Graduation project
Designing New Handling and Sorting Equipment
Final report
August 2013
Preface
This graduation report is performed from December 2012 till August 2013 (see timeline). This report concludes the design of a new handling and sorting procedure for Ball Packaging Europe with necessary corresponding equipment. Ball Packaging Europe has a problem which has been outsourced to Cargo Service Europe. Cargo Service Europe and its stakeholders will set up a new business called Curagon, Industrial Packaging Solutions.

In order to reach the final design, this project was separated into three phases, respectively; Analyses and establishing the objective, Designing new handling and sorting equipment, final design and materialization. Besides these three phases, the 1:1 model building will be presented and elaborated in this report.

This report is made possible thanks to the companies and partners of Curagon; Cargo Service Europe and Vega Systems, University chair I.r. J.F. Prins and Mentor Ing A. Kooijman. Special thanks goes out to the design engineering department of Vega Systems; E. van Vugt and C. Schevelier.

Jan Johannes Thissen
Oss, August 2013
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Executive summary
‘Savings, speed, ergonomically improvements and consistency in quality’.

Those are keywords in the development of a new machine for the (soda-) can industry, an innovative solution by Curagon.

A company description summary
A new company called Curagon, Industrial Packaging Solutions, is launched with the collaboration between -industrial laundry machine builder- Vega Systems BV, Transportation company Cargo Service Europe and TU Delft. The core business of Curagon is the improvement of current packaging processes within the (soda-) can industry. The first customer will be Ball Packaging Europe situated in Oss. The end-users will be employees at Ball Packaging Europe.

The problem
Within the can-industry, pallets filled with empty cans are transported from Ball Packaging to its customers. Coca-Cola and Heineken are an example of such ‘customer’. At the customers from Ball Packaging the pallets filled with empty cans are de-palletized and the sheets between the layers of cans are transported back to Ball Packaging Europe to be re-used. Before these sheets are re-used, they are manually checked by employees for imperfections. In order to improve consistency of quality and eliminate human error, Curagon has developed a new product which makes it possible for employees to check these separator sheets. It is crucial for the process that these sheets are in mint condition. If not, the process might be seriously delayed.

The solution
Curagon has developed a new machine which enables the employees to check the separator sheets. This machine is able to clean, scan and sort the separator sheets. Benefits are;
- It is faster and more consistent in relation to the current process
- Less employees needed for the same amount of work
- Ergonomic improvements for employees
- Financial benefits

Why now?
At this moment approximately eight people are needed in order to check and sort these separator sheets. In economic crisis the savings are the first profit for a company. This is also the case for Ball Packaging Europe. With the handling and sorting equipment of Curagon the number of employees needed will be reduced by 75%. Furthermore, the working conditions for employees are more and more important (ARBO, legislation) and this machine enables the employees to work in an ergonomically posture.

At this point approximately between 7,5 – 10 million sheets are handled and sorted each year. This is about 500 separator sheets a hour per employee, with the sorting and handling equipment an employee is able to process three times as much per hour. The same amount of work can be done with less employees and the consistency of quality will be much higher.

The customers will lease the handling and sorting equipment for a period of five years.
Introduction

Problem
Assignment
Context assignment

Figure 1: Amount of cans Ball produces and purchases

Figure 2: Filled pallets go to Balls' customers, separator sheets go back to Ball Packaging
This report is the result of the graduation project conducted for Cargo Service Europe, situated in Oss (NL). Cargo Service Europe is a business-to-business transport company which differentiates in their market by their slogan ‘Quality by Difference’. This means they will ‘go that extra mile’ for their customer. Their aim is to improve the logistic chain in co-operation with their direct stakeholders.

Cargo Service Europe distributes cans for Ball Packaging Europe. Ball Packaging Europe is a company specialized in creating cans for all kinds of consumer products, for instance soda cans. Cargo Service Europe wants to improve the logistic chain by supporting Ball Packaging Europe in this process with a business-to-business solution which will be explained in this report. The designed solution will result in a new company called; Curagon, Industrial Packaging Solutions.

In this report the three phases of design, as mentioned in the preface, will be elaborated. At the end of this report the final design will be presented as well as the conclusions and recommendations.

Problem

Ball Packaging Europe delivers their cans to mostly large enterprises like Bavaria and Heineken. The cans that Ball Packaging Europe delivers to their customers are stacked on a pallet. First a layer of cans is placed on the pallet; subsequently a plastic or cardboard sheet is placed on this layer of cans. On top of this sheet a layer of cans is placed again, followed by another plastic or cardboard sheet. This automated process is continued until the pallet is stacked with cans separated by plastic or cardboard sheets. An illustration of a stacked pallet can be seen in figure 1.

The sheets between the layers of cans will be re-used. Customers of Ball Packaging Europe retrieve those plastic or cardboard sheets back from the pallet. Customers send these sheets back to Ball Packaging Europe because of the deposit on these sheets or contract agreements.

When pallets with plastic or cardboard sheets go back to Ball Packaging Europe, employees have to check each sheet for imperfections (tears, bends and fluids) and separate the imperfect ones from the ones that can be re-used. The sheets that are too dirty will be 'shaken' off. The handling and sorting of the sheets is a continuous repeated process done by hand and naked eye. This process requires making the same motion during the entire shift in order to check the separator sheets.

Not every employee grades a sheet the same way, especially not later in their shift. An employee might reject a sheet whilst another employee might approve the same sheet. The same goes for brushing; some employees might grade the sheets dirtier than others.

Customers of Ball Packaging Europe complain about the quality of the separator sheets. Cargo Service Europe wants to make an in-house handling and sorting procedure (with necessary equipment) in order to help employees at Ball Packaging Europe with the sortation of separator sheets. This equipment would help the users (employees of Ball Packaging Europe) to grade, clean and sort the separator sheets all on the same quality level. This equipment would also improve the current ergonomic situation for the end-users, because it is designed with the end-user in mind.

It is crucial that these sheets are in perfect order for every phase of the logistic chain. Sheets in perfect order are beneficial for the continuity of the process and the working conditions. When a sheet is bend or teared, there is a possibility that, for example, cans fall off the pallet.

Ball Packaging Europe acknowledged that improvements are to be made in this particular area and outsourced this problem to Cargo Service Europe.
Assignment
In this graduation assignment a new handling and sorting procedure (including the design of necessary equipment) will be created for Ball Packaging Europe. The current manual handling (bends, tears and fluid detection, brushing and sorting) which is done by hand and naked eye, will be improved. With this new procedure end-users will be able to detect imperfections and grade the condition of the plastic and cardboard sheets better and more consistent in relation to the conventional method. With this procedure the consistency of the quality will be improved as well as the ergonomic conditions of the end-users.

Context assignment
In this part the context of the assignment is elaborated. This is done by using the visual presentation shown in figure 3. This figure shows the borders of this graduation assignment. It shows were the graduation assignment starts and ends.

Unsorted separator sheets are transported to Ball Packaging from their customers. A forklift unloads the truck and places the pallets into storage. The unsorted stored sheets go through the handling and sorting equipment and get sorted. Once these separator sheets are sorted, each pallet gets wrapped, sealed and labelled. The sorted separator sheets go into storage (if necessary) before they are used again in the process.

The 'blue cloud' is the main focus of this graduation assignment. The cleaned and scanned sheets will be sorted in three categories; A-choice, B-choice and reject. The design of the equipment for the cleaning, scanning and sorting of the separator sheets are all part of the assignment.

Figure 3: Main focus of graduation assignment
Analysis

Company overview
Product portfolio
Stakeholder overview
Functional analysis
Customer
Competitors
Competitive forces
Innovation
Ball Packaging Europe is a (soda) can manufacturer placed all over Europe. Ball packaging Europe is a part of Ball Corporation, among others, an international manufacturer of high quality packaging.

Ball Corporation consists of various departments shown above. Departments which manufacture beverage cans can be seen in the blue cloud presented in figure 4. Ball Packaging is placed in Northern America, Latapack-Ball in southern America, Ball Asia Pacific Limited in Asia and Ball Packaging Europe in Europe with its headquarters in Zurich. Ball Aerocan manufactures aerosol cans whereas Ball Aerospace is a manufacturer of innovative aerospace systems. The focus for this project is on Ball Packaging Europe.¹

Ball Packaging Europe has twelve plants situated all over Europe with Zurich, Switzerland as its headquarter. All these plants have a workforce of about 2,800 employees combined. These plants are located in the Netherlands, United Kingdom, Germany, France, Serbia and Poland (Figure 5).

Ball also has a technical centre in Bonn, Germany. Their research and development department is situated there. Annually Ball Packaging Europe produces billions of cans. These cans are made of steel or aluminium which are spread and distributed all over Europe.

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of plants</th>
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<tbody>
<tr>
<td>Germany</td>
<td>5</td>
</tr>
<tr>
<td>France</td>
<td>2</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>2</td>
</tr>
<tr>
<td>Netherlands</td>
<td>1</td>
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<tr>
<td>Poland</td>
<td>1</td>
</tr>
<tr>
<td>Serbia</td>
<td>1</td>
</tr>
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</table>

Figure 4: Ball Corporation

Figure 5: locations of manufacturing plants
Ball Packaging Europe produces cans of various sizes for different beverages. (Figure 6) These cans have various sizes for numerous beverages. Besides the different sizes, Ball Packaging Europe also has different features for their cans. Various features are possible. For instance embossing, luminescent overprinting and tactile cans are examples of how the can looks like and/or feels. (Figure 7) Not only the cans can be altered, also the caps and ends can be changed. They can be printed (pure brand end), resealed again, laser printed tabs and CDL. CDL is a smaller cap than usual which reduces the resources needed in order to make the cap. (Figure 8) Some additional features are twin caps. This allows the consumer to twist two cans on top of each other and mix them. The widget technology is a technology which provides a head of froth. Firstly only used for beer, nowadays also for milk, yogurt and coffee drinks². (Figure 9)
Stakeholder overview

Below the stakeholders for this assignment are visualised. This visualisation is made from the point of view of Curagon, Industrial Packaging Solutions, since this is the company that is going to lease their service and equipment to Ball Packaging Europe. (Figure 10)

Main stakeholders

Curagon will be a company created between two existing companies, Cargo Service Europe and Vega Systems. Therefore, the partners of Curagon are Cargo Service Europe and Vega Systems. The indirect suppliers are Heurkens en Van Veluw and Eagle Vision. Heurkens en Van Veluw already delivers to Vega Systems and therefore indirect to Curagon. Eagle Vision will become a new partner. The prototype will be built at Vega Systems. Heurkens en Van Veluw will deliver any custom made steel parts and Eagle Vision will deliver the optical hard- and software system. Vega Systems and Cargo Service Europe are the two main stakeholders in this project since Curagon is an alliance between the two companies. Besides Vega Systems and Cargo Service Europe, all partners and suppliers are replaceable.

