Handling of Air Baggage - A 10 week Thesis Work
Made by Simon Larsson - Kandidatprogrammet i Industridesign - Umeå Institute of Design
The Airport staff working with baggage handling have a tough job, lifting up to 15 tonnes/day per person. Every bag gets lifted manually 6 times on its way from check in to the baggage drop band, which is why the work is very repetitive and often leads to back, shoulder and other kinds of physical problems. My concept, the ABT (Autonomous Baggage Train), removes 4 of these manual lifting moments and also shortens the waiting time for the arriving passengers, reduces the wear on both baggage and the airport’s baggage bands and contributes to a safer working environment.
About the project

Examiners: Per Sihlen, Eva-Lena Bäckström

Tutor: Jens Näslund (Brand Design Manager, Husqvarna Group)

Collaboration Partners: Swedavia, TYA (Transportfackens Yrkes- och Arbetsmiljömänt), Aviator

Sponsors: TYA, Aviator, 3D Prima

Object: The object for the project is to investigate how we can reduce the workload and improve the safety for the baggage handling workers at airports.

Goal: The goal is to develop a concept of a product that could reduce the injury rates and improve the work conditions for the baggage handling workers at airports in the future.

Boundaries: I will not try to change the design of the airplane or look at what is called “container loading”. Container loading, also called ULD, stands for only 22% of the airplanes at Arlanda, while bulk loading, which is loading the bags one and one, stands for the remaining 78% and since this is more or less the same all over the world I will only focus on the bulk loading process in this project.

Time span: 10 weeks (week 9-17 2015 + one preparation week during 2014)

Made by: Simon Larsson, Kandidatprogrammet i industridesign (The bachelor programme in industrial design), Umeå Institute of design, Umeå University.

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The Airport staff working with baggage handling have a tough job, lifting up to 15 tonnes/day per person. Most of the lifting is made manually and because of repetitive work and unergonomic work positions the baggage handling workers are in the risk zone of getting serious health problems, especially in the back and shoulder region. The working environment is noisy and comes with lots of heavy moving vehicles that can be very dangerous as well if the workers are not cautious about their surroundings.
Research
The baggage workers at airports are working in unfavourable work-positions under such a big part of their work day so that experts say it means a high risk for injuries and physical problems, seen in a longer perspective. A study called Skadefria lastare (injury free loaders), made by TYA between 2010 and 2012 shows among other things that a baggage worker at airports works with his arms lifted more than 60 degrees under about 8% of the workday and with his back bent forward more than 60 degrees 2.8% of the work day. The nature of a baggage worker’s job is very monotonous with a lot of repetitive lifting which means that even a seemingly good work position can become harmful, especially if the lifting has to be done under time pressure. A stressed worker does not think as much about working ergonomically correct or using the lifting aids provided as he would do in a more relaxed context.

The physical problems that baggage workers are experiencing are more or less the same as in other professions where the body is used as a lifting tool. Many people have pain in their body but it’s rarely to the extent where they feel they need to be at home from work. The more serious repetitive strain injuries that are forcing many people to quit their jobs or cause them lifelong physical discomfort therefore build up slowly while being invisible in the sickness absence statistics. This is probably one reason why it’s only lately that people have started to realize that it’s really an urgent problem that needs action.
71% of the baggage workers answering TYA’s survey made for the project “skadefria lastare” are suffering from some kind of back problems or back pain. This is mainly due to the bad working position inside the airplane, the repetitive twisting movement when lifting baggage on and off the wagons, the number of lifts far from the body and the work tasks including pulling and pushing the heavy wagons.

60% of the baggage workers answering the survey are suffering from some kind of shoulder problems or shoulder pain. This is mainly due to all the high lifting that manual baggage handling mean, inside the airplane as well as outside. The repetitive nature of lifting bags on and off the wagons also contributes to these issues.

46% of the baggage workers answering the survey are suffering from some kind of knee problems or knee pain. This is mainly due to all the knee sitting that it means working inside the airplanes.

45% of the baggage workers answering the survey are suffering from some kind of wrist problems or wrist pain. This is equally caused by all manual lifting moments. Each bag gets lifted six times by the baggage workers from check in to the baggage drop band.

44% of the baggage workers answering the survey are suffering from some kind of neck problems or neck pain. This is mainly caused by the bad working position inside the airplane, but the stress factor could also prevent the workers from relaxing the neck/shoulder region and cause additional straining.
If you could get rid of parts of the manual handling, you could most likely save both time and inconvenience and injuries for the individual.

/Eva Bergsten (Höskolan i Gävle) - Responsible for the strain injury research and involved in the project Skadefria Lastare (Injury free airplane loaders)
Who is the baggage worker?

The personnel working with baggage handling is usually employed by external ground handling companies such as Aviator, SAS Ground Handling Sweden AB and Menzies Aviation on bigger airports like Arlanda. On smaller ones, like Umeå Airport, the baggage workers are sometimes hired directly by the owner, in most cases Swedavia. The workers often fit into one of the two following categories:

- Young men who have just finished school and wants to earn some money. These youngsters often believe that they are immortal and that they do not need the lifting aids, or do not want to use them because they feel stressed by the time pressure and believe that they can do the work quicker themselves. This group of workers often stay between one and three years and it’s often them who gets to do most of the heavy work inside the plane, even though the workers try to alternate these exposed position as much as possible.

- More experienced young to middle aged men who have more responsibility, like safety representative or load master competence. A load master is the person who is responsible for the loading of the particular airplane. He receives information of how the airplane should be loaded and makes sure that everything is done correctly. He also has the responsibility to check the airplane for damages and to fill in a report after each airplane. This group of workers have often worked a couple of years and plan to stay for a longer period which, together with the fact that an active load master cannot be inside the airplane, often means that they get to work in the less severe work positions, outside the airplane. These more experienced workers are often better at using the ergonomic aids available, even if that rarely means that they use them regularly.

