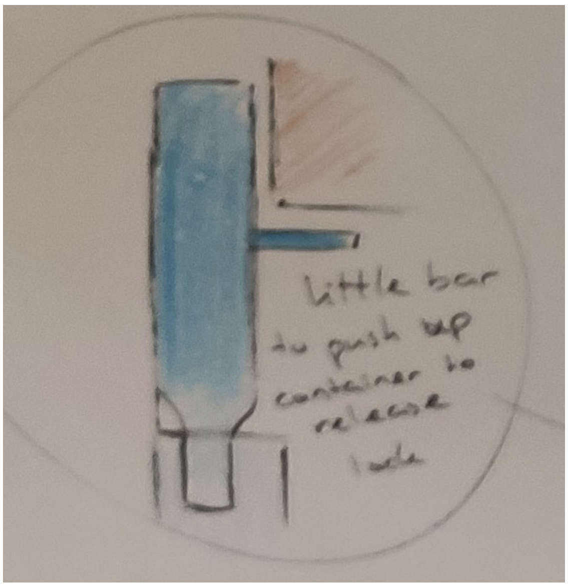


The wheel on the arm will drive the rollers of the dolly

Concept A 2.0 turning gate and tilting



After making concept A and B the idea came to combine both concepts in one concept to make a concept that barely uses any additional power. It all works with energy that is already present at the platform.
This concept uses the same turning gate as in concept A after which the unloading of containers is done by concept B. The arm of the transporter has been changed a bit. The arm has a smaller beam attached that will first push the container a bit up after which the lock can be released by just pushing the arm on the handle.

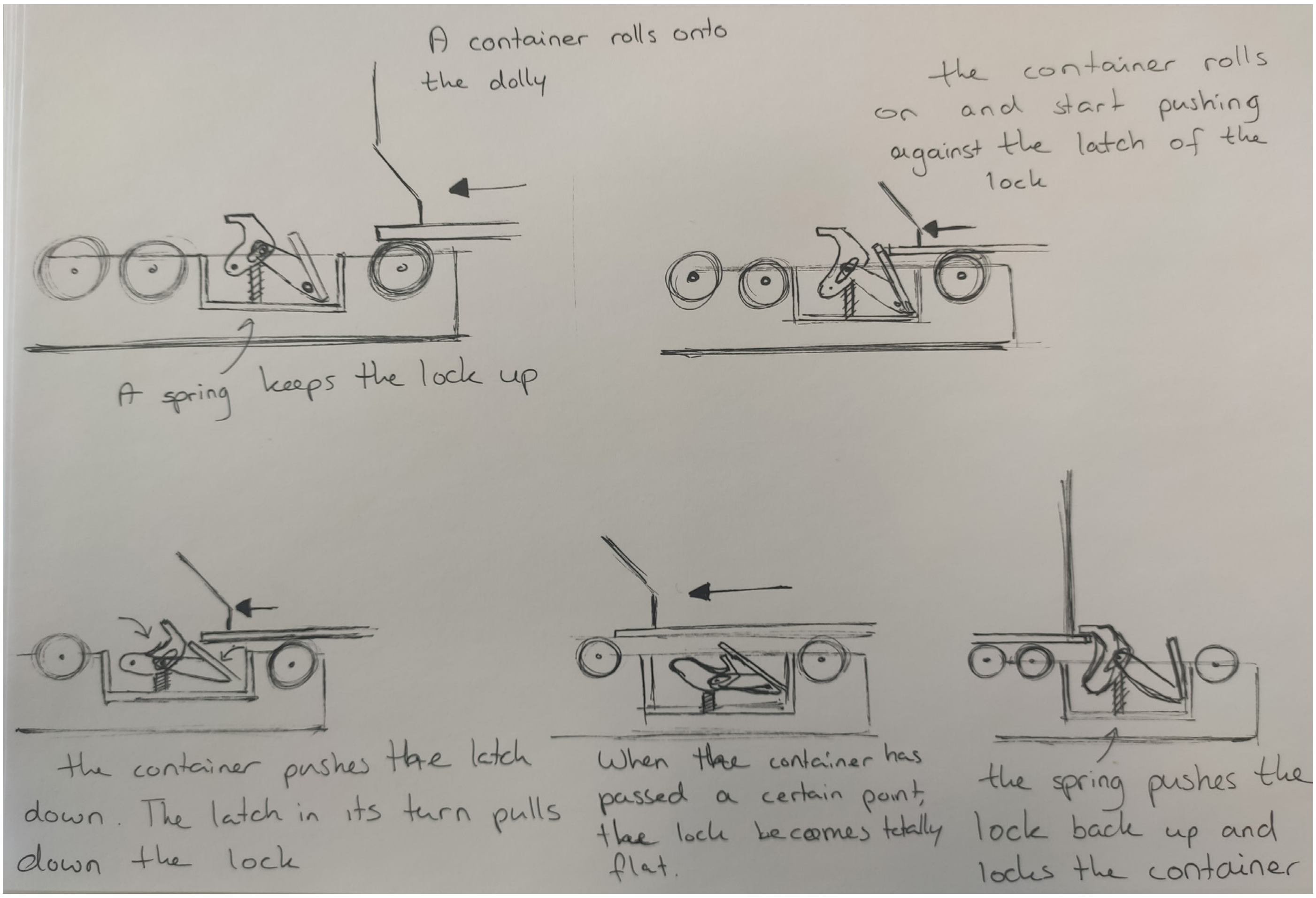


The arm has a beam at the side to relieve the lock from the pressure of the container

Appendix C: automatic lock

The lock

KLM has developed a new kind of lock that automatically opens when a container is pushed on a dolly. When a container has passed the lock, the lock automatically closes due to a spring. This lock will be used from now on. Because of this new lock nothing is required for opening or closing locks when putting a container on a dolly.



The working principle of the automatic lock.

The automatic lock is still in development. In the future all dollies will have this kind of lock.

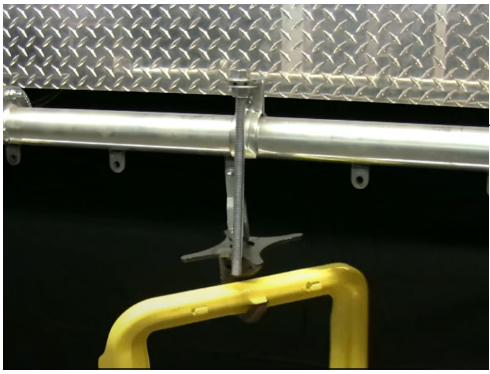
Appendix D: The road to reduced human labour

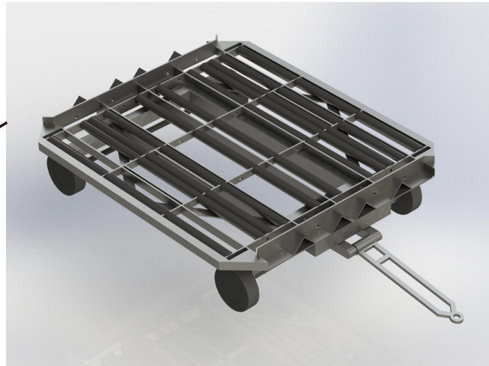
Narrowing down the directions there are two paths that can be taken towards a solution. The first path starts with a dolly where sideways loading is possible without rotating the dolly. The other path start with a rotatable dolly, that rotates before arrival on the platform.

The problem

The dollies have to be rotated otherwise the containers can not be unloaded from them. So a device automatically rotates all containers the same way automatically when the CLD drives past it

Dollies that can unload sideways do not have to turn to unload a container and can still fit through the baggage corridors.





To get containers of the dolly an extension on the transporter can be used.

To get the containers in the right orientation in the aircraft the loader could rotate them. Best would be rotating them on top of the loader.

The Transporter could rotate containers to get them in the right orientation for the aircraft.

No more physical human power needed

Explanation

If containers are either already rotated or unload from the side of a dolly, we open up the possibilities for the transporter to pull containers from the dollies without the help of an extra person. The transporter is used in the process to keep the load tool working. In both ways the containers are loaded on the transporter in the wrong orientation. To put the containers in the right orientation one of them has to be rotated. The rotation of that container can either be done by the loader or the transporter.
Both paths are made with the thought for using what's already there. KLM has enough equipment that can be used very versatile which makes the solution easier to reach and keeps the costs low.

Possible ideas

All the information in the previous chapter and a meeting with KLM has made it possible to divide the ideas into promising and not desirable. Below will be explained why an idea will be elaborated or why it is not desirable.
These choices were also made with a new insight that KLM want it to work with the new dolly with the automatic locks. The solution has to work with these lock

No human pushing

That means the transporter gets an attachment that can grab a container and pull it onto the transporter. With this the load tool can still work and no other person is needed to help with unloading containers from dollies. The attachment will be moving, that movement can also be used to release the lock. So this idea will be elaborated and combined with another idea that takes care of the rotation of the containers.

Loader rotates containers

The idea of rotating containers on the loader as a standard action in the loading was not accepted by KLM because of the essential role the loader has in the process. However the loader could be used to solve a small amount of wrong orientated containers.

Containers are loaded from the side

An idea that eliminates the rotation that is needed to unload containers. However an idea for KLM that is further in the future, as the current financial state will not allow KLM to change their whole fleet of containers. Dollies unloaded from the side also takes away some flexibility in the process. This idea will be put on hold.

Dollies are powered

The best way to create powered dollies is by powering them with movement that is already present in the process. A transporter driving against a dolly to power it for instance. In this way only the dollies have to be adapted. It can also be a rather simple solution to learn for the personnel. This idea will be elaborated into a dolly that has a powered rotation and unloading or only one of those to. If it has only one powered function it will be combined with other ideas

Push and rotation assist

KLM wants the person gone that is pushing containers. The reason is reduction of physical labour and safety. Also other loose tools have proven to be neglected in the process. This idea will stop here

Dollies rotated before arrival on apron

A good way to eliminate the manual rotation to make dollies able to load and unload. Only thing to think about is if the containers are all turned the same side or alternating. This idea will be elaborated and combined with a solution that helps unloading containers

Rotate containers with the transporter

The transporter is versatile enough to take another task. The transporter is already capable of rotating containers however small modifications can make it better.

Appendix E: Design directions

Introduction

This part is about the design direction. The next pages discover the possibilities in different directions, called principle solutions. This solutions are not fully set and complete solutions, they are more about where the solution can be found and implemented. This report will end with two or more paths that can be taken towards a decrease in human labour on the platform.

No rotation

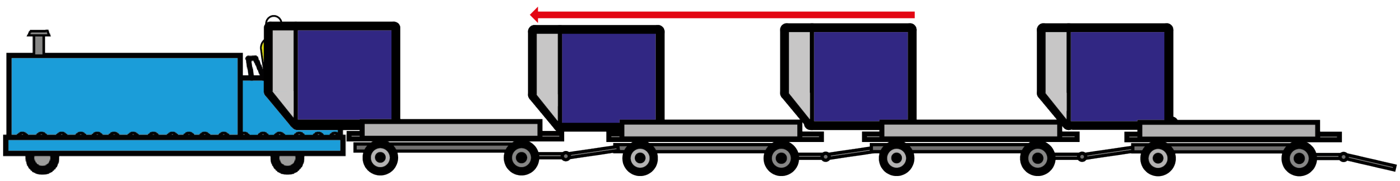
The rotation of containers has a large contribution in the physical labour on the platform. That also means rotation has a big contribution in the injuries apron personnel get. So what if this rotation is not needed or eliminated of the process?

Function of rotation

As earlier stated in the report the rotation has to do with the chamfered side of the containers. The chamfered side has to go against the wall of the cargo hull which has a corresponding shape. The rotation happens before they are loaded on the transporter for an efficient process. A second function of the rotation is to let of the containers. A dolly has to turn to be able to unload a container.

What does it mean

If containers are not rotated anymore it means that they need to get in the aircraft in the right orientation without any rotational movement. The containers are locked in the position in which they are when rotated. With this setup they should not have to be rotated anymore. However this will cause problems in the baggage basement as the containers will not fit through the corridors anymore. So let's say the containers stay in the same orientation, in other words the turning tables of the container dollies are fixed now. But now the containers are hard to get of the dollies. There is still a way to get containers of the dollies, which is rolling them over the whole CLD combination(See image below). The containers can roll off at the back of CLD combination. The front can not be used due to the pull bar obstructing the unloading area. The order of the CLD



now determines the loading sequence. Consequently, the load tool can not be used anymore, which is not desirable. Additionally, containers have to be pushed a lot further, thus making it physical more demanding. Conclusively it is not a feasible solution to unload containers at the en of the CLD.
Another solution is loading containers from the side, then they do not have to be rotated. Container will have to be loaded from the side of the dolly onto the side of the transporter. This means the dollies should be altered to a model that can unload and load from the side(see chapter "containers loaded from the side" page ....)
The load tool can still work when loading from the side without rotating the containers. The way to let the load tool work is if the transporter makes extra turns to get the containers in the right direction onto the loader. Multiple turns, as well forwards as backwards, will be needed to get the containers in the right direction on the loader and into the aircraft.

Conclusion

Making many turns with the transporter is not desirable as it takes too much time and is dangerous. Especially driving backwards with a transporter is dangerous. So containers have to be rotated somewhere in the process to get the right orientation for the aircraft and to keep the process efficient

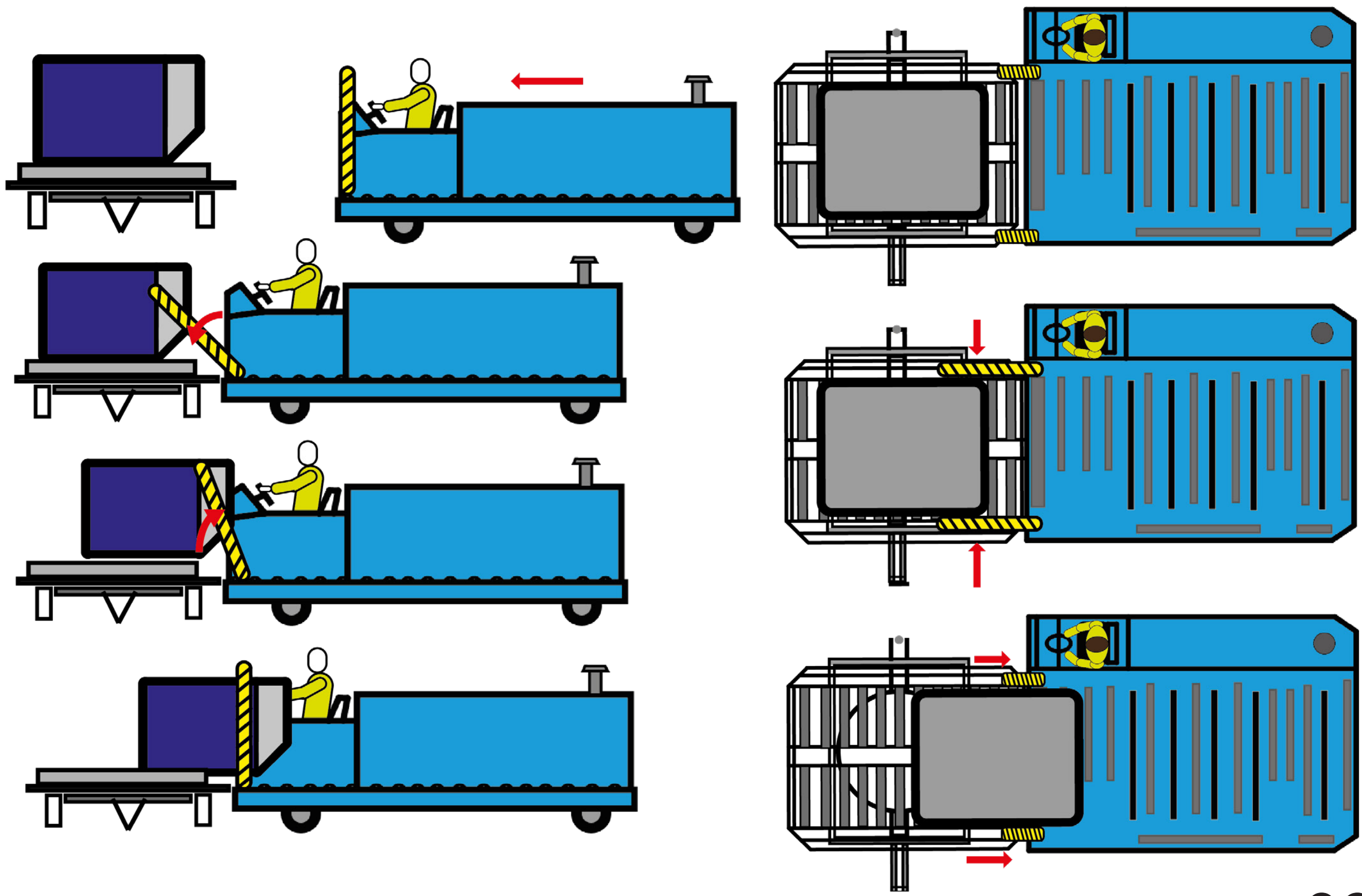
No human pushing

Another great contributor to the physical labour and injuries is the pushing of containers and pallets from dollies. The solution asks for a reduction in physical labour, so what if the reduction is 100% in pushing.

What does it mean

If the containers are not pushed by the personnel they have to get of the dollies by different means. So either an external source has to make the container move or a system has to make the container get of the dollies.
For the external source there are many possibilities on the platform that could be used as a power source. If an external source has to push of a container directly, it has to get at the other side of the container. However behind the containers is not a lot of space to move a vehicle. Although if the containers were pushed directly of the dollies at the loader it can be possible. In this case the push assist can be used to push containers of the dollies as there is enough space and the push assist does not have to drive big distances. Down side is that the load tool is usable up to the level of CLD's. If one container can be loaded that means the whole CLD has to be loaded, otherwise they have to drive CLD's continuously over the platform. There is however, a change possible in the sequence of the CLD, the CLD can go back and forth to load the containers in another sequence.

Another solution is to pull containers of the dollies. To pull the containers of the dollies, there should be some attachment on the source that can get a hold on the container and pull it. There are two options in the equipment on the platform that can be equipped with an attachment. One is the transporter and the other is the loader. If the attachment would be on the transporter the whole loading process could be the same as before only the pushing of containers is replaced by an attachment that pulls containers on the transporter bed. If the loader will be fitted with an attachment, the process has to change. The transporter has to be cut from the process and the CLD's have to be placed directly against the loader. Now the same problem occurs with the load tool, as is only works on CLD level.
The attachment should get a hold on the container to be able to pull it. The container can't be altered, so the attachment has to clamp the container in a way that is strong enough to keep a good grip when pulling. An example of this is a garbage truck with an arm to pull and lift garbage containers



Another method that does not require human strength is gravity. It is already used sometimes when PLD’s are on the slope of the platform. In this case they let the pallets roll of the dolly by their own weight. They only have to give the pallet a little push to release the lock, from then everything happens by itself. The transporter or other equipment is needed for the initiating push.

Conclusion

If the unloading of containers from dollies can happen through an external source. However when that external source is not the transporter the process has to change in such way that the load tool is not fully functional anymore. Also when using gravity, the transporter is still necessary to let the load tool work. If the transporter will do the unloading, also with gravity, it needs an attachment that can grab the container and pull them towards the transporter. If the transporter does the unloading, the load tool can still work.

Loader rotates containers

There is a strong opinion about rotating containers on dollies, most of the people do not want it to happen as it slows down the loader. The loader is seen as a bottleneck in the loading process of an aircraft and can't therefore be slowed down. To open the possibilities this opinion is neglected and the containers will be rotated on the loader.

What does it mean

To rotate the containers on the loader there as to be made an assumption that the containers are already on the transporter. The process of unloading is neglected as this solution is about the rotation of containers.

To rotate a container on the loader it should be in the 'sweet spot' on the lifting bed. This is a place in the exact middle of the lifting bed of the loader where the container can rotate the best. To find the middle, the operator of the loader has to pry a bit with the container to get it in that exact spot because he hasn't got a good view on the container. So if the loader will rotate the container, it has to be adapted so they operator has a good view on the container or some system that helps the operator to move the container into the right spot.

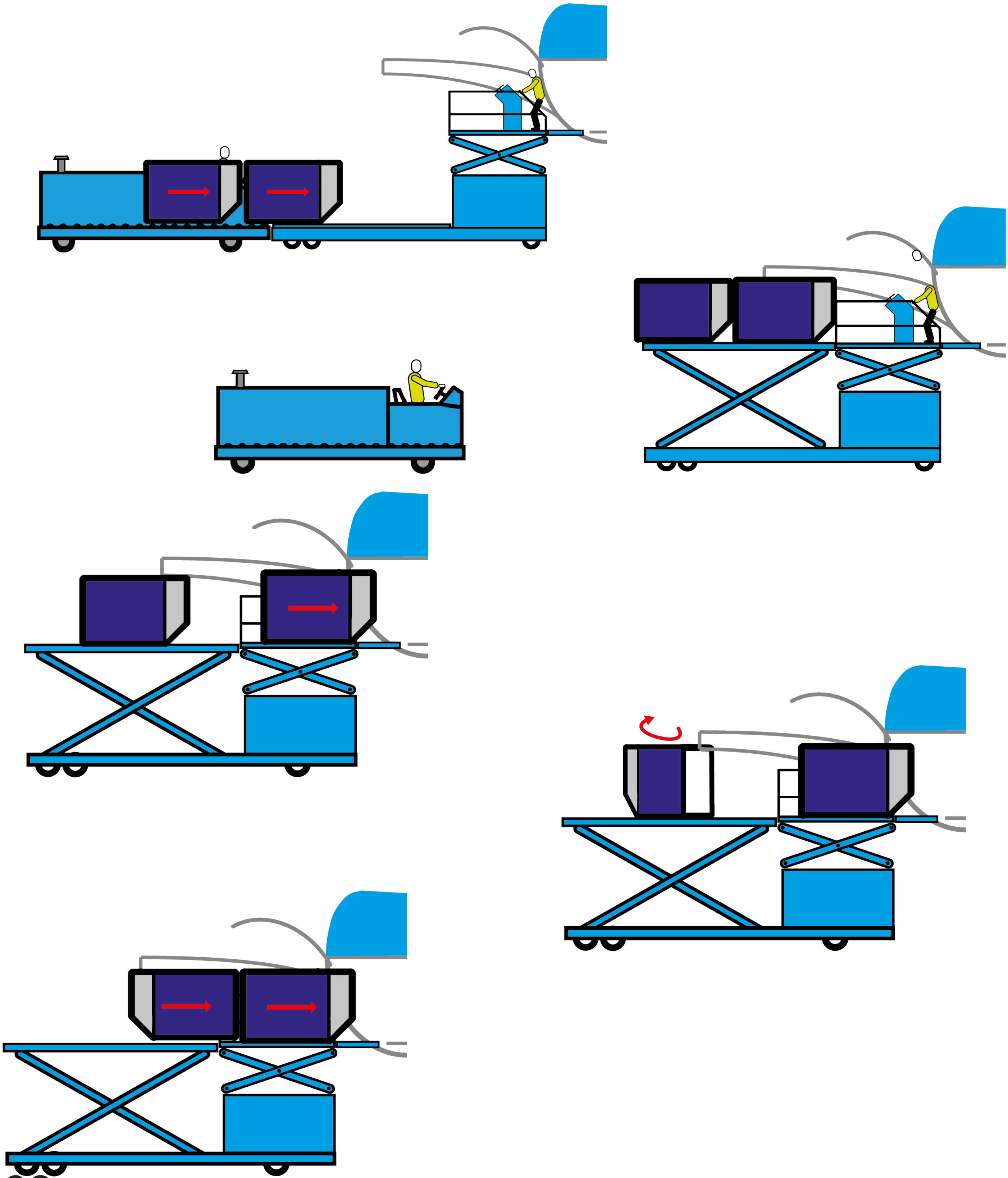
rotating container on loader.