Selling and distribution

Since Cargo Service Europe is a transportation company, they will distribute the equipment through The Netherlands and Europe. A maintenance or installation crew will travel from The Netherlands to the site in order to install the equipment if necessary.

Figure 10
Functional analysis

In figure 11 the functional analysis of the process is shown. The visualisation shows how the separator sheets are handled and transported in the current situation. Independent on customer, sheets sizes and material of the separator sheets, the procedure remains the same. Separator sheets are transported to Ball Packaging Europe’s customers. The customer retrieve sheets from the palletized (soda) cans and transport these sheets back to Ball Packaging Europe. At Ball Packaging the sheets are sorted and re-used. Zwaans kartonnage is the compagnie that supplies the separator sheets and retrieves the rejected ones.

Figure 11
In figure 12 a functional analysis is shown of how the process should work with the new handling and sorting equipment. Instead that the separator sheets are scanned with the naked eye and by hand, the sheets are handled and sorted by using equipment of Curagon, in-house at Ball Packaging Europe.
Customer

When the handling and sorting of the equipment is totally functional, the pilot will take place at Ball Packaging Europe in Oss. Curagon will deliver an in-house solution for Ball Packaging Europe and the latter will lease the handling and sorting equipment from Curagon for a timespan of at least 5 years.

This project will start at Ball packaging Europe in Oss (NL) and later, if successful, other Ball Packaging plants across Europe. Our customers will be can manufacturers, so the competitors of Ball Packaging Europe are actually potential customers for us. In figure 13 a number of can-makers are shown. There are many can manufacturers and the companies visualized are a selection of the biggest manufacturers in the business.

The can industry is only the start for the handling and sorting equipment. There are many more industries which use separator sheets. The spin-off are indirect customers, for instance customers in the glass industry, who also use these separator sheets. (Figure 14)
**Competitors**

As stated before the competitors of Ball Packaging Europe are actually customers for the handling and sorting equipment of Curagon. The main competitors of Curagon are not the competitors of Ball Packaging Europe, but the companies who place machinery inside the manufacturing plants. Since the manufacturing plants do not open their doors for public, an analysis was made through online footage. In the visualization below the main competitors of the handling and sorting procedure are shown. (Figure 15)

The main competitors are companies which build all sorts of equipment for brewery’s, beverage filling plants and other companies which make filling lines. These companies make the conveyers, the fillers, the labellers, the palletizers etcetera. They control the entire process (Installers). Second level competitors are competitors which make only one part of the handling and sorting system. Companies which only make the scanning/detecting system or a conveyor belt are considered to be not a big threat as the main competitors, which make total filling lines. (Conveyor/sorting/detecting and scanning manufacturers)
Competitive forces (Porter)

The competitive forces of Porter will show the attractiveness and profitability of this industry. Especially for the new company (Curagon) it is interesting if the market is attractive enough. This mix of forces will generate insights into the required resources and the adoptable strategies in order to be successful.

Rivalry amongst existing competitors

There is no –too little- product differentiation within this market. Competitors of Curagon are not really found. Our biggest competitors are not (soda-)can manufacturers of any kind, but the companies that place machinery inside these can manufacturing plants. There is one company called Mart (Italy) which makes machines with the ability to clean separator sheets. (Appendix E) However, their machines only clean separator sheets at a pace which is too slow.

Threat of new entrants

There is no such product as the handling and sorting equipment from Curagon. Therefore every entrant will add capacity to the industry and therefore competition. However, it will be very likely that potential competitors do not have any knowledge about this field and have to do their research before they can produce any handling and sorting equipment. Therefore the threat of new entrants will not be low, but it will take a longer period of time.
Bargaining power of suppliers
This will be relatively low because there are enough suppliers. The materials that are needed are probably quite straightforward and easy to access. The competitors from Curagon are all suppliers of parts of the scanning and sorting equipment.

Bargaining power of buyers
There are no products as this one yet and the buyer/leaser really wants to have this product. Therefore the bargaining power of the buyer will be relatively low. However, there are only about twelve main can manufacturers on the planet that account for a large portion of industry sales. They might gain concessions. On the other hand there are other markets where this handling and sorting equipment can be used. This can be seen in chapter customer on page 18.

Threat of substitute product
The threat of substitutes is moderately high. No other products are on the market yet but competition will catch on quickly. Direct competitors of Curagon all have a part of this equipment in their product portfolio. It is relatively easy for them to catch on into this market.

Innovation
The department in Bonn, Germany is the research and development department for Balls Packaging Europe (soda-) can industry. The strategic driven innovation from the management team is put into practice at this facility. In Bonn, Germany they constantly develop ideas and turn these into new products. Ball claims to be the global leader in innovation in their industry. Ball is interested in any form of collaboration in order to improve their production line. Metal processing technologies, sensory properties (taste, smell, visuals, texture) and new technologies and materials for the cans are particularly areas of interest according to their website⁴.

Both foregoing statements show that Ball Packaging Europe is not busy with improving their procedure on the handling and sorting of separator sheets. Ball Packaging Europe wants to be innovative, however, their aim is on the production of soda cans and not focused on supportive equipment. This is also substantiated in the chapter Trends and developments on page 31.
Analysis separator sheets

Separator sheet analysis
Use context
Separator sheet requirements
LCA analysis
In this chapter an analysis of the separator sheets will be presented. Since this is a crucial part of the entire project, it is looked at in detail. Employees work with these sheets the entire day and the equipment has to handle and sort these sheets. Also a closer look at the use context will be presented.

Separator-sheet analysis
The separator sheets (or divider sheet, layer pad or tier sheets) come in different sizes, colours and material (Figure 16). The current materials are cardboard and plastic (PP). Eventually all separator sheets shall be made of plastic because of its longer lifetime and it is better to clean in relation to cardboard. In a number of years all the cardboard separator sheets will be replaced with PP plastic separator sheets. An analysis if this is the right plastic for its purpose can be seen in Appendix C.

Separator sheets come also in different standard sizes which are stated below.

Typical Sheet Sizes⁵:
- 1120 x 1420 (mm)
- 1115 x 1415 (mm)
- 1200 x 1350 (mm)
- 1120 x 1300 (mm)
- 1115 x 1295 (mm)
- 1150 x 1250 (mm)
- 1180 x 1250 (mm)
- 1016 x 1219 (mm)
- 1137 x 1207 (mm)
- 1143 x 1207 (mm)
- 1000 x 1200 (mm)

These specifications are the same for both the plastic and the cardboard sheets. Almost all of the sheets differ a few millimetres from the dimension they claim them to be. All of them are shorter, not longer. This difference is a bit larger with the plastic ones, probably they shrunk a bit harder because of its thermal properties. The thickness of the plastic sheets varies from 0.6 mm to 0.77 mm and for cardboard the thickness varies from 0.75 mm till 1.05 mm. The sheets are made at different factories, which can be seen on the prints and logos on the sheets. Even separator sheets from the same factory might have different coloured sheets and logos and prints on various places (figure 17). For instance, ITW Plastics has different positions for their logo’s and has different colours. Also in the radius of the sheets is a difference between the factories and its margins which can be seen in figure 18. The radius per sheet manufacturer varies.

All these dimensions stated above are not rectangular but all have a radius. In general; all dimensions might have a radius of 50 mm, 60 mm or 70 mm. The dimensions which are underlined are the three most common sheets used by Ball Packaging Europe these days.

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⁵ These specifications are the same for both the plastic and the cardboard sheets.
Use context

To what are the sheets exposed?

The separator sheets are placed inside a palletizer. From there they are palletized between layers of cans. The pallet is filled up to 23 layers of (empty) cans. After palletizing, the pallets get wrapped with plastic and sent to Ball Packing Europe’s customers. At the customers filling plant, they depallitize the pallet and the separator sheets are placed on a pallet to be transported back to Ball Packaging Europe. Customers return these separator sheets because of the deposit they made on the sheets or because of contract agreements.

Back at Ball Packaging Europe, employees scan, clean and sort out these sheets by hand and neatly place them back on a pallet. This pallet goes to the palletizer again and the process starts over again. Sometimes pallets with cans are stored for a longer time before they are used again. The top separator sheet collects a lot of dirt during storage. There is also the risk of fluids on top of the separator sheets; for instance oil from machinery, which drips onto these sheets. Ball Packaging Europe does not want any fluids in touch with their empty (soda)cans, so any separator sheets which contains fluid has to be disposed.

Most sheets are exposed to improper use. Employees are not careful and forklifts bash into pallets filled with sheets, which make them tear and bend (Figure 19). When these tears and bends are too large, these sheets are not sufficient enough and has to be discarded. Exact requirements for the re-use of separator sheets are stated in chapter Separator sheet requirements, page 26.

Figure 19: Teared and bend by improper use
How do employees use these sheets?

Employees at Ball Packaging Europe retrieve a pallet filled with separator sheets, returned from Balls’ customers. The employees have to scan these sheets one at the time by the naked eye and by hand. In the schedule below it is visualised which steps an employee has to make in order to value the quality of the separator sheets.
Separator-sheet requirements

Ball Packaging Europe has some guidelines for the disposal of separator sheets. These guidelines are given by Michael Schäfer, Manager Qualiy Projects and Devices from Ball Packaging Europe’s headquarters. Employees which handle and sort separator sheets have to follow these guidelines. For a report on the visit to Ball Packaging Europe Oss, see appendix B.