There is also a small minority of female baggage loaders or workers who are past 40, but most workers quit, partly because of physical problems, before reaching even close to retirement age.
Lifting aids

Vaculex, a lifting aid that uses vacuum to suck the bags to a suspended lifting handle, is one of the most common lifting aids in the Swedish airports’ baggage halls. In theory it works well and is especially helpful when doing lifts far from the body when loading the wagons. It’s only available inside some of the baggage halls though and can, if used, only improve 1 or 2 of the 6 manual lifting moments that each bag goes through as it looks today. There has been plans on testing variants of this solution on other manual handling areas in the baggage handling process, but since only a few workers regularly uses this aid (and probably even fewer if it’s put at a more stressful moment) it can be questioned if that would really make a significant difference. I have been told the main reason why people don’t use it is because it feels like it takes longer time using it or that it feels a bit clumsy. The low percentage of use probably has something to do with the mentality as well that many of the baggage workers has, which is described on the previous page.

When unloading the baggage from the wagons to the baggage drop band Umeå Airport has a small ergonomic aid installed on the protection rail of the baggage drop band. It’s a sort of roll table which the baggage workers can slide the bags on instead of lifting them all the way to the baggage drop band. This has two big benefits: 1. It improves the ergonomics for the workers, since they can more or less halve the angle that they rotate their body and reduce the lifting far from the body and 2. It decreases the damage that is caused on the bags and the baggage drop band. These benefits and the fact that it doesn’t seem to make the work much slower or less comfortable have given me the impression that it’s more appreciated by the workers than the Vaculex. Unfortunately the product used at Umeå Airport is in really bad shape and has some design flaws as well, which probably reduces the use of it drastically. When Per Lidman, who is using the roll table on the image, was going to show me how it worked he first had to crawl around on the ground to find some of the roles that had jumped out of position, not withstanding the force of the bags being thrown at it. At the moment Swedavia is developing a new product to replace it.
Power Stow is another ingenious invention that has revolutionized the baggage handling process. It’s a customized mobile baggage band (the vehicle that has a baggage band built in and is used when loading and unloading the airplanes) designed mainly for airplanes that do not have the sliding carpet built in. As can be seen on the image, it has a snake-like part at the end of the baggage band, consisting of motorized rolls that leads the baggage into the fairly deep cargo rooms which, just as the sliding carpet, reduces the crawling in and out of the airplane, as well as reducing the personnel required to do the work. It can be pulled several meters inside the airplane and seem to be very appreciated by the baggage workers. It even has one benefit that the workers do not get if the airplane has the sliding carpet and that is the “snake’s” head, which can be elevated and lowered to help the workers with the unergonomic lifting that stacking bags inside the airplane means. It’s arguably if it’s still a bigger gain if the airplanes has the sliding carpet or not, but what is for sure is that the Power Stow is not a sheep solution, which means that the fewer required the better for the ground handling companies.

Sliding carpet is a very clever solution that exists in around half of the passenger airplanes operating at Umeå Airport. It’s basically what it sounds like, a rubber carpet that slides inwards and outwards inside the cargo room, along with the length of the plane. It means that the baggage worker inside the airplane doesn’t have to crawl into the cargo room to reach the bags further in. He can sit close to the opening all the time and only work on the outer layer and then slide the carpet, together with the bags and the back wall, inwards with a push of a button. In one way it’s likely to become more common with Sliding carpets in the future since the trend is more and more bigger airplane models, which more often has this feature built in. However there is also a concern that it will become more rare since WIFI gets a higher and higher priority in airplanes nowadays, which requires the airplane to carry technology with about the same weight as the sliding carpet. Everything is about reducing weight when it comes to airplanes and because of that there is a risk that the sliding carpet will become outcompeted by the WIFI hardware. I personally believe that this can be a problem for the near future, but in a longer perspective the WIFI technology will probably evolve to the point where it becomes light enough not to outcompete the sliding carpet.

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The baggage handling process (Bulk loading)

1. Before the airplane lands, information about the plane is sent to the airport. This information includes the amount of bags, measured in kilos, that the airplane carries and how much baggage weight is stored in each of the airplane’s two cargo rooms (how many cargo rooms depends on the size of the airplane). The information gets printed out by the Load master who uses it when he decides how many wagons and staff will be needed for this particular unloading.

2. Before the airplane reaches its parking spot the baggage workers put everything in place and prepare for receiving the airplane. This moment usually means more work on smaller airports compared to larger ones since you have to pull the heavy electric cable about 50 meters. This is particularly strenuous if ice and snow makes the ground slippery.

- Heavy pulling
- Slippery ground

3. Receiving the airplane.

4. Many people don’t realize that it’s actually the baggage workers who does almost all the work around the airplane when it docks. This includes placing wheel stops, cones, walking cables, stairs (if needed) and connecting the electric cable that will charge the plane while stationary. The loadmaster is also responsible for checking the airplane for any small damages that might have formed under the flight or in conjunction with the landing and he carefully investigates the engines and the outside of the airplane.
The mobile baggage band is put in place by one of the baggage workers who then usually jumps into the airplane to do the unloading from there. If the airplane has more than one cargo room multiple mobile baggage bands are usually used, one for each cargo room (a Boeing 737, probably the most common airplane, has two cargo rooms, but the number can vary between different planes).

One baggage worker drives the cargo train, which consists of one electric pulling vehicle and usually up to 3 baggage wagons, depending on how much baggage the airplane carries. Safety regulations says that no vehicles are allowed to drive under the wings.

All work moments inside the cargo rooms is very strenuous and ergonomically bad for the baggage workers because of the low roof height and the fact that almost all airplanes have the cargo room doors on the right hand side. This means that all the repetitive and twisting lifts are made towards the workers left hand side. Still unloading inside the airplane is not the worst working moment since much of the lifting is more like pulling out the bags and letting gravity drop them down on the floor, from where the baggage worker can quite easily push it out of the cargo room and onto the mobile baggage band.

1st moment that means lifting baggage on or off the baggage wagons. The work position is quite good since the workers are usually two persons and can be standing with straight backs and do much of the twisting moment with their feet. However the work is very repetitive and since lifting baggage on and off wagons is the most common work tasks for the baggage workers it should not be seen as harmless. The baggage on the wagons are usually loaded in two rows in depth and two rows in height. This means that the bags placed far away from the workers or on the second layer, height wise, can still be quite heavy considering that many bags weight over 20 kilos.
The front cargo room contains more cargo like baggage and sometimes bags as well, depending on if the pilots feel that they need to balance out the airplane’s weight to make it fly properly. How much baggage is stored here can vary a lot and so do the workload. Some of the baggage can be very heavy with a weight on up to 150 kilos, though it’s more common that the heaviest packages weight around 50 kilos. Just like unloading inside the airplane at the back, this moment includes bad working positions and is usually a one man job.

