ANALYSING AND IMPROVING THE PERFORMANCE OF THE PALLET BREAK DOWN PROCESS BY SUEZ FOR SCANIA

MASTER THESIS INDUSTRIAL ENGINEERING & MANAGEMENT

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The most dangerous kind of waste is the waste we do not recognize. (Shigeo Shingo 1909-1990)

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Preface

For the completion of my Master of Science in Industrial Engineering and Management at the University of Twente, I carried out this research project. It was an interesting challenge to finalize my master, in which I have learned many new and interesting things as well as a different way of looking at problems. All that I have learned should give me enough opportunities to grow further. It is a nice addition and completion to my previous two studies.

I would like to thank my supervisor Anne Stienstra of Cofely Noord BV for guiding me through the assignment and useful discussions about the assignment. Moreover, Cofely Noord BV for giving me the opportunity to conduct this research within their organisation. Of course all colleagues at Cofely Noord BV for their support, advice and discussions that have helped me to fulfil the assignment. Cofely Noord BV gave me an interesting view of their business.

Furthermore, a word of thanks goes to my supervisors at the University of Twente, Peter Schuur and Henk Kroon. For their advice during the progress meetings, and the help to give direction to my research and provided insight to continue completing the research.

A special word of thank goes to Gerard Agterhuis and Johan Brinkman of SUEZ Zwolle and Thierry Bonin of SUEZ Angers, for helping me with all the information, data and facts needed for the research. Furthermore, I would like to thank all the staff and employees on the production site, for their advice, demonstrations, opinions and feelings that served as input for the research.

Last but not least, I want to thank my parents and brother for their support and encouragement to complete my study. Mom and dad, this is the last one!

Tim ter Huurne

Hengelo, March 2016

Management summary

This research paper is about the SUEZ pallet break down at Scania Production Zwolle B.V. SUEZ performs the pallet break down, along with other activities at Scania since 2011. When looking at the pallet break down SUEZ performs all Scania's return logistics on transportation and packaging materials. The pallet break down process consists of the following steps:

- Quality check (good, to be repaired, broken or contaminated);
- Remove labels and waste from materials and take out left over truck parts;
- Sorting materials (on Material Handling number);
- Preparing materials for transport (apply: identification labels, strapping and protection);
- Truck loading.

The pallet break down is operational during Scania's production time, in both regular and overtime. Based on a daily truck production schedule, Scania dictates the volumes that SUEZ processes. SUEZ is paid per unit loaded into a trailer, so not per hour or a fixed fee. A unit is a predefined collection of transportation or packaging materials that is sorted out, checked on quality and made transport ready. Working more efficiently or improving processes therefore results in lower costs. Especially since most of the work is done by temporary labourers and about 90% of all costs are wages.

Problem description

The SUEZ management believes that performance is not optimal. Furthermore, Scania has cut the premium paid for a unit by 8%. Due to lack of insight in the current performance, SUEZ does not know where to start improving. Therefore, research is needed to investigate the current activities performance and the costs of the pallet break down and to propose improvements for the pallet break down. An additional desire of SUEZ is to apply robotisation to decrease the required amount of temporary employees.

Approach

To gain insight this research starts by investigating the current activities, performance and the financial aspects of the pallet break down. Although many data are available, such an analysis was never performed and implemented until this research. With the findings, we can determine what kind of problem the pallet break down faces. The root cause of the problems at the pallet break down is the layout. Therefore, we applied the Systematic Layout Planning (SLP) framework to develop layout alternatives. SLP consist of 3 main steps: analysis, search and selection. With this framework in step 1, we quantified relationships between departments, flow between departments and determined the space required for all departments. In the second step, we applied our heuristic to develop alternative layouts for the pallet break down. We created a heuristic that calculates the total transportation costs between departments. Our heuristic is a simulated annealing construction heuristic based on literature review. The heuristic is made such that it can be reused in the future. In step 3, a selection of all feasible layouts was made. From the selection, we will choose the layout with the lowest total transportation costs.

Furthermore, the research analyses the logistics and processes of the pallet break down at SUEZ in more detail. We visited the SUEZ pallet break down for Scania in Angers in France and made a comparison between both locations.

Also likely changes of Scania that will affect the pallet break down in in the near future are analysed.

Finally, we have created a green field layout that is compared with the current layout.

Results, conclusions and recommendations

Analysing the current situation revealed that the performance of the pallet break down process is not optimal due to a layout problem and logistical and organizational problems. Both type of problems have to be solved to achieve full benefits in the future.

Layout

Improving the current layout by moving the non-production departments out of the hall will reduce transportation costs by 34%.

Another layout improvement will be to outsource the box-processing department to Wezo (social employment workshop). Doing this will lower the total transportation costs by 39.8%.

Separating the inbound and outbound material flow will result in 29.6% lower transport costs, assuming that the trailers are not positioned further away. Preventing rework will decrease total transportation costs by 2.4%. To achieve this, the strapping machine has to be improved.

In addition, we developed a green field location for SUEZ. Although moving to an external location is currently not possible, it can give direction where to grow.

Logistics

Material arrival at the pallet break down varies during the day. By far the largest peak for SUEZ occurs during the shift change of Scania. The cause for this peak is that Scania employees on average stop working a quarter before the end of the shift. The next shift needs some time to start up, drive back to the factory, and resume the work. All in all this ritual lasts an hour. Since SUEZ equipment and personnel planning is based on peak levels, avoiding this peak can save 2 FTE. In addition reducing this peak may avoid investments by SUEZ in additional capacity of the conveyor system required when Scania would increase their production level to 180 trucks per day. Avoiding these peaks for SUEZ will require a change in Scania's working mentality. They have to work until the end of their shift or have to changing the shift on the work floor.

On average 200 units of boxes per day are strapped by hand. If this process can be automated it saves about 0.28 FTE. An entry point must be realised at the conveyor system and the strapping machine feature must be enabled which straps plastic boxes with a lower tension.

Currently, waste is deposited into crates and too many labels are attached to crates. Boxes are often stapled, something that is not allowed. As a result of these three examples, the efficiency of SUEZ decreases. At Scania Angers this does not occur like in Zwolle. Therefore, we advise Scania and SUEZ to work out a way in which Scania's own internal guidelines are followed better. This result in fewer waste, staples and labels applied on crates and boxes.

Processes

Currently 10% of all handled material needs to be repaired. Materials that need to be repaired or scrapped cause additional travel distance for the employees, as the materials need to be put further away. The extra travel distance results in extra working time that is estimated to be 0.13 FTE. On average, 32 units of material are scrapped per day, which SUEZ is not paid for. This equals a yearly loss of income of about €65,000. The box-cleaning standard in Zwolle is higher than for other pallet breakdowns and Scania guidelines. Following the Scania standard of box cleaning, like in Angers, will save at least 2-3 FTEs.

Overall conclusion

We recommend SUEZ a lean and continuous improvement program, to create a structure to force improvements and to stay efficient. To gain insight in processes and to trigger improvements SUEZ can monitor processes and detect changes in processes by introducing KPIs and PIs. Applying robotisation is currently not feasible. First SUEZ has to start improving the current pallet break down process and improve its organisation. Only then robotisation will be interesting.

Over the years, Scania has been satisfied by SUEZ' diligence. As a result, SUEZ may have lost sight of its own business. Financially speaking SUEZ is making a small profit but when all overhead costs are taken into account, it is questionable whether the current operation is profitable. To reduce costs and to improve throughput we propose Scania and SUEZ to cooperate on improving the arrival of materials to the pallet break down. Furthermore, we recommend that Scania focuses more on following their own guidelines. In addition, SUEZ must make its process more transparent. The implementation of a structural lean improvement program to trigger continuous improvement of processes and performance is recommended. By sharing knowledge, SUEZ Zwolle can learn a lot from SUEZ Angers.

To guide further improvements we propose the following implementation roadmap. The roadmap consists of three phases. In phase 1 awareness is created on SUEZ's own processes and organisation. The first step is completed with this research. In phase 2 short-term changes have to be made to get things right. The 2nd phase will result in higher efficiency and will provide a basis for larger improvements. When phase 2 is completed, SUEZ management can chose a direction to grow in the long term. We propose 4 solution directions for SUEZ that can of course be combined.

<table>
<tr><th>Phase</th><th colspan="4">Activity</th></tr>
<tr><td>1
Start</td><td colspan="4">Management acknowledges there is a problem</td></tr>
<tr><td>2
Short-term
(1 year)</td><td colspan="4">Define processes and standards at SUEZ
Start a lean program to improve operations
Introduce own KPIs and PIs to monitor processes
Collaborate more with SUEZ Angers
Standardise way of working
Start culture changes (e.g. shift change at Scania, think lean, following guidelines)
Implement logistic improvements</td></tr>
<tr><td>3
Long term</td><td>Direction 1
Further optimise current processes and way of working</td><td>Direction 2
Implement automation or robotisation at the current location</td><td>Direction 3
Overhaul of the hall, and change the layout of the pallet break down</td><td>Direction 4
Move the pallet break down to a green field</td></tr>
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Abbreviation	Description
COG	Centre Of Gravity
CTC	Centroid-To-Centroid
FLP	Facility layout problems
FTL	Full Truck Load
GA	Genetic Algorithm
I/O	Input/Output
JIT	Just In Time,
KD	Knocked-Down, partial truck assemblies kits
LC	Logistic centre, a warehouse facility for Scania material supply
MH-number	Material Handling number
PRU	Production unit, a Scania production site
QAP	Quadratic Assignment Problem
SA	Simulated annealing
SCV	Squared Coefficient of Variation (the ratio of the standard deviation to the mean)
SPS	Scania Production System
TPS	Toyota Production System
TS	Tabu Search

1 Introduction

For finalising my master Industrial Engineering & Management, specialisation Production & Logistic Management at the University of Twente. I have conducted research for Cofely Noord BV. The conducted research is for a client of Cofely, namely SUEZ, formally known as SITA. SUEZ is active in many places. This assignment is about the pallet break down at the Scania production site in Zwolle. Cofely, SUEZ and Scania Production Zwolle are introduced in the next paragraphs.

Amongst others, Cofely and Sita were part of GDF SUEZ group. Cofely felt under GDF SUEZ Energy services and Sita was part of GDF SUEZ Environment. Starting from 2016 activates of GDF SUEZ are separated. Energy and technical services activities are placed under one brand namely ENGIE, and all environmental activities became part of one brand: SUEZ.

1.1 Cofely and ENGIE

Cofely Nederland NV is the largest technical service provider in the Netherlands. Cofely has around 6,200 employees and a turnover of almost €1.2 billion in 2014. Cofely is active in many different markets like food, pharmacy, utility, industrial sites and petrochemical industry. Cofely is responsible for construction work, maintenance and asset management. Local Cofely offices are located in the Netherlands, near the local customers to provide services. Most offices have their own business specialties; in addition to that, there are some Cofely market-specialised offices located in the Netherlands. During this master assignment, I will work at Cofely Noord BV at the department of Industrial Automation in Hengelo.

Cofely is part of the GDF SUEZ group, and will be rebranded at the end of Q1 in 2016 to ENGIE. Other daughter companies of GDF SUEZ (e.g. Electrabel) have been rebranded to ENGIE on the 1st of 2016. ENGIE is the largest energy supplier in the world; ENGIE has five global business units:

- Exploration & Production International;
- Global LNG (Liquefied Natural Gas);
- Global Energy Management;
- Tractebel Engineering;
- GTT (Gaztransport & Technigaz).