The separator sheet requirements are shown on the next page.
Pulled out layers / corners (>5 mm)

Torn layers (>3 cm or in excessive quantity)

Damaged / bent or torn corners (>2 cm)

Marks: important marks of cans, folds

Foreign matters, stain, dirt, mould, corrosion, adhesive tapes, tickets, footprints, grease or oil stains and others.

Odor / smell (gasoil, chemicals, humidity)

Foreign bodies: insects, spider webs / splinters (glass, wood etc.)
Life-Cycle-Analysis

Scope and goal
This analysis is a comparison between three ways of handling the separator sheets. A Life-Cycle-Analysis is done on how it is in the current situation (1), how it will look like when Curagon will do the separation (2) and how it will look like when all the separator sheets will be thrown away and brand new ones will replace them (3).

Goal of this analysis is to show what the impact is on the environment by different ways of 'separator sheet handling' by looking at the eco-costs. This analysis is done with a focus on Ball Packaging Oss. The main focus is on cardboard separator sheets. The reason is that Ball Packaging Oss mostly works with these sheets. The analyses on PP plastic and cardboard sheets are in Appendix C.

The three ways of approach are stated below:

- How it is done in the current situation
- How it will be done with the Curagon equipment
- What will be the effect if all sheets get disposed and replaced with new ones.

System boundaries
To determine the scope of the analysis, first the whole life cycle analysis has to be mapped out for each approach.
In the current situation the cardboard separator sheets are manufactured / recycled and disposed in Ravenstein by Zwaans-Kartonnage. After manufacturing, the separator sheets are transported to Ball Packaging Europe were they are used and re-used.

8 per cent of all the separator sheets are rejected by the employees at Ball Packaging Europe and this 8 per cent is transported back to Zwaans-Kartonnage. They recycle and dispose the rejected sheets.

In the second situation a closer look was taken at the eco-costs when the equipment of Curagon would be used in this process. Eventually 8 per cent of the separator sheets go to recycling and landfill. From this 8 per cent, approximately 90 per cent is recycled.

In the third case an analysis was made when Ball Packaging Europe would chose to dispose all the separator sheets and get brand new ones every time.

Eco costs
The values which are used and measured are eco-costs. The eco-costs is a single Life-Cycle-Analysis indicator for environmental burden. This is based on the concept of ‘marginal prevention costs’, this means that these are the costs needed to bring back the environmental burden to a sustainable level.

The eco-costs in this analysis are calculated for each piece of cardboard separator sheet.
1 Current situation

- Wood
- Resin
- Pulping
- Injection
- Cutting & Packaging
- Transport
- Re-use
- Use

92% 8%

90% 10%

Transport
Zwaans-Kedonnie

Recycling
Landfill

€0.203

2 Curagon situation

- Wood
- Resin
- Pulping
- Injection
- Cutting & Packaging
- Transport
- Re-use
- Curagon’s equipment
- Landfill

92% 90%

Recycling

90% 10%

Transport
Use

Recycling company

90% 10%

Landfill

€0.176

3 Dispose-all' situation

- Wood
- Resin
- Pulping
- Injection
- Cutting & Packaging
- Transport
- Use
- Recycling

90% 10%

Recycling

Landfill

€0.200

The calculations are per 500 separator sheets, except for the Curagon situation. This is calculated with 1500 pieces, because the circulation time will be three times as high. With the Curagon equipment the process will be three times faster.

In the figures various situations are sketched. The first is about how the situation is now, the second situation is when it is done by Curagon equipment and the third situation is when all separator sheets are disposed and replaced with new ones. The entire calculations are in appendix C.

The eco-cost per sheet for each situation are as follows;
- Eco-cost in the current situation: €0.203
- Eco-cost with Curagon equipment: €0.176
- Eco-cost when everything is disposed: €0.200

The main reason that the eco-cost for the Curagon situation is lower is because of the volume. There will be less transport and less separator sheets rejected because of the equipment. Therefore the eco-costs will be lower and a lower environmental burden.
External analysis

Development and trends in packaging
Existing solutions
Anthropometry
A closer look was taken to the development and trends and the existing solutions and technologies within the packaging industry. This chapter presents the outcome of this analysis. These results might be used as input for the program of demands and wishes and eventually idea generation.

**Development and trends**

For the analysis on developments and trends two articles were analysed. The two articles can be found in appendix D. Two articles on development and trends in packaging industries were found (February 2011 and January 2013). These two articles were compared in order to see any comparison or similarities between them. With this comparison a prospect is drawn.

In *Current Development Trends in Packaging Industry* (Source: www.pack.net.cn)⁹ it is claimed that new products in the packaging industry have not shaken the tag off of being mere imitations instead of innovations. Competition within this industry is limited and improvements in efficiency are made by simply increasing the scale of manufacturing.

Further it is stated that new equipment in the packaging industry should be multifunctional, easy to adjust and to operate. According to statistics, the level of automation is increased and proving to be very popular. Equipment should save time and be cost effective. The combination between simplicity and multi-functionality would achieve this.

A third remark made is that the emphasis is solely on the production of the main machines, not on the production of supportive equipment.

The second article (*Top 10 trends affecting packaging in 2013-Lisa McTigue Pierce, Executive Editor - Packaging Digest*)¹⁰ is based on a survey amongst manufacturers in the packaging industry. These people formed a top ten on developments and upcoming trends. In this article there were several interesting points mentioned. According to the article the equipment should be efficient, reliable and it has to keep the manufacturing line going without stoppage which would reduce performance. A good balance between design, speed, efficiency, installation time and start-up procedures should be made. Also technical support and training are considered important.

Finally it was stated that ‘one size fits all’ does not apply in this market. Every plant is different and has a different lay-out and strategy.

Below the most important conclusions from these two articles are stated.

- Innovation is needed in the industry
- New equipment should be multifunctional
- Main machines should not be the only focus, also supportive equipment
- New equipment should not reduce performances
Existing solutions

The separator sheets have to be cleaned, scanned, sorted and handled. In order to get a better insight, a closer look was taken at existing solutions. Per category (cleaning, scanning, sorting and handling) a comparison was made. This comparison was conducted in order to see which one of the existing solutions would be the most appropriate for the situation. Each existing solution was valued and compared to another solution. This is done by valuating some parameters more important than others. In this chapter the most promising solutions will be shown. This comparison is further elaborated and explained in Appendix E.

<table>
<thead>
<tr>
<th>Cleaning</th>
<th>Scanning</th>
<th>Sorting</th>
<th>Handling</th>
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<td>(3D scanning)</td>
<td>(Belt sorters)</td>
<td>Vacuum grippers</td>
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<td>Vacuum</td>
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Comparison cleaning

A small comparison is made between the hand brush, round brush, steam and pressurized air. The criteria are based on:
- How easy is the method for the user
- How effective it is
- How easy it is to manufacture
- How easy it is for maintenance
- The costs.

According to the comparison the round brush was the most promising. It is very easy to use and it can reach high speeds which is crucial for our process.

Figure 20: Round brushes

Comparison scanning

Also for scanning a comparison is made. This comparison is made between 2D (AiScan/Geo scan) and 3D scanning (DAVID, Kinect, Laser, Minolta Konica/VI700). Looking at these techniques, there are some main differences. Not every technique has the same resolution and therefore quality of the image. For instance, the DAVID scanner has a higher resolution than the EXA scan or Ai scan. Of course, the distance between object is higher (DAVID is for buildings, EXA and Ai for objects.) In general, the quality of the scan is dependent on a few things. These are the quality of the laser and the camera, but also the distance from the camera to the object. For this project, speed is also an important matter; the faster a picture is scanned (relative speed) and processed (data transfer), the faster the overall process will go. For this project the scanner will be produced by an external party, Eagle Vision, this will be further explained on page 77.

Figure 21: Basic Scout system by Eagle Vision

32
**Comparison handling**

The sheets have to be handled; this means that the sheets have to be transferred from one place to another. This can be done in various ways. Also for this comparison high speed is required.

Techniques for handling are vacuum grippers, robotica and sheet feeders. These techniques can be seen in all kinds of disciplines, for instance in the paper business. This comparison focussed on speed (handling), applicability and costs. From this comparison it was shown that the vacuum grippers scored quite well. However, it did not distinguish itself from the rest convincingly.

**Comparison sorting**

For the sorting comparison various techniques have been analyzed. These are diverters, vacuum conveyors, *Activated Roller Belt*, the belt sorter, tray sorter, shoe sorter and push sorters.

The set-up of this comparison is the same as the cleaning comparison. How easy is the method for the user, how effective is it, how easy is it to manufacture, how easy is it for maintenance and eventually the costs.

In the comparison the vacuum conveyor scored the best. It can reach high speeds and it is easy to use and manufacture. Also the belt sorters and diverters scored really well in this comparison.
**Anthropometry**

Within the industry, tools are used in order to convey products and materials. This can be seen in the previous chapter as well. Using tools to transport items reduces the risk of overloading the body. However, transportation tools which are poorly designed will have a negative effect on the ergonomic side of the story. When the transportation tool is not designed according to ergonomic standards, people tend to lean forward or backwards. This would result in a negative effect of the transportation tool in which it was primarily intended; reducing the risk of overloading the body.

There are ergonomic guidelines available for conveyor belts and people working at these belts in different configurations. There is a difference between the ergonomically aspects of an employee sitting down or standing up during their work. When an employee is standing it is important that he has a steady floor to stand on. The platform he is working should be at least 700mm x 700mm. It is preferred to have no platform at all because of the risk of falling down.

The employee should also be able to stand as close to the conveyor as possible. It would be advisable to have some kind of cushioning where the employee would be able to lean against. When doing repetitive work, the best distance to do this in, is in a range of about 450mm in front of the torso. This can be seen in the illustrations below.

The weight of the product which has to be transported is crucial for the height of the conveyor belt. The heavier the product, the lower the conveyor belt will be. In the illustration below the height is shown for various types of lifting. Also the size of the product which has to be lifted is important.
In order to have the employee standing as close to the conveyor belt as possible, it is important that he can place his feet as close as possible to the conveyor belt. This prevents the employee from leaning forward which would result in back- and neck problems. For standing work the space an employee should have, should at least be 300mm in depth, 150mm in height and 600mm in width.