2nd moment that means lifting baggage on or off the baggage wagons. The varying baggage sizes is not an as big problem in this moment as in the previous one because you are most of the times two persons when you need to do heavy lifting. If there is not very much baggage in the front cargo room it’s common that the baggage workers skip using the mobile baggage band, which can mean some quite high lifts between the baggage wagon and the airplane. If this was a big problem the baggage workers would probably just use the mobile baggage band, so it’s not really an issue, but still it can result in some nasty lifts.

The now loaded baggage train is driven from the airplane and into the Arrival Hall.

3rd moment that means lifting baggage on or off the baggage wagons. The reason why this is one of the most strenuous working moments in the baggage handling process is that it’s usually only one person that drives the baggage train since the other workers now start loading the empty plane and he has to unload the passenger baggage from the whole airplane himself under time pressure, since the turnaround time for an airplane is usually not more than 25 min. This means that the workers are often not thinking very much on either ergonomics or the baggage, which leads to injuries, damage on the baggage and damage on the baggage drop band.

- One man job
- Twisting lifts
- Bad work positions
- Varying baggage sizes
  + Power Stow
  + Sometimes less baggage than in the back

- Twisting lifts
- No ergonomic aids
- Varying baggage sizes
- The mobile baggage band is sometimes not used
  + Two man job
  + Sometimes less baggage than in the back

- One man job
- Twisting lifts
- Lifts far from the body
- Very repetitive work
- Time pressure
  + Small ergonomic aid
4th moment that means lifting baggage on or off the baggage wagons and first moment of the loading process. Most of the baggage has already been loaded before the airplane arrives and the lifting work inside the Departure Hall is relatively light because of lower time pressure and many people that can work together. The lifting aid Vaculex is available but rarely used since many of the baggage workers think that it’s not worth the effort. Once fully loaded the wagons get connected to the pulling vehicle which often means heavy pulling and dragging of the wagons which can be damaging if done incorrectly.

The baggage train is driven out to the airplane. Most airports have a speed limit of 30 km/h but still there is plenty of careless driving which can result in costly damages on both personnel and material. The human factor seem to play a big role in these incidents.

5th moment that means lifting baggage on or off the baggage wagons. The problems are more or less the same as the other wagon related moments. Something that surprised me when I was speaking with an ergonomist called Jan-Erik Ståhl was that it’s actually worse for the baggage workers to have the wagons standing really close to the mobile baggage band. The reason is that it makes them twist the back more instead of using their feet, which becomes a natural reaction when the wagons are positioned a little bit further away.

Loading baggage inside the airplane is by far the worst single working moment in the baggage handling process. The reason is quite obvious. To sit on your knees and lift around 60-65 bags (which is about average for an airplane) in a twisting moment only to the left is not ideal. To make it a bit less strenuous on the body the workers have small built in knee supports in their pants and they try to alternate the working positions as much as possible.
6th and final moment that means lifting baggage on or off the baggage wagons. The problems are more or less the same as the other wagon related moments and this work task, as well as the others, becomes even worse if the wagons have been loaded with more than two layers of bags in height, which they should not be. Like mentioned before, the amount of cargo baggage is sometimes not very great, which can mean that the workers skip to use the mobile baggage band. This means some pretty high lifts and the image shows an example on how this can look.

Loading baggage inside the front cargo room is more or less similar to unloading the front cargo room. The bigger package size means less stacking and therefore a smaller benefit of not having to lift them in unloading compared to loading. Except for that, the problem with this work task is very similar to the other working moments inside the airplane since it’s a one man job that includes bad working positions and twisting lifts. The sliding carpet never exists in the much smaller front cargo room, compared to the one in the back, which also makes the work heavier.

Before the airplane can leave, the baggage workers have to remove all the things placed around it like stairs, the electric cable, cones and the wheel stops.

Then one of the workers gets into the vehicle that pushes the airplane out from the terminal while the load master controls that everything is done correctly.

- Twisting lifts
- No ergonomic aids
- Varying baggage sizes
- The mobile baggage band is sometimes not used
+ Two man job
+ Sometimes less baggage than in the back

- One man job
- Twisting lifts
- Bad work positions
- Varying baggage sizes
+ Power Stow
+ Sometimes less baggage than in the back
Baggage workers have a physically demanding job and are in the risk zone of getting serious injuries or body related problems. The main reason seem to be all the repetitive manual handling of the baggage, especially inside the airplanes, together with the stress caused by the time pressure that can be higher or lower depending on how busy the airport is. The stress is not usually a problem in itself, but it leads to less usage of the ergonomic aids that are provided. Today the average baggage size is also larger than ever which contributes to an even higher workload for the baggage workers.

My conclusion is that the three most important areas to focus on is:

- How to improve the work inside the airplane, since this is the single most demanding work position.
- How to improve the lifting on and off wagons in general since this is the by far most common work task.
- How to improve the unloading of the wagons inside the Departure Hall, since lifting bags from the baggage wagons to the baggage drop band is the worst single work task outside the airplane because one person has to unload the whole baggage train himself under sometimes intense time pressure.