1.2 SUEZ Recycling and Recovery, Netherlands

SUEZ Recycling and Recovery, Netherlands, will from now on be referred to as SUEZ. SUEZ is the problem owner in the conducted research. Most people are unfamiliar with SUEZ, but the previous brand name SITA is known by almost everyone. SUEZ is part of the GDF SUEZ group, for the integration of activities all over Europe the brand names are renamed and repositioned. SUEZ is known by most people as a garbage collector at their home or office. However, SUEZ does more than that; it provides total solutions to businesses in garbage management and recycling. For the different sites of Scania, SUEZ in Zwolle is responsible for:

- Garbage collection on the Scania terrain;
- Industrial cleaning;
- Sewage management;
- Managing chemical storages;
- Process transportation and packaging materials (the Pallet break down, also PBD);

- Sprinkling salt.

This research is about the pallet break down of SUEZ in Zwolle, the PBD is introduced in paragraph 1.4. The pallet break down activity is also done by SUEZ at the Scania production factory in Angers (France). The work is similar, the amount of trucks produced in Angers is about a third of Zwolle, and thus volumes are much smaller. In practice, there is no cooperation between both locations. Both locations work autonomous.

The pallet break down activity is unique for SUEZ in the Netherlands (and in France); this activity is only deployed at Scania Production. The pallet break down activities are performed by SUEZ since 2011, and the current contract ends July 2017. At the Scania location in Zwolle, SUEZ has a local office from which all customers in Zwolle and all other Scania sites in the region are managed, the local SUEZ office falls under the regional head office in Veendam.

1.3 Scania Production Zwolle B.V.

Scania is a bus, truck and engine manufacturer and service provider with the head office in Södertälje, Sweden. Scania has many production and logistics sites throughout the world. Scania is represented in over 100 countries. Scania was founded in 1891 in Malmö Sweden, and Scania has been producing trucks ever since 1905. In 1964, Scania opened a production facility in Zwolle, Scania Production Zwolle B.V. that builds and assembles truck on order. Since the opening, over half a million trucks have been built in Zwolle. In Zwolle, 60 per cent of all the European Scania trucks are built for over 60 countries. At this moment, Scania Zwolle creates about 160 trucks per day in a two-shift working day. In 2008, Volkswagen AG realised a shareholder majority in Scania, and Scania entered the Volkswagen Group.

Scania’s objective is providing the best profitability for its customers throughout the product life cycle by delivering optimised heavy trucks and buses, engines and services – thereby becoming the leading company in its industry (Scania’s strategic platform, n.d.). Scania relies strongly on the Scania Production System (SPS); this framework is adopted from the widely known Toyota Production System (TPS) and has been customised to suit Scania’s needs The core values of Scania are ‘Customers First’, ‘Respect for the individual’ and ‘Quality’ (Scania’s strategic platform, n.d.). Scania’s focus is primarily on the activities that have a direct contribution to truck, bus and engine production. Indirect activities, which do not directly contribute to truck production, for example the garbage management is outsourced to external contractors. Scania expects all suppliers, contractors and employees to contribute to the core values and to continuously improve processes and activities. This is explicitly demanded in the Request For Quotation (TPEP, 2010).

1.3.1 Production at Scania Zwolle

At this moment, there are two active production lines at Scania Production Zwolle B.V. Namely the Castor and Pollux production line. Both production lines were rebuilt and completed in 2003, The Pollux line was re enabled in the spring of 2015 to realise higher truck production rates. On both production lines trucks are assembled, the production rates are different but the largest difference is the production layout. The philosophy behind the Pollux line is more focussed on Scania’s future plans. Units are delivered in smaller quantities just in time when needed in production. That means that the goods that are sent to SUEZ will shift from large crates to smaller boxes. This, of course has an impact on all elements in the logistic chain, from transportation from and to the SUEZ site as well as the needed tools and labour. Scania states that is likely that the trend of smaller quantities will grow in the future, for all predictions this change has to be taken into account.

1.4 The pallet break down

SUEZ at Scania in Zwolle processes all transportation and packaging materials that are released after the truck production. These materials are mainly boxes, pallets and crates. The crates and boxes can be filled with packaging materials, waste and left over truck parts. At the PBD, packaging and transportation materials are prepared for shipment in order to be reused. The PBD is located at the Scania Production terrain, in a hall between two warehouses and the production line. In the picture below an aerial photo of the SUEZ pallet break down in Zwolle.

Figure 1.1 An aerial photo of the pallet break down

The block layout of the PBD can be found in Figure 1.2. At high level, the processes are as follow:

- Scania delivers a full Internal Transport Trailer (ITT) on the transhipment area, and decouples the ITT and couples an empty ITT which is brought back to Scania;
- A SUEZ forklift truck starts to unload the full ITT, pallets and crates are sorted on department (Special department and Pallet break down) and transported to the appropriate department;
- Materials for the pallet break down are loaded onto an inbound conveyor system, Specials are moved by pallet jack;
- In the departments, employees perform following actions:
  - Remove labels;
  - Check transportation and packaging materials on quality;
  - Sort out materials on kind (at the special department, PBD and inner units);
  - Remove waste;
  - Collect and return truck parts;
  - Make transportation and packaging materials ready for shipment (with a strapping machine or by hand).
- Completed materials which are ready for shipment are send back to the transhipment area, for the PBD with an outbound conveyor, for specials by pallet jack;
- The forklift driver picks up the materials, and stores the materials in the buffer or directly in the trailer for transport.

Boxes collected by SUEZ in the factory, are brought to the boxes department. At the boxes department labels and waste are removed. In addition, the boxes are cleaned by hand. Boxes that are contaminated with oil, water and dirt are separated by SUEZ and are send to VOITH Eschweiler (Germany) for cleaning.

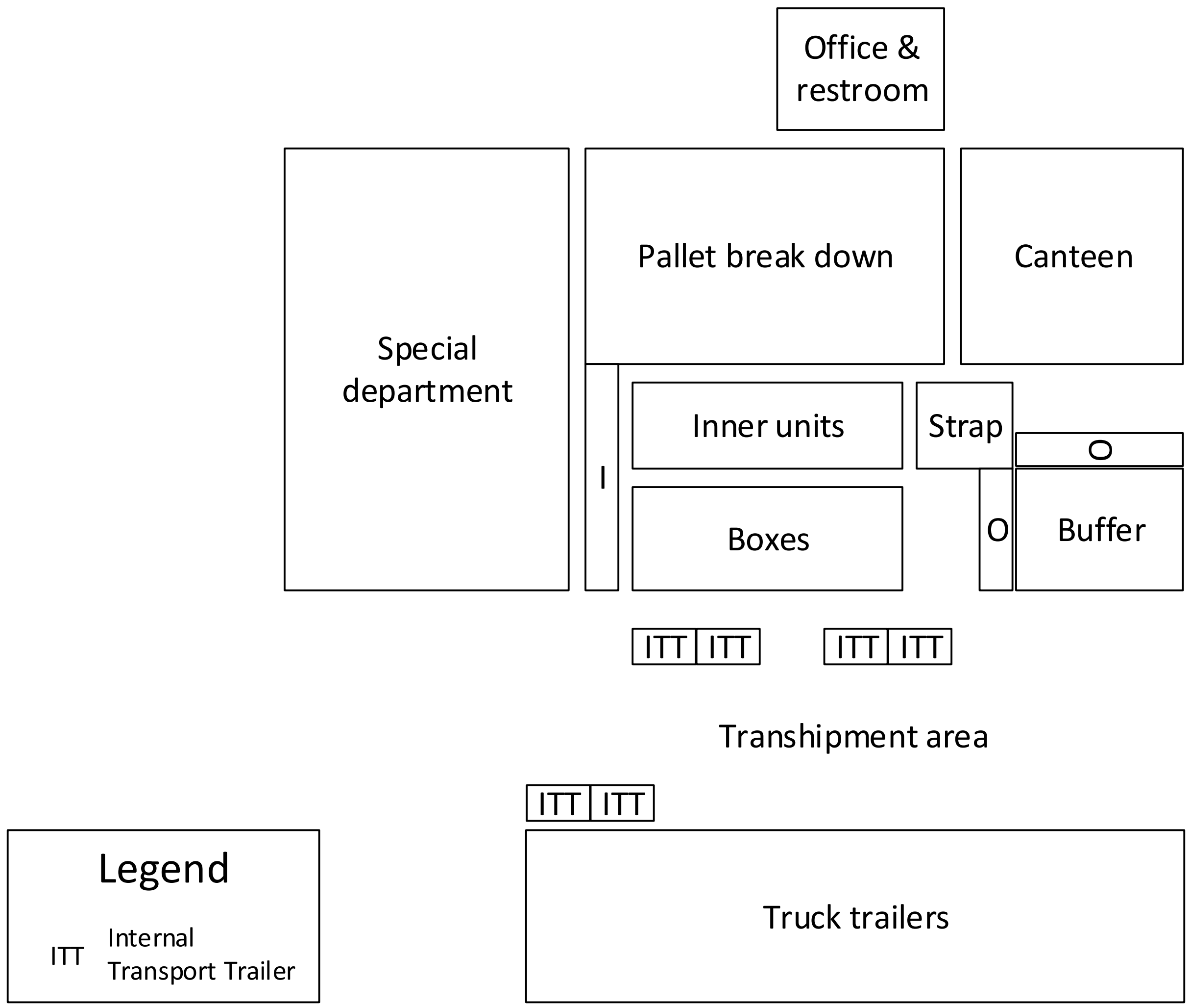


Figure 1.2 Global layout of the SUEZ area at Scania Production Zwolle

For internal transport of materials, small trailers are used in the factory. The Internal Transport Trailers (ITT) have not be confused with truck trailers. To prevent confusion during the research in Figure 1.3 an ITT is shown.

Figure 1.3 The Internal Transport Trailer

1.4.1 Purpose of the pallet break down

The main purposes of the pallet break down activities are the following:

- Sorting;
- Quality control;
- Shipment.

SUEZ sorts all incoming materials, in such a way that a supplier can order specific materials and predefined quantities of packaging or transportation materials to ship their parts to Scania. Quality control is done to take out damaged materials for repair or if materials are damaged too much, the materials are discard. Crates are collapsed to compress the required volume in transporting the materials.

1.5 Unit

Because the term “unit” is frequently used, a definition is given. A unit is a predefined collection of transportation or packaging materials that is sorted out, quality checked and made ready transport. SUEZ is paid per unit that they load into a trailer, so not per hour or a fixed fee. A unit is therefore the only source of income. A unit is build up out of a number of items; all units are predefined and specified by Scania. For example some units are:

- 11 euro-pallets;
- 20 plastic boxes;
- 34 lids;
- 60 pallet collars;
- A crate full with specific packaging materials.

Scania has specified and predefined all units in the internal Scania packaging manual. This packaging manual specifies how a unit is build and how it should be shipped. For example, a unit for packaging material is built up with a crate (with a euro-pallet, three collars and a lid) filled with the specified quantity packaging material. On the outside of a crate, at the front and back, labels are placed for identification, to display which packaging material the crate contains and which contractor made the unit. A unit of boxes exists out of number of stacked boxes, protected by a plastic covering sheet of a plastic pre moulded lid. In total, just over 100 different units can be assembled and shipped. Units have various sizes, dimensions, weighs and quantities. Different units also require different amounts of time and effort to make, the price paid however is an average price. After a unit is built-up, it will be strapped for transportation, placed in storage or directly in a trailer for transportation. In the picture below some units that SUEZ makes are displayed.