To rotate a container on the loader it needs enough space on the lifting bed. With two containers on the lifting bed it is not possible to rotate any of the containers. For that reason first one container must be loaded on the lifting bed, then it has to rotate and next the second container can be loaded. If the first container is already in the right orientation the sequence should be: load both containers, lift both up and already put one container partly in the aircraft or load it fully. When the first container is of the lifting bed you can rotate the second container and move it into the aircraft. When rotating on the top the transporter does not have to wait and the operator of the loader has a much better view on the container.

However dollies can't unload from the side now, so they have to be rotated to get a container off. Still there is an advantage when rotating on the loader. Now all container can be rotated immediately when arrived at the platform and they can all be rotated the same way, without interfering with the working of the load tool. They way the rotation happens on the loader influences the orientation the containers need on the dollies. If containers are rotated when the loader is down the chamfered side of the containers has to face the outside of the platform. When the containers are rotated when the loader is up, the chamfered side needs to face the aircraft.

Conclusion

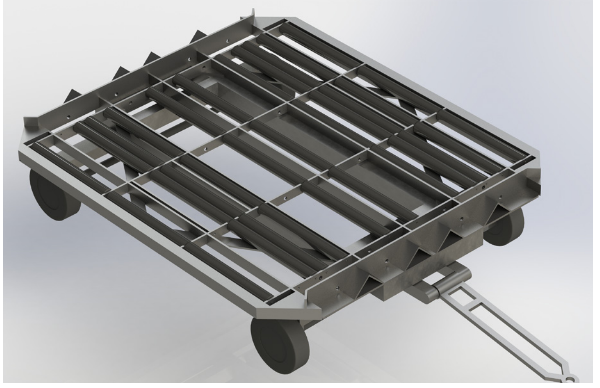
The most efficient en easiest way is rotating container when the loader is up. Then the transporter doesn't have to wait and the operator has a better view on the rotation. The solution can be implemented right away, only that would mean the container still have to be rotated before. So it will make the process more efficient but does not solve the problem of rotating containers. On the plus side, it opens possibilities to other solutions.
The solution can also be implemented when the dollies are changed into dollies that can unload sideways. If those dollies are present on the platform, nobody has to ever rotate a container by hand anymore.



Containers are loaded from the side

The dollies KLM is currently using to transport containers need to drive with their turning bed in a position parallel to the driving direction. This means that container cannot unload unless the turning table in rotated. The previous principle solutions talked about dollies that can unload from the side. Then containers are loaded the same way as pallets, at the side of the transporter. In this setup the containers do not have to be turned anymore.

What does it mean

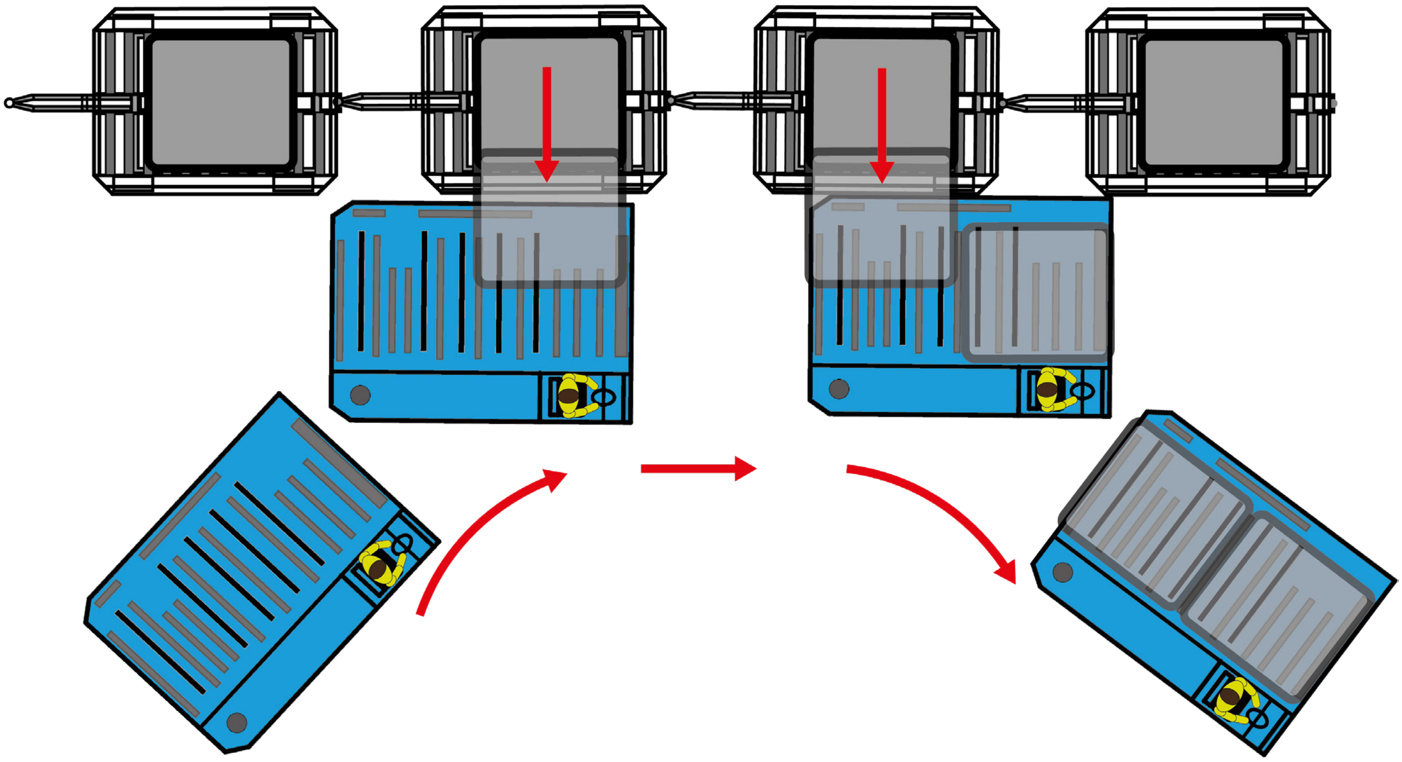


To make a dolly that it can unload from the side multiple changes have to be made. The first is locking the turning table parallel to the drive direction. Second is the relocation of the side plates from parallel to the drive direction to perpendicular to the drive direction. The rollers also have to turn a quarter, but also have to be elongated or an extra row of rollers need to be added. For the locks it means that they also have to turn a quarter, however the rotation lock is no longer needed and can be deleted.

Another solution is a dolly with a bed full of roller ball bearings. This dolly needs four locks to keep the container from moving. This type of dolly gives the personnel a lot more freedom in the movement of a container.

Conclusion

To load and unload from the side of a dolly, KLM needs to invest in new dollies. Fortunately these dollies already exist and for instance Air France is already using them.



Dollies are powered

The dollies that KLM uses do not have any form of a power source. They need an external source to perform an action. For moving they need the tractor and for rotation or unloading they need human power. So what if these dollies are powered in a way that the human power is no longer needed to rotate the dolly or push of the load of the dolly.

What does it mean

To power dollies there are two options. One option is to power them by giving the dolly their own power source. The other option is to power dollies with the use of an external power source.

When dollies will have their own power source they can rotate the turning table on their own and also roll of containers on their own power. The controls can either be remotely or by buttons/levers on the dolly. For the turning table the dolly should have a simple motor than can make the rotation happen. For the rolling of containers it means the dolly need to have a row of rollers with rubber to get a grip on the container, otherwise the rollers would spin but not moving the container. Furthermore, the dolly need to have a motor to power those rollers.
If the dollies are self powered the best way to do it is with electricity, which means every dolly needs to have a battery to power themselves. These batteries need to be charged and maintained, which will be very labour-intensive.

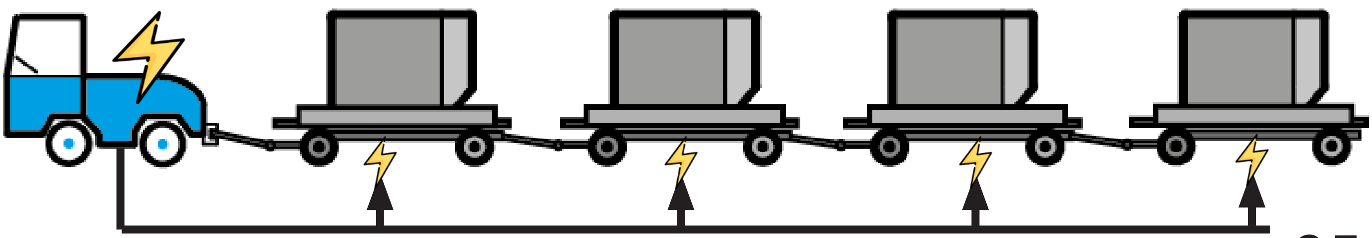
The other opportunity is powering the dolly by other equipment on the platform. The powering of the dolly can be done in different ways. First is indirectly powering the dolly with power, so the dolly itself has the motors only not the juice to power them. Other equipment will plug into the dolly and power it. In that case the equipment works as a generator
The second option is powering the dolly directly. The other equipment only has to hook up to a set of gears on the dolly an drive them. For both options the equipment needs some sort of connector to transfer the power, like the secondary axle of a tractor.
Equipment that can power dollies this are the transporter, loader and the dolly tractor. If the transporter powers the dollies the whole process will be very flexible as the transporter can choose the dolly and which side it will turn.

Secondary axle of a tractor powering a drill

The loader could also power the dollies, however if it will power them directly the dollies need to come close, and that gives problems with the load tool as described previously. The loader could also power them indirectly but then al lot of cables are needed.
The dolly tractor could power the dollies, very easily throughout the connection they already have. That connection would be indirectly. For direct powering the dollies the tractor should drive towards the dollies. However the tractor needs to leave the platform to get other CLD's. Concluding, it can be efficient to let the tractor power the dollies indirectly to rotate them. But to let the tractor roll of dollies will take to much time, plus it will make the platform only more crowded.

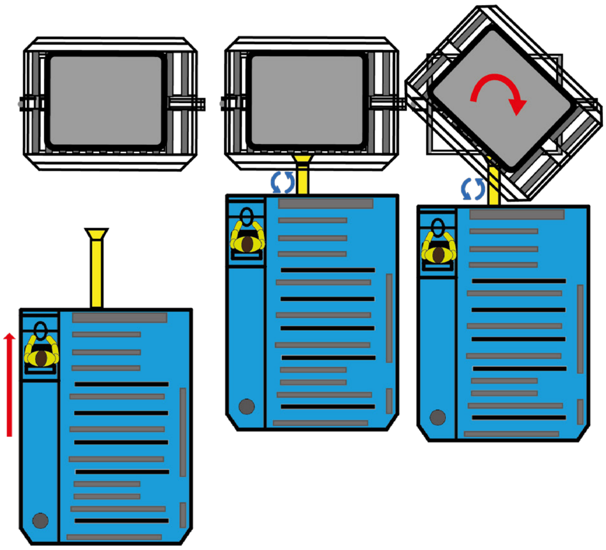
Critical note

KLM told that everything on the platform is happening fast and not always with fine subtleness. So putting a small beam on a small connector on the dolly is not desirable. It also slows the transporter due to the action taken to pinpoint the beam on the exact place.



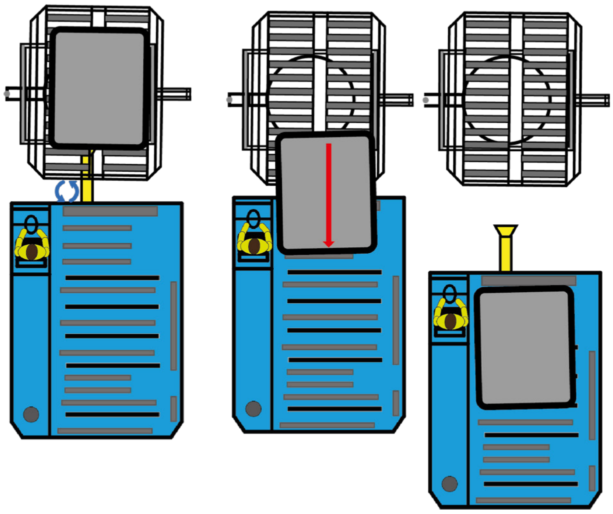
Conclusion

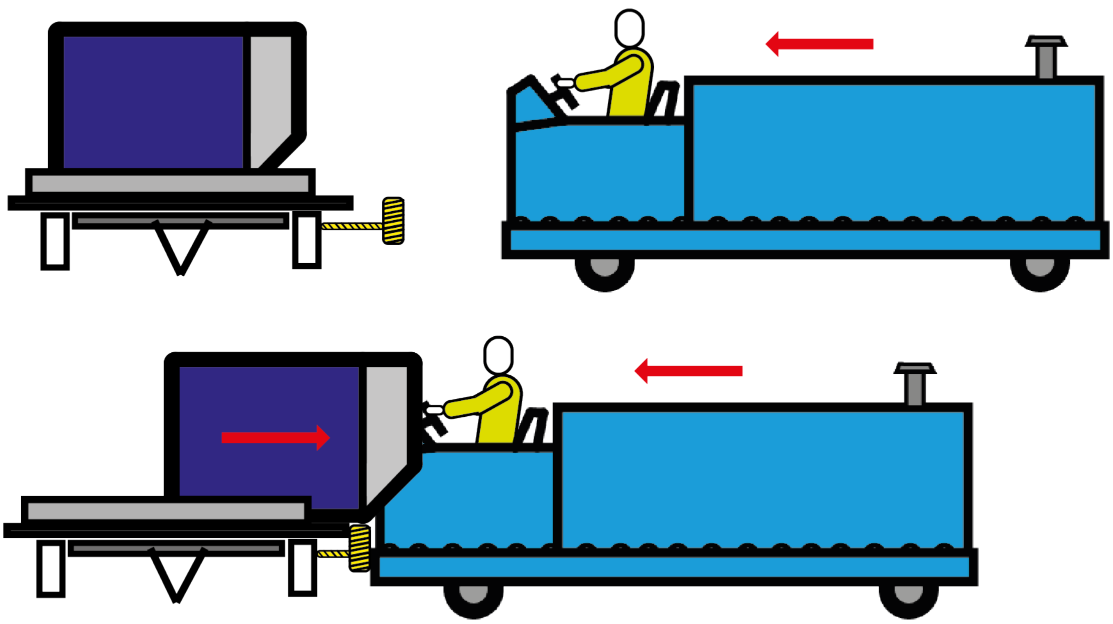
The best way to make powered dollies is to power them with equipment. Self powered dollies will have batteries that require to much maintenance to make it feasible. The tractor could be used to rotate the dollies, as the connection is already there. To let the containers roll of the dollies the transporter would be the best options. The transporter has to get close so the connection will not be a problem. Moreover, as the transporter does the unloading the load tool keeps available for use. The down side of this principle is that two pieces if equipment have to be adapted to make it work.



Addition

KLM has developed a dolly that has an automated lock. The lock is engaged by the container and locks automatically. This lock is only activated by the movement of the container. That means dolly can also be "powered" by simple movements, just by making a smart construction. The plus size of this kind of solutions is that they are very simple to operate, the lock can not be missed. It also means that the adaptation only has to be made to the dolly, and that for instance the system is activated by just driving the transporter against the dolly.





Push and rotation assist

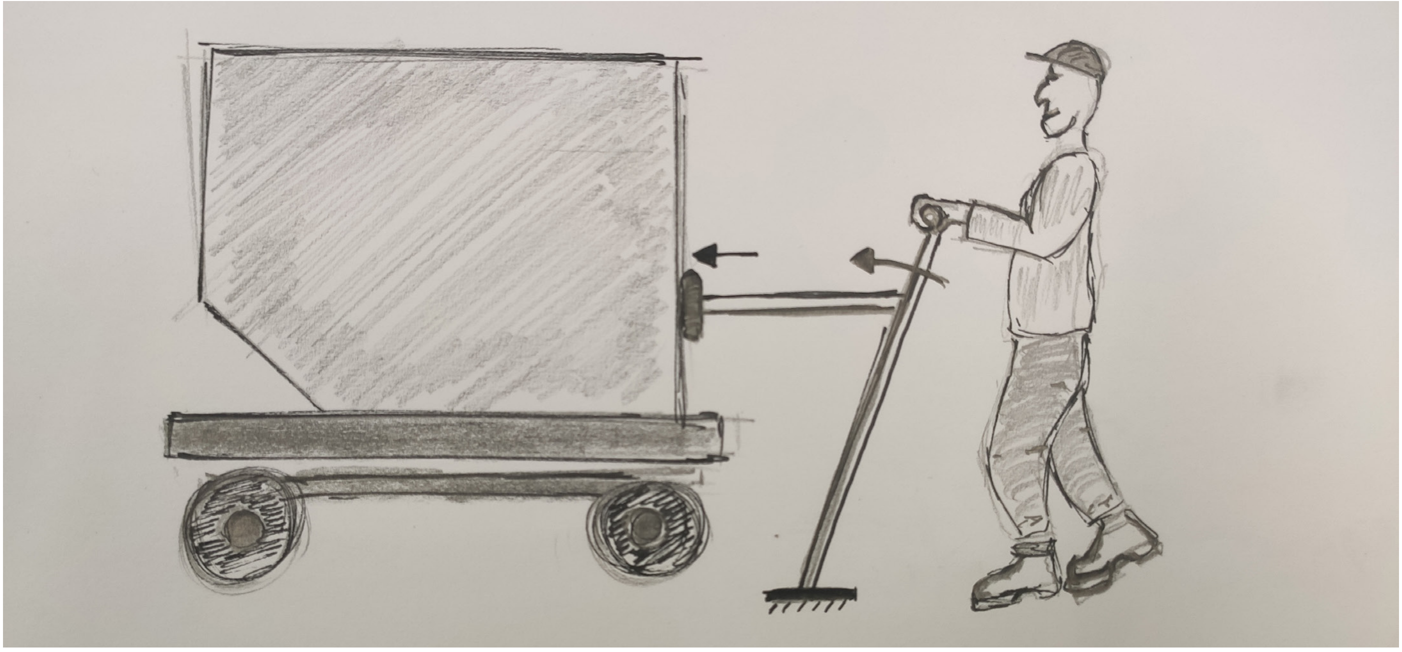
KLM already developed a push assist to help personnel with heavy pallets and containers. Nevertheless the push assist is not used as many as it would be desirable. So what sort of equipment can be designed that can help the personnel of KLM's apron service with rotating and pushing containers.

What does it mean

The push assist is almost never used for containers because it can't get behind the containers and then it becomes useless. The push assist could be reversed in which it becomes a pull assist, but then it will get in the way of the transporter, so also not a good solution. Therefore an extra tool or new equipment should be very agile to work with and operational in small areas.

The tool should be very robust as the work on the platform requires heavy duty tools. On the other side the tool should be very easy to grab, the threshold for using it should be very low.

An example of such a simple tool is shown below. It can be just some rods to create a lever that enlarges the physical strength of the personnel.



Critical note

The ultimate goal of KLM is to create an autonomous loading process. In that process there is no personnel pushing containers from dollies. So if this will be the solution it will be a temporary one. All the other solution have the possibilities to work with or on an autonomous vehicle.

Conclusion

A hand powered push assist can be a low cost solution for pushing or rotating containers. However it will not fit in the vision of KLM. Next to decreasing the physical burden, this project would be the start of an autonomous apron service. Therefore the idea of an extra tool as a push or rotation assist will not be designed.

Rotate containers with the transporter

A transporter is a very versatile piece of equipment that is the backbone of the loading process and the piece of equipment that makes the use of the load tool possible. However the transporter is now used in a very linear ways. What if the transporter becomes even more important in the process and is able to rotate dollies.

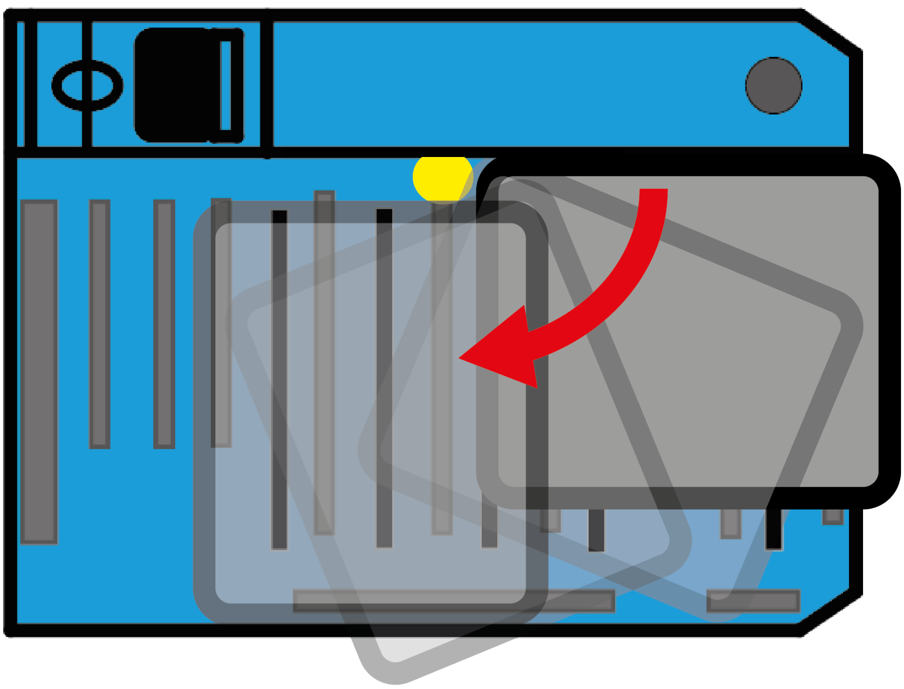
What does it mean

The only way a transporter can have an influence on the orientation of the container is by loading it on one side and unload it on the other or the side. But other than that is the transporter not able to do. So to make the transporter more flexible in the rotation of containers is to add something to the transporter that can make it possible.
This principle is not about the transporter making containers rotate on the dolly. This principle is really about rotating containers on the transporter itself.
The transporter has the ability to move containers in all directions the horizontal plane. So the powered rollers could be used to rotate the container, the container only has to be hold at one corner and then it is possible. This method is frequently used with conveyor belt. They have a bump on the side that holds the corner for moment and the rest of the product rotates around that corner.
Another way is to fit a device on the transporter that can rotate the containers. This would be a much bigger device than the 'bump' principle as it needs to get hold of the whole container with enough room to rotate it.