If we could develop ergonomic aids which the workers actually want to use, or change the way that baggage handling is done so that it meant less manual lifting in any of these three areas, that would most likely bring down the injury rates and save many people from much pain and sometimes lifelong discomfort.
Process
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**Budget**

- **Study visit Aviator**: 1 000 kr
- **Study visit Swedavia**: 100 kr
- **Meeting with TYA**: 1000 kr
- **Group workshop**: 200 kr
- **Visit at Konstfack**: Print 50 kr
- **Mockups**: 500 kr - 3 000 kr
- **Print**: 50 kr

**Other expenses**:

- **Documentation equipment**: 4 500 kr - 6 000 kr
- **Model making equipment**: 500 kr - 7 000 kr
- **Other expenses**: 0 kr - 2 000 kr

**Total cost**

- Small budget: 12 700 kr
- Large budget: 27 300 kr
This is the time plan and budget for the project. As an industrial designer I am working according to a method called the Design Process. This means that I start with understanding the problem by doing research. In my case I have done an own study including three study visits on two different airports and with two different ground handling companies, Swedavia and Aviator, on top of the information that I already had access to from the project Skadefria Lastare (Injury free airplane loaders) through another collaboration partner, TYA (Transportfackens Yrkes- och Arbetsmiljönämnd). I did this to be able to create my own perception in which areas of the baggage handling process I can make the biggest difference. Once I had found three problem areas to dig deeper into I started developing ideation concepts in form of sketches and thoughts and after discussing these ideas with my collaboration partners and my tutor I could choose one concept to keep working with. From there the rest of the design process has been about deciding form and function and creating material for presenting the concept. This means a physical model of the product, a virtual 3D model, images describing both form and function and the compilation of the report.

Before the summer my work will be presented and exhibited at a design conference called Design Talks, held at the Umeå Institute of Design. The conference will be visited by people from all around Sweden who are interested in design and new technology. As I’m writing this I have already presented my thesis work on TYA’s yearly conference for discussing issues regarding ground handling on Swedish airports. I will also present the project for Bagageutvecklingsgruppen, The baggage development group, which is Sweden’s leading group in developing baggage handling on airports. Throughout the summer and the autumn I will present my thesis work on multiple companies with connection to design and if someone else would be interested I’m always eager to share my work.
Study visits

Study visit 1
I head started the project by doing a study visit with Swedavia at Umeå Airport during one evening work shift a couple of weeks before Christmas (the project starting officially week 9). I didn’t really have a clear plan for the visit other than getting a first look at the area and taking some photos. I felt I got a good connection with Per Lidman which has lead to a long mail conversation where I have been asking questions as they have come up during the project, which has been very helpful for the project.

Study visit 2
Study visit number 2 was done with Aviator at Arlanda Airport, Sweden’s biggest airport during one day. It was very interesting to see the difference between a small airport like Umeå Airport and a bigger one like Arlanda, but apart from size and a much more complex automated system taking care of the bags before they reached the baggage workers and their wagons, the work task was surprisingly similar. The main difference in baggage handling at bigger airports seem to be a higher percentage of container handling, since they host more big airplanes. I did some interviews and had a lot of conversations with different baggage workers, asking them mainly about which areas they found most strenuous and where they thought that least had been already done. I was guided around at the airport by Micael Johansson, a man with many years experience from baggage handling. I took many pictures here as well to document what I saw.

Study visit 3
After I’d had time to start analysing my material from study visit 2 I started to get a picture of which major knowledge gaps I had left to fill before I could feel that I had enough meat on my bones to start thinking of ideas. So I prepared some more questions and checked which sorts of photos I lacked after the two first study visits and went once again to Swedavia at Umeå Airport to fill the last gaps.
When I was at my last study visit at Umeå Airport I got invited to a meeting regarding how to improve the work environment for the baggage workers at Umeå Airport. Except for Per Lidman, Ibrahim Al Turk and “B-O”, the highest boss at Umeå Airport, was also present at the meeting. They showed great interest in my project and except for a better general understanding of how the baggage handling process works they gave me some useful information on what ergonomic aids are available, but not get in use on most airports.
In the early stages of the ideation phase I gathered some other students from UID and did an one hour ideation workshop to see if I could get some of my ideas confirmed and to see if I could get some new input as well. I started by showing the five participants (six including me) the most relevant parts of my research with focus on the three most demanding working areas: Loading baggage inside the plane, lifting bags on and off wagons and unloading baggage at the baggage drop band. After that we split up two and two and spent 15 minutes on each of the areas, trying to come up with solutions on how to make the working moment less strenuous for the baggage workers. The first 7,5 minutes was spent individually brainstorming and sketching ideas while the second 7,5 minutes was spent discussing the ideas with the other person in the group.

I got some of my ideas confirmed and some new input as well, even though there was nothing really new that I could use. I had told the participants to only focus on bulk loading (and not container loading) but I forgot to tell them that they should not focus on changing the airplanes, which meant that some of the ideas where useless to the project.
After the ideation workshop I spent some days thinking and tried to challenge myself to see the problem from new directions by discussing different possibilities with different people: My classmates, my tutor Jens Näslund, my good friend Narayan Subramaniam (studying transportation design) who were living at my place for a couple of days and another good friend Eric Höglund who graduated from kandidatprogrammet i industridesign the year before, with whom I took long walks in the nature while discussing my ideas.

After a lot of thinking I had formed five ideation concepts in my head and started sketching them down. To get some relevant feedback on the concepts I had booked two meetings, one with Swedavia and one with TYA. My contact from TYA - Roger Nilsson - had also invited two very experienced external experts in baggage handling at airports. It resulted in two very interesting meetings where I not only got my research and some assumptions I had made confirmed, but we also had some really interesting discussions about my ideas. I finished both meetings by telling the people involved that I was going to send them each an E-mail where I quickly reminded them of every concept and where I asked them to write some short sentences about each. This feedback, together with what I remembered from the discussions during the meetings and the feedback I got from my tutor and other people at UID who have a better understanding of the design aspect of the project, became the ground on which I built my decision making on. I have compiled the feedback and a point system, explaining why I choose the concept I did, on the following pages.
Concept 1 - The Smart Wagon

A new kind of baggage wagon where the floor is adjustable to reduce the distance to the baggage bands. The floor is also able to move up and down to decrease the harmful high lifting that is made today when loading/unloading the second layer of bags. This could be combined with Kirunavagnen, which is an already existing solution that decreases lifting far away from the body.
I think the idea is realistic and feasible, but unfortunately I cannot see the benefit of it. Sure, it could be practical at occasional wagons and situations but it’s not revolutionary.

/Per Lidman (Swedavia) - Baggage worker and Safety representative at Umeå Airport

Clearly possible! But remember Jan-Erik’s comment “Rather a bit too far away than too close, to force the person to take a step in between which results in a twisting movement of the entire body which is more healthy than just twisting the upper body.