Upper left: unit euro-pallets
Upper middle: unit euro collars
Upper right: euro lids
Down left: unit B1 boxes
Down right: unit packaging materials

Figure 1.4 Different kinds of units

1.5.1 Shipping

Orders for units packaging and transportation materials are sent to the SUEZ office. Other units are pushed as inventory to the packaging pool. There is almost no (final) inventory of units at SUEZ, only for special orders. Suppliers, manufacturers or logistic centres built-up crates again and fill them with materials and subassemblies. A majority of the processed boxes are send to the logistic centre in Zwolle. This is done with a milk run transport, at fixed times twice a day. At Scania Logistics in Zwolle, the empty boxes are filled again with truck parts and send back to the PRU. This is a small loop in the entire packaging pool of Scania. SUEZ fills the trailers with units at its own discretion, a full truckload (FTL) is not required but the aim is to fill a trailer as much as possible. All transportation over the road is done by a Lead Logistics Partner, appointed by Scania (UTMS, 2015).

1.6 Philosophy of transportation and packaging materials

Packaging materials have three basic functions; it serves as protection, identification and provides containment to persevere the product. (Trott, 2012). The packaging materials for Scania are mostly used for the first two functions, protection and identification. Scania has its own closed loop transportation and packaging material loop, called the packaging pool (TPEP, 2010). All transportation and packaging materials are owned, selected and defined by Scania (TPEP, 2010). Materials and parts that are delivered and used in the production and assembly of trucks, busses and engines are delivered in predefined and standardised crates, boxes or pallets at the production location where the parts or assemblies are used. All suppliers and manufacturers of Scania are obligated to use the Scania owned transportation and packaging materials for deliveries to Scania, and to follow Scania's predefined packaging and sorting instructions (UTMS, 2015). All transportation and packaging materials have their own "MH-number" (Material Handling number) which is an internal identification number that define the specific part. Most materials in the packaging pool are universal parts, for example, a crate is built up from different parts, and can be used for different kinds of truck parts or subassemblies. Suppliers and manufacturers deliver to a logistic centre, or directly to the Production Unit (PRU). Delivery to the assembly line is just in time (JIT) and in the right amount needed for production; this can be in crates, boxes or pallets. After all parts are used for production, the empty crates, boxes and pallets are taken out, and placed on Internal Transport Trailers (ITT). On a frequent basis the trailers are moved to the 'pallet break down', this is in front of the SUEZ site where the trailers are disconnected by a mini truck, which will connect an (almost) emptied trailer. The trailers are placed in the factory again where they are filled again; this process continues throughout the entire production time.

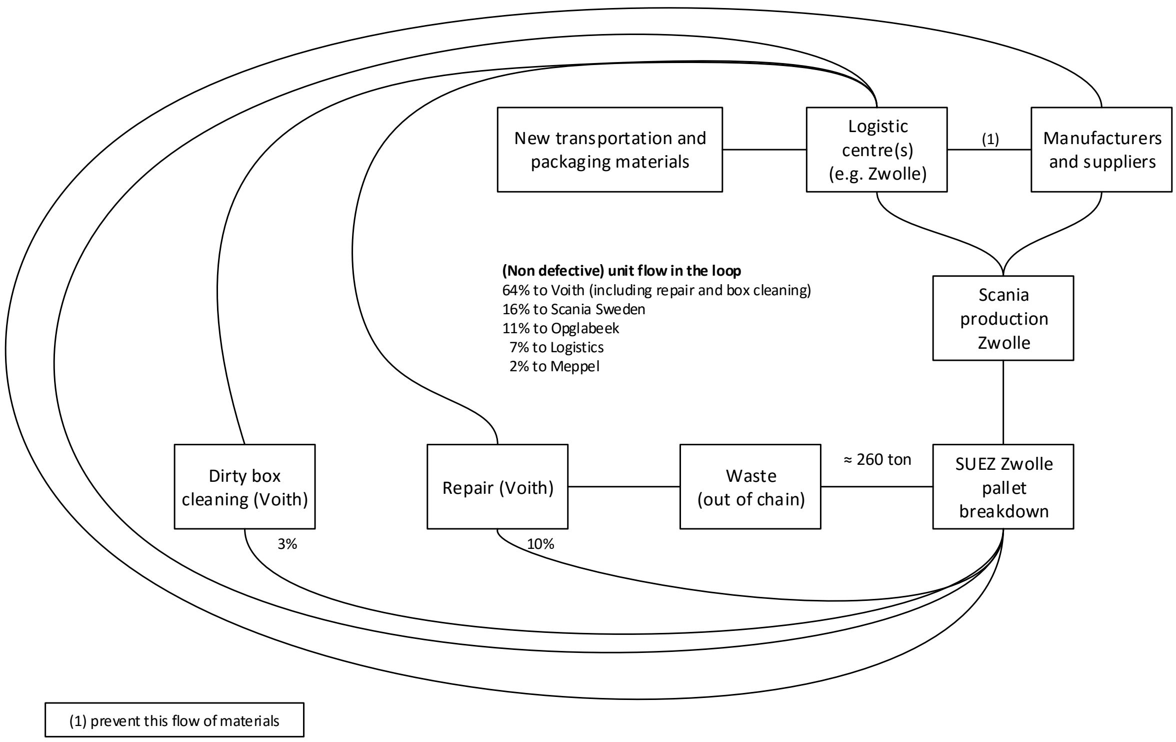


Figure 1.5 Closed loop transportation and packaging materials

1.6.1 Lifecycle

Transportation and packaging materials are reused as long as possible. This means that all materials are reused until they are broken, contaminated or worn out. In practice, some parts are reused for more than ten years. If the amount of damage is low, wooden components are repaired (externally). If a part is too damaged, or if the part is contaminated with for example oil, the part is scraped or recycled. This entire process is designed accordingly with the philosophy to be green and sustainable.

1.7 Research plan

In this paragraph, the structure of the research is outlined. Starting with a short description of the problem and the goal of the research. Followed by a main question and several sub questions that will be answered during this research. To limit the research, the scope and limitations are set, which will be the set boundaries of the research.

1.7.1 Problem description

SUEZ does not know how the process at this time performs, both on financial and operational level. Over the last years, more and more work is accepted from Scania and added to the portfolio. This is never done in a structured way. The major activity of SUEZ is the processing of boxes and crates that are released after truck manufacturing. This work also gives the largest turnover of all activities at Scania Zwolle. In mid-2015, the premium paid for the delivered work was cut by 8 per cent for the rest of the year. Therefore, the management requested to research whether improvements can be made in the PBD process in order to increase its efficiency.

1.7.2 Objective of research

The objective of this research is to analyse the actual situation, and to come with improvements. SUEZ does not know how the process performs currently and where improvements can be made to improve the performance of the processes and activities performed by SUEZ at Scania productions in Zwolle. To gain insight in the actual process and performance, research is conducted to investigate the problem. In addition, improvements are proposed to improve the current processes. Therefore, several research questions have been formulated to investigate the problem. The research questions that are answered during the research can be found in the next paragraphs.

1.7.3 Main question

During the research an answer is given to the main question, which is:

How can the current process at the pallet break down of SUEZ Zwolle be improved by reducing operational costs and increasing throughput by changing the pallet break down?

1.7.4 Sub questions

To answer the main question, sub questions are formulated to structure the research and to help answer the main question. The sub questions in this research are:

1. What are the current activities in the process, what is their performance, and what are the costs and benefits of these activities?
2. What are bottlenecks and problems in the current process?

The first two sub questions focus on analysing the current situation at the pallet break down. For the first sub question, observation of the current process and organization is applied. To further quantify the data, historical data that has been recorded is used. The available data comes from two sources, data on the operational performance, and financial data from the administration system. For the second question, experiences and feelings of personnel is used as the main source of information.

Supported by the findings of the first sub question to quantify their feelings and find other or indirect causes of the problems, three more sub questions have been formulated which are respectively:

3. Which feasible alternative layouts can be made to improve the current performance of the pallet break down?
4. What do these alternatives cost and how do they perform compared to the current situation?
5. Which improvements can be made on a logistical and organisational level to improve the performance of the pallet break down?

These three sub questions are about what can be improved in a future situation at the pallet break down. The following approach is used. First by analysing the current performance and identifying its bottlenecks, a first step to make improvements has been made. To make improvements, a framework has been used to guide the process. Before improvements are generated, a literature review is performed. In the literature review, more in depth information is searched for and reviewed, to support the framework and to work out possible improvements.

6. What are advantages and disadvantages to move the pallet break down to a green field outside the Scania terrain?
7. What are possible changes in the future of the production plant of Scania, and how do these changes influence the current process?

Parallel to what can be improved, questions will be asked to find out what could be achieved in the future or at a new location and start over. In the 6th question, a more hypothetical approach is used The hypothetical solution gives a perfect green field in which all old constraints can be neglected. This hypothesis can then be compared with the brown field (current location), and give directions for further long-term improvements. For the last question, information of Scania is required about the future state of the production plant and which changes will occur in the future. This information will be gathered by meetings with Scania personnel that are involved with long term plans.

1.7.5 Scope & limitations

The project scope only includes the crate/special disassembly and the processing of boxes. From unloading the materials until loading the trailers. Other activities of SUEZ such as waste collection and industrial cleaning are not part of the research or the project.

The arrival and demand of disassembled products is unchangeable. No direct change can be made in the production process of Scania, just like the external demand for units. Solutions to improve the process are designed for the current location of SUEZ. Only a rough comparison has been made to move the process to an external location. The implementation of a solution is not part of the assignment.

Furthermore there are a number of limitations of the assignment, these limitations are:

- The composition and amount of arriving crates is random, unstable and not specified;
- The content of the crates is not specified. Crates can be empty, they can contain packaging material, left over parts or contain garbage of production or from personnel;
- There is no information exchange about the arriving crates, like volumes, composition or numbers;
- Scania dictates according to the production process how many shifts are needed. At this moment there is a two-shift production schedule;
- Normal working times are from 06:00 until 22:30, from Monday until Friday.

- The factory of Scania is in continuous operation, there is only a four-week period in the summer where the factory is shutdown to perform maintenance or overhauls. Only in this four-week period, changes in the process layout can be realised. All other changes have to be possible during operation without interfering work or during the weekends, or during production stops;
- In the current layout of the process, the ownership of equipment is quite complex. The ownership of equipment is partly Scania and partly SUEZ or with obligations to buy equipment when contracts are not renewed. Moreover, different suppliers of equipment are involved. The ownership of equipment is not a part of the assignment;
- Scania specifies the packaging specifications according to its own standards; this is the same for all contractors and sites such as SUEZ;
- Scania works with short term contracts for SUEZ, all investments have to be profitable within two years, or an obligation for a buy-over has to be considered;
- The SUEZ pallet break down in Angers is not part of the research for improvements, it is only used to make a comparison with Zwolle;
- All other pallet break downs at the different Scania locations are not part of the research.