Rotation with the help of a simple bump. link: https://www.youtube.com/watch?v=vHnEmHZuqt4

Conclusion

The transporter has the power and the tools(the rollers) to let containers rotate. However the transporter is not suitable right now. Nonetheless, when using the 'bump' principle the transporter could be able to rotate containers, with minor modification.

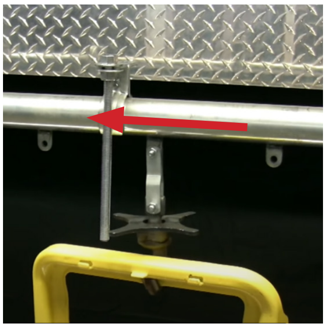
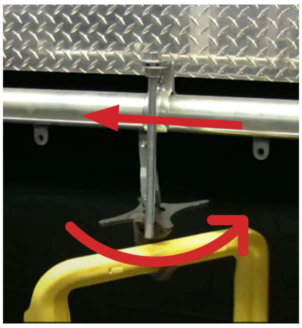
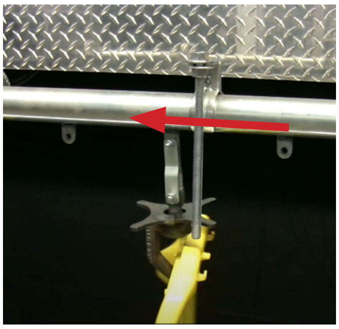


Dollies rotated before arrival on apron

The containers are now rotated until the last moment. When the load tool indicates that a container can be loaded then the personnel rotates that container. This way the orientation can be adjusted to the demand of that moment. But what will happen if containers are already turned before they arrive at the platform.

What does it mean.

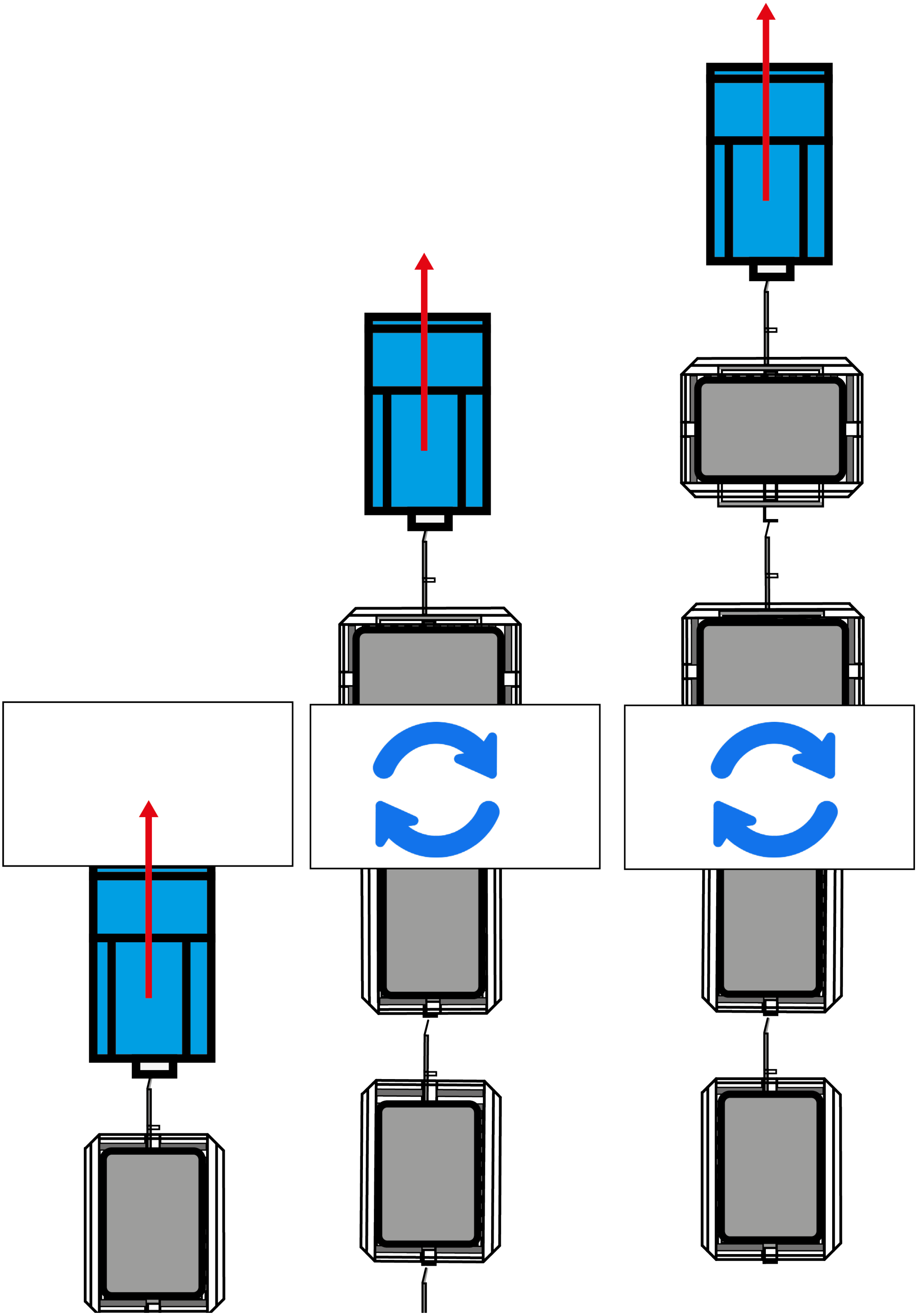
The container can be rotated the moment they leave the basement. Out of the basement is enough space to drive with an CLD in a wide setup. However when the CLD leaves the basement the orientation the containers need to have is yet unknown. However it still can cause a decrease in the physical burden on the platform. For instance, the containers are rotated alternately, chamfered side left then right then left and so on. In this setup containers can be picked up by the transporter in combinations that have the right orientation for the aircraft. They could still work with the load tool but then some container will have to be rotated to match the sequence given by the load tool. In the end less containers have to be rotated so the physical load on the personnel will decrease. On the contrary, it is harder to rotate a container 180 degrees then rotating it 90 degrees. The 180 turn is harder as the pusher has to step over the tow bar to keep the lock pressed down. If the lock is not pressed down the container will lock after 90 degrees and can't keep momentum, so the pusher has to push it again. In the end there will be less repetitive rotation of containers but the action itself will put a lot more physical stress on the personnel. Moreover, stepping over the tow bar increases the risk for accidents like tripping.
There could also be chosen to rotate all the containers the same direction, because that would be easier for an automated process later on. The same problem occurs as described before, containers have to be rotated 180 degrees to get two containers in the right orientation on the transporter.
Either way there has to be some construction or equipment that is able to rotate containers before they arrive at the platform.
Automatically turning products is already happening in many industries with conveyor belts. In these industries they have many ways of rotation products in production lines. An example in overhead conveyors is a carriage with star shaped plate on top. If the plate hits an actuator, like a rod, the product turns.

rotation with star shaped plate. link: https://www.youtube.com/watch?v=f_pbBekCBbE

Conclusion

The setup with alternate rotated containers is better when all rotation is done by hand. However if the rotation of the second container is done by machines it is better to have all the container in the same orientation on the dollies. As the final goal is an autonomous apron service it is better to have a standard setup. Therefore a setup with all containers facing the same side is the best option.



Appendix F: Combinations
The assignment is about loving the physical burden on the platform when handling containers. That means the physical labour that is executed when rotating containers on dollies and pushing containers of the dollies. Most of the concepts solve one of these problems, combinations have to be made to solve the whole problem. There are three concepts that are able to push a container of the dolly, the transporter arm, push bar and the push/rotation tool. For this part the rotation bit is removed from the transporter arm and the push/rotation tool to see if the rotation done different is better.

Transporter arm+powered dolly(battery)
This version is better in terms of efficiency because the transporter does not have to be present at the dolly for the rotation. Therefore, the transporter can immediately pick up the container when arriving at the dolly. The downside is that multiple sorts of equipment have to be changed which will lead to higher costs and a potential longer downtime of the pieces of equipment when initializing the solution.

Transporter arm+powered dolly(equipment)
In this version the transporter should be equipped with two arms/rods. The rod can make it easier to aim for the connector on the dolly. However, in the end it means making two pieces of equipment where one could do the same job with almost the same efficiency. Additionally, the dollies also need to be changed and then there are 3 changes needed in total, which will make the costs and down time even higher than the previous version.

Transporter arm+rotation gate
This is the same problem as the transporter arm and the powered dolly. A plus side can be that the arm could also rotate, which solves the problem with the wrong orientated containers.

Transporter arm+sideways dolly
This is comparable to the combination with the rotation gate and also the possibility to rotate wrong orientated containers.

Transporter arm+rotation tool
A possible feasible setup as this setup is more efficient than the transporter arm doing everything, because the tool can rotate containers in advance, same as with the powered dolly(battery). However, in this case the down time is lower and costs are probably lower.

Push bar+transporter arm
This setup is very inefficient because the transporter needs to rotate first, back up and then drive against the dolly to get the container off the dolly. Besides that, there is a high chance of both concepts blocking each other. The only thing that could work is when the push bar opens the locks, in that case the transporter does not have to aim for the locks.

Push bar+powered dolly(battery)
This is a good setup because both systems are on the same piece of equipment, which results in easier implementation. The push bar is also good for the efficiency because the container can turn before the transporter arrives at the dolly and the employee that rotates the containers can keep ahead of the transporter

Push bar+powered dolly(equipment)
This is the same case as with the push bar and transporter arm as the transport has to be present at the dolly for the rotation and has to wait for the container to be rotated.

Push bar+rotation gate
This combination has the same efficiency as with the powered dolly(battery) because the transporter can immediately pick up the container on arrival. Only still a problem with wrong orientated containers.

Push bar+sideways dolly
This combination has the same efficiency as with the powered dolly(battery), because the transporter can immediately pick up he container. Only remark is that the push rod should be adapted in a way that it works when the transporter drives alongside the dolly.

Push bar+rotation tool
This has exactly the same advantages with as the powered dolly(battery), the rotation tool can rotate the containers before the transporter arrives and does not have to wait for the container to push the container onto the transporter.

Push tool+transporter arm
This is a combination that could work, but why not get the containers of with the arm? Why build two pieces of equipment as they could be combined into one that is more efficient and solves the problem better?

Push tool+powered dolly(battery)
It does the job and has the same efficiency as the current situation. In this case the employee still has to wait at the container for the transporter to arrive.

Push tool+powered dolly(equipment)
Could work but is less efficient as the current situation as the transporter has to be present for the rotation of the dolly

Push tool+rotation gate
This is a good combination and has the possibility to solve wrong orientated containers with the tool.

Push tool+sideways dolly
This is the same as with the rotation gate because the push tool could also be used to solve wrong orientated containers.

Appendix G: Research on forces handling containers.

The new way of handling containers is one in which the loading and offloading is driven by the transporter. This new system will be subjected to different forces applied on either the container or the dolly. This research will determine the scale of those forces. The outcome of this research will help to specify the parts in the system.

Research questions

Research Goal: Which amount of force is needed to handle a 900 kg container
Design Goal: What forces should the push bar be able to withstand and how should the pulley be designed
Research Questions:

- What force is needed to push a 900 kg container off the dolly?
- What force is needed to pull a container onto a dolly?

Method

In the method section of this article is explained how the study is conducted. This research is part of a design project to decrease the physical burden when handling containers on the platform at airports.

Participants

There are two participant needed. One participant will drive the transporter and the other participant will push, rotate and pull the container.

Apparatus

The research will be conducted with the use of a CD-01 5FT container dolly, this will be the base where the container can move over to (un)load The container that will be used will be a LD3-AKE. This container will be filled with a water tank that can be filled up to 900 litres to simulate a fully loaded baggage container. The total weight of the whole combination of water tank, water and container will be 57+900+57=1014kg. Water is used so the weight can be determined exactly.
The TLD-10-FTC transporter is needed, otherwise the container will drop on the ground or topple off. The transporter is also used to simulate the slope of the platform by lifting the dolly.

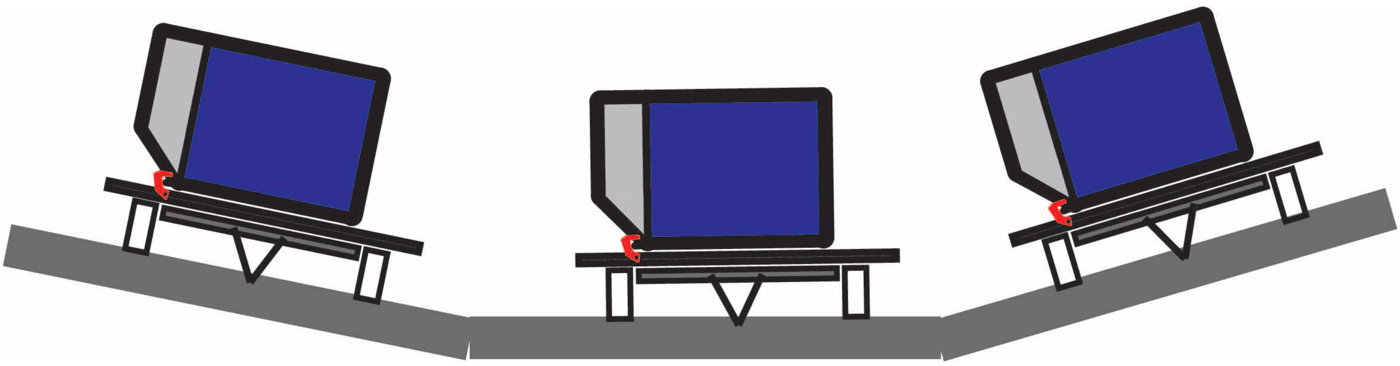
Test setup

To measure all the forces a digital force gauge, model DFG500, is used. This force gauge can measure forces up to 500N. The peak function on the gauge will be used to read the highest force used for the actions.

Force gauge

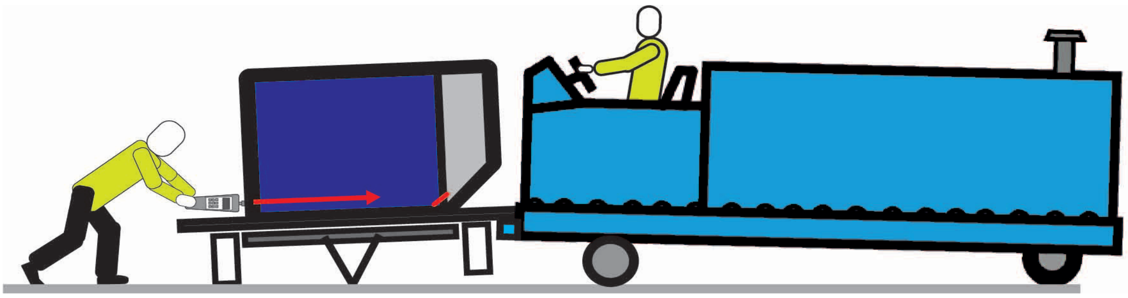
Procedure

There are three situation a dolly can be placed in that could affect the required force to handle a container. Those situations are: descending slope, ascending slope and horizontal. However, the maximum forces are needed to be measured, that means the force when pushing a container up the slope of the platform. The force of pushing a container up a the slope is assumed to be the same as puling a container up the slope



Possible positions of dollies

The test starts with the transporter driving against the dolly. When the transporter is parked, it lifts the front of the dolly. First the lock is pushed down to able the container to move. Then the gauge is placed at the back of the container and the container is pushed with the gauge off the dolly until it hits the transporter. Then the gauge is read and the value noted.



The transporter lifts the dolly and the container is pushed with the gauge

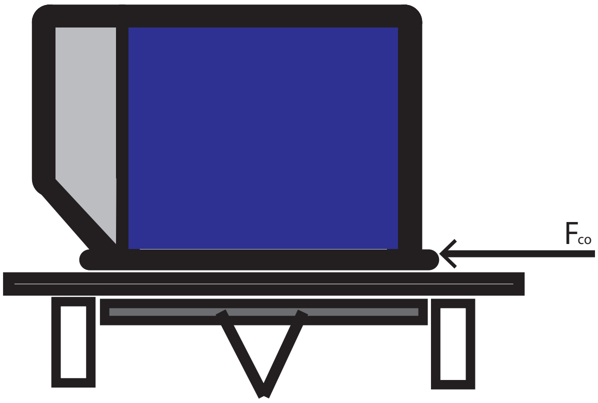
Friction and resistance

The maximum container is not 900 kilos but 1500 kilos. To make the transition to the heaviest container the factor of friction should be taken into account. Because when a container is pushed, it is experiencing drag as a result of the friction from the rollers. The factor for the friction is 1.0, this has to do with friction being proportional to the coefficient of friction and the object's mass(Uzinngo 2019). The coefficient will stay the same as the area of contact and material will stay the same with every container. For this reason the force of pushing a specific mass can be transferred to the force needed to move any container.

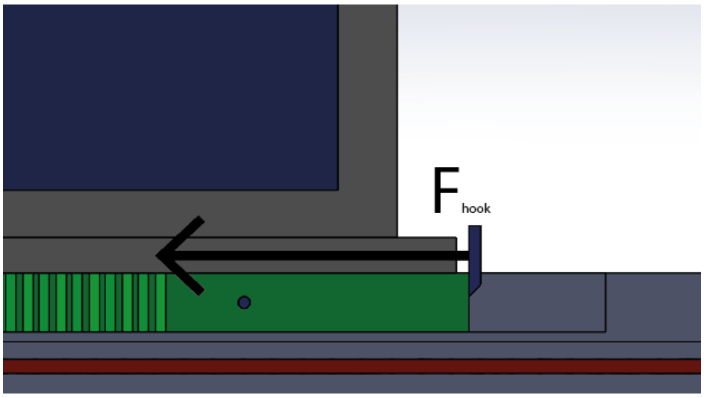
The rollers have a specific friction that give a reaction force on the container when pushing it

Results

The results came down to a and a maximum of 539Newton for pushing a container (All the result can be found in appendix I) . As said in the chapter before, that the friction can be assumed to be directly linked to the mass of the container. The force required to push the heaviest container comes down to 898Newton. That means the hook should at least exert a force of 898 Newton on the container to move it.



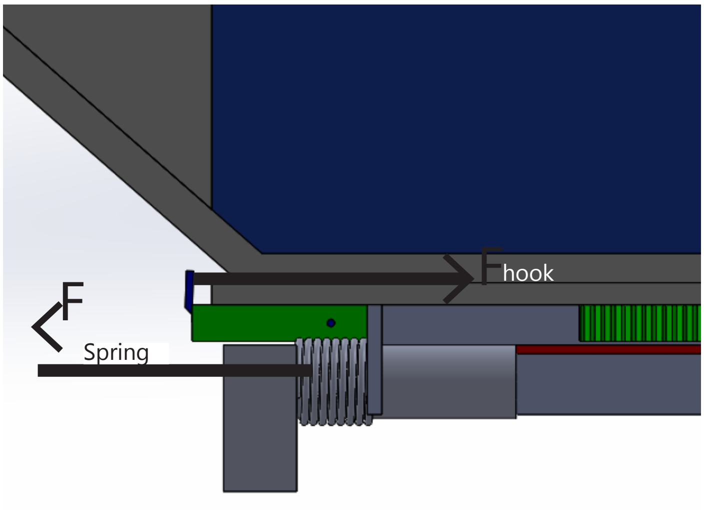
The force exerted on a container to push it off the dolly



The force of the human is replaced by that of the hook

The result of 898 newton to move the container also means the spring needs to exert a force of 898 newton to pull a container back onto the dolly. That will result in a force of 6740 Newton the transporter has to exert to get the mechanism moving.

As said the transporter has to exert a force of minimal 6740 newton. That is possible because the transporter is able generate a force of 70000Newton, although it is advised to not push more than 10000 newton with the transporter. Still the transporter is able to power the system.



Active forces when pulling a container onto the dolly

test#	rotation left	rotation right	push container	push container onto slope
1	250	301	383	538
2	245	300	400	535
3	243	295	391	539
4	239	270	395	520
5	248	278	390	539
6	241	305	398	532
7	248	297	379	529
8	246	298	401	531
9	249	304	396	524
10	246	293	393	536

Results of the force reserach

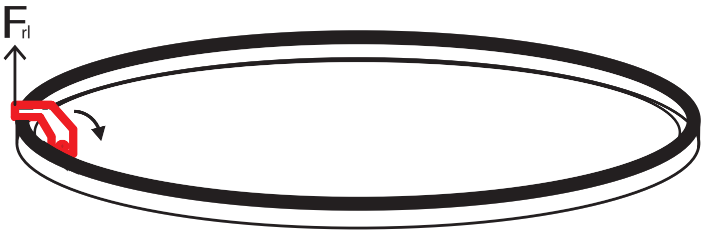
Appendix H: Forces of rotation

The system of rotating at need certain forces to work and will have certain forces to bare. This chapter will explain the different forces that are active in this process of a powered rotation.

- What force is needed to rotate a 900kg container?

Rotation

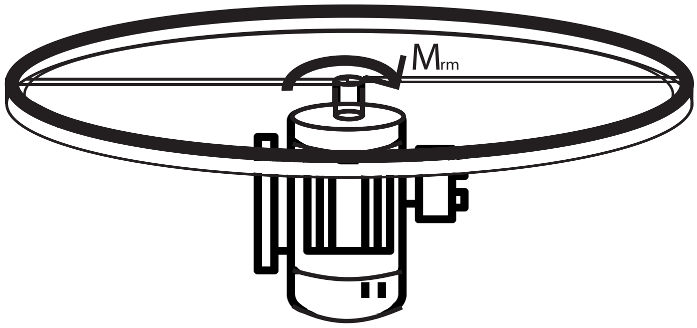
There is a force needed to open the rotation lock. This force should open the lock to make the rotation possible. The lock rotates to open up and has a spring attached to push it back when the next opening passes.



Force of opening the lock

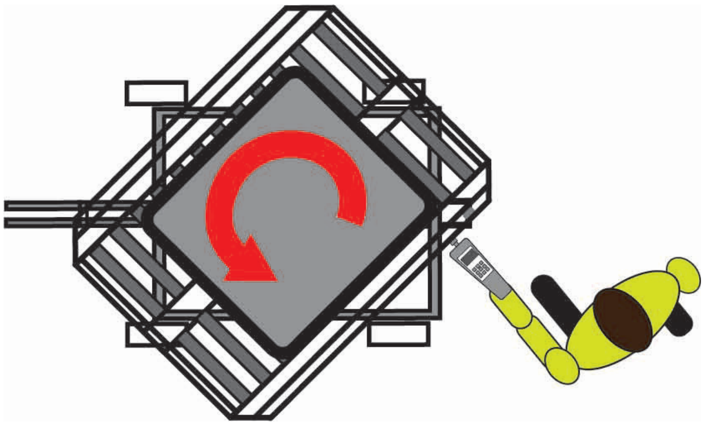
The other force needed is the force that rotates the top bed of the dolly. This force will be a moment that will be generated by a motor. The motor will be attached to the turning table and mounted on the base of the dolly.