Work; sitting down

It would also be possible for the employee to sit down. This would change the dimensions that would be needed in order to make that happen. An employee which is sitting down would not get tired that quickly and is most suitable for small and medium products which do not need that much force. A common height for a chair would be 800mm and it must be adjustable at least 125mm each way. When an employee would sit down during work, this would result in more space for the legs underneath the conveyor belt. For sitting work the space an employee should have, should at least be 750mm in depth, 750mm in height and 600mm in width.
Implementation

The people that work on these separator sheets in the current situation as well in the future situation, are mainly women of around 30 years of age. Most of these women come from Eastern European countries. In order to gather information on dimensions, the Dined website was consulted. The sheets these women work with are considered light, below three kilo’s. If they are standing up, the height of the conveyor would be between the hip and elbow height.

In the data, the P50 of Dutch and Eastern European females aged 20-60 are shown. It shows the stature, chest depth, hip height and elbow height. The only data of Eastern European women available is the stature. Therefore a comparison is made between the Dutch females and the eastern European females in order to subtract missing data. This is needed to see what the height of the conveyor eventually should be.

The Eastern European females are 97.6% of the height of Dutch females. With this percentage the missing data of the Eastern European females was extracted and the values are shown in the data above. As stated above, the height of the conveyor belt should be the average between hip height and elbow height. Therefore the height of the conveyor should be 919 + 1009/2 = 964mm according to the anthropometry.
Input

VEGA / CSE input
Visit to printing house
Vega systems and Cargo Service Europe input

These two companies are both involved in the start-up of the company Curagon, industrial packaging solutions. However, they both have different input into this project. The inputs these companies have are elaborated in this chapter. This chapter is relevant because the input of these companies has effect on the final design.

Both companies had some aspects they thought would be important and these factors have to be implemented if possible.

Input Vega Systems BV

The input of Vega Systems is quite crucial in this project. Some engineering choices had to be made and Vega Systems has the experience and knowledge in order to make good decisions. Some examples are the choice of the correct type of actuator or wall thickness. These decisions were made by me, but having the experience of someone to check (and perhaps correct) is important.

The choice for the right (pneumatic) actuators is also the input from Vega Systems. Another example is ‘wall thicknesses’. Making sure wall thicknesses are as similar as possible throughout all the parts is a smart decision because this would lower the production costs. Also the fact that not every wall thickness is that common is something that can only be known through experience. Most common wall thickness is 2mm, 3mm and 6mm. Therefore it is thrived to use these dimensions.

The color scheme of the machine is also in the same colors as the machines Vega Systems makes. The reason for the choice of colors is that Vega Systems is an already renowned machine builder and this color scheme gives the association with the quality Vega Systems is known for.

Input Cargo Service Europe

The assignment is a task of Cargo Service Europe initially given to Vega Systems. Cargo Service Europe saw potential in an in-house improvement at Ball Packaging Europe. Also the decision to sort the separator sheets as an A-choice, B-choice and reject is input from Cargo Service Europe.

The company mentor, Martijn Vos, also worked for a number of years at Ball Packaging Europe and all the knowledge on the inside of Ball Packaging Europe comes from Cargo Service Europe. This connection between Cargo Service Europe and Ball Packaging Oss makes sure we are able to perform our first pilot at a manufacturing plant of Ball Packaging Europe. This also gave us the opportunity to present our ideas to the CEO of Ball Packaging Oss and other board members.

Cargo Service Europe also has the connections that probably will enable us to get subsidized for the innovations during this project.
Visit to printing house

On March 16, 2013 a visit to a printing house was conducted. It was already clear that this industry has many ways of working related to my assignment. The visit was to a small company in Alphen aan de Rijn called 'GSB Grafische Afwerking'. About 6 people work here. The owner and one employee were able to inform me on things I have to pay attention to during the design of the handling and sorting equipment.

In order to reach high speeds there are some tips and tricks which were useful for the design of the handling and sorting equipment. During manual input by the employee, it would be wise to have the sheets placed on top of each other with a small offset and let a vacuum roller worry about the input in the machine. This will create larger quantities instead of placing the separator sheets after each other.

It is also crucial that one side of the separator sheet is straight and preferably in the beginning of the process. This can be achieved by sliding the separator sheets against something and from there on further. By doing this, it is easier to check the sizes of the sheets and separate them.

Walking in this printing house was also inspiring in order to create ideas for concepts. Also small parts of machines might be useful. For instance the way a vacuum roller works was inspiring to see and how the machines deals with failed (paper) sheets.
Hands-on testing

Testing approach
Ironing test
Ergonomic test
Brushing test
Testing approach
Some small tests were executed in order to get better insight in the ergonomic situation and the behaviour of the material. The goal of these tests was to gain input for the program of demands and wishes. A more elaborated version of these tests can be found in Appendix G.

Ironing test
In order to have some insights in the material that must be handled and sorted, an ironing test was conducted. This was a small test in which the cardboard and plastic sheets are ironed. Once cold, once hot and once with steam. It was noticeable that it is beneficial to use heat and steam to flatten sheets but this also had a downside to it. The plastic sheets tend to get stuck on the iron and steam makes them ‘wavy’. This is also the case for the cardboard sheets. Steam is no option at all but even heat makes them ‘wavy’.

The reaction of the cardboard and plastic sheet on a cold iron was relatively the best. Not in displacement but with the least problems afterwards. With a cold iron no ‘wavy’ layers were created.

Cold - displacement
<table>
<thead>
<tr>
<th>Cardboard</th>
<th>Plastic (PP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20mm</td>
<td>10mm</td>
</tr>
<tr>
<td>30mm</td>
<td>15mm</td>
</tr>
<tr>
<td>40mm</td>
<td>17mm</td>
</tr>
</tbody>
</table>

Warm - displacement
<table>
<thead>
<tr>
<th>Cardboard</th>
<th>Plastic (PP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20mm</td>
<td>4mm</td>
</tr>
<tr>
<td>30mm</td>
<td>5mm</td>
</tr>
<tr>
<td>40mm</td>
<td>6mm</td>
</tr>
</tbody>
</table>

Steam - displacement
<table>
<thead>
<tr>
<th>Cardboard</th>
<th>Plastic (PP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20mm</td>
<td>5mm</td>
</tr>
<tr>
<td>30mm</td>
<td>7mm</td>
</tr>
<tr>
<td>40mm</td>
<td>9mm</td>
</tr>
</tbody>
</table>

Ergonomic test
Conclusions from this test were that the ideal working height is not achieved in the current situation and physical problems are encountered quite fast. Also the speed for the conventional way of sorting and handling the separator sheets was taken a look at. At the conventional way it took 7.48 seconds per sheet to scan and handle. When turning of the sheet is eliminated, the time was three times as fast. (2.58 seconds)

Brushing test
It became clear in chapter existing solutions that the round brush would be the best option to clean the sheets. However, there are a lot of brushes to choose from and therefore a test was done. After testing 16 different brushes it became clear the brush needed is a PA6 brush, electrically conductive with a diameter of 0.5mm. A combination of the two brushes below.

Besides the type of brush, also the angle was tested on how big it should be. This angle is important to clean the sheets but also to get most displacements and imperfections out of the sheets. Goal is to flatten the displacement as much as possible as can be seen in the ironing test. The conclusion was that the best angle to get a displacement out of the sheet is 15 degrees.
Synthesis

Design goal and vision
Program of demands and wishes
Estimations
Design goal

The design goal is to design a new procedure for the handling and sorting of separator sheets for eventually Ball Packaging Europe. The goal is to improve the quality of the re-used separator sheets and the speed of the process through standardisation of the scanning and sorting process. An employee will work in better ergonomic conditions and has more pleasure in the scanning and sorting procedure. Besides, he has the feeling he makes a difference in the process.

Design vision

The vision is to improve the working quality for employees. Besides being proud of their work, the procedure makes sure it goes faster. Also an improvement of consistency in quality is achieved. Using the scanning and sorting equipment makes the employee feel like a specialist in their field. They did not do this alone, they are a team.
Program of demands and wishes

Technology and development
- The equipment should not make too much noise. Employees should be able to work with it without ear protection. That is less than 90 DB for 8 hours.\textsuperscript{13}
- The equipment should be modular, meaning the way the separator sheets are sorted should be variable. Instead of three different sheets are sorted out, the possibility should be there to expand this to more than three, five for instance.
- The separator sheets should be ‘scanned’ on both sides.
- The separator sheets should be ‘cleaned’ on both sides.
- The equipment should be able to ‘scan’ all available sizes of the separator sheets as stated in the chapter separator sheet analysis.
- The equipment should distinguish logo’s and other things that are already on the separator sheets as such, not as stains.
- The equipment should be adjustable to different requirements. For instance; a tear in a sheet can be set to 1 cm or 2 cm, dependent on various wishes.
- The equipment should be able to distinguish stains and tears, regardless the position on the sheet.
- All values should be made adjustable (and parametrically) so that the customer can adjust his wishes.

Manufacturing\textsuperscript{14}
- The number of working hours to manufacture may not exceed 250 hours. This is including assembly (mechanical and technical) and testing hours.
- The equipment can be manufactured with two persons within 250 hours.

Distribution
- The equipment should fit inside a truck. (12000mm x 2550mm x 4000mm, L x W x H)\textsuperscript{15}
- The separator sheets should be able to be stacked at a height of 750mm, excluding the height of the pallet. (166mm)
- Various dimensions of pallets can be stacked with separator sheets. (CHEP/ EURO)\textsuperscript{16}
Maintenance
- Any part of the assembly can be replaced within two working hours. This is excluding testing time and fine-tuning.
- Maintenance should be able to access any part within 15 minutes.
- Parts which are likely to break easily (or earlier) should be reached by car within two hours.

End of life
- At least 90 per cent of the equipment (in volume) should be recycled/re-used.