1.8 Deliverables

After this research, we will produce the following deliverables:

- Give insight in the current problems and bottlenecks at the pallet break down;
- Alternative layouts at the current location;
- A program to generate alternative layouts for the pallet break down;
- A set of possible improvements and changes to improve logistics and processes;
- A pro and cons plan for a green field for the pallet break down.

2 Current situation

In this chapter, an answer is given to the first two sub questions of this research. The current situation will be analysed, described, and quantified as far as possible. At first sight, the management is convinced that the current situation can be improved. The analysis of the current situation focuses on operational performance as well on financial performance of the pallet break down, because both performances are unknown to the management. Moreover, financial performance measurement can aid to plan and control business processes (Blommaert, Blommaert, & Wytzes, 2008).

2.1 Current activities

In the next paragraphs, the transportation and packaging materials that are processed by SUEZ are explained. All materials are processed at dedicated departments in the same hall. Personnel changes every two hours after every break from the department. Job rotation is applied to have variation in work and to avoid physical burdens. All activities that are explained in the next sub paragraphs are also visualised in flow charts in Appendix: D.

2.1.1 Sorting incoming materials

When the Scania mini truck disconnects the full Internal Transport Trailer (ITT) at the SUEZ site, SUEZ comes into action. The decoupled ITT is unloaded by SUEZ forklift trucks, and the materials are sorted on department. Crates are loaded onto a conveyor track and all crates and pallets larger than a euro-pallet are dropped at the 'Special department' (a euro-pallet has the dimensions of 800 by 1200 millimetres).

2.1.2 Crates

The (half) euro pallets and crates are loaded from the ITT on to an automatic conveyor system. This conveyor system transports the pallets and crates to one of the three workstations where a pair of workers disassemble the crates and staples all the parts at the appropriate location. For example, the crate in Figure 2.1 contains labels, waste and packaging materials (green plate at the bottom). First, a visual quality check is performed, broken or bad parts are separated. Packaging materials are sent to the inner units department. Waste is thrown away in a garbage bin. Leftover truck parts are collected in a dedicated crate, which is returned twice a day to Scania. The crates are broken down, and sorted on lid, collar and pallets for both euro and half-euro size. All work is done by hand, without any supporting equipment, weights up to 23 kilograms have to be lifted and moved, which is physical work. After a crate is disassembled, automatically a new crate is sent to that workstation. When a unit with specific items is full it is sent away to the automatic strapping machine. After strapping the unit, the unit is taken from the conveyor with a forklift truck and loaded into a trailer or placed in a buffer storage.

Figure 2.1 A crate with labels on the outside and contains inner units and waste

In the current layout, there are two counters active in de conveyor system. The first counter counts the number of incoming crates and pallets and the other counter counts the number of units that are strapped. Both characteristics can be fitted in a distribution, the input conveyor approaches a normal distribution (with $\mu=89.24$ and $\sigma^2=596$) and the output conveyor approaches a gamma distribution (with $\alpha=12.98$ and $\beta=2.54$). See Appendix: A for all details. The distributions are used in the research to model the process.

Diagrams and schemes are made to clarify the current:

- Processes;
- Process sequence;
- Decisions;
- Material flows;
- Process times

A simplified view is depicted in Figure 2.2. In Appendix: I, the detailed diagrams and schemes for crates and the special department can be found. In Appendix: D, flow charts for all processes are depicted.

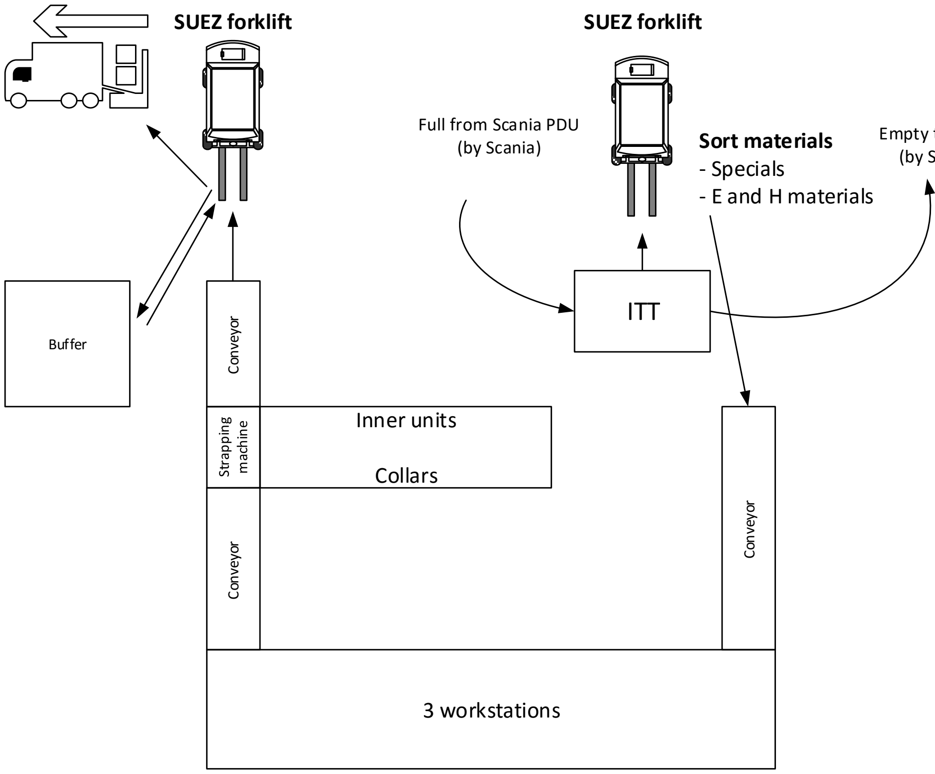


Figure 2.2 Simplified view of procces at the pallet break down

2.1.3 Inner units

At the inner units department, all packaging materials that are coming out of the crates are checked on quality and are sorted on species. When a crate of packaging material is full, a lid and plastic cover is applied and the crate is sent to an automatic strapping machine. A new crate is placed and identification labels of the contents are attached on the outside. Packaging material that has been rejected during the quality check is discarded as waste and noted on a scrap list.

2.1.4 Special department

The special department handles all pallets and crates larger than a euro pallet. These larger pallets are for example used for the transport of transmission boxes. The forklift driver places the crate or pallets on a pallet flow rack where at the other side it is taken out with a pallet jack and the same activities takes place as with the (half) euro crates and pallets, the only difference is that packaging materials are sorted out by the same person. Finished units are first strapped by hand and then placed on a pallet flow line outwards where the forklift driver places the unit in the trailer or in the storage.

2.1.5 Boxes

An ABC analysis is made to characterise the proportion of materials into three classes (A, B and C). The entire ABC analysis can be found in Appendix: E. In the ABC analysis, the plastic blue boxes score unexpectedly high. After investigating SUEZ's Zwolle historical data of boxes it became clear that the amount of blue boxes grew rapidly since 2013, much faster than the truck production. In Appendix: B the detailed information can be found where the growth of plastic boxes is compared to the truck production. In Figure 2.3, the growth of plastic boxes over time can be seen. The blue line represents the total amount of units blue boxes per day (left vertical axis). The red line represents the ratio of units boxes per produced truck (right vertical axis).

Comparing the number of blue boxes that are released from the factory for every truck produced over 2015 showed that in angers 0.75 unit of boxes are created and that in Zwolle 1.08 unit of boxes are created, this is a 44 per cent difference. This explains why the SUEZ Zwolle management was accused of low efficiency on plastic boxes, a third lower compared to the SUEZ site that is located in the Scania factory in Angers, France.

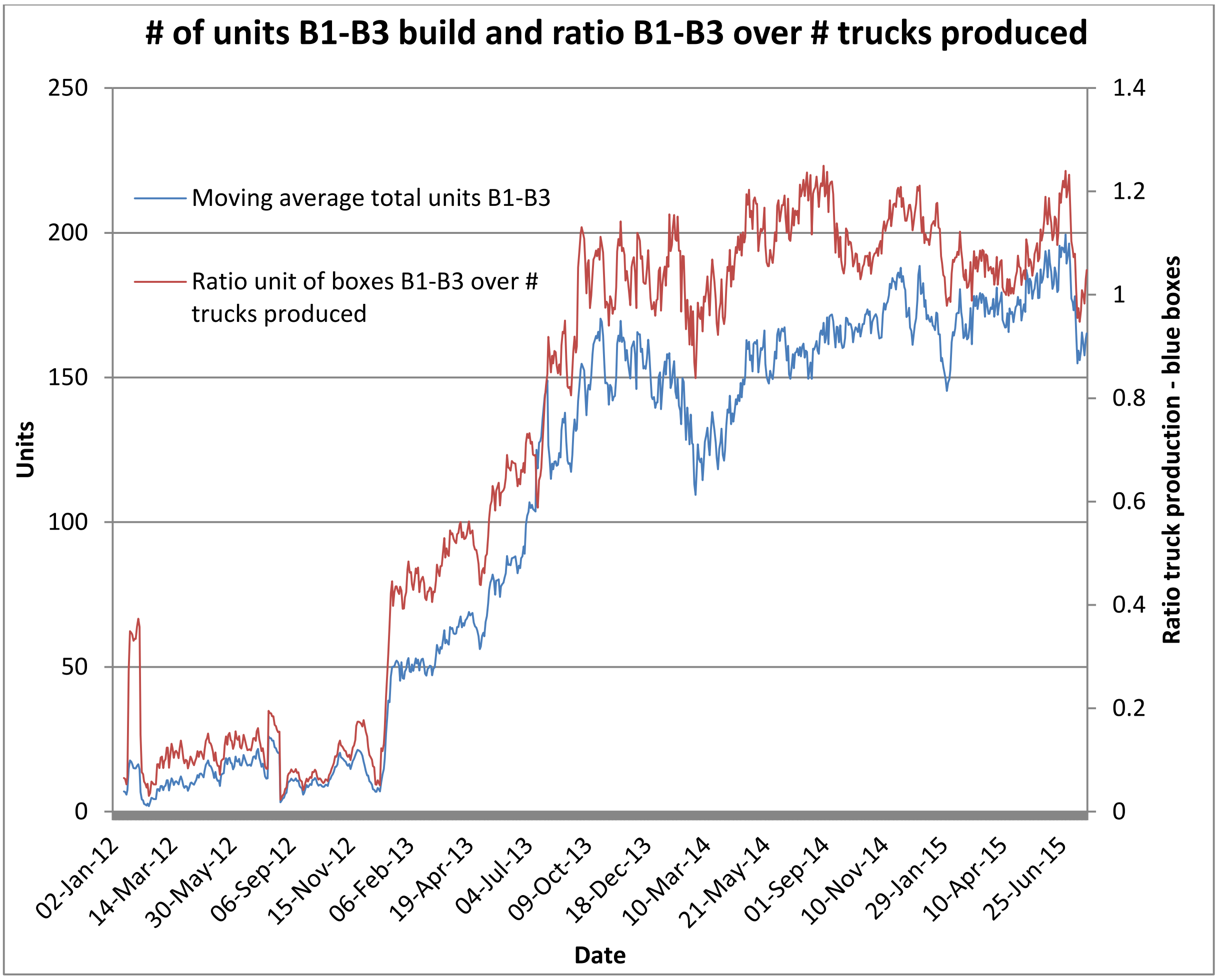


Figure 2.3 Grow of unit of boxes per truck (2012-2015)

At this moment, the work in Zwolle is done by 7 persons all by hand. On average, they create 200 units of boxes per day, this correspond to over 4,000 boxes. The processing of boxes is organised in the following way. In the Scania factory, collection bins are stationed where the used blue boxes are deposed by Scania's production personnel. The bins are collected and transported by SUEZ to the box-processing department. Where the boxes are emptied, an inspection is made on defects namely: good quality or dirty. Defective boxes are scrapped and listed. Dirty or contaminated boxes are taken apart and transported to the packaging-pool in Eschweiler, Germany for washing. From the good quality boxes, labels are removed and if present staples are removed. Boxes are wiped in the inside. At last, the boxes are sorted on size and stacked on a pallet.