The force of rotation is dependable on which direction the chamfered overhang has to go. The container is centred on the bottom plate, but the overhang is also filled, therefore, rotating the overhang up the slope is the heaviest.



The torque the motor needs to rotate the dolly

The test start with the turning table of the dolly in the driving orientation. The gauge is placed on the side of the turning bed. When the lock is released a person start pushing against the turning bed with the gauge until the turning bed locks into the 90 degree position. Then the peak force is read and noted.

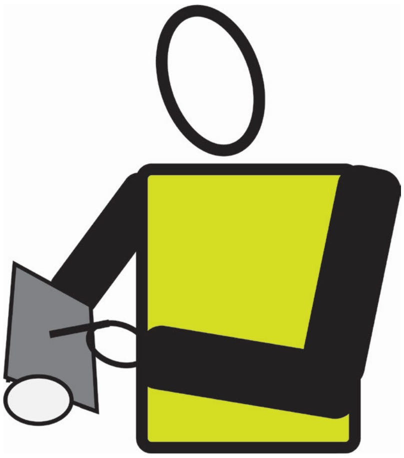


pushing the container with the gauge

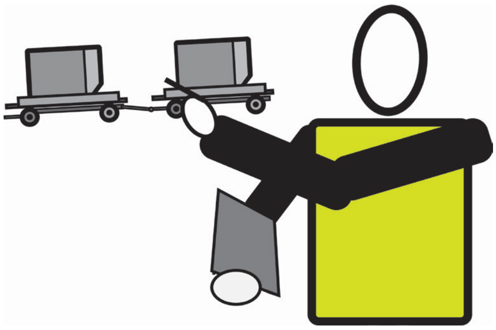
A maximum of 305 Newton for the rotation of the container That will bring the maximum force needed to rotate a container of 1500Kilos to 508Newton. That means the motor should be strong enough to generate 508 newton at 0.5 at the centre or a torque of 254Nm.

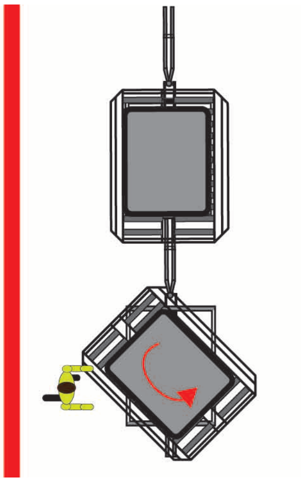
Appendix I: Powered dollies concept

This chapter will quickly describe how the powered dollies will work and after that give a description for the parts that will be used. As said the project will be elaborated until a stage where someone can pick it up after 5 years, however technology can change, therefore the process and parts of the rotation with the powered dolly can change too.

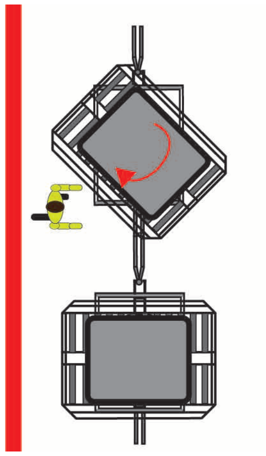


The process starts by the team leader, who will see on his tablet which containers can be loaded and what the orientation should be. The Team captain will communicate to the pusher which containers have to be loaded and which way.

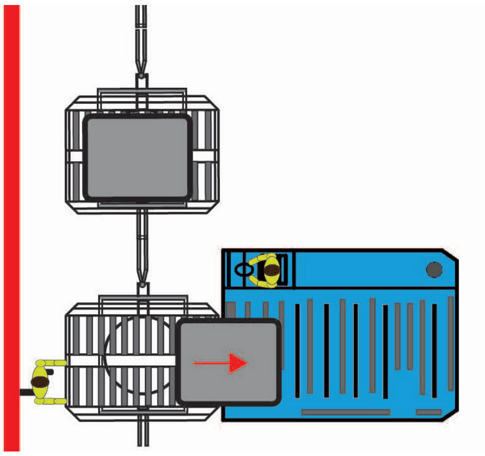


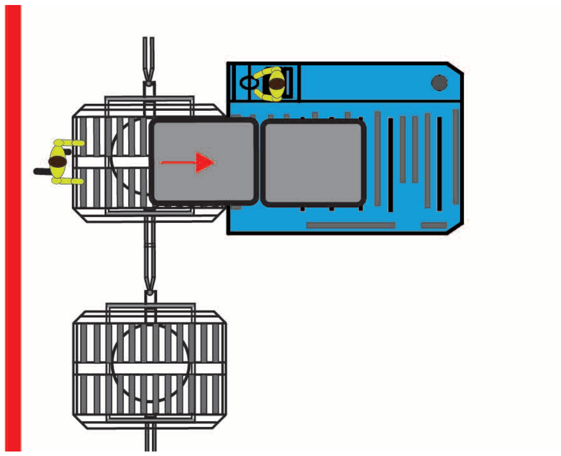


The pusher will walk towards the dolly and push a button on the dolly to make the rotation. Then the pusher will walk to another container and push the button to rotate that one. It depends on the location of the containers if both containers can be rotate in advance. Sometimes the containers will not be next to each other, then the first container is rotated and loaded onto the transporter and then the second is rotated and loaded onto the transporter.



Both containers are loaded onto the transporter. When both containers are on the transporter the process can start over again.

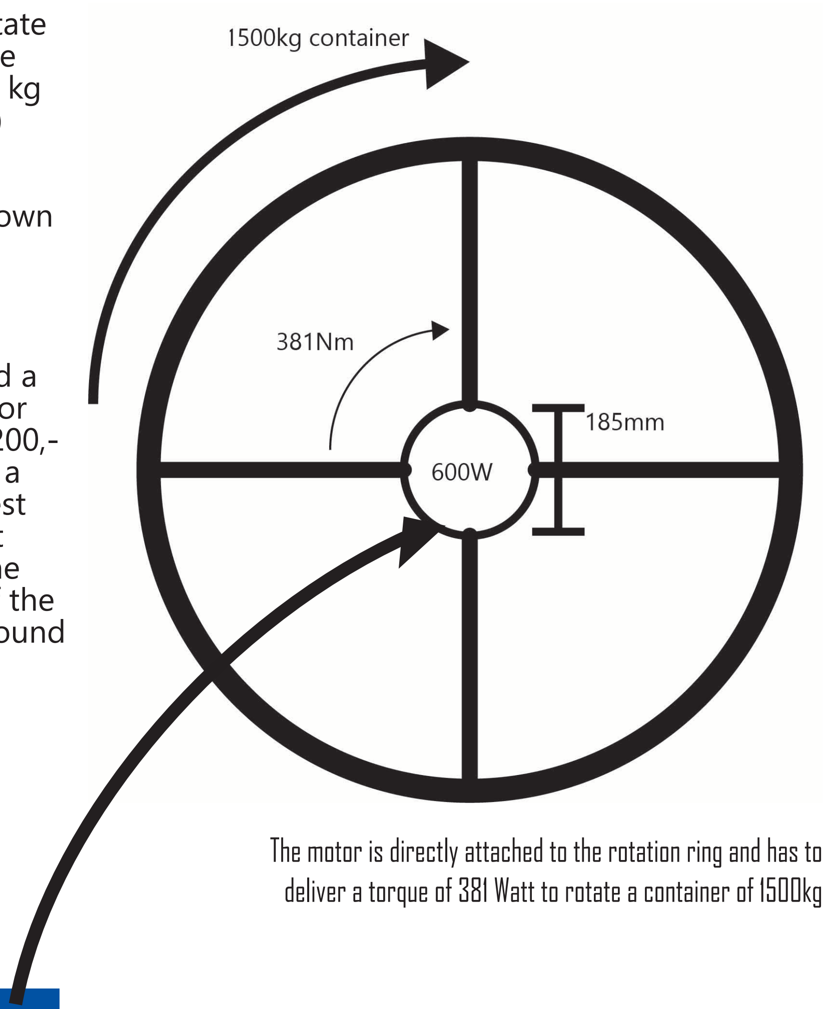




Motor

The motor for the rotation is placed on the bottom bed of the dolly and will rotate the turning table of the dolly.

The maximum force that is needed to rotate a container at 0,5m from the centre of the dolly is 305N, that means that for a 1500 kg container a force of 508N(305/900*1500) is needed to rotate. That 508N translates to a torque of 254Nm(508*0,5). With a needed safety factor of 150% it comes down to a peak torque of 381Nm. This results in a actuator with a diameter of around 185mm and a height of around 450mm and weighing around 21kilos. The motor will approximately run at 50 Amperes and a power of 600W(Tecnadyne, 2014). A motor with this specification will cost around €200,- But that not the only motor, there is also a motor needed that will open the lock. Best is to change the locks for one piston that is attached to the bottom of the dolly. The pistons matches with holes on the top of the dolly to lock it. This will be a piston of around €30,- that would do the job.(RS, 2019)



The motor is directly attached to the rotation ring and has to deliver a torque of 381 Watt to rotate a container of 1500kg

600W 540Nm motor(Tecnadyne, 2014)

Battery

Deep cycle battery (Accu.nl 2020)

One rotation is very short and would not use a lot of power, therefore the battery does not need a large capacity. The biggest concern should be holding power on the dolly.
The motor needs 50 amperes to run and a rotation will take approximately 5 seconds. The battery should have enough for 4 rotation before it has to be recharged. That means the battery should be able to contain 50*20/3600=0,28 Ah. However, a battery should not be discharged to many times below 20%. That results in a battery with a capacity of 0,048*1.2=0,33Ah. Best battery to use in this situation is a deep-cylce battery as it can cope with more frequent discharging before recharging(Summit Racing, 2018). However deep cycle batteries start at 10Ah, that means a lot more rotations than initially set. On the other side that opens the possibilty to charge the battery at a more central point as with a bigger deep cycle battery it can stay outside for a long time. A battery with the right capacities will cost around €25.

Charging

Charging can be done in two ways, one is through an alternator an the other through a central charging point. An alternator will make the dollies more independent, they are only dependent on a drive once in a while. On the other side it means that every dolly has to be fitted with an €70,- alternator. This alternator has an output of 50A at 6000rpm, however, the axle of the dollies spins at 400rpm when driving 30km/h. To get to that 6000rpm some transfer mechanism is needed to crank up the rpm’s otherwise the alternator wil not work properly(Laukonen, J. 2019)
A central charging point would make the dollies more dependable on a certain route they have to take every once in a while. It will also require some extra action to charge, because there has to be direct contact. Wireless charging could be an option, but is not yet efficient enough and sensitive to errors(M. Verwaal TU Delft, 16-07-2020). However the dollies could be taken into the plans to make Schiphol totally electric. That means that the dollies will also be taken into account when building more charging points.

Sensors and Software

To make the rotation work there have to be sensors that register which button is pressed, sensors that register if the lock is closed and sensors that register if the dolly is rotated 90 degrees. For those sensors and the control of the motors has to be some sort of software that could control and switch everything.

Instalment

The dolly does not have to be altered very much for this system. The main adjustments are brackets that have to be bolted on for the motors, battery and the alternator.

Conclusion

The total cost of the rotational mechanism will come down to approximately €450 per dolly. But that is done with a very positive calculation and a lot of unknown factors. Also all the cable-work is not included and the brackets for the parts are also not thoroughly calculated.

Appendix J: force calculations

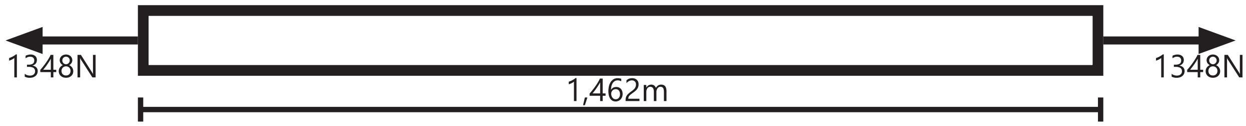
This section contains the calculations for the mechanism. Each equation is done with a 1,5 safety factor.

Cradle strain

The rod of the sled will be subjected to the force of the cable and the container. To calculate the minimum thickness of the rod the next formula is used.

$$Q = \frac{P}{A}$$

Q=Yield strength[Pa]
P=applied load[N]
A=cross sectional area[m^2]



To calculate the minimum thickness, first the cross sectional area is calculated, from that the thickness is subtracted.

$$Q = \frac{P}{A} ==> A = \frac{P}{Q} = \frac{1348}{172 * 10^6} = 0{,}00000784m^2 ==> D = 2 * \sqrt{\frac{0{,}00000784}{\pi}} = 3{,}16mm$$

To stay within the elastic limit the rod should be 3,74 mm thick. However it is also important that the rod would not stretch to much. This means the elongation is also important for the design of the cradle. If the cradle will extend to much to mechanism will not work anymore. So a maximum of 0,5mm elongation is the limit for the cradle to stretch.
To calculate the thickness of the rod the next formula is used.

$$\delta = \frac{P * L}{A * E}$$

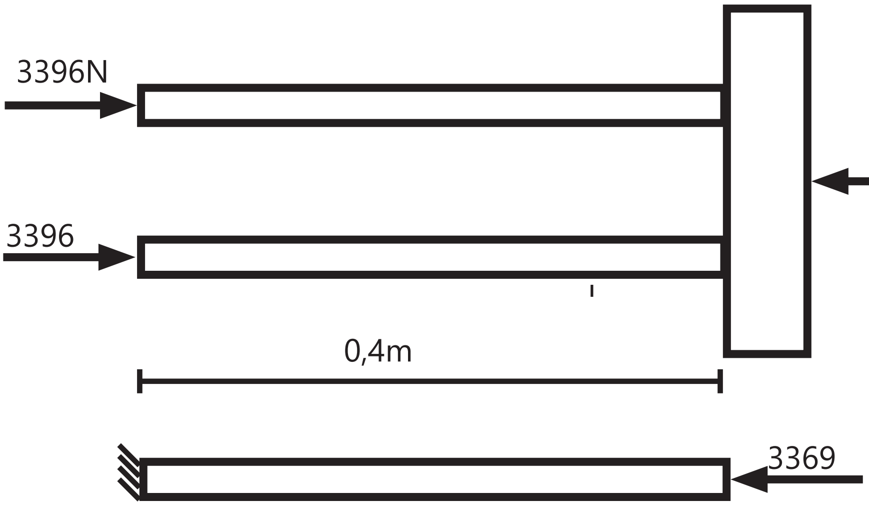
To calculate the minimum thickness, first the cross sectional area is calculated, from that the thickness is subtracted.
δ=Displacement of one point on the bar relative to the other point[m]
P=internal axial force at the section[N]
L=original length of the bar[m]
A=cross sectional area of the bar[m^2]
E=modulus of elasticity for the material or Young's modulus=[Pa]
D=diameter of the rod[m]

$$\delta = 0{,}0005 = \frac{P * L}{A * E} = \frac{1348 * 1{,}462}{A * 255 * 10^9} ==> A = \frac{1348 * 1{,}462}{0{,}0005 * 255 * 10^9} = 1{,}55 * 10^{-5}m^2$$

$$==> D = 2 * \sqrt{\frac{1{,}55 * 10^{-5}}{\pi}} = 4{,}44mm$$

Buckling of bumper rods

When handling the heaviest container possible the maximum force will be 4 times the force that reacts on the cradle. That multiplying comes from the pulley. Also the force of the gas spring has to be calculated into equation, which is 1348N.



$$\frac{1348 * 4 + 1348}{2} = 3369$$

The formula to calculate the minimum thickness of the rod to cope with the pressure is:

$$P = \frac{\pi^2 EI)}{L^2}$$

P=critical or maximum axial load on the rod just before it begins to buckle[N]
E=modulus of elasticy or Young's modulus[Pa]
I=moment of inertia for the rods cross sectional area[m^4]
L= unsupported length of the rod[m]
r=Radius of the cross section of the rod[m]

To calculate the minimum thickness, first the moment of inertia is calculated, from that the thickness is subtracted.

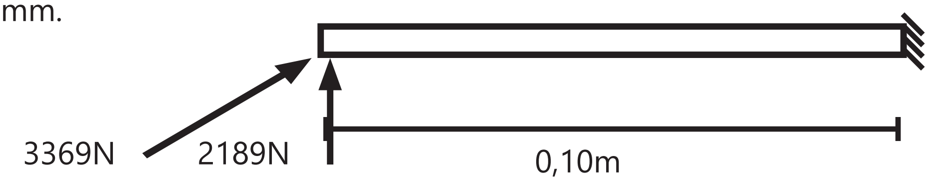
$$P = \frac{\pi^2 EI)}{L^2} = 3369 = \frac{\pi^2 * 205 * 10^9 (0{,}25\pi r^4)}{0{,}4} ==> \frac{3369 * 0{,}4}{\pi^2 * 205 * 10^9} = 0{,}25\pi r^4 ==> r$$

$$= \sqrt[4]{\frac{6.6 * 10^{-10}}{0{,}25\,\pi}} = 0{,}0054m = 5{,}40mm$$

This means the rods of the bumper need to be at least 11.79mm thick to cope with the force without buckling.

Bending of the bumper rods

The possibility exist that the bumper is hit under an angle and therefore a sideways reaction force is created on the bumper rods. The biggest angle will be 18 degrees, when the bumper is at 100mm of the dolly. A bigger angle will mean the transporter hit the side of the dolly. If the transporter hits the bumper under an angle it will result in a perpendicular force on the rods of 2194N which will be distributed over both rods. The bending can block the mechanism as the rod can get stuck in the bearing. To keep the blocking from happening the rod can not bend more then 0,5mm.



The formula used to calculate the minimum thickness of the rods to stay within the 0,5mm bending is:

$$v = \frac{PL^3}{3EI}$$

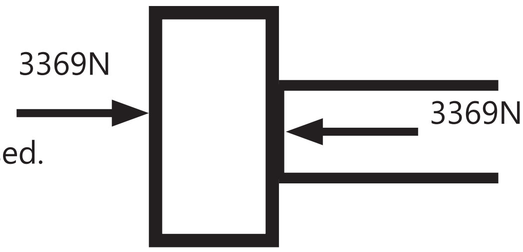
v=the maximum allowable deflection at the end of the rod[m]
P=The sideways load applied on the rod by the transporter[N]
L=length of the rod[m]
E=modulus of elasticity or Young's modulus[Pa]
I=moment of inertia for the rods cross sectional area[m^4]
D=diameter of the rod[m^2]

$$v = \frac{PL^3}{3EI} = 0{,}0005 = \frac{1094 * 0{,}10^3}{3 * 205 * 10^9 * I} ==> I = \frac{1094 * 0{,}10^3}{0{,}0005 * 3 * 205 * 10^9} = 4 * 10^{-9} m^4 ==> D$$

$$= 2 * \sqrt[4]{\frac{4 * 10^{-9}}{0{,}25\ \pi}} = 16{,}4mm$$

Shear on the bumper

When the bumper is pushed the rods exert a force on the bumper which causes shear stress. This calculation will determines the wall thickness of the bumper. To calculate the minimum wall thickness of the bumper the next formula is used.



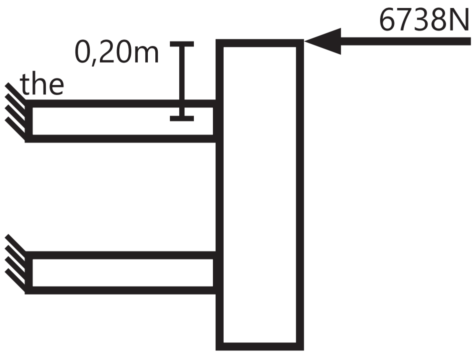
$$\tau = \frac{P}{A}$$

τ=maximum allowable shear force=[Pa]
P=load applied to the bumper=[N]
A=cross section of the bumper=[m]

$$\tau = \frac{P}{A} = 172 * 10^6 = \frac{3369}{2\pi * 0{,}008 * d} ==> d = 0{,}4mm$$

A wall thickness of 0,2mm will be enough to cope with the shear.

Bending of the bumper.



The bumper should not bent to much when the transporter drives against it, especially not when the bumper is hit on one side. However the bumper can have some more deformation then the rods, because it has more clearance. To calculate the measurements of the cross section of the bumper the following formula is used

$$v = \frac{PL^3}{3EI}$$

After that the formula below is used to calculate the width and height of the bumper.

$$\frac{B * H^3}{12} - \frac{(B-d) * (H-d)^3}{12}$$

v=the maximum allowable deflection at the end of the bumper[m]
P=The load applied on the end of the bumper[N]
L=length of the rod[m]
E=modulus of elasticity or Young's modulus[Pa]
I=moment of inertia for the bumpers cross sectional area[m^4]
B=width of the bumper[m] H=Height of the bumper[m]

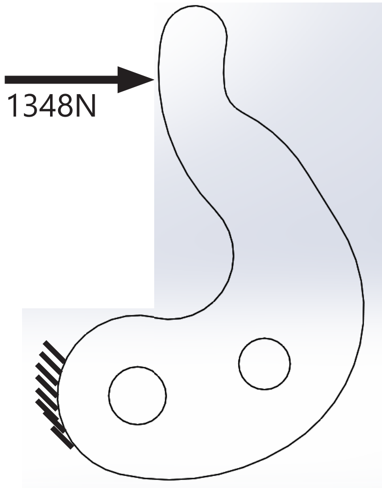
$$v = \frac{PL^3}{3EI} = 0{,}001 = \frac{6738 * 0{,}26^3}{3 * 205 * 10^9 * I} ==> I = \frac{6738 * 0{,}26^3}{3 * 205 * 10^9 * 0{,}001} = 1{,}93 * 10^{-7}\ I$$
$$= \frac{B * H^3}{12} - \frac{(B-d) * (H-d)^3}{12} = \frac{0{,}06 * H^3}{12} - \frac{(0{,}06-d) * (b-d)^3}{12} =$$

The formula above shows how the moment of inertia is calculated and how the moment of inertia is used to calculate the dimensions of the beam. The beam has a width of 60mm, because that fits perfectly onto the dolly beam. In terms of cost it is better to use standard beam sizes. All the beam sizes with the corresponding wall thickness are in the sheet below, showing the deformation of the beam. However because the 260mm overhang has a pretty big deflection, the size is changed to 200mm which will make the bumper 500mm in width. That will also help in reducing the force a transporter can put on the bumper when driving at it under an angle.

moment of inertia	Beam width	wall thickness	Deformation Bumper 620mm	Deformation Bumper 500mm
3,18853E-08	0,02	0,002	6,039277329	2,748874524
5,25058E-08	0,03	0,0015	3,667491098	1,669317751
6,39787E-08	0,03	0,002	3,009821567	1,369968851
8,3792E-08	0,03	0,003	2,298123577	1,046028028
9,03983E-08	0,04	0,0015	2,130178081	0,969584925
1,13272E-07	0,04	0,002	1,700017398	0,77379035
1,54132E-07	0,04	0,003	1,249347123	0,568660502
1,89005E-07	0,04	0,004	1,018830354	0,463737075
1,42841E-07	0,05	0,0015	1,34810529	0,613611875
1,42841E-07	0,05	0,0015	1,34810529	0,613611875
1,81765E-07	0,05	0,002	1,059411975	0,482208455
2,52672E-07	0,05	0,003	0,76211203	0,346887587
3,14952E-07	0,05	0,004	0,61140863	0,278292503

The sheet shows that to have less than 1mm deflection a beam of 60x40x1,5 is enough.