Wishes
- Preferably the equipment should fit inside a standard sized container for shipment. (5910mm x 2345mm x 2385mm)

Ergonomics
- The equipment should be designed following the anthropometric analysis.
- The equipment should enable the employee to do his work faster with less effort. (From one pallet to approximately 3 pallets)
- The equipment should be able to enable the employee to change his posture or do other work during his shift.
- The employee should be able to stand close to the equipment in order to spare his back. (within 150mm)
- The employee should have enough room for his feet. (according to anthropometry)
- The equipment should be adjustable in height.
### Estimations

**Separator sheets**

Ball Packaging Europe in Oss use up to 7.5 million separator sheets per year. Assume that all these sheets have to be checked once a year, with 8 employees, during 40 weeks, 5 days a week, for 8 hours a day. One employee has to check around 586 sheets per hour in the current situation.

The aim for Curagon is to have this work done with only 3 employees instead of 8 in order to save costs. This means that one employee has to process about 1563 sheets per hour instead of 586 separator sheets with the handling and sorting equipment. This means the equipment has to clean, scan and sort about 1563 per hour, the equivalent of three pallets.

In the program of demands and wishes it is stated that the equipment should be able to run for 16 hours a day. The main reason is the fact that Ball Packaging Europe has peaks of 10 million sheets per year.

<table>
<thead>
<tr>
<th>For 8 hours per day during 52 weeks</th>
<th>For 8 hours per day during 40 weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of sheets annually</td>
<td>7.500.000</td>
</tr>
<tr>
<td>Number of sheets per week</td>
<td>144.231</td>
</tr>
<tr>
<td>Number of sheets per day</td>
<td>28.846</td>
</tr>
<tr>
<td>Number of sheets per hour</td>
<td>3.606</td>
</tr>
</tbody>
</table>

Number of sheets an employee at Ball has to check per hour

<table>
<thead>
<tr>
<th>Number of employees</th>
<th>Number of sheets</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>451</td>
</tr>
</tbody>
</table>

Number of sheets an employee at Curagon must be able to check per hour

<table>
<thead>
<tr>
<th>Number of employees</th>
<th>Number of sheets</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>1.202</td>
</tr>
</tbody>
</table>

In the program of demands and wishes it is stated that the equipment should be able to run for 16 hours a day. The main reason is the fact that Ball Packaging Europe has peaks of 10 million sheets per year.
Savings and costs
In order to estimate how much the equipment may cost, an estimation of the annual costs for Ball Packaging Europe is made (Figure 25). This estimation will give us an insight in how much Ball Packaging Europe might save when leasing the equipment from Curagon. This estimation is made in consultation with Vega Systems. 17

Below is a calculation of how much the handling and sorting equipment will cost. These calculations can be seen in chapter Cost calculations on page 84.

Estimate savings for Ball Packaging Europe on employee costs:

<table>
<thead>
<tr>
<th>Current situation Ball Packaging Europe</th>
<th>Future situation Curagon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual costs employee € 25.000,00</td>
<td>Annual costs employee € 25.000</td>
</tr>
<tr>
<td>Number of employees 8</td>
<td>Number of employees 3</td>
</tr>
<tr>
<td>Total € 200.000,00</td>
<td>Total € 75.000</td>
</tr>
</tbody>
</table>

Annual savings for Ball € 125.000,00
Monthly savings for Ball € 10.416,67

Figure 25

Using the equipment will save Ball Packaging Europe 10.000 euro per month on labour costs.
Design

First drawings
Morphological chart
Configuration chart
Horizontal vs. vertical
Harris profile Horizontal vs. Vertical
From orientation to concepts
CSM (Curagon Sorting Module)
Concept description
Harris profile CSM
The first ideas which are shown here are a result of combined factors. Together with the analyses, input and tests the first ideas are drawn. These drawings started with small sketches and extended to more elaborated sketches. During this project a lot sketches were done, mostly on small pieces of paper or napkins. Eventually these small sketches turned into concepts. In the next pages mostly 3D CAD drawings are shown because it will get the message across better than my pen and paper drawings. A collection of drawings made can be found in Appendix P.
Morphological chart

With all prior information the goal is to create a morphological chart. This morphological chart enables to create concepts by connecting the sub problems.

The sections which are used now are;

- Centration
- Flattening
- Cleaning
- Control ‘Borders’
- Control ‘Stains’
- Sortation

These sections were also used during the brainstorm (Appendix F). The information from the brainstorm, together with earlier ideas, drawings and sketches, forms the morphological chart. The morphological chart is in Appendix I.

With this morphological chart a configuration map is made which allows us to combine solutions for sub-problems. These solutions combined will give us the orientation and configuration of the eventual handling and sorting equipment.

The goal of the morphological chart is to make a decision on which orientation of the handling and sorting equipment would be best. It is easier to design and make concepts, if it is clear which orientation is used. For that reason the morphological chart is made. From this morphological chart, a configuration graph is created which is presented on the next page.
**Configuration graph**

With the morphological chart a configuration graph is made. This graph shows the solutions for sub problems into one column. In this morphological chart are only two concepts, and each has a different orientation. Before any other decisions could be made it would be very important which orientation the handling and sorting equipment is going to have. Therefore these two orientations are elaborated into two concepts and shown in the next pages. Later a Harris Profile will show which one of these two orientations is the best orientation to use for the handling and sorting equipment.

The reason why these components are chosen from the morphological chart into the configuration graph is a result from the analysis existing solutions on page 32 and Appendix E.
Orientation 'Vertical'

This concept has a length of about 9.5 meters, a width of about 2.5 meters and is approximately between 800mm and 950 mm meter high at the beginning. This is only in the beginning because the ideal working height is in between these dimensions. The height of the handling and sorting equipment will be higher because the widest sheet is already 1220mm. In order to get the pallet to the right height, a pallet lift will be used.

This first concept is based on a combination of solutions from the morphological chart. The idea to transport the separator sheets vertical is because it would make sure one side of the separator sheet is always straight. This is decided after a visit to the printing house. They claim that you always need one straight edge in order to align the sheets.

From there on, it would be easier to see what the dimensions are of a sheet. Also in vertical orientation there would be less vacuum force needed in the vacuum conveyors. The vacuum would not be as high as when this configuration would be in a horizontal position, as in concept 2 ‘Continuous’.

The idea of this concept is that it is a modular system with separate components. Therefore it would be easy to adjust the configuration of the equipment. When for instance one component breaks down, it would be relatively easy to replace the broken component with a new one. This way the process will never have to stop for a long period of time and repairs are easy.

The separator sheets are cleaned both ways with high pressurized air. This air will blow in an angle top-down to the bottom of the cleaning unit. Here a vacuum cleaning system will suck off all the dust which is blown off by the pressurized air. All sheets are blown off/ cleaned before going further into the process.

Another feature of this concept is that the separator sheets which are rejected by the line laser, because of too high bends, are transported to the ‘flattening’ unit. Therefore the speed of the process will be maintained whilst rejected separator sheets will be flattened in the flattening section. Two sheets can be placed next to each other in the flattening unit. Once flattened, these sheets will go back into the system, via the scanning compartments to the sortation part. In these concept drawings only one flattening compartment is shown but there might be more added if needed. At the sortation part the sheet will be interrupted whilst travelling along the vacuum conveyor line. A metal part will move mechanically in front of the separator sheet and makes sure it falls onto the right pallet. In these concept drawings these lids are not shown, but the separator sheets will fall through a lid (or bin) onto the pallet. This makes sure the separator sheets are lined up onto the pallet.
Concept 1 'Vertical'

Flattening

Cleaning

Sortation

Scanning

Feeding

Cleaning
Concept II

This concept also uses a pallet lift in order to get the separator sheets to an ergonomic height. The position of the feeder station can be altered in height in order to adjust the working height.

In this concept the separator sheets will hit a steel plate right after feeding the sheets. This makes sure one side of the separator sheets is straight. This is necessary for measuring the size of the separator sheet.

This concept is also modular and the number of (sortation) stations can be endless. Sheets which are rejected will be flattened during the process instead of going into a separate unit as can be seen in concept I.

The employee will get immediate feedback on the quality of the sheets by a LED information system. This tells by showing various colors what the state of a sheet is and when a pallet is filled with 500 separator sheets. The employee knows he has to change the filled pallet with an empty pallet through LED feedback.

The separator sheets are scanned by a line laser and are immediately flattened in the process. Only the rejected sheets are flattened by the flattening module. When these sheets are still not in order, the camera system will register this and reject useless sheets.

All sheets are brushed with a round brush on both sides. These brushes will turn in opposite direction in relation to the conveyor. This way the most dirt will get off according to a salesman of Minck Bursten. Close to the brushes a vacuum cleaner will be placed in order to suck off most dirt.

At the sortation module the vacuum of the conveyer will be shut down and a steel plate will interrupt the separator sheet of continuing his journey. The sheet will fall into a bin and stacked on a pallet.
**Harris profile Horizontal vs. Vertical**

In order to make a choice between a horizontal or vertical configuration, a Harris Profile was set up. This Harris Profile will determine which direction we are going with the design of the handling and sorting equipment. The sequence of criteria in the Harris Profile is done on purpose. The top criterion is considered the most important and the bottom criterion is considered the least important (financial advantage). The criteria are briefly elaborated below:

<table>
<thead>
<tr>
<th>Ergonomic advantage</th>
<th>Horizontal</th>
<th>Vertical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ability to improve damaged sheets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance ergonomically</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Financial advantage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall credibility</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Ergonomic advantage**
In this criterion the ergonomically advantages for the end-user are considered. Which of the two configurations will be a benefit for the end-user?

**Speed**
At least 7.5 million sheets have to be processed every year and therefore speed is very important. Are we able to reach these speeds with this configuration or is the other configuration better?

**Ability to improve damaged sheets**
The sheets which are damaged or bend have to be fixed or at least the separator sheets have to be altered so they are good enough for the palletizer. Which of these configurations is most likely to fulfill this task?

**Maintenance**
Sometimes some parts might break down and have to be repaired. Which configuration will allow us the best access to components in case of damaged or broken parts?

**Financial advantage**
Costs is always an important factor. Which of the two configurations is likely to cost the most money, labour, testing etc?

**Overall credibility**
Looking at other processes, machines and all criteria above, which of these configurations is most likely to succeed for the task of cleaning, flattening, scanning and sorting separator sheets?