/Roger Nilsson (TYA) - Responsible for TYA’s flight sector

The Wagons need to be developed and most of all become lighter. Kirunavagnen is a good solution but weights too much. Some sort of adjustable floor might most of all be useful when unloading the wagons to get closer to the baggage bands. I don’t think that it has a big impact when loading the airplanes out at the apron.

/Jan-Erik Ståhl (Ergomore) - Ergonomist with much experience in handling of air baggage

Combined with making the wagon according to the Danish model (narrower) and with the ability to adjust the wagon both up and down and sideways would be the best alternative.

/Reidar Pettersson (Arbetsmiljölotsen) - Project leader for the project Skadefria Lastare (Injury free airplane loaders)

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Another kind of baggage wagon that removes the manual lifting when unloading the baggage inside the airport. When time for unloading the whole baggage train gets driven over a baggage band at ground level and, since the wagons’ floors work as trapdoors, the baggage can be smoothly dropped down onto the band. The ground level band is significantly slower than the baggage drop band, which means that the bags get lined up neatly one and one when joining the faster moving band. To make the trapdoor principle work the wagons can be highered and lowered. This also improves the ergonomics when loading/unloading the wagons outside the airplanes.
Check out this product: http://goo.gl/LKBQD7. Seems like it’s possible to have a solution where the whole wagon gets dropped and the baggage is sorted automatically. The concept is realistic.

/Per Lidman (Swedavia) - Baggage worker and Safety representative at Umeå Airport

Movable floors/low friction floors is good, as long as the baggage doesn’t slide off too easy in for example the corners. It’s probably a good note that the wagons need to come in along the baggage drop band and not across, because of the space issue. Bottom dumping is both ergonomically good and time winning!

/Roger Nilsson (TYA) - Responsible for TYA’s flight sector

To be able to unload the baggage without manual handling would be a dream. Today both personnel, baggage and baggage band is damaged in the unloading process, so this is probably something that the owners of the airports would be willing to pay quite a lot money for if the problems could be solved. It’s also difficult to have lifting aids at these positions.

/Jan-Erik Ståhl (Ergomore) - Ergonomist with much experience in handling of air baggage

For incoming baggage wagons to be able to drive in over a baggage band at ground level, leading directly to the arrival hall, is a very clever solution. Probably it’s only going to be viable at new constructions though, since big rebuildings of today’s airports will become very expensive.

/Reidar Pettersson (Arbetsmiljölotsen) - Project leader for the project Skadefria Lastare (Injury free airplane loaders)

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17/24
The idea behind this concept is to use some kind of exo suit to give the person inside the airplane more strength when doing all the heavy lifts in the bad working positions that this work task includes. The exo suit would have some kind of knee support to reduce the strain that the knees experience when working in this vulnerable position.

This suit would probably be quite expensive, considering the fact that it requires a lot of high-tech components and doesn’t actually remove any manual lifting completely. That’s why only the person inside the airplane - the most vulnerable workposition - would get to benefit from this aid.
The concept is a bit too high-flying. I think many people would not fancy using this, but I could be narrow-minded. ;)

/Per Lidman (Swedavia) - Baggage worker and Safety representative at Umeå Airport

Like we said before, it already exists.

/Roger Nilsson (TYA) - Responsible for TYA’s flight sector

If you want to do something for the baggage workers after you have graduated and earn some money you should develop the knee pallet that I was speaking about when we met.

/Jan-Erik Ståhl (Ergomore) - Ergonomist with much experience in handling of air baggage

Future imaginable innovations.

/Reidar Pettersson (Arbetsmiljölotsen) - Project leader for the project Skadefria Lastare (Injury free airplane loaders)

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This is a completely new concept of what a baggage train looks like. This autonomous train has the ability to load and unload the baggage automatically because of the built-in baggage bands and is remotely controlled by a powerful computer, taking care of all the baggage trains at the airports. It removes four of the six manual lifting moments that each bag goes through, reduces the time it takes for the first baggage to reach the waiting passengers, and is more kind to the baggage as well. The train follows lines in the ground to be as safe and accurate as possible and has a built-in camera to detect anything that accidentally comes in its way. The camera can also be used to follow someone or something if the baggage train is needed somewhere where the lines in the ground don’t go. I call this "The Duck Principle".
I can absolutely see that this could be possible after you explained the idea. As a concept I’m sure this is something that you can suggest. I see this solution as quite far ahead in time since large parts of the airport would need to be reconstructed because it’s so different from today’s solutions. The solution is feasible.

/Per Lidman (Swedavia) - Baggage worker and Safety representative at Umeå Airport

Absolutely! Combined with several floors...?! Autonomous vehicles should be the future. It’s a good thing to reduce the amount of manual handling of the baggage!

/Roger Nilsson (TYA) - Responsible for TYA’s flight sector

A very exciting futuristic concept with autonomous trains that could become even safer than how it is today, considering all the careless driving both inside and outside the airport buildings, with damages as a result. And to combine this with self-emptying wagons - success.

/Jan-Erik Ståhl (Ergomore) - Ergonomist with much experience in handling of air baggage

Doubtful gains and complicated and expensive constructions.

/Reidar Pettersson (Arbetsmiljölotsen) - Project leader for the project Skadefria Lastare (Injury free airplane loaders)

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This new kind of mobile baggage band extension is in short a remotely controlled plate, consisting of a short baggage band pointing 90 degrees sideways compared to the mobile baggage band itself. It is designed to only work when loading airplanes who has a sliding carpet installed, which is about 50% of the airplanes, and its main function is to let the person controlling it sit in a much better working position outside the airplane instead of inside, which today is clearly the most vulnerable working position when loading an airplane. The plate is controlled either from a chair directly outside the airplane or from the cockpit of the mobile baggage band vehicle. It can move up and down, sideways across the airplane’s body and slightly to the right (towards the front of the airplane) when placing the bags and it should not slow down the loading process, which is essential.
"A solution that I’m sure could be implemented at old bands, maybe as an expansion module? This could very well become interesting for airport bosses since they could keep the costs down. Considering this solution: http://goo.gl/WHKMS6, I see that the idea is plausible. What the users would think might be another thing though.