Shear force on the hook



To cope with a the force of the rim of the container the hook has to have a certain cross section. To calculate the minimum cross section of the hook the next formula is used:

$$\tau = \frac{P}{A}$$

τ=maximum allowable shear force[Pa]
P=load applied to the bumper[N]
A=cross section of the bumper[m²]

$$\tau = \frac{P}{A} ==> \frac{1348}{172 * 10^6} = 7{,}84mm^2$$

To cope with the shear force the hook should have an area of at least 7,88mm2. However for bending the dimensions will be adjusted.

Bending of the hook

The hook should not bend to much to prevent it from jamming on the rim of the container. Therefore the hook should not bent for more than 0,5mm.
To calculate the dimensions of the cross section of the hook the following formula is used.

$$v = \frac{PL^3}{3EI}$$

v=the maximum allowable deflection at the end of the hook[m]
P=The load applied on the end of the hook[N]
L=length of the hoo[m]
E=modulus of elasticity or Young's modulus[Pa]
I=moment of inertia for the hooks cross sectional area[m⁴]
The formula for the area of a circle is used to get from a moment of inertia to a thickness

$$v = \frac{PL^3}{3EI} = 0{,}0005 ==> I = \frac{1348 * 0{,}07^3}{3 * 205 * 10^9 * 0{,}0005} = 2 * 10^{-9} \qquad \sqrt[3]{\frac{2 * 10^{-9} * 12}{0{,}015}} = 10.6mm$$

The hook should be 10,5mm wide with a thickness of 15mm

Shear on the lifting rim of the bumper

When the transporter lifts the dolly the bumper needs to hook under the dolly to prevent bending. To make sure the rim on the bumper will not shear off the formula τ=P/A is used to calculate its thickness.

$$\tau = \frac{P}{A}$$

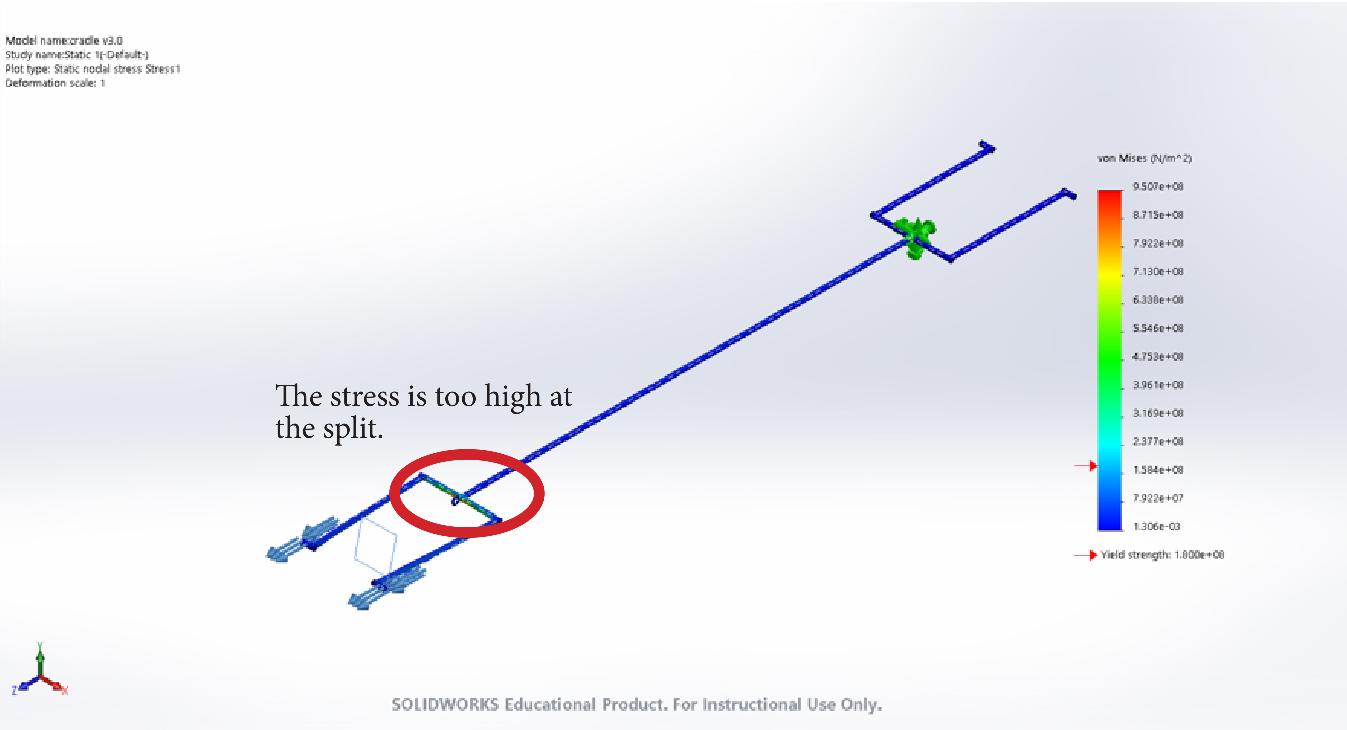
τ=maximum allowable shear force[Pa]
P=load applied to the rim[N]
A=cross section of the bumper[m²]

$$\tau = \frac{P}{A} = 172 * 10^6 = \frac{35095}{0{,}5 * b} ==> b = 0{,}5$$

The rim has to be at least 4mm thick

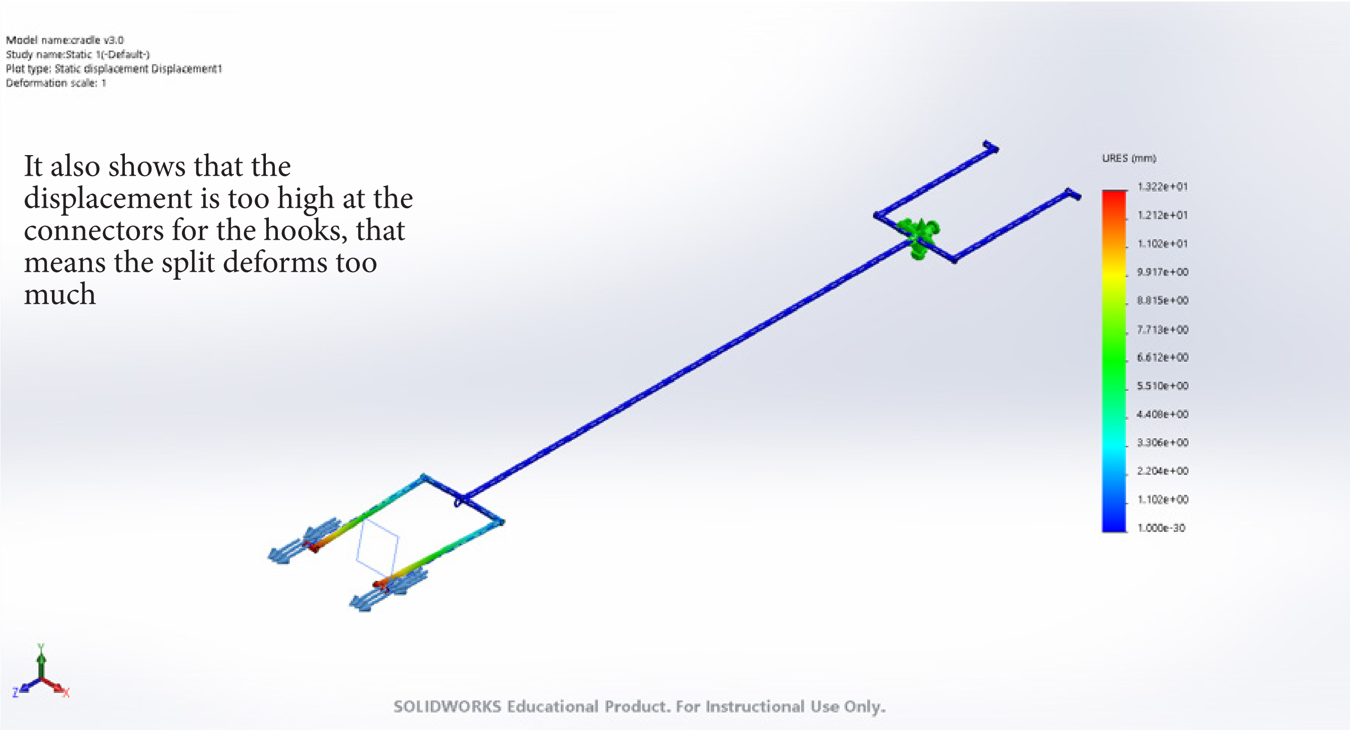
Appendix K: Force simulations

Name	Type	Min	Max
Stress1	VON: von Mises Stress	1.306e-03 N/m^2 Node: 17030	9.507e+08 N/m^2 Node: 7939



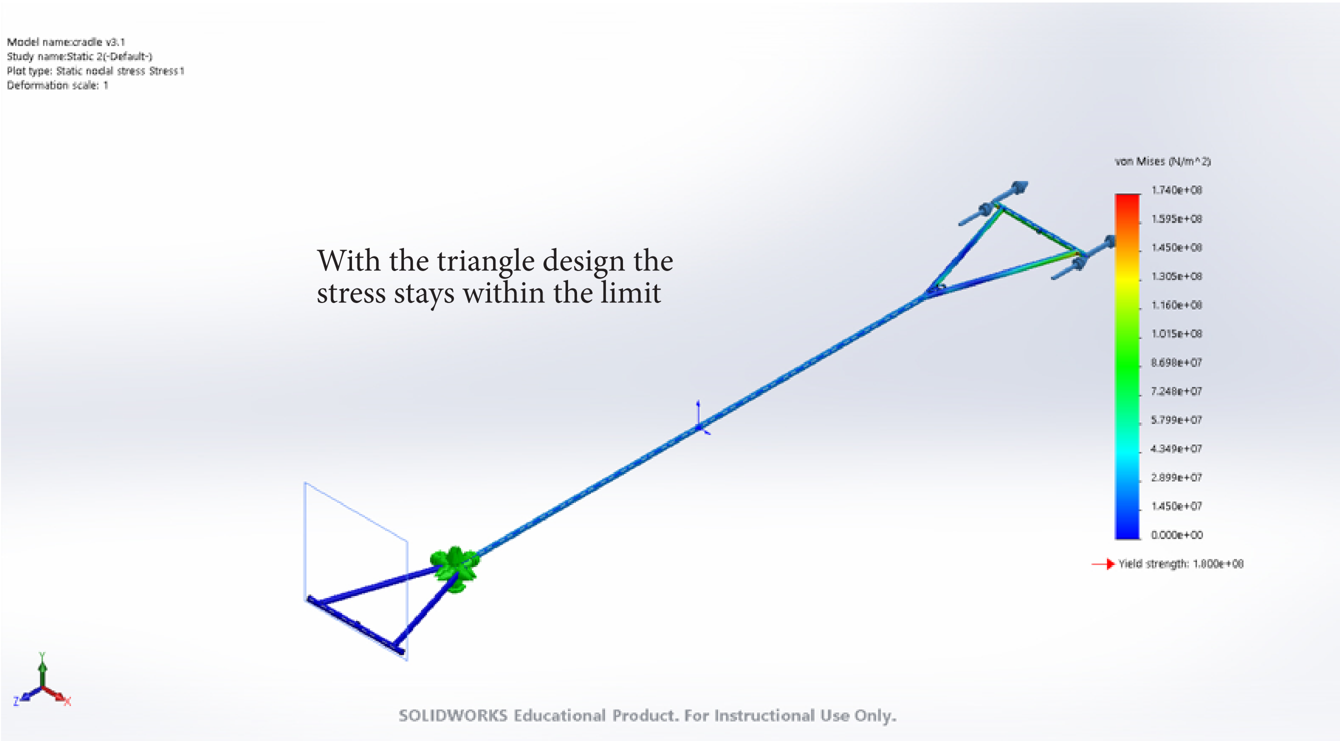
cradle v3.0-Static 1-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+00 mm Node: 39	1.322e+01 mm Node: 2858



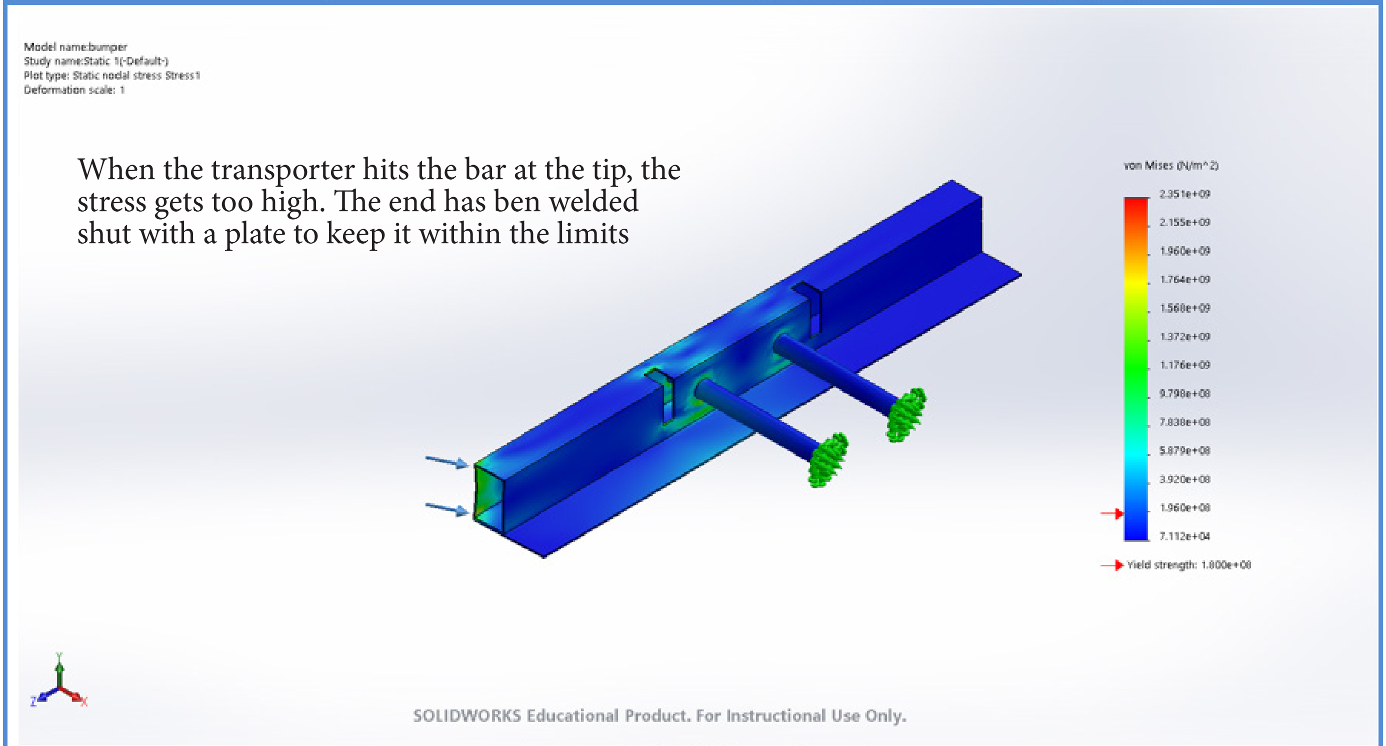
cradle v3.0-Static 1-Displacement-Displacement1

Name	Type	Min	Max
Stress1	VON: von Mises Stress	0.000e+00 N/m^2 Node: 77	1.740e+08 N/m^2 Node: 22337



cradle v3.1-Static 2-Stress-Stress1

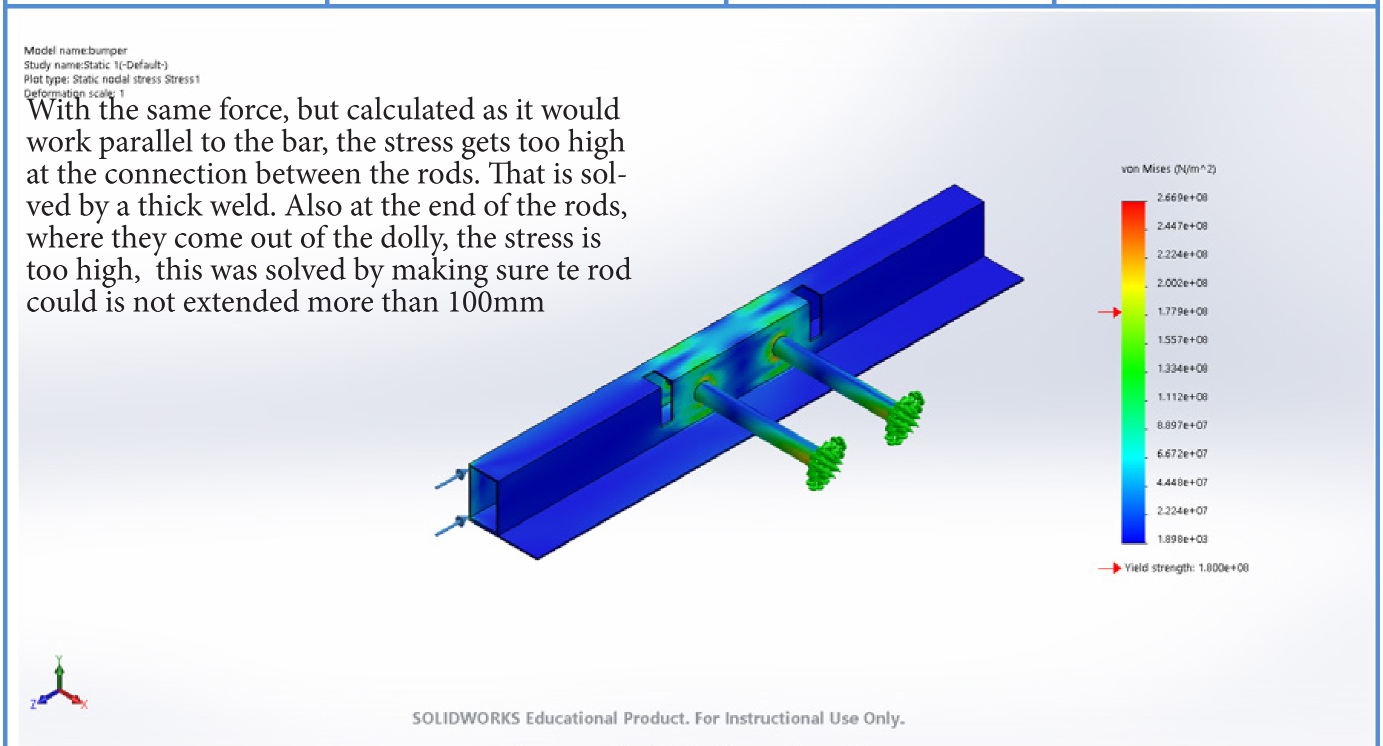
Name	Type	Min	Max
Stress1	VON: von Mises Stress	7.112e+04 N/m^2 Node: 24543	2.351e+09 N/m^2 Node: 3004



When the transporter hits the bar at the tip, the stress gets too high. The end has ben welded shut with a plate to keep it within the limits

bumper-Static 1-Stress-Stress1

Name	Type	Min	Max
Stress1	VON: von Mises Stress	1.898e+03 N/m^2 Node: 10850	2.669e+08 N/m^2 Node: 38482

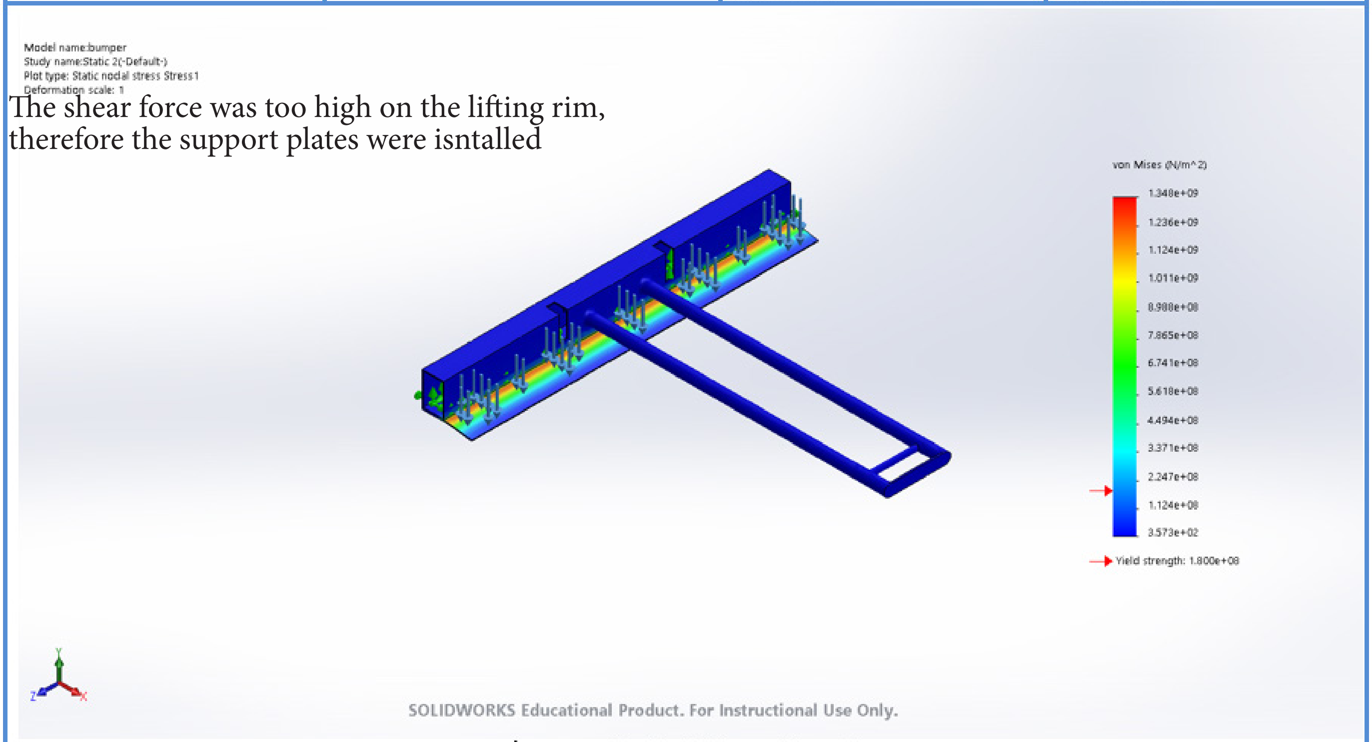


With the same force, but calculated as it would work parallel to the bar, the stress gets too high at the connection between the rods. That is solved by a thick weld. Also at the end of the rods, where they come out of the dolly, the stress is too high, this was solved by making sure te rod could is not extended more than 100mm

bumper-Static 1-Stress-Stress1

Name	Type	Min	Max
Stress1	VON: von Mises Stress	3.573e+02 N/m^2 Node: 77	1.348e+09 N/m^2 Node: 2554