**Conclusion**
From this Harris Profile it is quite clear that the best orientation to go is a horizontal one. The vertical orientation is not that good because there is a doubt whether the speed can be reached which is needed. Furthermore, when a damaged sheet is placed vertical it is more difficult to adjust any damages in relation to horizontal. Also the maintenance for a horizontal orientation will be more easy and efficient because it is almost on ‘working height’.
**From orientation to concepts**

Now we know that horizontal is the orientation we are going to use, we will take a closer look at the orientation as it is presented above. When we take a closer look at the horizontal orientation we see that the handling and sorting equipment will consist out of different components.

It was already stated in before that modularity is quite important. When we look at the horizontal orientation with this modularity in mind; we see that this equipment consist of various modules. These modules are;

- A sorting module CSM
- An upper transportation module BTM
- A bottom transportation module OTM
- A scanning module Outsourced
- A brushing/cleaning module CBM
- A flattening module CFM

With the modularity in mind, the decision was made to start designing the sorting module (CSM) first. The reason for this decision, is because other modules are are likely to be relatively similar.

The bottom transportation module is the same without the pushers (OTM) and the idea was to design an upper transportation module with almost similar parts (BTM). The scanning, brushing and flattening module will be different and partly outsourced. The scanning module is outsourced and the brushing and flattening module will be presented later.
**Concept description**

Before designing the final Curagon Sortation Module, a number of things were already decided. These decisions are, among other chapters, listed in the program of demands and wishes.

Main aspects that are already decided on are (Figure 26);
- The orientation is horizontal
- We are going to use vacuum conveying for the handling and sorting equipment
- The size of where the sheet is hanging is not larger than the largest sheet because of loss of vacuum (1420mm x 1220mm)
- The height of the module is 500 sheets excluding the height of the pallet (approximately 800mm)
- Pneumatic actuators are used

From there on the most important thing was how separator sheets are pushed out. After idea generation (Appendix P), the four most promising ideas were transferred into concepts. These four are;

- Scrape the separator sheets off
- Blow the sheets off
- Push the separator sheets off the vacuum conveyor
- Turn off the vacuum

or perhaps a combination of these concepts.

---

*Figure 26: Decided aspects*
Scraper

The first concept is the scraper. The separator sheet travels from left to right (figure 27) and when the sheet is coming, the scraper is pneumatically pushed out. The separator sheet gets released from the vacuum conveyor and because about 60 per cent of the separator sheet is scraped off, the sheet falls onto the ground. The scraper consist of elf similar parts, all connected by two rods. The left part of the subassembly is connected to the frame with two bearings which pivots the subassembly. The right side of the scrapers is pushed downwards by two pneumatic actuators. This subassembly is pushed through the lid were the vacuum is created. In this lid there is enough room for the scraper to be pushed out.

Advantages
- Very precisely controllable

Disadvantages
- Parts can be expensive
- Seems too fragile to assemble
- Not sure if it is enough to get the separator sheet from the vacuum conveyor

Pusher

Another way is to vertically push the separator sheets downwards. Whenever a separator sheet travels underneath a module, it is pushed out by a pusher. This pusher is connected with 4 pneumatic actuators which simultaneously push the sheet from the vacuum conveyor onto the pallet. The pusher consists of 4 identical POM parts all connected with each other with bended steel plating. This subassembly is connected to the pneumatic actuators and switched on when necessary. When switched on, it pushes downwards and immediately goes back up. The POM pusher are able to push out 70mm. This will be enough to push the separator sheets from the vacuum conveyor.

Advantages
- Easy to manufacture
- Very precisely controllable
- Easy maintenance

Disadvantages
- Parts can be expensive
**Air valve**

The air valve is used to switch off the air flow from the ventilator. This air valve is pneumatically controllable. The air flow can be controlled by placing the valve in different positions. By closing the valve, the vacuum which is created inside the vacuum lid will disappear and consequently the separator sheet will come off the vacuum conveyor.

**Advantages**
- Easy to manufacture
- Cheap
- Air flow can be controlled quite precise

**Disadvantages**
- It might take too long before the vacuum is entirely gone and the separator sheet falls off.

**Blow pipe**

The blow pipes are switched on when a separator sheet has to be rejected at a certain location. The blow pipes are made of copper and small holes are drilled in the pipe. Pressurized air is pushed through the pipes. The air is pushed inside the pipes on both sides of the tube so that there is no significant loss on either side of the tube.

The drilled holes are 40mm apart from each other and the air coming out will be at a pressure of approximately 6 Bar.

**Advantages**
- Very easy to manufacture
- Relatively cheap
- Air flow can be controlled
- Will not break so easily. Therefore, easy maintenance

**Disadvantages**
- Holes might get filled with dust and dirt
- The speed is questionable in relation to concept *Scraper* and *Pusher*
The four concepts were compared with each other by using a Harris Profile. The Scraper, Pusher, Air valve and ‘Blow off’ are compared with 5 criteria which are briefly explained underneath.

Modularity
It is important for every part and components that it is modular. Parts have to be as modular as possible for various reasons. The higher the modularity, the easier the maintenance is and the lower the number of different parts are.

Speed
The equipment should be designed in order to withstand high speeds in order to reject as many separator sheets as possible. From previous calculations it was clear it has to handle at least 1500 sheets per hour.

Maintenance
Whenever some part is broken it should be easy to fix or replace. This is also a demand in the program of demands and wishes; it should be replaceable within two working hours and accessible within 15 minutes.

Financial
The components should not be too expensive or difficult to produce. The easier the concept is, the easier it will be to produce and this will keep the costs low.

Overall credibility
The overall credibility is the one which is believed to be the better one.

From the Harris Profile it becomes clear that the pusher concept is the best concept. This does not mean other concepts are not good enough. Probably the fans which are used should be shut off when a separator sheet has to be pushed out because the vacuum is not immediately gone when the fan is switched off. Therefore not only the pusher is applicable to the design, but also the air valve will be used in the design of the Curagon Sortation Module.
**Curagon Sorting Module**

As stated before the Curagon Sortation Module (Or CSM for short) is considered to be the main module of the entire handling and sorting equipment. This module is the base for other modules. From the CSM other modules can be extracted. When you do not place the pusher on the CSM, you would only have a vacuum conveyor belt. This is also known as the OTM, abbreviation of ‘Onder Transport Module’.

When the vacuum lid is flipped around and the legs are a bit shorter you would have a ‘BTM’. This is an abbreviation for ‘Boven Transport Module’. These modules will be elaborated later.

All parts in these modules are custom made except for actuators and associated parts and components.

The CSM has a length of 1790mm, width of 1520 and a height of 1610mm.

**Vacuum lid**

The vacuum lid is a lid with slots of 3mm wide and 33mm long. These slots are positioned in such a matter, when the conveyor belt moves over the slots, there will always be at least one hole which sucks air (Figure 32).

The vacuum lid is closed with two bended steel plates. The reason why this are two edged plates instead of one big one is because this is more easy to assemble. One big bended steel plate would be too large for an employee to handle.

Also within the vacuum lid, spacers are welded in which makes it easier for assembly.

The vacuum lid has a RAL 6009 green colour. This colour is needed because the scanner that is used needs a large contrast between the background and the item that has to be scanned. In our case these items are separator sheets and these are (light-) grey or blue. For this reason also the conveyor belt has this green colour.
Legs
The legs are made of standard size 60mm x 60mm tubes. The height of the legs is 1000mm, with adjustable inserts in the bottom of the legs. These insert (Figure 33) are standard components which are bought at PeHaVo, a local hardware store. These inserts make it possible to adjust the height.

Side plates
The two plates which are placed on the sides of the vacuum lid are exactly the same except for the fact they are mirrored. On the side of the plates a tube with an inner diameter is welded from 50mm. These tubes are for the connection to the ventilators which will create the vacuum. On one side the ‘Aandrijftrommel’ is placed and on the other side the ‘Keerrol’ is installed. Both of these rolls are adjustable with an extra piece of laser-cut steel which can be seen in the pictures below. These components gives the ability to adjust the rolls and therefore the tightness of the conveyor belt.

Curagon plating
The back plate which says ‘Curagon’ also has a function. Separator sheets which are pushed out will bump against this back plate and fall down. Not only has the word ‘Curagon’ and the laser-cut slots aesthetic value, it also has a function. The function is to release air coming from underneath the falling separator sheet. The two blue top lids are for aesthetic use but also for protection. Underneath these lids pneumatic pushers are installed.

Conveyor belt
The conveyor belt is made of two layers, one is for strength and the other one is stretch. The total thickness is 2 mm thick and it has a green colour. The colour is Pantone P362U (RAL6009). The reason why it has this colour is the same reason for the vacuum lid. It has to be green because of the contrast with the separator sheets. In the conveyor belt holes are punctured of 5mm, this is slightly bigger than the slots which were 3mm. This is done on purpose because you will have more suction power.

POM pushers
In total 4 POM pushers are connected with bended steel plating. These POM parts are 5mm in thickness and slide through the holes in the vacuum lid. A picture of this subassembly can be seen in the next page, on the left side bottom.
Actuators
SEW motor
For each module the choice was to use a WA-30/TDRS71s4 SEW motor. This motor can reach desired speeds and its torque is high enough for this purpose. This company is specialised in motors and have dealers all over the world.

MetalWork
In each Curagon Sortation Module, four MetalWork pneumatic components are placed. The choice for this actuator is input from Vega Systems, it has the right stroke and strenght to push the separator sheets from the conveyor. Also MetalWork has dealers and components all over the world.

Elektror Vacuum ventilators
Per 2.5 module one SD-7 is needed to create enough vacuum. This SD-7 vacuum ventilator is a component from Elektror, which also has its companies all over the world. This vacuum conveyor is advised by Elektror. 17

The choice for these companies is not a coincidence. All these companies are globally represented. Whenever a component breaks down, a new one or spare part, will be quickly on site all over the world.
**Transition from CSM to OTM-BTM**

The main reason why the sorting module is build first is because the other modules would be quite similar. Only a few adjustments have to be made in order to create an OTM. In general, the OTM is the same as the CSM. The main difference is that the OTM does not have any pushers to push the separator sheet from the vacuum conveyor.