When the boxes are stacked on a pallet, the boxes are covered with a plastic sheet for protection against dirt during storage and transport. Finally, the unit of boxes is strapped by hand with two straps, and moved to a collection point where a forklift truck picks the unit up for further transport.

Looking at the internal Scania guidelines for packaging, the guideline specifies that staples are not allowed to be present or even used to retain labels on the outside of boxes. In practice, staples are used to retain labels, and SUEZ is obligated to deliver staple free units, and is called for explanation when quality checks find staples in units delivered by SUEZ. It is not known who uses staples within Scania. By preventing the usage of staples, it will solve this issue by the roots. Moreover, it is increasing efficiency on the blue boxes.

2.2 Performance

For the operational performance, both the indirect and direct added value activities are investigated. Both activities, influence each other, but cannot work without each other, so it is likely that causes and effects are present in both direct and indirect activities. In the future, both the direct and indirect activities have to perform well and have to be in line with each other, thanks to a good strategic objective and long-term vision.

2.2.1 Personnel employed

At this moment, work is done in two shifts of 8 hours each, 5 days per week. Each shift consists on average of about 17 persons. Furthermore, there is a small team during the dayshift that consists on average of 6 people. A team leader and an assistant team leader oversee each shift. At the office, during daytime a coordinator is present who is the contact person for Scania and the SUEZ regional office. This regional office performs a part of the administration. Apart from the office staff and team leaders, almost all workers are temporary employees of Randstad. The number of temporary employees is derived from the scheduled truck production which statistically does not differ from the realised schedule (t-test: $p=0.985$ $df=52$). Due to governmental regulations, temporary employees earn more rights after 1.5 years of employment; SUEZ does not want to have many employees with extra rights. This choice has led to the following practice: the labour turnover is large, almost every week new employees are introduced, and employees are mostly low educated. Due to the reason that personnel is sent away after 1.5 year they have no motivation to work hard and efficient, they know in advance when their last working day is.

2.2.2 Technical installations condition

Because the weather conditions in the hall are almost equal to outdoor conditions, equipment suffers a lot, like humans. The large temperature span and high humidity or even rain (mostly due to condensation) in the hall, causes equipment breakdown more often and degrades faster than in a conditioned indoor situation. Moreover, due to the design of the conveyor system, the conveyor system has several weaknesses. Crates or units can fall between the conveyor lines, when they are not positioned correctly and cause collisions with nearby equipment, machines and sensors. Not all sensors are designed to work in outdoor conditions. Both the conveyor system as well as the automatic strapping unit are not programmed with a think ahead routine that causes many minor delays in transportation and strapping. Altogether, the conveyor system and stations have large variations in the processing and inter arrival times. Several times per day congestion occurs and (all) processes halt and workers are forced to stop working until the congestion is solved.

2.2.3 KPIs and data

The SUEZ offices measures and keeps track of some KPIs, these KPIs are defined by Scania in the contract. Currently these KPIs are:

- Processed units in normal and overtime;
- Specified in number of pallet types;
- Plastic boxes including the percentage of dirty boxes;
- The amount of some packaging materials;
- A specification of where the fraction of units were sent to.

At this moment the KPIs are compared every month with the KPIs of the previous month(s), unfortunately the number of units strongly depend on the number of trucks built, so it is only comparable with similar production rates. The KPIs measured have no strategic vision for SUEZ to improve business. Not to mention to keep track on internal performance. When something is not measured, it is also hard to manage (Marr, Schiuma, & Neely, 2004). Therefore, we propose to reconsider the current KPIs, and to define real strategic KPIs for SUEZ to trigger improvements from strategic level within SUEZ or to maintain a specific level. KPIs can be:

- Profit;
- Number of complaints;
- Personnel absenteeism.

Moreover, internal metrics have to be measured like:

- Machine availability of conveyors system;
- The availability of the automatic strapping machine;
- Personnel efficiency.

Advantage is that a lot of performance and data is gathered. Meanwhile many years of data are (Many years of data is plural) available, which is useful to verify and quantify processes and activities. To support this research some statistical test has been performed on the data. There is no significant difference between the weekly truck production schedule and the weekly-realized truck production schedule. There is also a significant correlation between the realized truck production and realized units ($R^2 = 0.84$) and between realized truck production and the amount of employed temporary labour ($R^2 = 0.89$). Therefore, the truck planning can be used in all models to predict the number of units that are realized and the required temporary employees. In other words, with the truck production planning the income and labour costs can be predicted.

Further improvement of the expectation of the number of units can be achieved by specifying the type of trucks that are being built by Scania. Now it is unknown which type of trucks are built. The number of parts and assemblies needed differs for a tractor and a box truck, for the latter the truck has several options, for example the number axes.

2.2.4 Office and paperwork

To start with the office activities, there is an administration of activities in Excel, where for example the counting lists are entered, Embassy (Scania’s own administration system) is updated and the invoice information is sent to the regional office of SUEZ. Although it is possible at the site office, SAP is not used for invoicing and performing SUEZ’s own administration. In other words, the administration is done currently in Excel, Embassy and SAP at the regional SUEZ office, in total the same information is entered at least three times. For example, the invoice data is sent to the SUEZ regional office an invoice is made for Scania, that invoice is then sent back to the site office, corrected, but mostly rejected due to small errors and is sent back to the regional office for correction. This ritual occurs structurally, and should be eliminated. This can be simply done by having the site office create the invoice directly with the right data and the right invoice- and contract information. The forklift truck driver counts from the cabin the number of units that he or she loads into the trailer. These counting lists are then entered in Excel at the site office. At the end of each month, the total number of units send in that month are summed up and are invoiced. In the counting process a danger occurs, the forklift driver does the count and has no direct interest in whether the counting is correct or not. Although the team leaders have to conduct a sample check, this will occur rarely. The reason for this is that checking the count lists is devious because the other side of the trailer has to be opened and there are rarely complaints from the receiver about miscounted loads, in other words there is no incentive to count correctly. This may not be the reason that counting goes well. There is a large difference in the interest in counting; SUEZ is paid for every unit. Therefore, SUEZ has great interest that the amount of units is counted correct. The receiving side has no direct interests that the counts are correct. When the receiving side receives too few materials they simply order internally more materials, and if they receive too much they simple consume all materials.

2.2.5 Output analysis

Although payment is per unit, SUEZ counts all individual units when the units are loaded into the trailer. This data is very useful to analyse which units contribute to the total turnover. An ABC analysis has been made and shows that about 20% of all products contribute to 80% of the total income, 30% of the products contribute to 15% of the income and 50% of the products add 5% to the income. The entire ABC analysis can be found in Appendix: E. Although SUEZ could wish to remove the 50% of items that rarely contribute to the income, SUEZ cannot change the items they deliver. Every department is present in all three classes, all departments needs focus whether the current activities are organised properly. In other words, items in class A and B should receive more attention than the low contributing class, for example by placing these products nearby workplaces. Management was surprised that 10% of all outgoing units are damaged units. Although this is a unit for which is paid, this high amount was not expected. A unit with damaged materials costs more time to make because the damaged materials are located further away from the working places than good materials.

2.2.6 Supply

Near to the truck production lines of Scania, trailers are positioned where all empty crates and pallets are gathered by Scania personnel. Periodically during the day, the trailers are brought to the SUEZ site by Scania’s mini trucks. In front of the SUEZ site the trailers are disconnected, an empty trailer is connected and brought back in to the warehouse where it is loaded again, and brought to the factory. The disconnected trailer is then emptied by a SUEZ forklift truck. Currently the supply rate is not stable, although truck production rate is almost constant due to the ‘tact time’ and so parts consumption is nearly constant, the flow of empty crates and pallets is not. Due to the arrival waves of trailers, supply to the disassembly stations is fluctuating and so is the variation on machines and personnel. Any form of control on inbound materials will reduce the impact of random received loads (Tompkins, White, Bozer, & Tanchco, 2010). Especially during rain, this wave of materials becomes a problem. At a high rate, crates and pallets are buffered outside, because the trailers have to be emptied quickly. Before the conveyors and flow line, the crates and pallets are standing in the rain. This buffering is not allowed, but due to lack of space and in regular supply, buffering is inevitable in practice.

As shown in Figure 2.4 a boxplot was made per hour with the percentage of material arrival at the pallet break down, for each shift. Where the blue horizontal line is 12.5% (100% / 8 hours), of the arrivals per hour, which theoretically results in a constant arrival rate. At the moment that the boxplot and whisker is large, this means that the variation of arrival is large, and if the red dash (median) is far above the blue horizontal line relatively more crates arrive on average in that hour. At 15:00 hours shifts change, between 14:00 and 15:00 the arrival decreases slightly, but after the shift change arrival variation 'explodes'. Variation at the end of the day is explainable due to fact that production can be finished earlier some days and therefore it fluctuates. Normally production finishes at 22:30, and the arrival of materials stops. This can be seen between 23:00 and 24:00 hours, there are two concentrated areas, production in overtime and no production. Furthermore, SUEZ personnel has a half an hour break at 11:00 and at 19:00 hours, which explains the lower arrival rate, also because Scania has a break during that time.