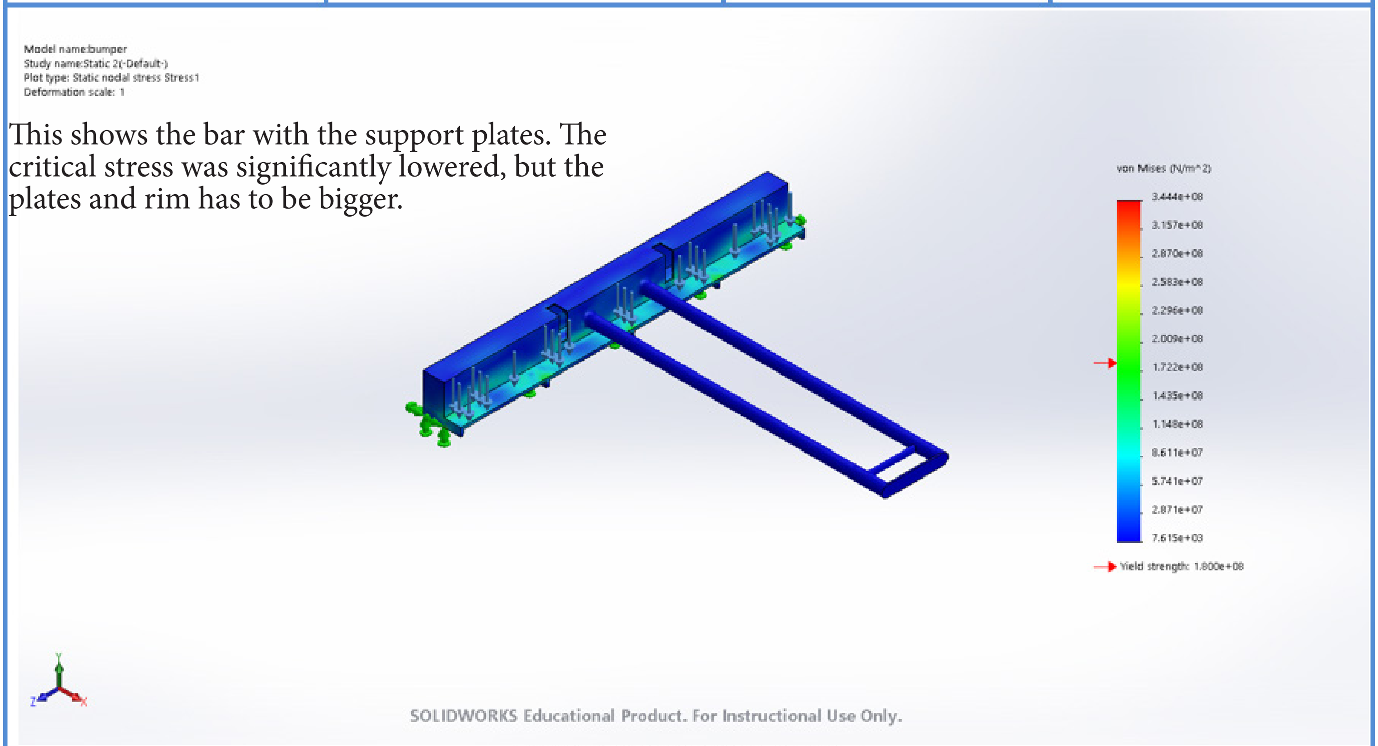
The shear force was too high on the lifting rim, therefore the support plates were isntalled



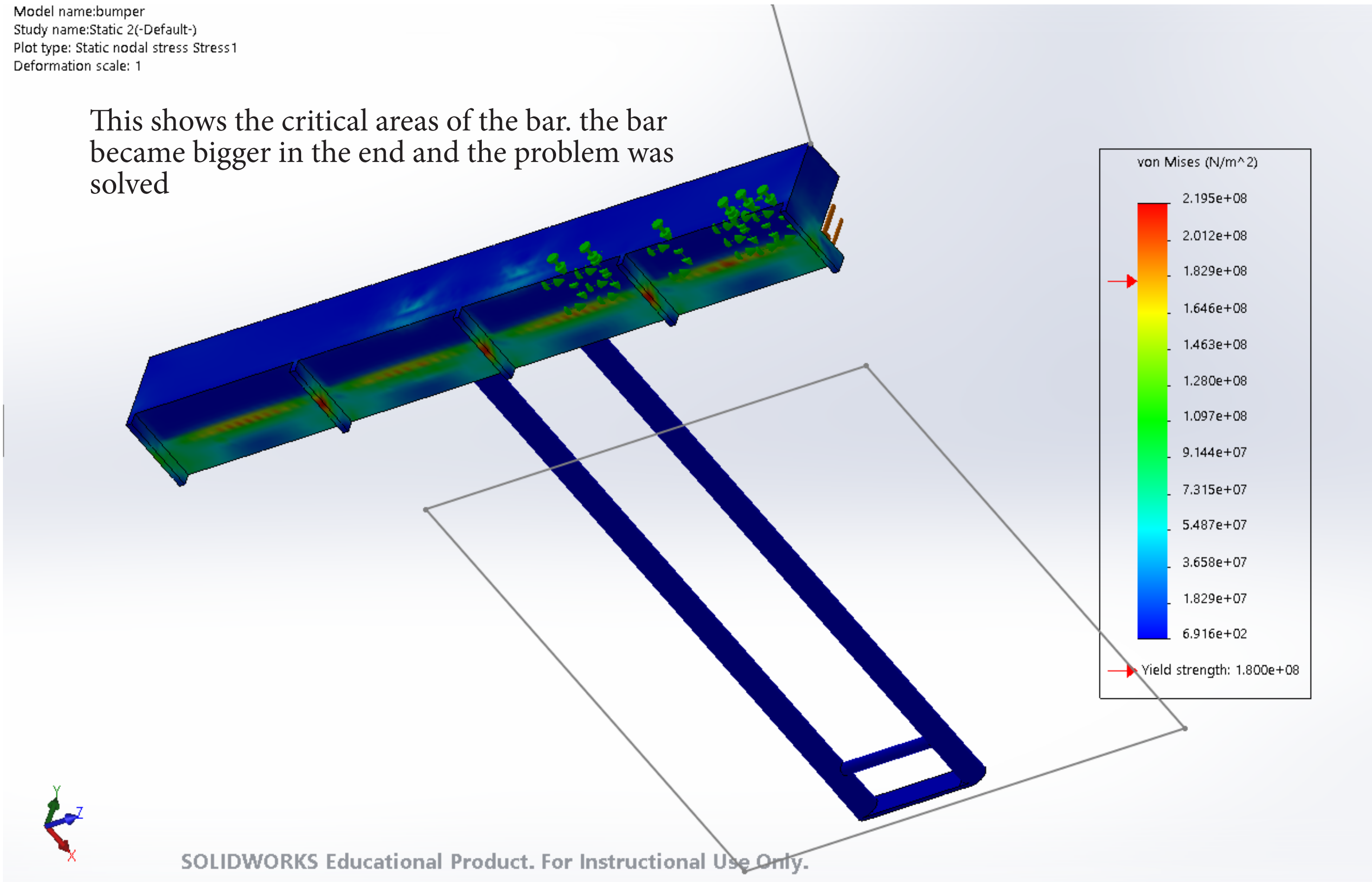
bumper-Static 2-Stress-Stress1

Name	Type	Min	Max
Stress1	VON: von Mises Stress	7.615e+03 N/m^2 Node: 4773	3.444e+08 N/m^2 Node: 5047

This shows the bar with the support plates. The critical stress was significantly lowered, but the plates and rim has to be bigger.

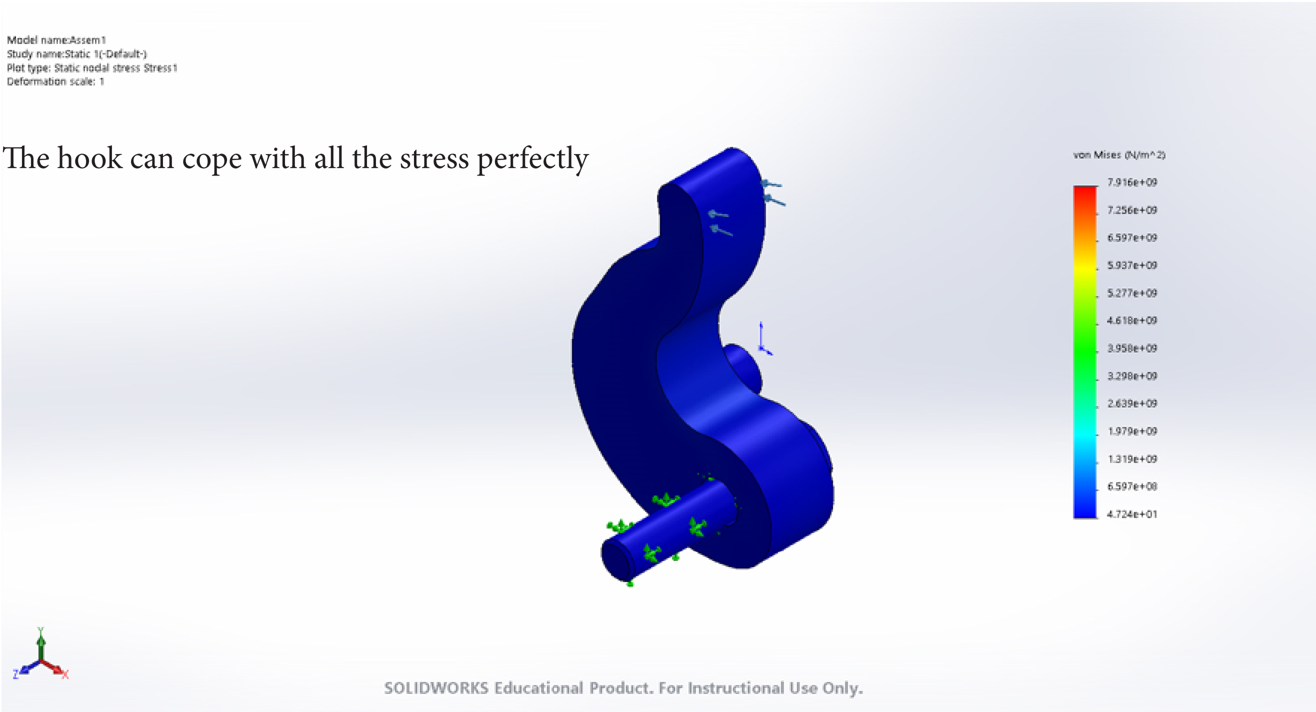


bumper-Static 2-Stress-Stress1



This shows the critical areas of the bar. the bar became bigger in the end and the problem was solved

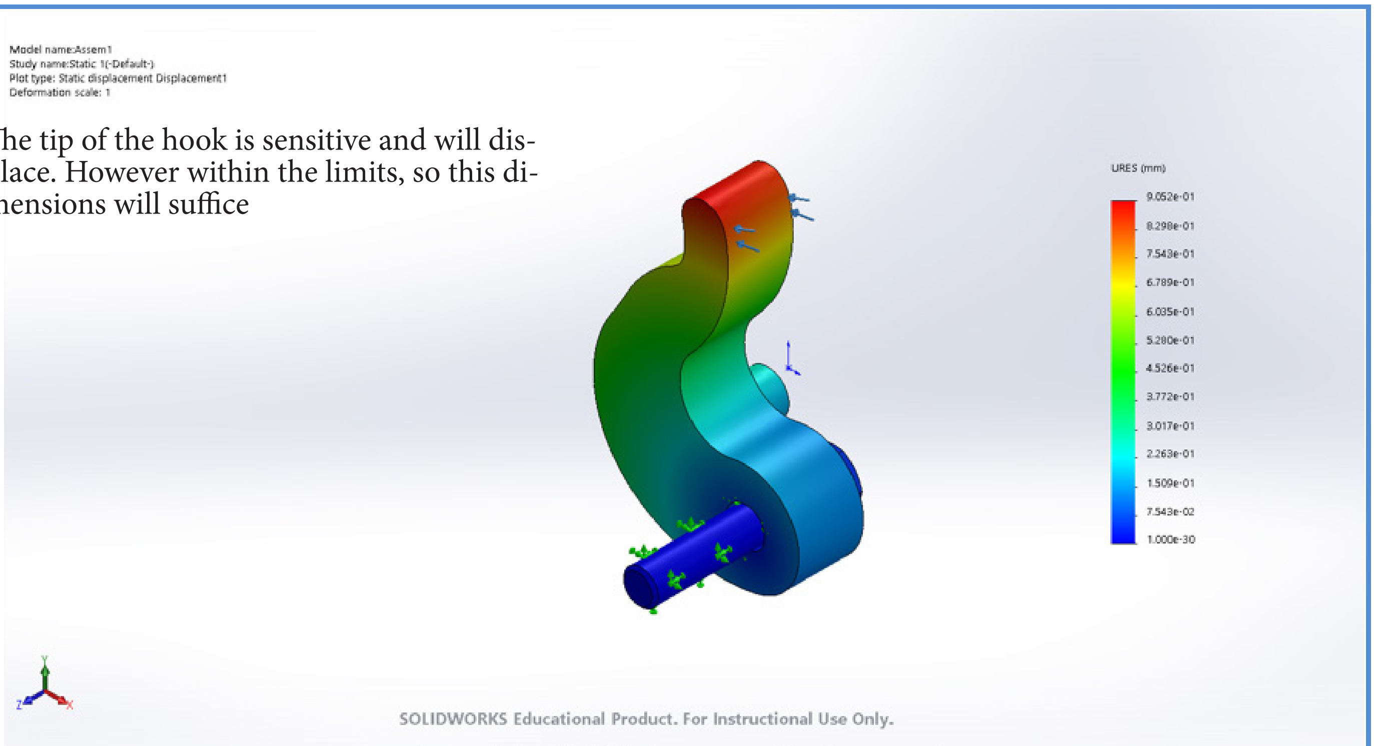
Name	Type	Min	Max
Stress1	VON: von Mises Stress	4.724e+01 N/m^2 Node: 23710	7.916e+09 N/m^2 Node: 24371



The hook can cope with all the stress perfectly

Assem1-Static 1-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+00 mm Node: 21084	9.052e-01 mm Node: 18427

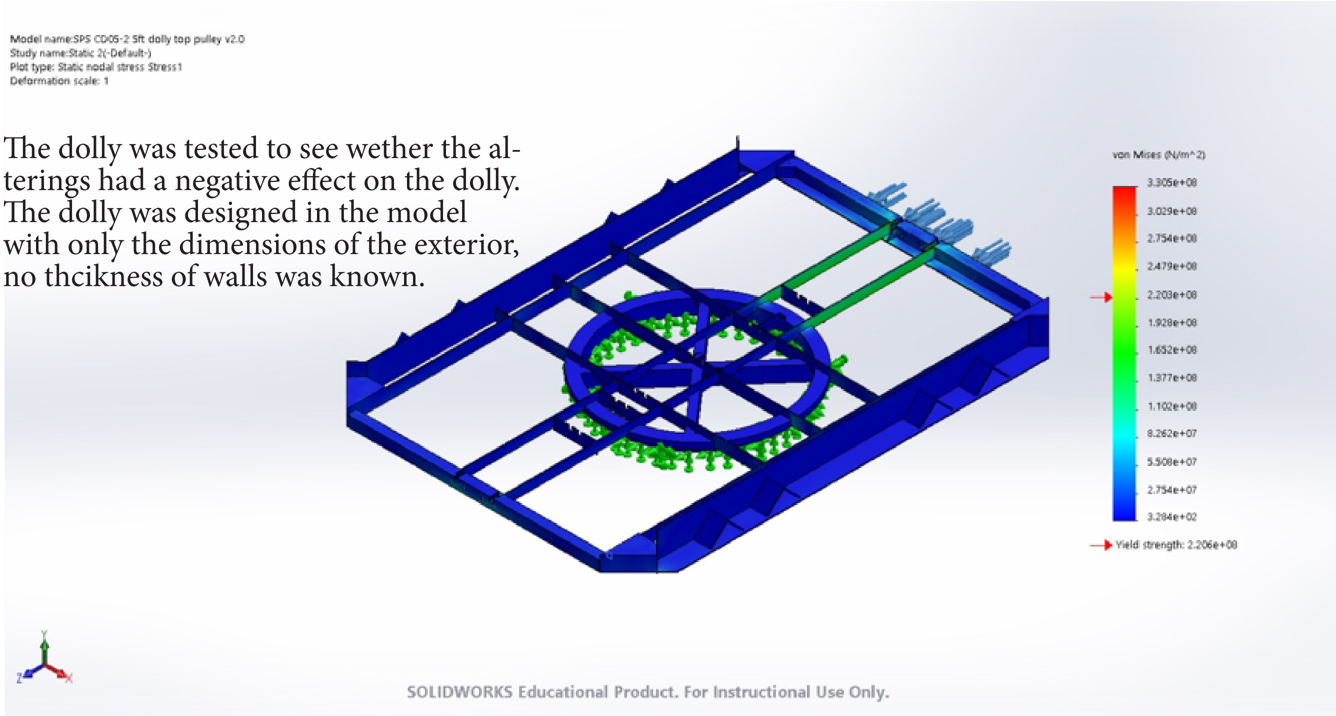


The tip of the hook is sensitive and will displace. However within the limits, so this dimensions will suffice

Assem1-Static 1-Displacement-Displacement1

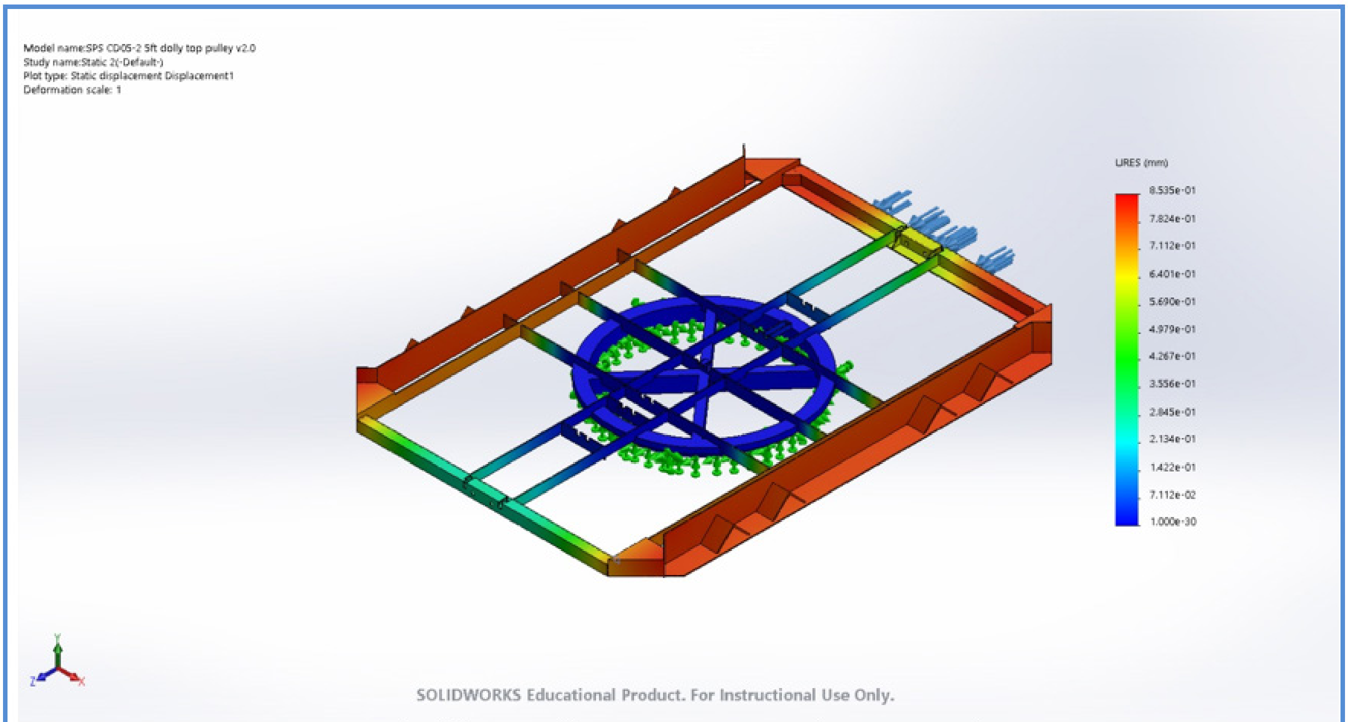
Name	Type	Min	Max
Stress1	VON: von Mises Stress	3.284e+02 N/m^2 Node: 72172	3.305e+08 N/m^2 Node: 70883

The dolly was tested to see wether the alterings had a negative effect on the dolly. The dolly was designed in the model with only the dimensions of the exterior, no thcikness of walls was known.