The assembly of the OTM is exactly the same as the assembly of the CSM to a certain extend. On page 79 the assembly of the CSM is shown and after ‘step 8’ (out of 12) the OTM is assembled. The assembly of both components are the same, but a few parts are different. These parts can be found in the vacuum lid. In the CSM, the vacuum lid has holes for the pushers. This is not needed in the OTM and therefore another lid, without holes, is made. This is shown in appendix ‘Technical Drawings’, drawings OTM-0001/OTM-0002 and OTM-0003. These components have to be replaced with CSM-0004/CSM-0011 and CSM-0020 respectively. The OTM has a length of 1790mm, height of 1300mm and a width of 1520mm.

**Transition from CSM to BTM**

The transition from CSM to BTM is quite a similar story as the transition from CSM to OTM. Only other parts have to be altered. In order to assemble the BTM, components of different modules are needed. The reason behind this is that with similar components, multiple modules can be build.

The main difference between the BTM and CSM/OTM is that the vacuum is created on top instead of underneath the conveyor. For the BTM you need the same vacuum lid as the OTM (OTM-0001/OTM-0002/OTM-0003), shorter legs (BTM-0003), other side plates (BTM-0001/BTM-0002). The other parts are all the same as the CSM. These are the rolls (‘aandrijftrommel’ and ‘keerrol’), conveyor belts, motor, leg positioners and insert for the legs. All parts can be found in appendix ‘Technical Drawings’, with exception of the bought components (SEW, MetalWork, Elektror). The BTM has a length of 1790mm, height of 1050mm and a width of 1520mm.
CBM and CFM
Initially the Curagon Brushing Module (CBM) and the Curagon Flattening Module (CFM) were two different components. Through tests conducted it became clear that it would be possible to clean and flatten the separator sheet at the same time. The first idea was to roll the separator sheets flat but this would encounter problems. Upstanding displacements would not be bended in the correct direction and a B-choice sheet would become a rejected one.
In the brush test is became clear that it would be possible to use the brushes to clean and straighten the displacements in the sheets. This would also be beneficial for the speed of the process, doing two tasks in one module.

Conveyor belts
The conveyor belt chosen is a brush-belt with brushes made of PA6, electrically conductive with a diameter of 0.5mm. There are 22 belts inside one CBM, 11 on the top side and 11 on the bottom side. The choice was made to use conveyor belts of 100mm wide instead of one big. In this case there would be room to blow off dirt with pressurized air in between these belts. The direction of the vacuum conveyors is the same direction as the brush-belt. It would be better if this was in opposite direction according to a representative of Minck Bursten. But because the handling and sorting equipment should reach a high enough speed, and sheets are not that dirty, the direction of brush-belt in the same direction as the vacuum conveyors should be sufficient enough. The belts are adjustable in height and this can be altered to the customers’ wishes.

Blow pipes
As a supportive feature, besides the brush-belt, also blowpipes are installed. These make sure the dirt stays within the CBM. These blowpipes act as a shield and prevent the dirt from going out. The blowpipes continuously blow air unless the equipment is shut down.

Suction
The dirt is sucked away. A steel bended vacuum cleaner head is placed close to the belt-brushes. Together with the blowpipes and the suction in the vacuum cleaner head, dirt gets sucked away. The dirt is collected inside a filter within the CBM and the suction is created with the same ventilator as the vacuum conveyors, the SD-7.

Actuators
In the CBM the same motor is placed as in the other conveyor belts, the WA-30/TDRS71s4. The SD-7 makes sure, dirt is sucked off.

Anti-static brushes
In the CBM, electrically conductive brush-belts are placed. Beside the fact that these are electrically conductive an extra pair of anti-static brushes is placed. The reason for this extra anti-static pair is because brushing the plastic sheets in combination with plastic brushes, might create high static electricity. An extra pair of anti-static brushes is just an extra insurance.

Air filter
On the side of the CBM an air filter is placed. Air is sucked by the SD-7 through an air filter where dust and dirt is collected. When opening the side door of the CBM, the air filter is easy accessible.
Final design

Renders
Building 1:1 testing model
(Ergonomic) improvements
External parties
  Eagle vision
The first step for an employee is to insert, which type and size of separator sheet he is going to sort.

The employee places the separator sheet on the first BTM, from there on it travels through the CBM/CFM and it is picked up by an OTM. The sheet is scanned on the bottom side before it is picked up by a BTM again. Now it can be scanned on the topside.

After scanning, it travels towards the CSMs and is ejected by one of the three CSMs. It is an A-choice, B-choice or reject. Once pushed out it falls on top of a pallet. The scanning system will show on the screen when there are 500 sheets on the pallet and the employee has to remove the filled pallet and replace it with an empty one. The equipment will stop when one CSM reaches 500 sheets.

The system is 12500mm long, 1950mm wide and 2300mm high.

Note: the assembly which contains the Eagle Vision camera’s is designed but not in this report because it has to be altered to new dimensions which are not defined yet. Its main function is to protect the scanner and it has aesthetic value.
Building 1:1 testing model

For the first version of the handling and sorting equipment, the scanning system is considered the most important part. The scanning system has the highest priority and therefore a part of the scanning and sorting equipment is built. With five vacuum conveyors, it is possible to test numerous things and attach a scanning system. 

The scanning system is outsourced to Eagle Vision. This scanning system will be more elaborated on page 77 and appendix J.

For this first test set-up a number of things has to figured out and perhaps adjust them. With this test we want to see if;
- The vacuum conveyors work correctly and subsequently fine tune them.
- If all components line-up and if any adjustments have to be made in the technical drawings.
- Conclude if the vacuum will be strong enough to keep the separator sheets in place.
- Testing and fine tuning actuators

When the scanning system is placed we will see if the system is able to scan our separator sheets and judge them parametrically by our standards. This will require a lot of fine tuning but soon enough it will be clear if this system will work for our purpose. At this point (half August 2013) the scanner is not installed yet. Therefore this is not in the report yet.
At this point some tests are done. The conveyors work and the separator sheets are transported on the BTM. Also a ventilator are connected to an OTM, but one ventilator was not enough to hold a separator sheet. After installing two SD-7 ventilators the sheets stayed in place. One ventilator should be enough to create a vacuum for 2.5 vacuum lid. This is not the case yet. Later a smaller hose was installed and a significant change in vacuum was noticeable but still not enough. More testing should be conducted in order to create a vacuum which is good enough. The pneumatic actuators were tested and work but still need fine tuning. The testing is a process which is still going.
Ergonomic improvements

In order to see if the design of the equipment is suitable for earlier mentioned ergonomically demands and wishes, it was tested with the 1:1 testing model.

How does this handling and sorting equipment help the employee?

Working height

The working height for the employee is improved. The employee is now able to adjust the height of the pallet as well as the conveyor. This makes sure the employee is able to adjust the working height to his wishes.
Not so heavy
The employee does not have to flip the separator sheets anymore. Initially, the employee had to flip the separator sheet in order to scan both sides with the naked eye. With the handling and sorting equipment the employee does not have to do flip the sheets anymore which will make it less heavy.

Room for feet
The employees initially did not have much room to place their feet and therefore their stature was not anthropometrically sufficient. Employees would tend to bend a bit. With the handling and sorting equipment they have more room and are able to stand directly next to the conveyor without bending over.

Faster
The work is done faster. Employees will be able to process the sheets three times faster. Because it is faster, it will have less effect on the back and hands of the employees.

More accurate
The separator sheets are scanned better and more accurate with the handling and sorting equipment in relation to the naked eye. Working with the handling and sorting equipment would make sure the separator sheets are consistent of quality at a higher pace.

Ability to work from left to right and vice versa
The employee is able to stand on both sides of the handling and sorting equipment. Initially, the employee was only able to work from left-to-right. With the handling and sorting equipment the employee is able to stand on both sides of the conveyor.
Eagle Vision
As an external party in this project we contacted Eagle Vision. This company has almost 20 years of experience in the scanning industry. The meeting with this company was at a packaging fair in the Brabanthallen Den Bosch. Their core business is providing scanning systems for the food- and beverage industry. Their scanning system (Basic Scout) is the system agreed on to be the best scanning system for our problem.

This system can be placed on an existing line or conveyor belt without any adjustments. It is also equipped with a touch screen interface which allows the employee to select which type of separator sheet he is going to sort.

In the brochure on this page the main features are listed of the basic scout. More elaborated specifications and features can be seen in Appendix J.

The basic scout system has the ability to;
- Scan the sheets on both sides
- Distinguish logo’s
- Set parametrically
- Faster than the naked eye
- Reach speeds higher than 1500 sheets per hour

These aspects were demands in the program of demands and wishes on page 46.
**Module set-up:**
- Basic: combined multiple inspections in one system
- Modular: inspection on existing or new lines
- Connect: 3-4 specialties (camera, illumination)

**Compact:**
- Mini control cabinet, monoblock into
- Flexible installation in existing and new lines
- Optional parameters

**Standard configuration:**
- Same look required by all inspectors in history
- Jointly system or integrated to network
- High/low frame processing

**Easy maintenance:**
- Remote maintenance with modern network
- Self-activation incoming
- No losing paint, no product handling

**Reliable inspection:**
- Proven technology designed with majors of industry
- Years 0.000% products per hour
- Customer specifications possible

**Guarantee:**
- Modular system pricing
- Low cost of ownership
- Long-term
Materialization

Parts and assembly
Maintenance
Flowchart
Pneumatics
Parts and assembly

Parts
All steel parts are ordered at a Heurkens en Van Veluw. In the appendix ‘Technical Drawings’ all ordered parts for the test set-up are shown. The drawings in this appendix are not conform the industrial design standards but adjusted conform the standards in this business. In the appendix also the overview is shown with all wall thicknesses. Some parts are 2mm, other parts are thicker. The reason why some parts are thicker than others is because of the forces some parts encounter. For instance the ‘Stootplaat’ is only 2mm thick. This part encounters the force of a cardboard sheet and does not have to be so thick.

The thicker components are the parts that need to handle bigger forces. For instance, the ‘lagerplaat motor’ has more forces to encounter and therefore it is thicker.