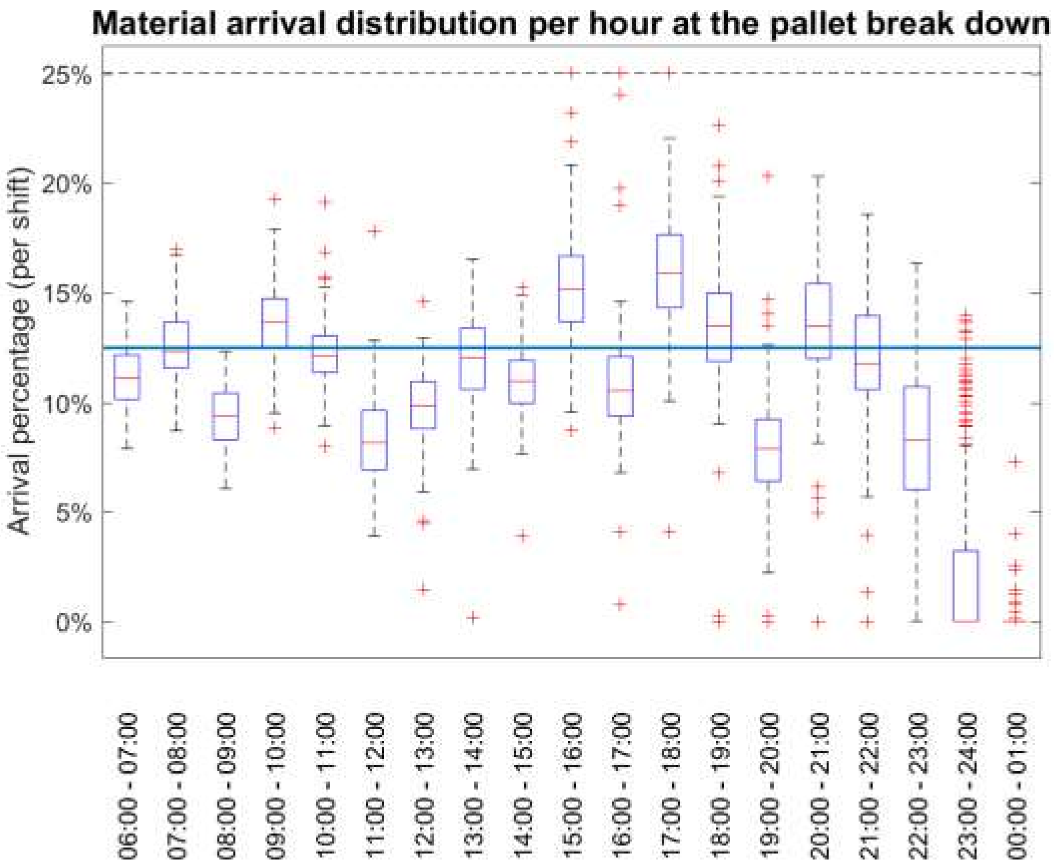


Figure 2.4 Arrival percentages per hour and per shift (based on firth 10 months of 2015)

Scania recognises that employees stop working a quarter earlier at the end of the first shift (15:00), and drive already to the takeover point. After the shift change, some instructions can be given, and a beverage is taken by the forklift drivers. On average over 20 to 30 minutes there is a minimal supply to SUEZ, the backlog will be processed. The Scania management suggests that SUEZ has not enough capacity to deal with the incoming materials when SUEZ starts to buffer the incoming materials on the ground. Although the root cause of the problem is caused by Scania itself, by first minimising the flow to SUEZ and then flood the system.

2.2.7 Traffic

The traffic intensity on the transhipment area is large and has many crossing paths. In Figure 2.5 the forklift traffic and mini truck traffic (for ITT transport) is depicted. There is even more traffic, but this traffic has no reason be there. Other traffic consists of for example suppliers, Scania trucks and customers. Due to the many crossings of traffic, there is congestion and dangerous situations with (near) accidents and damages to forklifts.

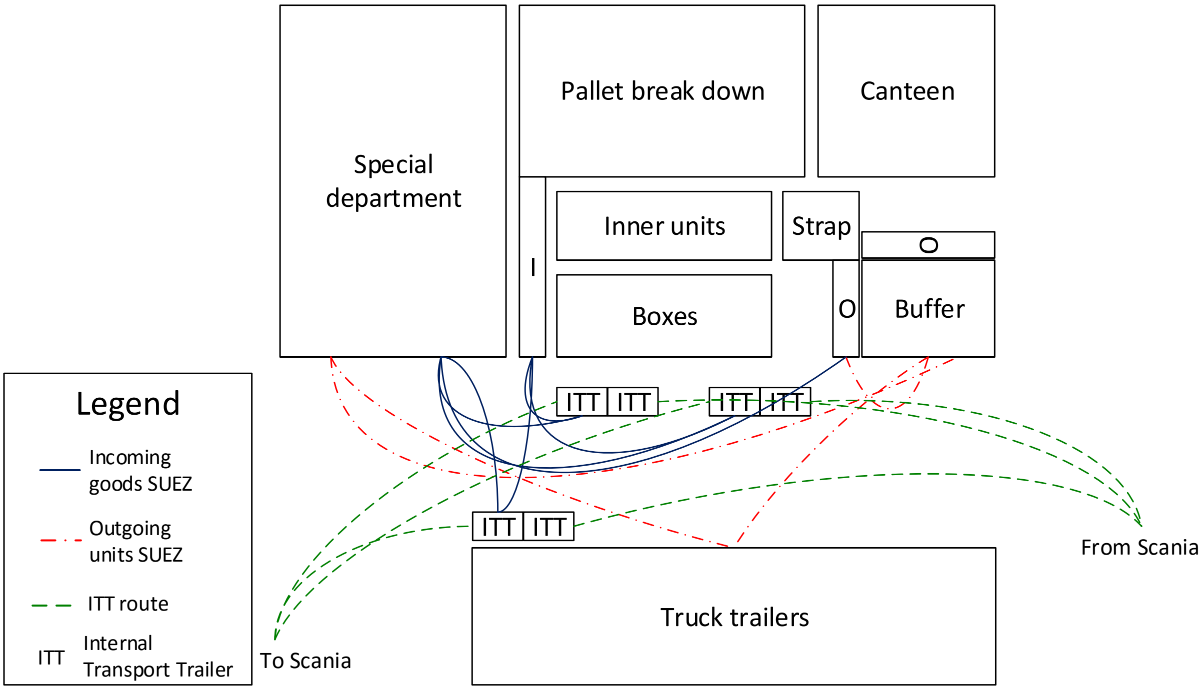


Figure 2.5 Traffic on SUEZ transshipement area

2.3 Costs and benefits

With the current way of bookkeeping the costs and benefits for all activities in isolation per departments are unknown. Costs and incomes for all activities in Zwolle are summed up in the SAP system. Therefore, it is unknown what monthly costs and benefits of the pallet break down in isolation are. As stated by the management all individual activities performed by SUEZ have to be profitable. To overcome this problem and for later in the research a spread sheet model is made of the pallet break down in which the actual costs and incomes can be calculated for the specific production rates. Moreover, changes in the process can be integrated to look whether it is financially attractive to make a specific change.

2.3.1 Costs

As mentioned in the introduction, the costs and incomes that directly contribute to the pallet break down are unknown. Additionally, some costs are made for all activities that SUEZ performs, for example company clothing, which is bought centrally, the cost of company clothing have to be divided over the percentage of workers employed at the pallet break down. At the PBD large part of all costs are personnel costs, in total 90 per cent of all costs are personnel costs. After the economic crises, SUEZ has decided that it prefers to pay more for temporary labour rather than employing cheaper personnel within its own organisation. The philosophy behind this idea is that with the fluctuating production more or less personnel can be employed quickly and without extra costs. Only the coordinator, some team leaders and a few site employees are directly employed by SUEZ. Because

SUEZ is stationed at, the Scania terrain no costs are incurred for example rent, electricity, buildings, usage of drinks and canteen. Furthermore, nearly all equipment is rented or leased. All forklift trucks, pallet stackers are leased, and when equipment is needed that is not used every day it is rented. Other equipment costs are made with repairing equipment, purchasing service contracts of machines, new forklift tires, depreciation costs and damages made to equipment. Due to the payment model SUEZ has to keep costs low to earn money, this is in contrast with for example the industrial cleaning where costs are charged to Scania.

2.3.2 Incomes

The incomes for SUEZ are easy to calculate. There is only one real source of income, and that is from Scania. SUEZ is paid per unit loaded into a trailer; the fee per unit is based on the average day production of trucks over a week. Therefore, the income does not depend on the costs made, or personnel deployed at the pallet break down. The process and risk of unit counting is described in an earlier section. All errors made in the process have direct effects on the financial income.

Furthermore, a very small income (less than 0.01%) is mentioned for completeness. All euro-pallets that are non-Scania branded have to be removed from the packaging pool of Scania. Because there is, a deposit on these pallets SUEZ can hand in these pallets for the fee.

2.3.3 Incomes during overtime

When Scania decide to go in overtime with the production, the pallet break down stays operational during overtime. All incoming materials have to be processed directly, no inventory may be built-up, and therefore the pallet break down remains operational. Because labour costs in overtime increase to 130% of the hourly wages, the unit price is increased by the same percentage. The estimation how many units are made in overtime that day are simply calculated with the following formula:

$$Estimated\ units\ made\ in\ over\ time = \frac{over\ time}{total\ working\ time} \cdot total\ units$$

2.3.4 Gross profit

The monthly gross profit is easy to calculate as the total income minus the total costs that month. For the yearly gross profit there are roughly eleven months with production and one month with no production, 4 weeks during the summer and 1 week during Christmas. For all assumptions and calculations during this research, the ratio of 11 months and 1 month of fixed costs is used. All overhead costs are taken into account in the gross profit margin.

2.3.5 Financial balance model

To gain insight in the costs and incomes for the pallet break down, we made a financial analysis on the costs and incomes at the pallet break down. Until now, SUEZ only made a financial analysis for all activities together, does not know how what the pallet break down really costs, and yields. Certainly not what the result are of different tact times at Scania. To gain that insight in the real costs and benefits on different production schedules a model has been made in Excel, which evaluates all different tact times that are feasible with the production plant of Scania. To do this, VBA runs the model on all given production rates, and makes a graph of the data. On the Pollux and Castor line together 200 trucks per day could theoretically be made, plus some Knock Down (KD) production, which is estimated at a maximum of 20 trucks. At KD, trucks are not completely assembled final truck assembly is done at the end customer. Therefore, the model should be able to calculate all costs and incomes in a range of 0 until 220 trucks; the unit fee is differentiated in steps of 10 trucks. Assuming that there are 11 months of production every year and one month no production, the yearly costs and incomes can then be calculated.

Incomes

Calculating income in the model is easy; there is an almost linear relationship between the number of trucks produced and the number of units produced (R^2 = 0.84), this is tested for a weekly truck production range of 500 to 950 trucks per week. The full analysis can be found in Appendix: G. The relationship is easy to calculate with the following formula:

$$number\ of\ units\ created = number\ of\ trucks\ produced \cdot 8.63$$

The fee paid for a unit depends on the tact time this is included in the model in order to automatically select the correct fee for a certain tact. Because the fee is not fully given for all production rates, historical prices are used to make up a complete range. This is mostly for the production rate below 130 trucks per day. The income of units made in overtime is calculated with the formula that is given in 2.3.3. For completeness, the income of non-Scania pallets is to be taken into account.

Costs

For the costs, 90 per cent of the costs are labour costs. The personnel that has been employed directly is easy to calculate; take the gross income and multiply this by 130% to determine the real costs for SUEZ. Temporary labour is production dependent. We continued to make a linear regression to estimate the correlation given the planned truck production amount of needed labour. Assumption that there is correlation between planned truck production and hours of temporary labour is supported by the statistical test, a R^2 of 0.89 that confirms a strong relationship between the variables. The full analysis can be found in Appendix: F.

For all other costs made at the pallet break down, the SAP output is used of the SUEZ site in Zwolle. Costs are split between pallet break down and other departments. Shared costs are shared by a percentage for which it could be related to the pallet break down costs. For maintenance and planned repairs like forklift trucks a general maintenance schedule is followed that SUEZ uses. All other costs used from SAP are split between fixed and production dependent costs. The production dependent costs are made in such a way that they depend on production rates in the model.

Controls

To make the model more flexible. Controls have been included which can be used in a further state for what-if analyses. For example, what if we extend the total hours per week that will be worked. Although it is not part of the research, if production rates will increase to over 200 trucks per day, Scania would only be able to do this by increasing the working hours per week. Moreover, controls that are more realistic can be used, this year the premium paid per unit has decreased. What would happen if Scania decreases the fee again?