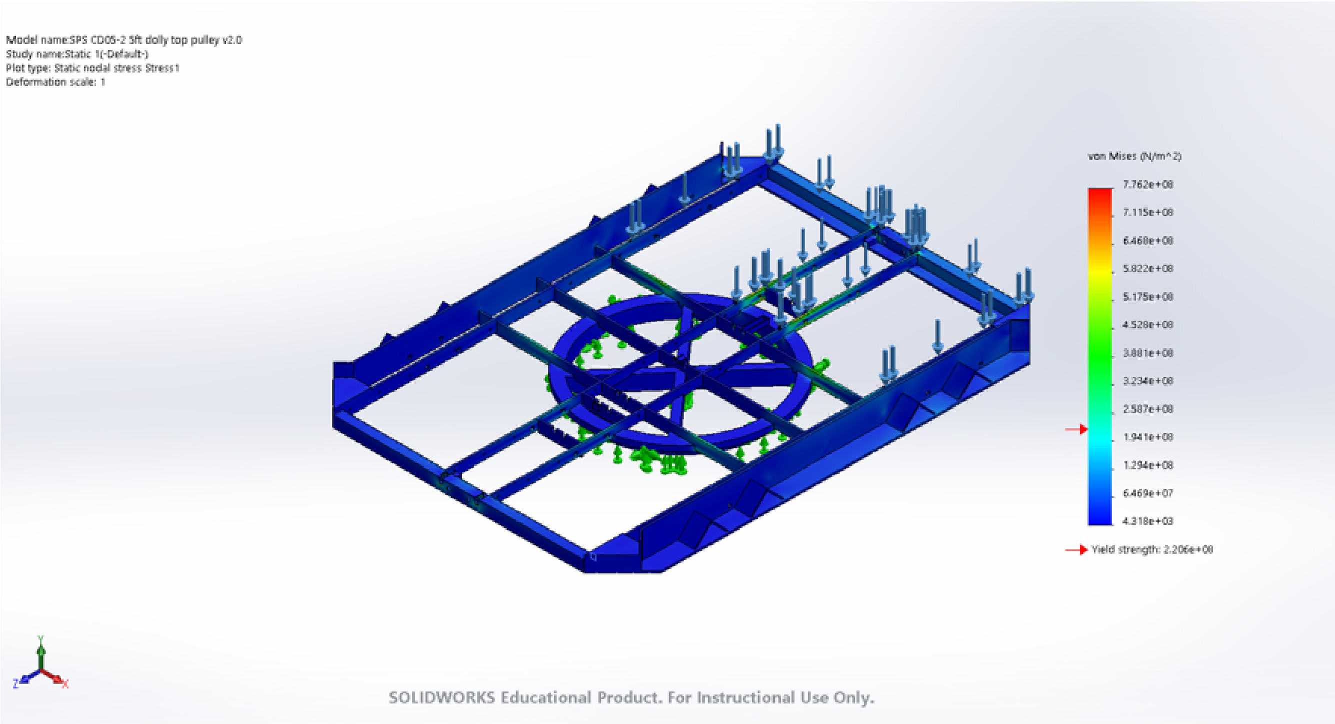
SPS CD05-2 5ft dolly top pulley v2.0-Static 2-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+00 mm Node: 246	8.535e-01 mm Node: 8714



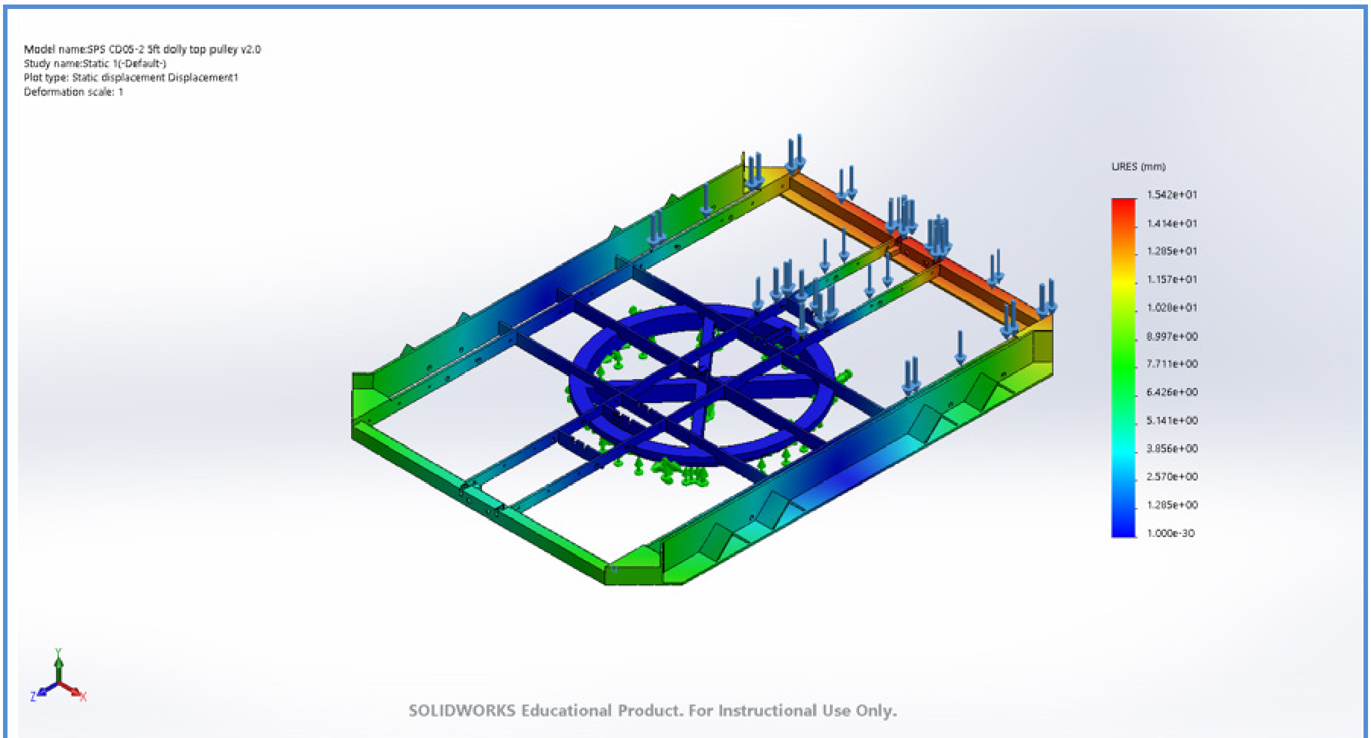
SPS CD05-2 5ft dolly top pulley v2.0-Static 2-Displacement-Displacement1

Name	Type	Min	Max
Stress1	VON: von Mises Stress	4.318e+03 N/m^2 Node: 53951	7.762e+08 N/m^2 Node: 199159



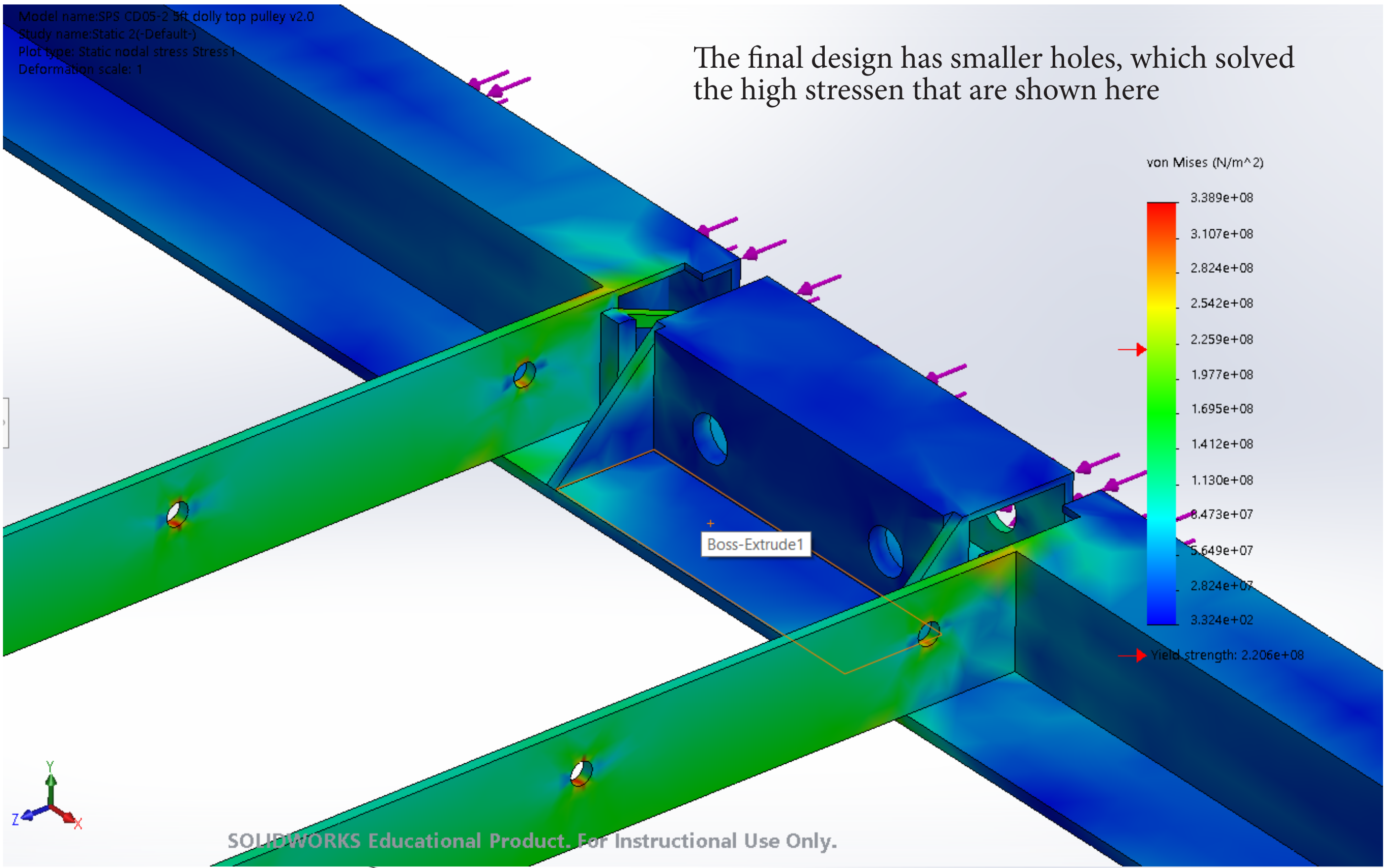
SPS CD05-2 5ft dolly top pulley v2.0-Static 1-Stress-Stress1

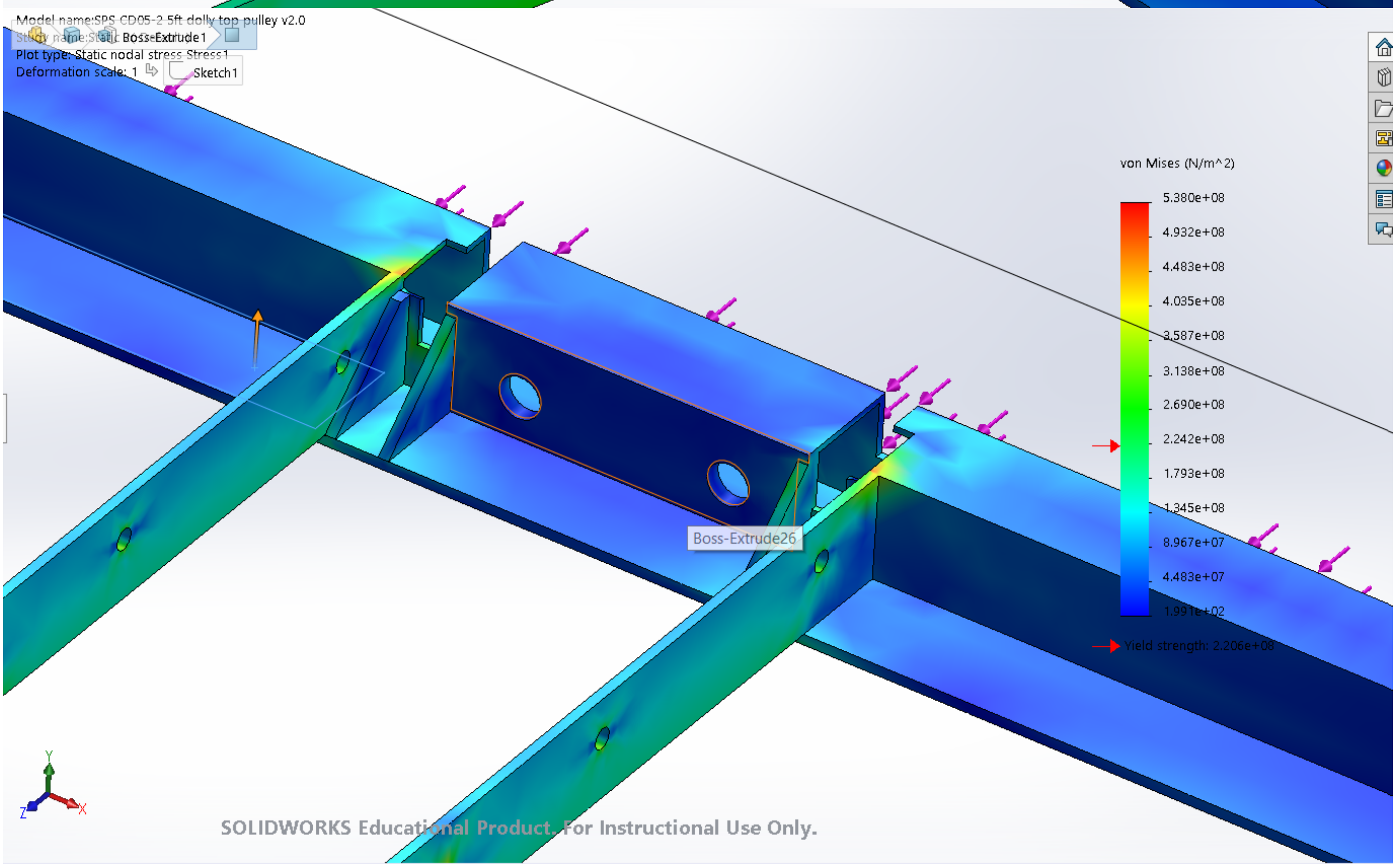
Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+00 mm Node: 1211	1.542e+01 mm Node: 7842

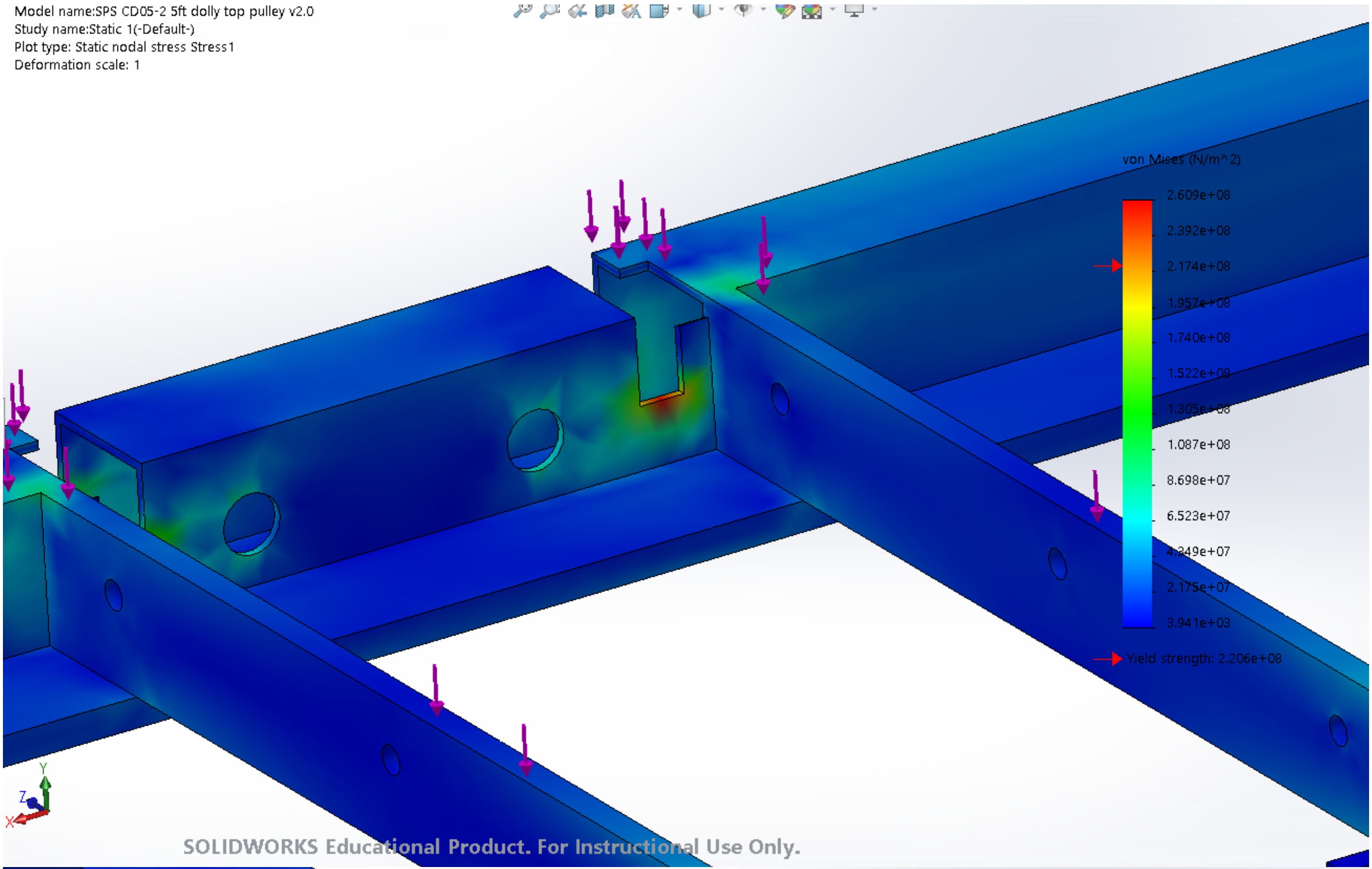


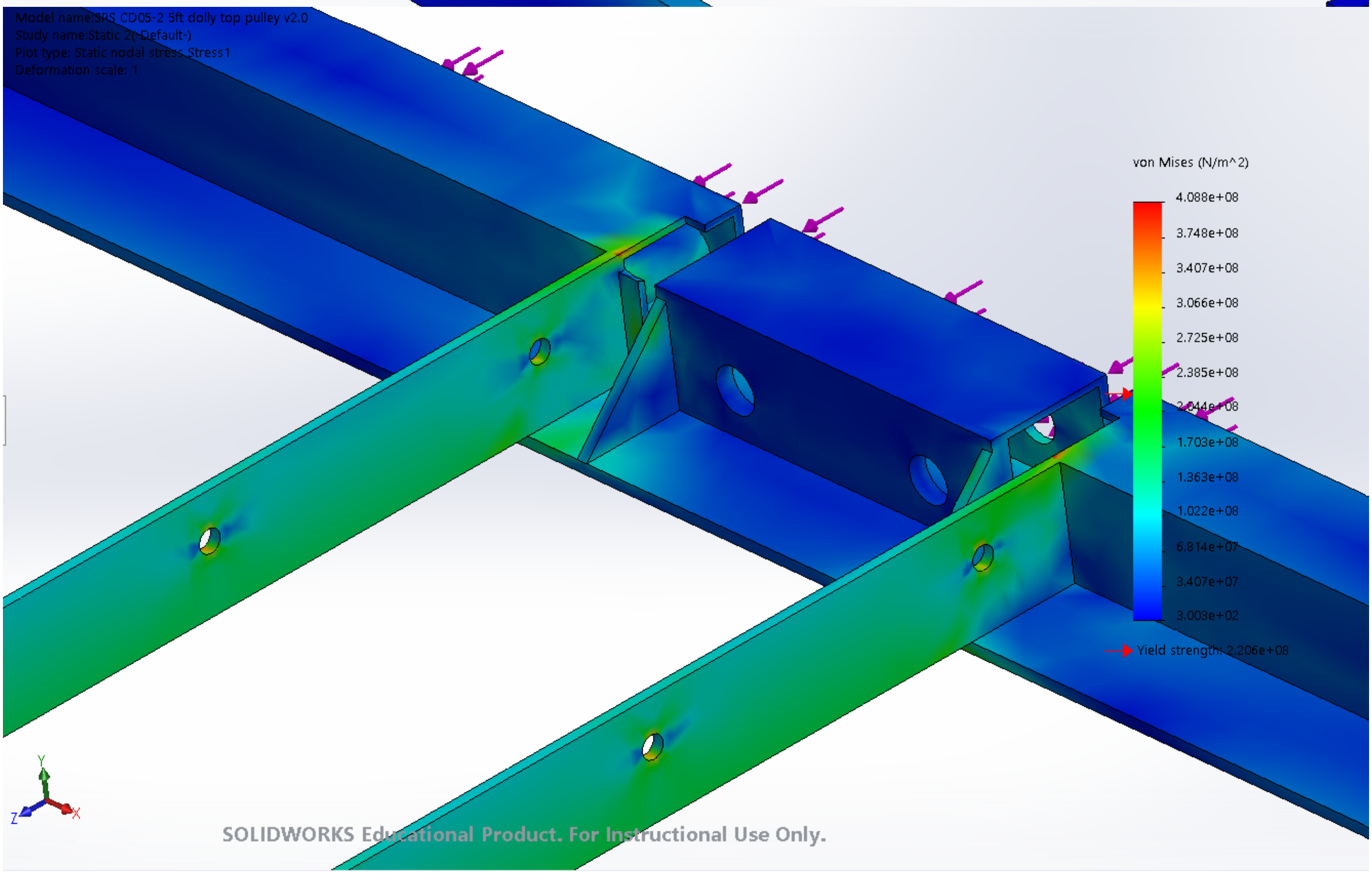
SPS CD05-2 5ft dolly top pulley v2.0-Static 1-Displacement-Displacement1

The final design has smaller holes, which solved the high stressen that are shown here






Model name:SPS CD05-2 5ft dolly top pulley v2.0
Study name:Static 1(-Default-)
Plot type: Static nodal stress Stress1
Deformation scale: 1
von Mises (N/m^2)
2.609e+08
2.392e+08
2.174e+08
1.957e+08
1.740e+08
1.522e+08
1.305e+08
1.087e+08
8.698e+07
6.523e+07
4.349e+07
2.175e+07
3.941e+03
Yield strength: 2.206e+08
SOLIDWORKS Educational Product. For Instructional Use Only.