Assembly
In this chapter the assembly of the Curagon Sorting Module is shown. There are 12 steps which are needed to complete one CSM. As stated before in this report, the OTM has similar steps as the CSM. In order to make an OTM, only eight out of twelve steps need to be made.
Step 5

Bolting parts together.
M8 x 15
Washer M8
M8 locknuts
Quantity: 8x

Step 6

Place components inside CSM-0003 before bolting to the rest
Bolting parts together.
M8 x 80
Washer M8
M8 locknuts
Quantity: 8x
Make sure they are lined up before fastening

Step 7

Place CSM-0023-1 eleven times
Connection with belt joint

Step 8

Bolt INA bearing with 2 x M8 x 40
Bolt ‘Reactiearm’ to WA-30 before fastening with M8 x 40
Insert gusset 50mm into ‘Aandrijftrommel’

Step 9

Bolting parts together.
CSM-0022/CSM-0012/ 24x M8x20
Washer: M8
M8 Locknuts

Step 10

Place subassembly as shown on the left

Step 11

Bolting parts together.
- CSM-0013 to CSM-1001/CSM-1002 8x M8x20  
- CSM-0013 to CSM-1007; 8x M8x20
- Bolt pneumatics to CSM-0013 with 16x M5x20 and springwashers, use loctide
- Bolt pneumatics to CSM-0012 8x M8x20
- Use M8 washers and M8 locknuts for all above steps

Step 12

Place CSM-0015 into place
Place CSM-1005 into place and secure with 2 bolts on top left and top right.
Finally; adjust and fine tune the conveyor belts with bolts on each corner.
Maintenance

For this project some choices were made in relation to the maintenance of the equipment. It is important that it is a modular device and also broken components should be replaced easily. Also spare parts should be accessible all over the world in case fast repairs have to be made.

Steel plating
The steel plating is designed, so that one person can lift a component, regardless which components it is. This can also be seen in the assembly of the vacuum lid. The bottom part is quite heavy, but can be moved by one person. Nevertheless, the two lids which has to be bolted to the vacuum lid could be made from one piece but this would be difficult to assemble. Besides it would be hard to apply any maintenance to these parts. All other parts can be easily lifted and replaced.

Actuators
The choice of actuators is not a coincidence. The choice of motors was on the brand of SEW. This brand has dealers all over the world and it would be relatively easy to access spare parts where ever you are in the world. This is also the case the ventilators of Elektror and the pneumatic components of MetalWork. Also MetalWork has dealers all over the world which are able to supply any broken or damaged components.

Control
The control of the handling and sorting equipment is done by Siemens. Siemens has a 60 per cent market share all over the world in PLC controlling. Therefore the choice for Siemens was made. Not only spare parts and components are easily accessible all over the world for the Siemens controlling unit. Also employees and courses are available all over the globe. When the handling and sorting equipment would not work because of the Siemens control, PLC maintenance and programmers are never far away.
**Flowchart**

In order to see how the handling and sorting will work, a flowchart is made. This is a chart which will show which handling of the machine will come next. This flowchart is also made for the PLC programmer. The programmer needs this flowchart in order to convert it into a block-diagram. This block-diagram is the base for every PLC-program. With this PLC-program the handling and sorting modules (Basic Scout, BTM, OTM, CSM) will communicate with each other. Within this PLC programming the Eagle Vision system will be placed in order to tell which CSM for instance has to push out at what time.

A larger flowchart one can be found in appendix K.
Pneumatics

For the Curagon Sortation Module (CSM), a pneumatic diagram is needed. This pneumatic diagram can be seen in Appendix L. The four actuators need to be controlled and fine-tuned in order to work perfectly. In this diagram the following components are shown:

The W1430162100
- There are the four actuators per Curagon Sorting module. W143 stands for the type, 016 for the middle rod, 2 stands for bush bearings and 100 stands for the stroke of the actuator. The stroke which is needed for the POM pusher is only 70mm but we are able to control the stroke and therefore the choice was to use a bigger stroke. The components we need in order to control the stroke are called read contacts and can be placed on the pneumatic actuators.

- The MRFO V1/8” x D6
  This component makes sure the air flow is controlled and fine-tuned. This part controls the air coming out of the pneumatic actuator.

- The 5-2 1/8 EL.M
  This is called a 5/2 way valve. This means it is able to switch between two gates. This is electrically manipulated (EL.M) with a PLC. These components are connected to the Siemens PLC program which will communicate with the scanning system of Eagle Vision and the speed of the motors, when the pneumatic actuators have to be pushed out and when subtracted.

- Air inlet
  The symbols on the bottom left corner are the symbols for a standard air inlet. This is an air filter, together with an air regulator which is set-up on 6 Bar at this point.
Cost calculations

A cost calculation is made for the handling and sorting equipment. This cost calculation entails machine costs, the number of hours on development, manufacturing and testing. This cost calculation is not the costs at this point (August 2013) but it will be the total development and manufacturing costs. Therefore the costs are an estimation of what the entire handling and sorting equipment will cost. These costs are for the first prototype, following machines will become cheaper. Reason for this is that development costs are also in the calculations.

A more elaborated calculation on machine costs can be found in Appendix M.

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| Material costs         | Machine |       | € 78.518 |
|                       | Development (2 PC’s, CAD pakket, office supplies) |       | € 11.000 |

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For the CSM, BTM and OTM an Failure Mode and Effects Analysis is made. The Failure Mode and Effect Analysis is an analysis which enables to find faults, or potential breakage, during design. By finding these potential faults in an early phase gives the opportunity to prevent the fault from occurring.

Every part of the design is described and its potential failure. The severity, probability of occurrence and detectability are ranked. By multiplying these three factors a score comes out.

In the analysis made the CSM, OTM and BTM are taken a look closer look at.

From the analysis the largest potential failure was the connection of the pneumatic actuators to the frame inside the CSM. This potential failure was by far the biggest one. The connection of the actuators to the frame is most likely to fail due to a lot of motion. The bolts which connect the actuator to the frame might shake loose. Therefore the choice for another bolt was used in combination with loctide. This adjustment would be enough in order to prevent the fault from happening.

The entire worksheet can be found in Appendix N.
With the handling and sorting equipment the employee is able to work on a more ergonomic matter than the conventional way. The employee is able to adjust the working height of the pallet and the height of the first vacuum conveyor (BTM) where sheets are placed on. Also the sheets do not have to be turned around anymore which gives ergonomic advantages. That the employee does not have to turn the sheet around anymore means an increase of speed by three times. The employee is able to scan and sort all known dimensions of separator sheets, both cardboard and plastic.

The equipment has the ability to scan the sheets on both sides and sort them. It is able to sort sheets for various dimensions, colours, logo’s, material, radius, stains, tears and foreign bodies. By using the scanner to scan the sheets will increase the consistency of quality of the sheets. The room for human error has been minimized.

The choice for another party on the scanning system was made because this company has years of experience. Their core business is scanning systems and using this party for this purpose seems the best solution.

The entire system is made modular so the customer is able to extend the equipment if wanted. In the standard configuration the customer is able to sort the sheets for A-choice, B-choice or reject with three CSMs. The system enables the customer to expand this machine to as much CSMs as wanted. The system is programmed parametrically so the customer can adjust specifications if wanted. Another reason why the system is made modular is because this will keep the costs low on production and manufacturing stays easy.

The entire equipment is designed with the help of professionals. The engineering department of Vega Systems BV helped by ordering parts and checked each part, component and actuators. For each actuator a representative of a particular company is talked to for advice.
Recommendations

For Curagon, Industrial Packaging Solutions recommendations are listed below in three categories;
- Manufacturing
- Testing
- External parties

These are the three main parts in which Curagon has to take a closer look at.

Manufacturing
There are some parts, mainly the sides of the vacuum conveyor, which do not fit that perfectly anymore after powder coating. The ‘keerrol’ and ‘aandrijftrommel’ were very hard to assemble. It would be wise to alter the dimensions a little bit so these components are easier to assemble.

In this first prototype the choice was made to use conveyor belts which are not endless but with a so called ‘riemverbinder’. For future conveyor belts using seamless conveyor belts would improve vacuum. The ‘riemverbinders’ are not totally flat on the vacuum lid so air is able to escape.

When a separator sheet is rejected by the CSM, it falls down on a pallet. Components which make sure these sheets perfectly align on the pallet still have to be made.

Photocells
After each module a photocell has to be placed in order to see where the separator sheets are going and if the sheets did not get stuck somewhere.

Emergency stops
On each module an emergency stop has to be installed.

Testing
- Vacuum

The vacuum needs testing. So far, a separator sheet is able to stay underneath the OTM but not beneath the CSM yet. The vacuum has to be improved because for the OTM already 2 vacuum ventilators were needed instead of 0.4 ventilator. In order to reach a better vacuum testing has to be done with the hose which connect the ventilator to the vacuum lid. Also testing has to be done with the vacuum lid. Perhaps a lower vacuum lid (currently 70mm) would increase the vacuum inside as well. Testing with holes inside the vacuum lid, hoses and conveyor belts might also increase vacuum.

Scanner
The scanner of Eagle Vision – the Basic Scout, still needs a lot of testing. The Basic Scout system is made for testing labels on (glass) bottles and cans but not on large separator sheets yet. For Eagle Vision this is also a new way of scanning. Therefore, testing with the scanner in combination with the colour and motion of the conveyor belt is necessary.

Pneumatic
Also the pneumatic pushers need testing. These pneumatic actuators need to be strong and fast enough in order to push a sheet off under (high) speeds.

Total testing
When all components work independently from each other, the entire system has to be checked. The scanner should be able to scan a moving sheet on both sides. The OTM and CSMs should have enough vacuum to hold the sheet until one of the CSMs will push the sheet of the vacuum conveyor. All these components have to work simultaneously and in harmony.

CBM
The Curagon Brushing Module needs testing because it is not clear if the combination of the brushes and blow pipes will make the sheet clean enough. Also it is not clear what the static electricity will do with plastic separator sheets.

External parties
At this point the PLC programming is in hands of Vega Systems Germany. They have a Siemens PLC programmer which programs the PLC for us. It is advisable to have a Siemens programmer closer to the prototype, especially in the early state of this project. A lot of changes have to be made and communication lines will be shorter when the programmer is in the neighbourhood.
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