Limitations

There are also some limitations and assumptions in the model. All fixed costs are spread out evenly over the months. During the holiday break no temporary labour is present, although at some days a small group is present. Operational costs, which are made at the head office, are not included in the model, for example insurance costs, IT costs or back office costs.

Results

As can be seen in Figure 2.6 the results are surprising. The blue line represents the gross profit per month in Euros, given a certain truck production (left vertical axis). The red line represents the profit percentage (right vertical axis). As can be seen the gross profit percentage is about 10 per cent of the turnover. The production between 0 and 130 trucks should be considered as an estimated profit, because there is no actual or reliable data available. Moreover, the fee paid is not defined in the contract.

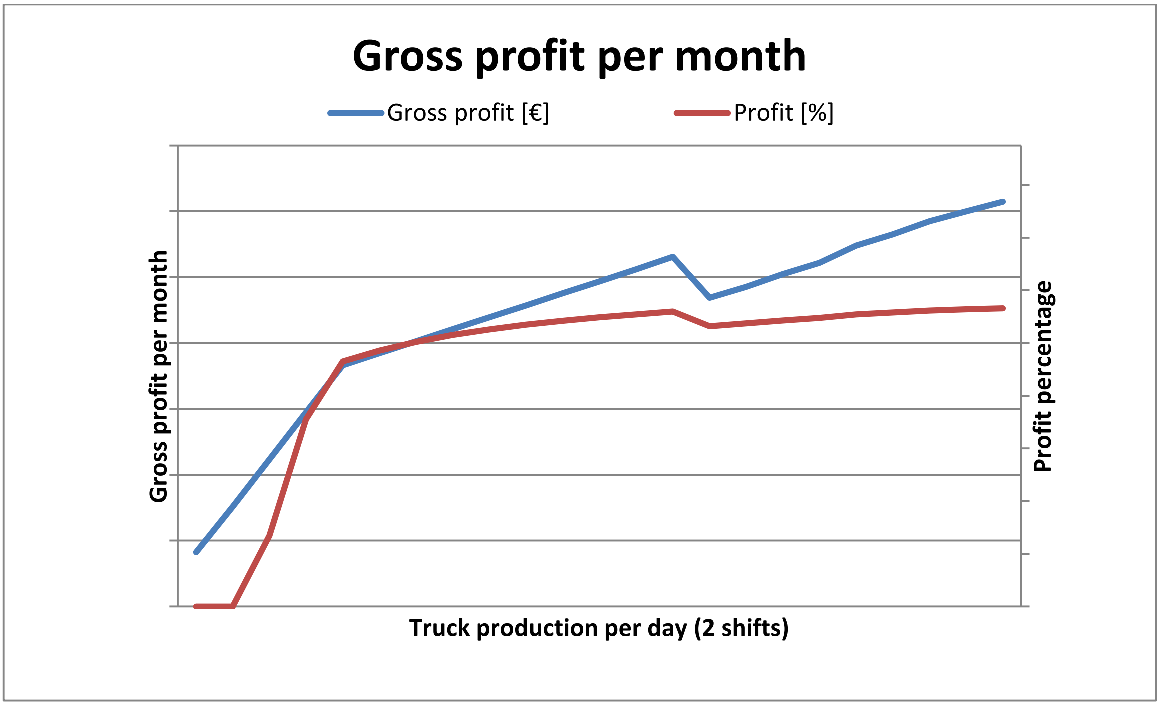


Figure 2.6 Gross profit pallet break down

To clarify Figure 2.6, we have enlarged the gross profit in Figure 2.7. The enlarged region is around the current production rate of 150 trucks, SUEZ makes with this production rate a gross profit of less than 10%.

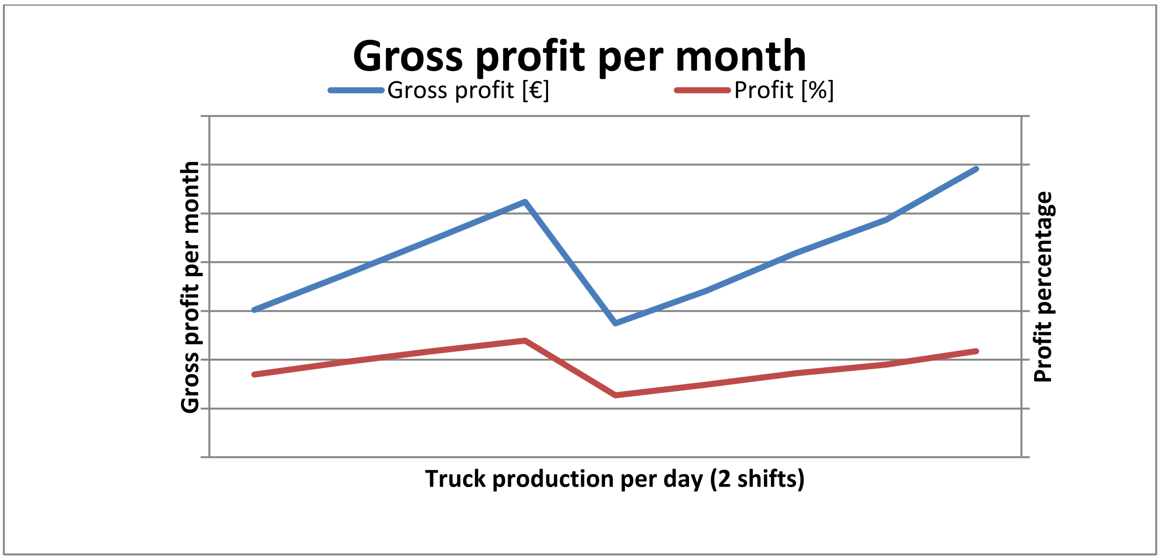


Figure 2.7 Enlargement of monthly gross profit (of Figure 2.6)

2.4 SUEZ Angers

In the scope and limitations is mentioned that the SUEZ location in Angers is not part of the research. Although for comparison and to relate the performance in Zwolle, a visit was made to SUEZ and Scania Angers in France. After research in Zwolle is completed, a visit was made by us accompanied by the department Packaging Supply (OIP) of Zwolle.

2.4.1 Impression of Angers

During the visit, it became clear that there are many similarities, but also many differences in the process. This is strange for some processes because Scania expects the same result. In line with the philosophy that there can be only one way to run the process; the best of the two ways, an extra look has to be taken to see where the difference comes from. Both departments of SUEZ work autonomously, both locations are the only SUEZ location in their country occupied with 'pallet break down' activities. Looking at the processes in Zwolle and Angers, the truck production rate per day is different, in the comparison the first half year of 2015 is taken, in Zwolle per day on average 73 trucks are made (146 trucks in two shifts, so $\frac{146}{2} = 73$ in 8 hours) and in Angers 45 trucks are made (only one shift per day).

At the first impression, in Angers, due to lower truck production rate, there seems to be a calmer environment for both SUEZ and Scania compared to Zwolle. Moreover, there is much more the mind-set 'follow the rules' and discipline. The working conditions for SUEZ employees and temporary labour are better in Angers, almost everything is indoor, clean and tidy and a good climate to work in. Supplied materials are delivered as expected by the Scania internal rules.

In Angers, the layout of the SUEZ site is organised more efficiently. The area used by SUEZ is not used by other vehicles or activities. In Angers, the different movements of materials are less frequently crossing each other, in other words, ingoing and outgoing flow are more separated. Another advantage is that Angers only has one truck loading destination and not seven different destinations as in Zwolle. The latter causes many simultaneous loading of trucks, possible mistakes of loading in the wrong trailer.

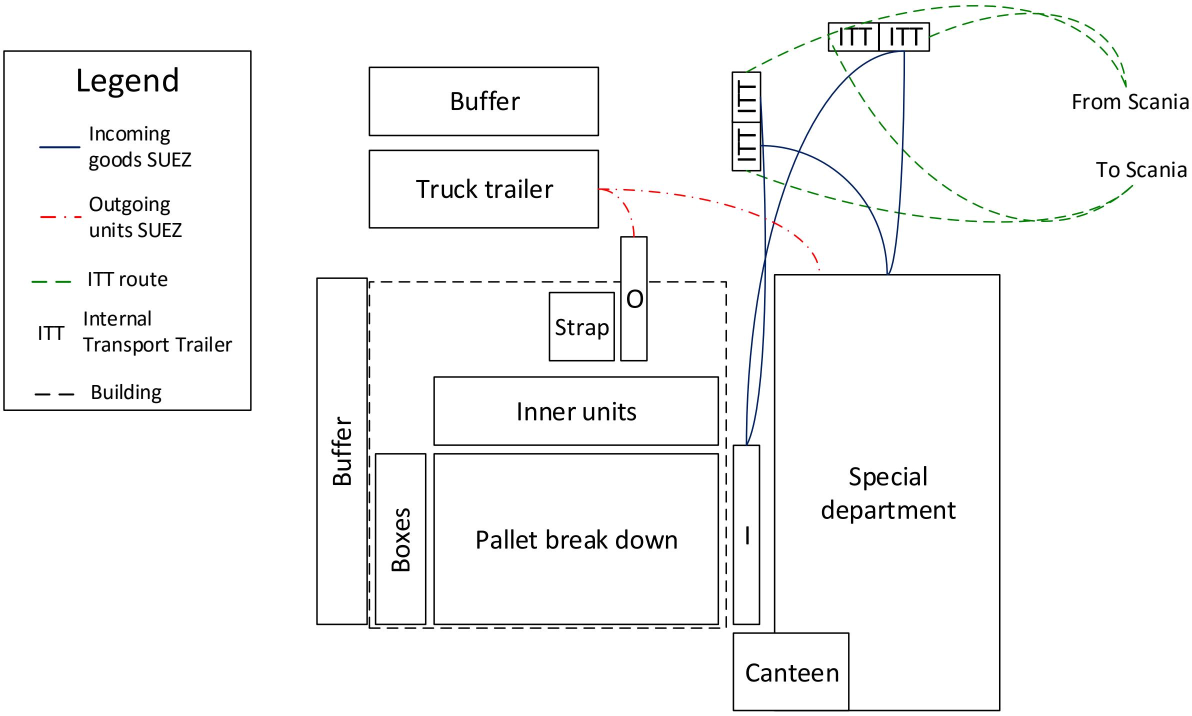


Figure 2.8 SUEZ layout in Angers

In the picture above, the layout of Angers. As can be seen, in the upper left corner the truck is loaded, in the upper right corner, the internal transport trailers are emptied. Down left the pallet break down is positioned, together with the box processing and downright the special department.

2.4.2 Unit repairs and scrap

Some large differences are the number of repairs, in Zwolle this is 10% and in Angers only 6%. A larger difference can be found for scrapped materials. In Zwolle on a yearly basis 186 tons of residual waste and 80 tons of wood is scrapped. The amount scrapped is equal to 15 units and one unit wood per 8 hours production, where this is in Angers is at most one complete unit of waste per day.

Looking at the productivity per employee (units created per employee), and then in Angers employees are more efficient. However, if you correct the efficiency by including the units for repair and scrape, the employees in Zwolle are more efficient.