Model name:SPS CD05-2 5ft dolly top pulley v2.0
Study name:Static 2(-Default-)
Plot type: Static nodal stress Stress1
Deformation scale: 1
von Mises (N/m^2)
4.088e+08
3.748e+08
3.407e+08
3.066e+08
2.725e+08
2.385e+08
2.044e+08
1.703e+08
1.363e+08
1.022e+08
6.814e+07
3.407e+07
3.003e+02
Yield strength: 2.206e+08
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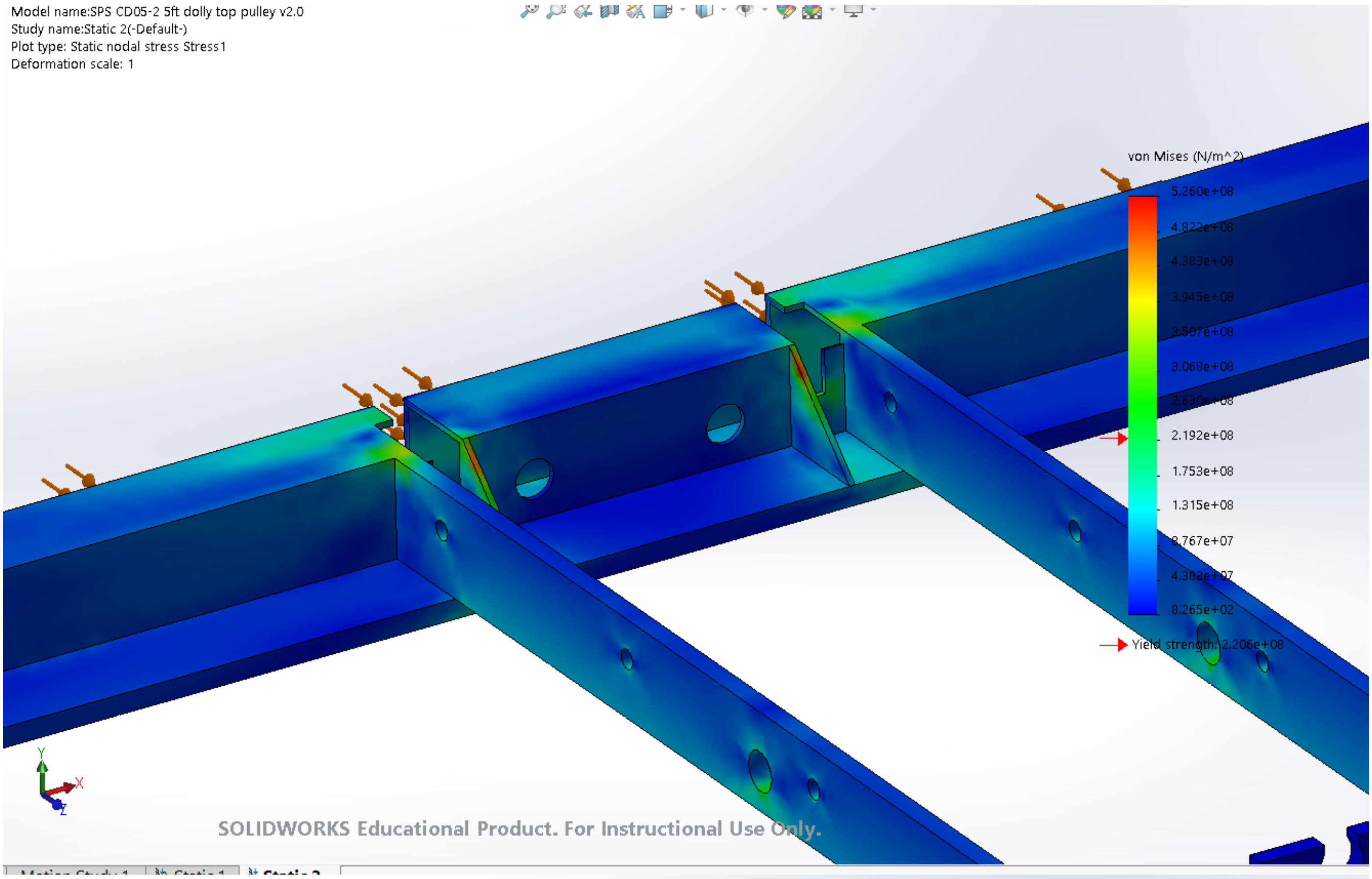

Model name:SPS CD05-2 5ft dolly top pulley v2.0
Study name:Static 2(-Default-)
Plot type: Static nodal stress Stress1
Deformation scale: 1
von Mises (N/m^2)
5.260e+08
4.822e+08
4.383e+08
3.945e+08
3.507e+08
3.068e+08
2.630e+08
2.192e+08
1.753e+08
1.315e+08
8.767e+07
4.383e+07
8.265e+02
Yield strength: 2.206e+08
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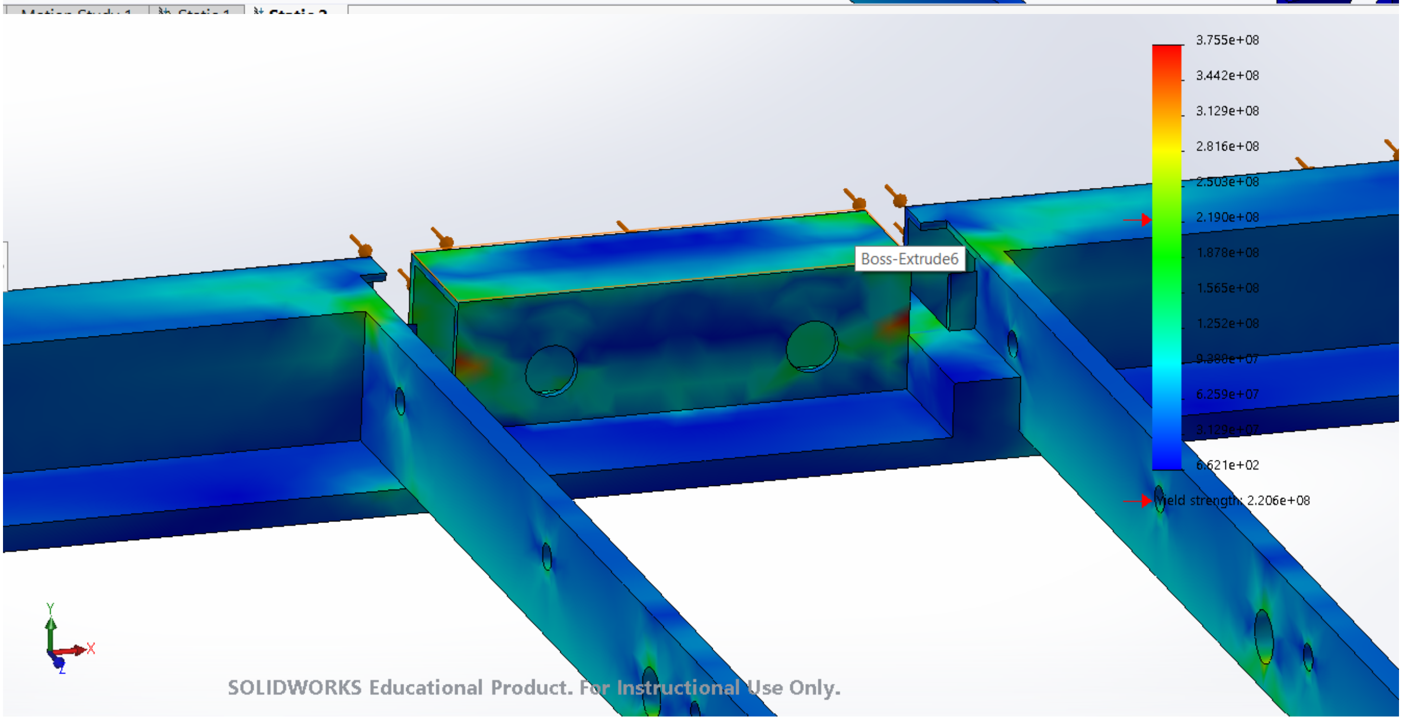

3.755e+08
3.442e+08
3.129e+08
2.816e+08
2.503e+08
2.190e+08
1.878e+08
1.565e+08
1.252e+08
9.388e+07
6.259e+07
3.129e+07
6.621e+02
Yield strength: 2.206e+08
Boss-Extrude6
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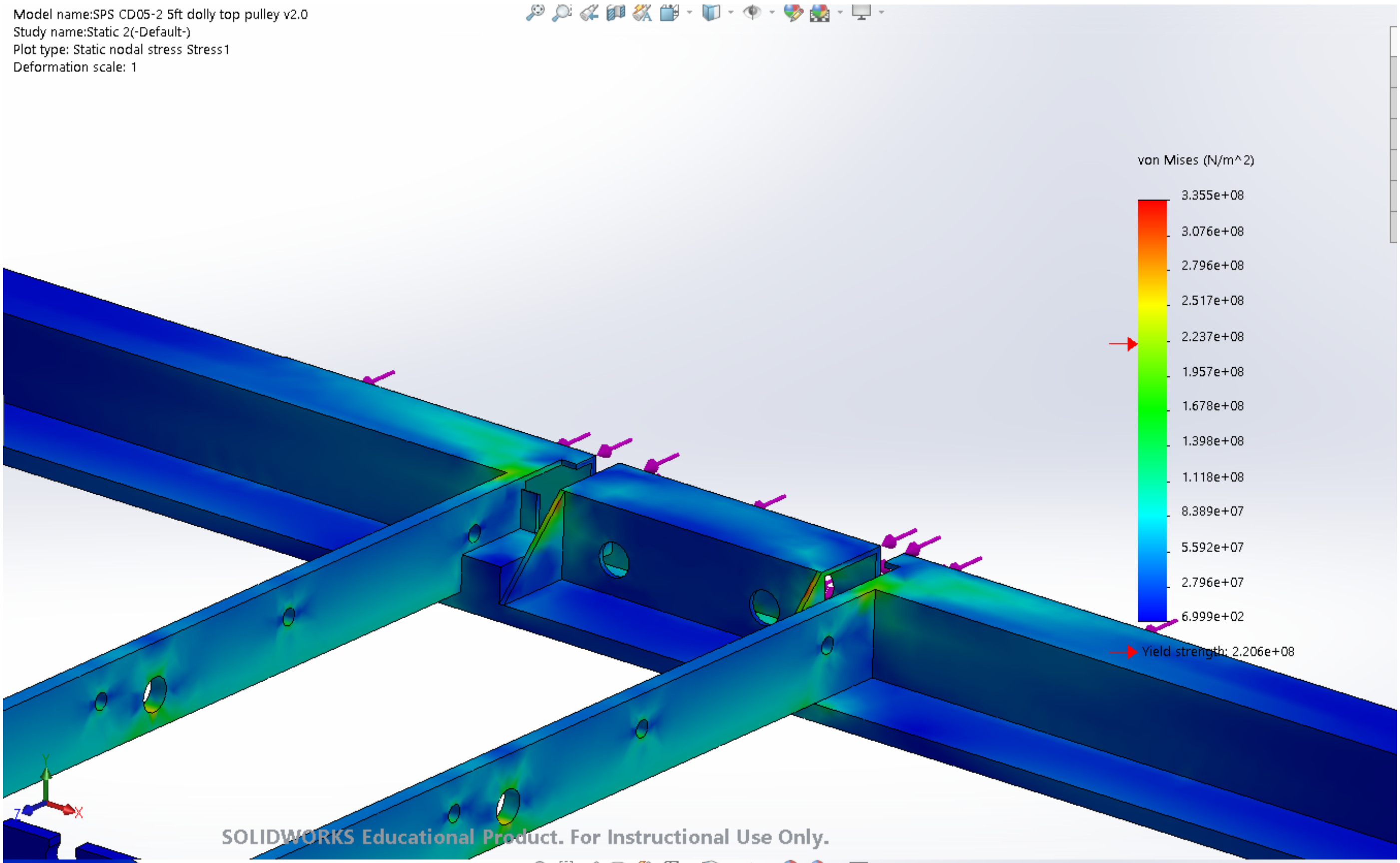
Model name:SPS CD05-2 5ft dolly top pulley v2.0
Study name:Static 2(-Default-)
Plot type: Static nodal stress Stress1
Deformation scale: 1
von Mises (N/m^2)
3.355e+08
3.076e+08
2.796e+08
2.517e+08
2.237e+08
1.957e+08
1.678e+08
1.398e+08
1.118e+08
8.389e+07
5.592e+07
2.796e+07
6.999e+02
Yield strength: 2.206e+08
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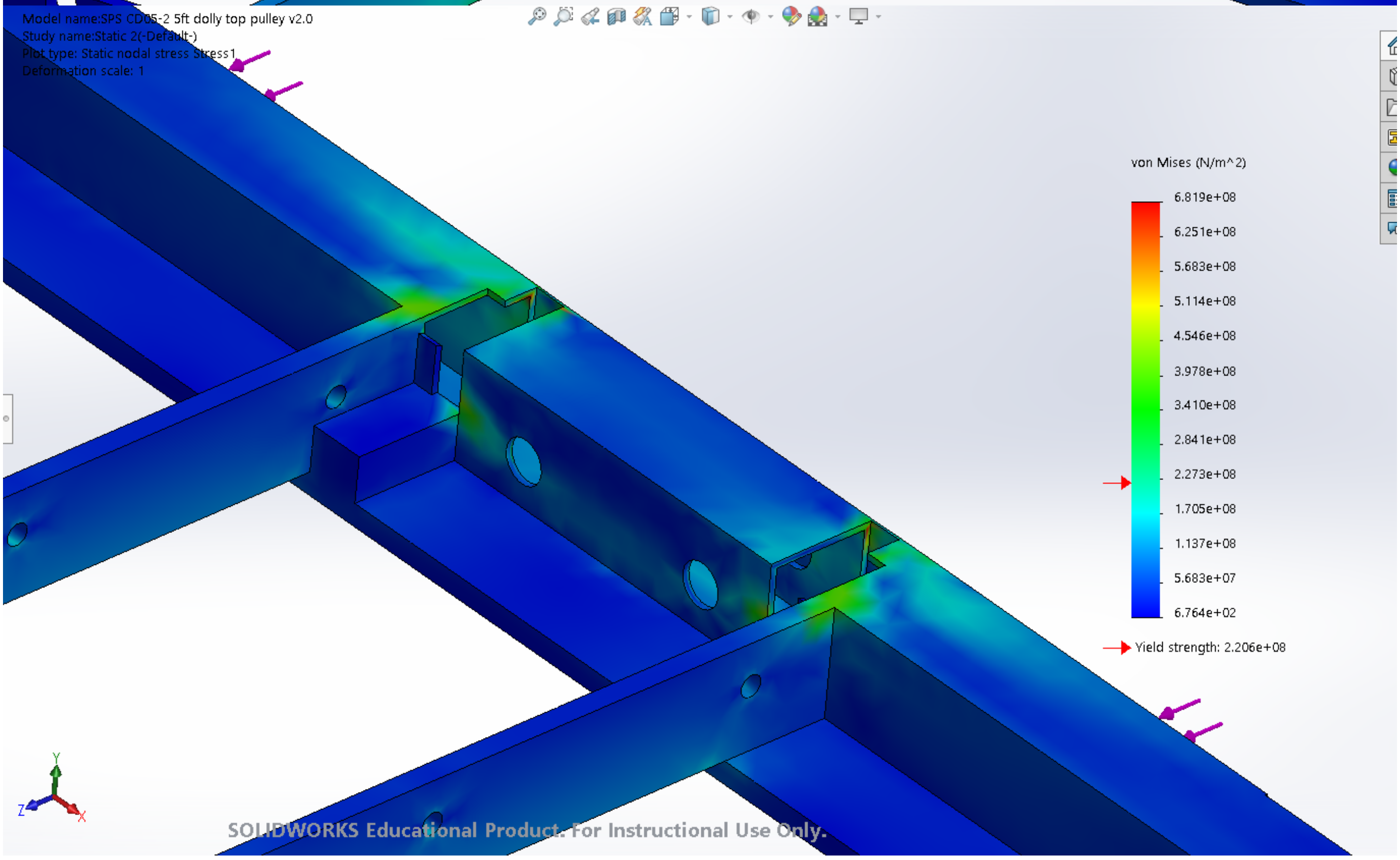
Model name:SPS CD05-2 5ft dolly top pulley v2.0
Study name:Static 2(-Default-)
Plot type: Static nodal stress Stress1
Deformation scale: 1
von Mises (N/m^2)
6.819e+08
6.251e+08
5.683e+08
5.114e+08
4.546e+08
3.978e+08
3.410e+08
2.841e+08
2.273e+08
1.705e+08
1.137e+08
5.683e+07
6.764e+02
Yield strength: 2.206e+08
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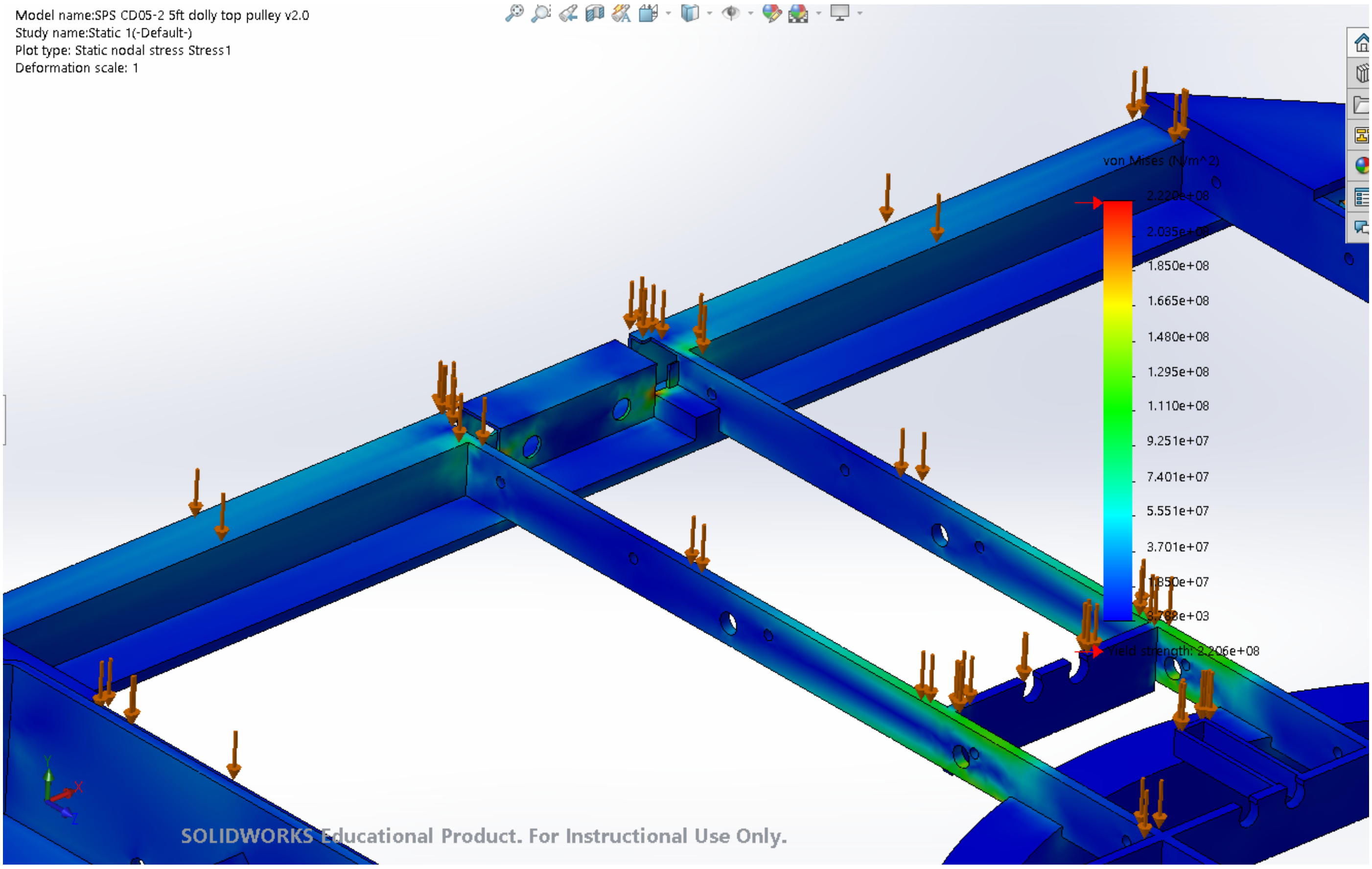
Model name:SPS CD05-2 5ft dolly top pulley v2.0
Study name:Static 1(-Default-)
Plot type: Static nodal stress Stress1
Deformation scale: 1
von Mises (N/m^2)
2.220e+08
2.035e+08
1.850e+08
1.665e+08
1.480e+08
1.295e+08
1.110e+08
9.251e+07
7.401e+07
5.551e+07
3.701e+07
1.850e+07
3.768e+03
Yield strength: 2.206e+08
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Appendix L: cost analysis

Drilling holes in dolly and bumper	2 minutes per hole==> 40 minutes for alle the holes. Make it 1 hour for changing bits and measuring.	€28 an hour	€28,-
cutting slots for hooks	1 minute for simple cut, 2 minutes for difficult cut. 28 easy cuts and 16 difficult ones. Plus 20 minutes for measuring	€28 an hour	€ 37,33
welding	7minutes for a bumper 2 minutes for bumper rods 2 minutes per pully 8 minutes for the cradle 5 minutes for the gas spring mounts 5 minutes in between part comes to a total of an hour per dolly	€ 30,76	€ 30,76
rest assem	bolting nuts and bolts and placi	€ 14	€ 14
			€ 82,09

Onderdeel	#	materiaal	€/kg	totaal	bron
Bumper 500x60x40x3	2	Carbon steel AISI 1010 (annealed	€14,1775/m	15	https://structuralsteeluk.co.uk/Shop/hollow-sections/rectangle-hollow-box-en/60-x-40-weld/?variation_id=1551 https://www.parkersteel.co.uk/Basket https://www.steelexpress.co.uk/shop/product/mild-steel-rectangular-hollow-section/ https://www.metalmaniauk.com/Steel/Rectangular-Hollow-Section/Rectangular-Hollow
bumper rod 400x16.4	4	Carbon steel AISI 1010 (annealed	€7.78/m	€ 12,45	https://www.parkersteel.co.uk/Product/0591866/Circular-Hollow-Section/21.3-x-3.0mn https://www.steelexpress.co.uk/shop/product/mechanical-seamless-tube/ https://www.metalmaniauk.com/Steel/Tube/Steel-tube-ERW-1905mm34-OD-x-12mm.a
Gas spring 950N	2		€36,50p.pcs	€ 73,00	https://www.tevema.com/en/webshop/gas-springs/gasveren/10-101140
lifting plate 500x70x5	2	Carbon steel AISI 1010 (annealed	€1,579 p.plat	€ 3,16	https://lakelandsteel.uk/metal-sheet-steel-sheet/mild-steel-s275-and-s355/mild-steel-sh profiles-blanks-custom-cut-to-size-free-of-charge-enter-exact-dimension-for-pricing/ https://www.themetalstore.co.uk/products/5mm-thick-mild-steel-sheet https://steelonline.co.za/product/mild-steel-plate-5mm/
lifting plate supports 70x10x5	10	Carbon steel AISI 1010 (annealed	€ 0,03	€ 0,20	
Hooks	4	Carbon steel AISI 1010 (annealed	€ 6,45	€ 25,78	http://iron-foundry.com/cast-steel-price-calculator.html https://www.amazon.co.uk/Grade-Hooks-Lifting-chain-hooks/dp/B01BSV7YI0 https://sunlightforging.en.made-in-china.com/product/BvLQZqbHLopk/China-China-Mar Lifting-Hook.html https://www.ebay.co.uk/itm/Clevis-slip-hook-10mm-Alloy-Steel-ZINC-Plated-Lifting-Hoc
steel cable 6ı	2	Stainless s	€ 8.689	€ 17,38	https://www.hendrikvedergroup.com/_asset/_public/Hendrik-Veder-Group/Downloads/ rope.pdf https://docs.rs-online.com/56d1/0900766b81584a0b.pdf https://nl.rs-online.com/web/c/enclosures-storage-material-handling/material-lifting/wi by=Safe%20Working%20Load&sort-order=desc&pn=1

pulley 63,5mm 6800 Newton	4	stainless steel bracket and axle with a Lubra-Tuf sheave	€ 11,45	€ 45,81	https://www.farmtek.com/farm/supplies/prod1;ft_cable_rope_chain-ft_cable_pulley_h https://trademarks.justia.com/731/68/lubra-tuf-73168731.html
Hook slot 870mm	4	Carbon steel AISI 1010 (annealed	€ 5,50	€ 22,00	https://www.bouwmaat.nl/knauf-u-profiel-4540-verzinkt-staal-400-cm/product/0000394573?channable=e75966.MDAwMDM5NDU3Mw&vat=in&gclid=Cj0K bP4rtH0Ua6sJA_9O8XRatbFPBFk0FkaIvzhUaAoZVEALw_wcB https://metaalcenter.nl/staal/koudgewalst-u-dikte-15-mm/koudgewalst-u-profiel-10-x-1
22mm bearings	4		€8.22	€ 32,88	https://www.amazon.co.uk/SBR35LUU-Linear-Bearing-Motion-Support/dp/B07Q1CMYK https://www.joom.com/en/products/5c89fc608b2c3701019d103e
dolly reinforment plates	2		€1.60	€ 3,20	
dolly reinforment triangles	4		€ 0,54	€ 2,16	
dolly reinforment rods	4		€ 0,97	€ 3,89	
10mm bearing	1		€ 3,44	€ 3,44	https://www.technobotsonline.com/linear-bearing-slide-unit-10mm-sc10uu.html
assembly				€ 82,09	
				342	