/Per Lidman (Swedavia) - Baggage worker and Safety representative at Umeå Airport

"For sure something is needed here to get rid of the bad working positions inside the airplane. Clearly possible!

/Roger Nilsson (TYA) - Responsible for TYA’s flight sector

"Attaching an existing, similar version to your idea. (Mulag 7.5 E med front og rearlifter - Brugermanual)

/Jan-Erik Ståhl (Ergomore) - Ergonomist with much experience in handling of air baggage

"Already exists? In different test versions. (Arlanda)

/Reidar Pettersson (Arbetsmiljölotsen) - Project leader for the project Skadefria Lastare (Injury free airplane loaders)
Since the chosen Concept 4 is a train like vehicle that needs to both work time efficient and be able to bend like a snake in the turns I wanted the design to express the word "Dynamic". "Agile" comes from its twisting nature of movement, "Adaptive" means that it can adapt its form and function and cooperate with other similar vehicles depending on the size of the airplane and "Motion" indicates that it’s a moving vehicle that needs to operate quick and time efficient. It’s also important that the vehicle expresses "motion" for safety reasons, so that it isn’t mistaken for a stationary object when it is fully loaded and suddenly starts to move.
The automated and innovative nature of the concept made me think of the word "Intelligence". It needs to feel like a clever product since its work tasks are more or less advanced. "Autonomous" stands for the fact that the vehicle is driverless and controlled by an intelligent computer, "High-Tech" for the more or less advanced (existing) technology that it needs and the word "cooperative" has to do with its ability to cooperate with other sister vehicles and with the baggage workers as well.
It’s important for the design to express the word “Trustworthy” to help convincing people that the concept is actually clearly feasible with today’s technology and equally to earn the passengers trust, so they feel they dare to leave their baggage in the hands of this autonomous baggage train if the concept where to become reality. "Safe" stands for the mentality at airports where everything is about safety, "Robust" means that it should feel like a quality product that doesn’t break down and cause costly delays and “Enclosing” means that it should feel like it’s enclosing its content, just like a car child seat, and prevents it from falling out. To leave some parts with it’s natural colour and appearance can also add a feeling of transparency and quality.
Since I had some trouble keeping the time plan in the finishing stages of the project the sketch phase and the form work had to be a bit compromised. That meant I only had time to come up with two different directions that I thought was interesting before I had to move on to form evaluating. My main focus with the upper sketch, direction 1, was to try to play with form directions. The vehicle will be able to drive in both directions and I wanted to make that clear in its appearance as well.

When making the second sketch/rendering, direction 2, I tried to keep it more down to earth and think more logical. So I did higher walls to really try to achieve the enclosed feeling that I mentioned on the previous page and tried to make the whole concept feel more trustworthy by filling in the (now straight) gaps in between the different sections with an accordion like rubber part to eliminate every risk of bags falling off in the turns. I also tried hiding the wheels under the body work of the side panels to see what feeling that would give to the vehicle and tried some different options on how to split the yellow and the gray sections. That’s the reason why I felt I needed to do some quick rendering work on it, to really be able to see how the division between the two colours worked. The reason why I wanted to have the bottom part gray was because I noticed that many products that I think feel robust have some sort of gray parts close to the edges, where it feels like the product could easily get damaged. The argument to have yellow as the main colour was the fact that it’s a signal colour that is easy to see, even in darkness. Yellow is also a common colour when it comes to vehicles that operates at an airport, probably for the same reason.
To evaluate the sketches I had some friends with design background and schoolmates look at my sketches and tell me what they felt. Examples on the feedback I had was that *Direction 1* felt fragile, especially in the middle where it almost could feel like it was about to snap in half if the weight became too great. They also said that it felt like the bags would fall off because of the low side rails and the big gaps between the different section of the baggage train or, like my friend Eric Höglund is pointing out on the image during a bike tour in the outskirts of Umeå, that the shapes felt more aggressive than "in motion" which was my goal.

Generally people preferred *Direction 2* since it felt much more thought through. However I got some tips that I could possibly make the side panels more interesting by playing with edges and form direction changes in combination with the gray/yellow split.
To know what dimensions the baggage train would have to be I spent one evening collecting all the bags I could get a hold of in my student corridor (the ones that were big enough to be checked in when flying). I got a nice range from the biggest ones to smaller ones, hard ones and soft ones and I measured the height, depth and width of them all. Then I compiled the most important data which was:

The biggest bag: 76x55x25 cm
The average bag: 65x45x28 cm
The smallest bag: 55x34x28 cm
More Sketching

Personally I think that direction 2 felt a bit boring and uninteresting, but I could also understand the feedback I had been given regarding direction 1, some of which I had already realized. So I went back to the sketch table to try to find some kind of compromise where there was much direction in the form (symmetrical towards both ends) but without making the vehicle feel fragile or untrustworthy in the sense that the bags could fall off. I quickly discovered that the most obvious thing to do, to be able to create symmetry, was to add another mid section so that the number of sections became uneven. I had also realized that the division between the gray and yellow part probably would look better if it was more simpler and that exposed wheels would not only be better maintain wise, but also enhance the motion expression that I was looking for.

This is the calculations I used when choosing which dimension the baggage train should be:

1 Airplane = ca. 65 bags
72 bags / 2 baggage trains = 36 bags/train (I wanted two collaborating baggage trains to be enough to offer space for all the baggage on most airplanes, so I took the average number of bags per plane, ca. 65 bags, and added 7 more just to be sure and divided it by 2 to know how many bags would need to fit on each of the baggage trains.)
36 bags / 2 rows = 18 bags/row (The baggage train can take two rows of bags in width, as the sketch suggests, which means that the actual train length doesn’t have to be longer than 18 bags.)
18 bags x 50 cm = 9 meter. (The bags are lined up with the long side across the baggage train, which means that the train doesn’t have to be longer than 9 meter to have room for all the bags, using the average width dimension for the bags from the previous page (45 cm) and adding 5 cm when calculating just to be sure and to leave some space between the bags to prevent squeezing when the train turns.)
2 bags x 78 cm = 156 cm (The biggest bags are around 76 cm long. If we add 2 cm to that and multiplies it by 2, when calculating the width of the baggage train, it should not become a problem that the bags won’t fit next to each other, even if two big bags would be lined up together.)
Before I went into 3D modelling I felt I needed to do some small function models to figure out exactly how the different sections would turn in relation to each other. I first did some really simple models to find out where the turning axis would have to be to prevent the bags from getting further and further away from the inner edge as they go from one section to the other, since the baggage trains are very likely to be turned when the bags are going on and off out next to the airplane. After that I did two versions of the mockup, one with straight gaps in between the sections and one where the form was more inspired by the sketches.
Since the form was not fully decided after the sketch process I did quite a lot experimenting in Rhino (a CAD software) and I worked much with trying to make something interesting with the shape of the side panels. The bottom part’s shape of the connections is taken more or less directly from the mockups, to get the rotation axis right in relation to the where the baggage bands end. As can be seen in the images the vehicle is divided in 5 sections, each with a conveyor belt overlapping the next one to prevent any gap from forming when being in a turned position.
Result
The ABT

The final result of the project is called the ABT, *Autonomous Baggage Train*, and is a 9.5 meter long snake-like vehicle designed for one purpose: To reduce the amount of manual lifting in the baggage handling process as much as possible. As far as I know the concept is a completely new approach to the problem and does not exist today. It removes 4 of today’s 6 manual lifting moments that each checked-in bag goes through and shortens the waiting time for the passengers as well. The technology behind the idea exists today, but for this product to become a reality some rebuilding of the airports would need to be done and because of that I would say that this concept is probably realizable within a 10-year period.
The ABT is simplified a motorized conveyor belt on wheels that has been split into 5 parts to make it able to turn and to load and unload bags in both a straight and turned position. The conveyor belts overlap each other to prevent a gap from forming when the vehicle turns. This means all though the vehicle can drive in both directions it has one side for loading and one for unloading. To get the bags on and off a foldable conveyor belt is used. Since the bags will be stacked in two rows motorized high friction balls are used to shove every other bag to the right and every other to the left. The ABT is also equipped with an interactive display, to enable the baggage workers to interact with the vehicle. The wheels have distinct treads and are quite big to make sure that they offer good grip even in the worst weather conditions. This is important since each ABT vehicle is designed to carry around 36 bags, which adds a weight of up to 700 kilos. The wheel rims are inspired by the shape of the fan in a jet engine.
Exploded view

- High Friction Rubber
- Low Friction Rubber
- Head Lamp
- Turn Signal Lamp
- Hubless Wheel Axel/Brakes
- Electric Engine (Driving the wheel)
- Batteries
Electric Motor for the hydraulics

Interactive Display

Electric Motor

Small Electric Motors

Hydraulic piston (For turning)
The ABT:s will be parked in two different locations at the airport. Half of the vehicles will be used mainly for arriving flights (unloading airplanes) and the second half for departures (loading airplanes). The baggage trains are battery driven and get charged automatically every time they are stationary in either the Arrival Hall or the Departure Hall and the powerful computer, controlling all the vehicles, chooses which baggage trains to use for each loading/unloading job based on the vehicles’ battery status. The computer also calculates how many baggage trains will be required for each airplane (most commonly 2 or 3). The calculations are based on information that is sent to the airport about the arriving airplane before the airplane even touches the ground (this system already exists today).

On the image you can see how the two ABT:s to the left (following the blue arrows) are on their way to unload the arriving airplane while the other airplane is getting loaded by three ABT:s from the Departure Hall (following the green arrows).
The ABT:s follow lines in the ground along the sides of the Ramp to make sure that they reach the airplanes in the safest way possible without risking collisions with a sister vehicle, an airplane or anything else that moves across the ramp. It’s possible that the vehicles will rely fully on GPS systems in the future, but today this technology is not precise enough. Since safety is the most important thing when it comes to airports the lines also have built in lamps that start flashing in the direction which the approaching baggage train is travelling, so that people around make sure to keep out of the way and not park vehicles in the ABT’s path. This becomes even more important on bigger airports where it can be a lot of traffic and where delays can have bigger consequences. If an airplane is approaching, as seen on the image, the airplane always have precedence and this is visually communicated to the pilots by leaving the part of the line which the airplane is about to cross unlit. If the mentioned safety measures would not be enough the baggage trains are equipped with cameras so that they will stop if something would accidently come in its way.
Concept scenario - Loading

1. When the bags get checked in, they get transported to the Departure Hall and the right ABT machine automatically by a computer. This system already exists today on all medium/biggest airports. Once the bags reach the ABT, they get loaded in two rows, every other to the right and every other to the left, as seen in the picture. The reason why the baggage train is filled up from the front to the back and not the other way around is because that leads to less wear on both baggage and the conveyor belts and helps keeping the two baggage rows intact as well. This is the 1st manual lifting moment removed by the ABT.

2. Once fully loaded, the ABT sets course towards the departing airplane and follows lines in the ground that light up when the train approaches to make people aware that the trains are coming. The ABT vehicles are autonomous, which means that they are remotely controlled by a powerful computer, controlling all the baggage trains on the airport. This means that the human factor is removed and careless driving like missjudgements or exceeding the speed limits are significantly reduced. The trains are designed so that two cooperating ABT vehicles should have room for around 72 bags, which is about 5-10 more bags than the average airplane usually has onboard.

3. As the baggage trains approach the airplane, they stop and wait for the loadmaster to confirm that the mobile baggage band is in place and ready to receive the ABT:s.

4. The mobile baggage bands are placed and the driver jumps into the airplane to do the manual lifting inside the plane.

+ 1 reduced manual lifting moment
+ Less wear on the bags

- Manual lifting inside the plane

+ Contributing to a safer working environment with less careless driving
5 The loadmaster walks over to the waiting baggage trains and confirms that the mobile baggage band is placed correctly and at the right cargo room door by clicking “accept” on the touch screen. The screen has been placed at the side of the vehicle so that the person using it does not stand in front of the ABT when it’s about to drive away. To avoid feet to get run over the screen counts down to 5 and tells the person to step away from the vehicle before it starts rolling.

6 This is the first time that the ABT leaves the lines in the ground and with help from an external GPS transmitter on the end of the mobile baggage band it finds its way towards the docking spot. When it’s getting closer the ABT’s built in camera makes sure that the vehicles align perfectly and that the distance is just right.

7 The docking process is finished when the foldable conveyor belt is lowered into the height of the mobile baggage band by an electric motor at its base.

8 Thanks to the ABT’s built in conveyor belts the bags can just slide off onto the mobile baggage band and into the airplane. This is the 2nd manual lifting moment removed by the ABT. Today the bags often gets tossed onto the baggage wagons which can damage the baggage.

+ 1 reduced manual lifting moment
+ Less wear on the bags
Concept scenario - unloading

Arrival Hall

Departure Hall
Since the turnaround time for an airplane is only around 25-30 min it’s very important to be able to load/unload the airplanes as efficient as possible. The manual lifting inside the airplane is clearly the most time consuming work task when loading the plane and therefore it’s very important that there is a constant flow of bags to this position. That’s why the second ABT docks to the end of the first one and slides over all its bags to it, as can be seen on the image, instead of letting the first ABT drive away so that the second one can dock directly to the mobile baggage band. If the ABT:s would have swapped places that would mean a stop in the flow of bags for probably around half a minute and you would also get the problem that the second baggage train is in the way when the first one is about to leave. Today the baggage workers need to move the empty baggage wagons out of the way before they can start unloading the next one, which mean an interruption in the flow of bags.

Once the second ABT is empty it leaves and heads back to the Departure Hall. Since the train need to be able to load and unload baggage in a turned position it has a limited turning radius and partly because of this the vehicle can drive in both directions. When it leaves the ABT’s back end becomes it’s front and this is communicated to its surrounding through the colour of the headlamps. Notice how the ABT closest to the airplane has red rear lights, while the leaving ABT’s head lights has changed colour since it’s now driving in the other direction. Also notice how the lines in the ground has already lit up to show that the baggage train is approaching.

Once the ABT reaches the Departure Hall it gets charged while waiting for its next airplane to load.

**Concept scenario - Unloading**

When an airplane arrives to the airport, one, two or three ABT:s (Depending on the number of bags on the airplane) are sent out towards the airplane’s parking spot. The information telling the airport how many bags are on the airplane is already today sent from the airplane to the airport even before it touches the ground.

- Shortens the waiting time for the passengers
- Contributing to a safer working environment with less careless driving
13 As the baggage trains approaches the airplane they stop and wait for the loadmaster to confirm that the mobile baggage band is in place and ready to receive the ABT:s.

14 The loadmaster confirms that the airplane is ready for the ABT:s by clicking "Accept" on the ABT:s touch screen. But since these vehicles will operate in all seasons and weathers it’s not an ordinary touch screen. It’s more like a big button which consists of a screen. The button/screen can be clicked on the sides, the bottom and in the middle. This is enough to make the relatively simple choices that needs to be done. This also means that the loadmaster can wear gloves while using the screen.

15 The first ABT docks to the mobile baggage band while the driver of the mobile baggage band climbs into the airplane and begin unloading the bags. The second baggage train follows the first one and docks to the back of it.

16 With help from the camera the second ABT gets more or less perfectly aligned behind the first one and stops at the exact right distance, so that the two foldable conveyor belts at the end of each baggage train folds down only millimetres away from each other.

- Manual lifting inside the plane
The fully loaded baggage train reaches the Arrival Hall where it will connect to its loading station while unloading the baggage. Since the time it's operating without being charged is relatively short the ABT can get by with relatively small (and cheap) batteries.

The baggage get unloaded onto the baggage drop band, which leads to the waiting passengers. This is the 4th and last manual lifting moment removed by the ABT.

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17 This is the 3rd manual lifting moment removed by the ABT. As mentioned before it's important not to interrupt the flow of bags from the person sitting inside the airplane to the mobile baggage band. Therefore it's always the last train in the line that gets loaded first, so that it can leave without interrupting the flow of bags. The ABTs ahead of the last one simply work as conveyor belts, transporting the bags to the last baggage train, until a laser censor at the back of the loaded baggage train is telling the computer that it's full and ready to leave. Each train is equipped with four laser censors, marked as red dashed line on the image, one just before and one after each of the sections shoving the bags to the right or to the left. They help the computer know where the bags are and how full the train is. These lasers could easily be programmed to count the bags as well when loading the airplane, so that the baggage information sent to the next airport can become even more accurate. Today the amount of baggage is calculated from how much it weighs, which rarely generates the exact number of bags.

18 The now fully loaded ABT undocks from the other baggage train and sets course for the Arrival Hall where it can start unloading the bags while the airplane is still being unloaded. Today the baggage workers load the whole train of baggage wagons before driving them away to the Arrival Hall. This means that by using the ABT we can significantly shorter the time it takes for the first ca. 36 bags to reach the waiting passengers. When doing my research I found out that it takes approximately 4 seconds for each bag to get loaded. That means that the ABT saves the passengers up to 4x36=144 seconds in this single moment. This time gain could become even greater if the airplanes are big enough to require 3 ABT:s to hold all the bags. The time gain could also become non-existent if the airplanes are small enough to be unloaded by only one ABT, which is quite uncommon.

19 The fully loaded baggage train reaches the Arrival Hall where it will connect to its loading station while unloading the baggage. Since the time it's operating without being charged is relatively short the ABT can get by with relatively small (and cheap) batteries.

20 The baggage get unloaded onto the baggage drop band, which leads to the waiting passengers. This is the 4th and last manual lifting moment removed by the ABT.

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+ 1 reduced manual lifting moment
+ Shortens the waiting time for the passengers
+ Less wear on the bags
+ Could improve the accuracy of the baggage information sent to the next airport

+ 1 reduced manual lifting moment
+ Shortens the waiting time for the passengers with around 2 minutes

+ 1 reduced manual lifting moment
Concept benefits

By using the ABT instead of today’s baggage trains we could:

- Remove 4 out of 6 manual lifting moments
- Shorten the waiting time for the passengers
- Reduce the wear on baggage and the airport’s baggage bands
- Help creating a safer working environment with less careless driving
I would like to say a special thanks to my collaboration partners, my sponsors and the following persons for their contribute to the project:

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Thank you!
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What if baggage handling at airports could become more automated?