2.4.3 Units

At high level, both pallet break down receive per truck build an equal amount of units, 9.4 units per truck in Angers, and 9.5 units per truck in Zwolle. In the table below, the units created per department are listed. In the left two columns the uncorrected data, in the most two right columns two corrections are applied. First, the scrap and repairs are included, secondly because the production rates of both Scania factories are different; the volumes of Angers are linearly extrapolated to those of Zwolle.

Department	Uncorrected		Corrected		Difference after correction
	Zwolle	Angers	Zwolle	Angers	
E/H materials	145	109	170	184	9%
Special department	200	161	249	271	9%
Inner units	109	74	124	125	1%
Boxes	129	52	142	87	63%
Wood	6	5	8	8	7%

Table 2.1 Comparison between units per department Zwolle and Angers

On all departments, except the boxes department, there is no difference in units, and thus work. Only the number of boxes is 63% higher in Zwolle than in Angers, which cannot not be explained directly.

2.4.4 Other differences

The contract between Scania and both SUEZ's are equal. However, there are differences between Zwolle and Angers are the scope of the daily work. Some differences are:

- In Angers, SUEZ has worked out all activities and processes on paper, with warnings, advices and descriptions. In Zwolle, the work is not completely recorded on paper.
- In Zwolle, SUEZ carries out the transport of boxes from the factory, although it is a Scania task;
- SUEZ Zwolle receives much more truck parts than Angers;
- In Zwolle wooden spacers are collected in the factory by Scania, the crate is then sent 'incognito' to SUEZ and disturbs the process, because it cannot be disassembled on the conveyor system;
- Parts found at the pallet break down in Zwolle are returned by SUEZ at least twice a day, often more frequently;
- In Zwolle the amount of applied labels, papers on crates is much larger, in Angers the Scania guidelines are followed, which state one label per crate.

Lastly, the exact definition of a clean plastic box is not defined. On request by Scania Logistics, the plastic boxes are cleaned with a towel, to attain a high standard. This is to pack boxes with air valves, which cannot be stored in a box with dust. In Angers, none of the boxes are cleaned with a towel.

In Zwolle, 5 forklift trucks are used and in Angers 4. At first sight, this seems strange, because the quantity of flow in Zwolle is much larger, and the forklift trucks in Angers have less distortion compared to Zwolle. The number of units to move has less influence on the number of forklift trucks that are required. Better parameters to explain the number of forklift trucks are distance to travel, and average speed. Compared to Angers, in Zwolle due to extra activities and the layout of the pallet break down, forklift trucks have to travel longer distances. Furthermore, the average speed is lower due to all the crossing traffic and congestion in front of the pallet break down.

Summarising the differences, in Zwolle many extra work is done in favour of Scania. For which no extra budget or payment is made. All the mentioned differences cause SUEZ Zwolle to decrease the efficiency per employee.

2.5 Conclusion

The instincts off SUEZ' management are right. SUEZ performs many activities, which are mostly added over time to the portfolio. In the current situation, many activities are not organised in an optimal way, and can therefore be improved. Although the financials indicate that there is no problem, the operations have to be improved to secure operations. The pallet break down does not cost money, but does also not result in a moneymaking business. Improving the pallet break down can be done for two reasons:

- Scania demands a continuous improvement from its contractors;
- For contract renewals, showing realised improvements can put SUEZ in an advantageous position compared to other contractors, because they can show their commitment to continuous improvement.

These two reasons aide in the long term, operational improvements will reduce costs and postpone the moments that due to higher production rates new investments have to be made. By improving, the current situation capacity expansions can be realised without the investments in new machines and will realise a significantly higher utilisation and capacity as well as a decrease in throughput time (Tan, Mohd-Lair, Nai-Vun, & Chau-Leong, 2013). Furthermore, we recommend using other internal KPIs to be measured and evaluated to trigger improvements.

Strategic KPIs need to be introduced and measured by SUEZ. Own KPIs are needed to control the business and are required to check whether changes improve business.

A possible hazard in the current process occurs in the current way of counting units. There is no certainty that the unit counting is performed correctly. This is very important because the incomes directly depends on the counting process.

We recommend to Scania and SUEZ to work out a way to improve the arrival flow of materials in order for it to be more constant. The variation in material arrival only causes difficulties and troubles.

The most inspiring realisation from the visit to Angers is that there is extra work being done in Zwolle, which is not separately paid or included in the price. SUEZ Zwolle can learn from Angers how to record the processes, and how to look at their standards of work that they deliver. SUEZ Zwolle can also use the information and way of working to convince Scania Zwolle that Scania' requested quality and standard of work is different. SUEZ can benefit from the following changes at Scania, for example:

- Decrease the amount of labels on crates;
- Reduce the cleaning standard of blue boxes;
- Mark the boxes full of wood;
- Reduce the number of truck parts that arrive at SUEZ.

SUEZ can cut production costs which will benefit Scania in the future. Over the last years, the plastic boxes have increased significantly in volume and the model of pricing units dates from several years ago. We recommend reconsidering the pricing model. In addition, SUEZ can reconsidered whether these labour intensive items can be priced appropriately to the required extra labour and activities that are necessary for this operation.

Maybe the most surprising outcome was the amount of scrap materials. At Scania Zwolle an average of 32 units of materials are scrapped every day. This is almost 8,000 units per year for which SUEZ is not paid. Moreover, the amount of damaged materials have to be reduced. Damaged materials causes a loss of productivity.

3 Literature review

To continue the research, first a direction of the research must be chosen. With the help of possible frameworks, we review what kind of problem occurs at the pallet break down, and the chosen direction is to perform a literature review. The founded literature is applied further in the research to solve the problem in this research.

3.1 Theoretical framework

As a foundation for possible improvements on the shop floor of the pallet breakdown, a theoretical framework is followed. All improvements have to fit within the scope mentioned in paragraph 1.7.5. Firstly, it is necessary to determine what kind of problem occurs at the pallet break down; it could be a logistic problem or a layout and flow problem. For a layout of logistics problem, several frameworks are available in literature.

For a logistics problem, a possible framework that could be used is Taylor's framework. The framework of Taylor consists out of 5 steps (Taylor & Taylor, 1997):

- Situation analysis;
- Identification of main issues and problems;
- Generation and evaluation of alternative solutions;
- Recommended solution and justification;
- Implementation;

In the first step, the primary focus is on the performance of the current state, compared to other supply chains and individual logistics. The second step identifies problem, categorises and ranks the problem in order of impact. For the generation of alternative solutions a funnel technique is used. Create many ideas and distillate the promising ideas. In step four, the solution is proposed and justified and in the final step, an implementation report is created. A complete overview of the framework is given in Figure 3.1.

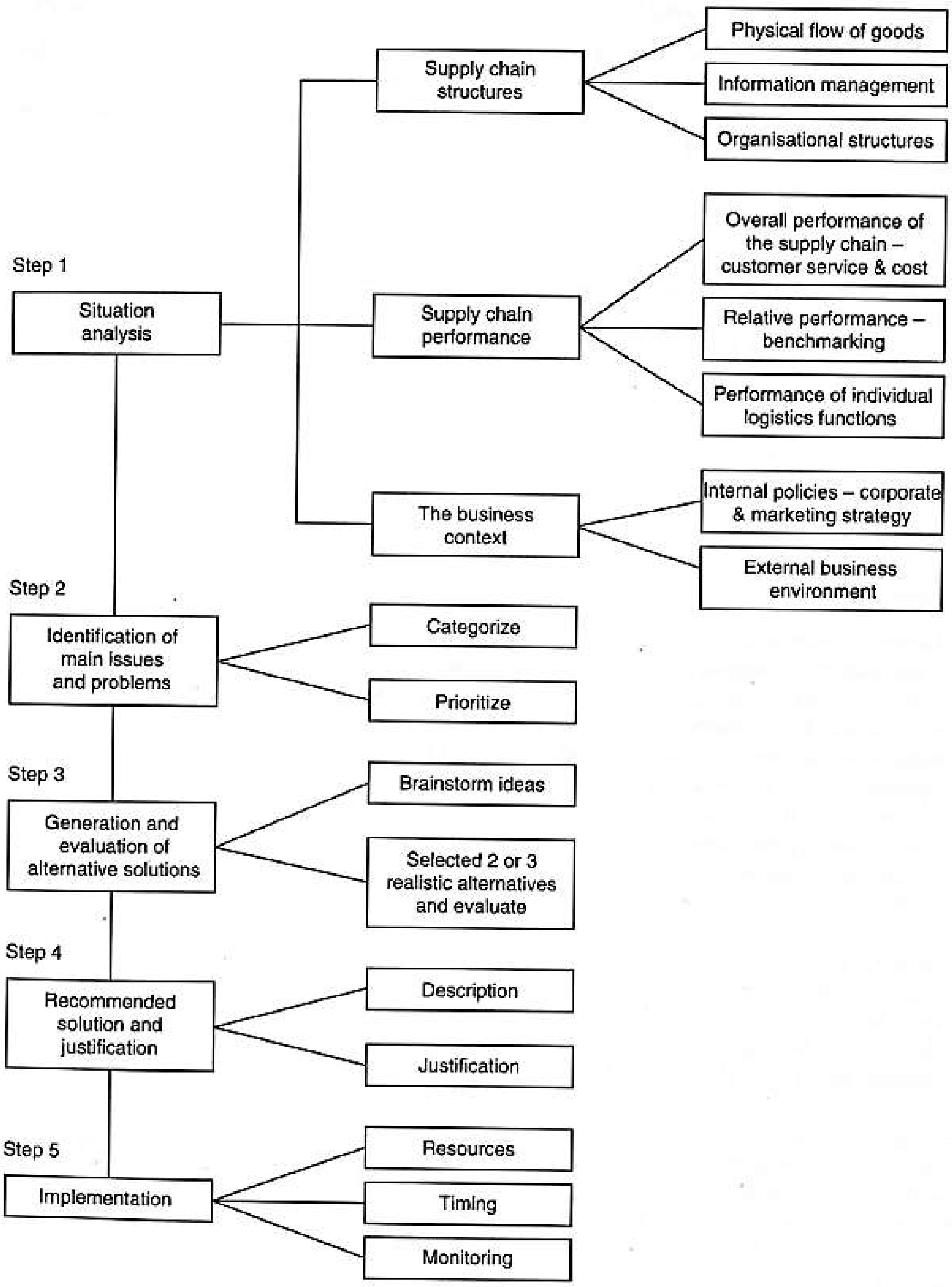


Figure 3.1 Framework of Taylor (Taylor & Taylor, 1997).

In a layout problem, Systematic Layout Planning, in short SLP, from Muther (Muther, 1973). Can be used as a framework. This framework is widely known and used for all kinds of layout problems. It is quite simple to use according to (Tompkins, White, Bozer, & Tanchco, 2010). The first three steps focus on material flows, activities and in step three a relationship diagram. Steps 4 and 5 focuses on the space that is required and available for the departments. These steps are part of the analysis phase, in the next phase, we will search for alternatives. In step 6, a relation is made between the material flows, activities and space, namely the space relationship diagram. Steps 7 is about modifying considerations and in step 8 the limitations are taken into account. Which all results in a set of alternative layouts, in step 9 an alternative is selected. In the third and final phase, which is the selection there is only an evaluation step. SLP demands for the use of the framework to make use of your intuition, judgement and experience (Tompkins, White, Bozer, & Tanchco, 2010). In Figure 3.2 an overview is given of SLP, where the phases and steps are graphically shown.

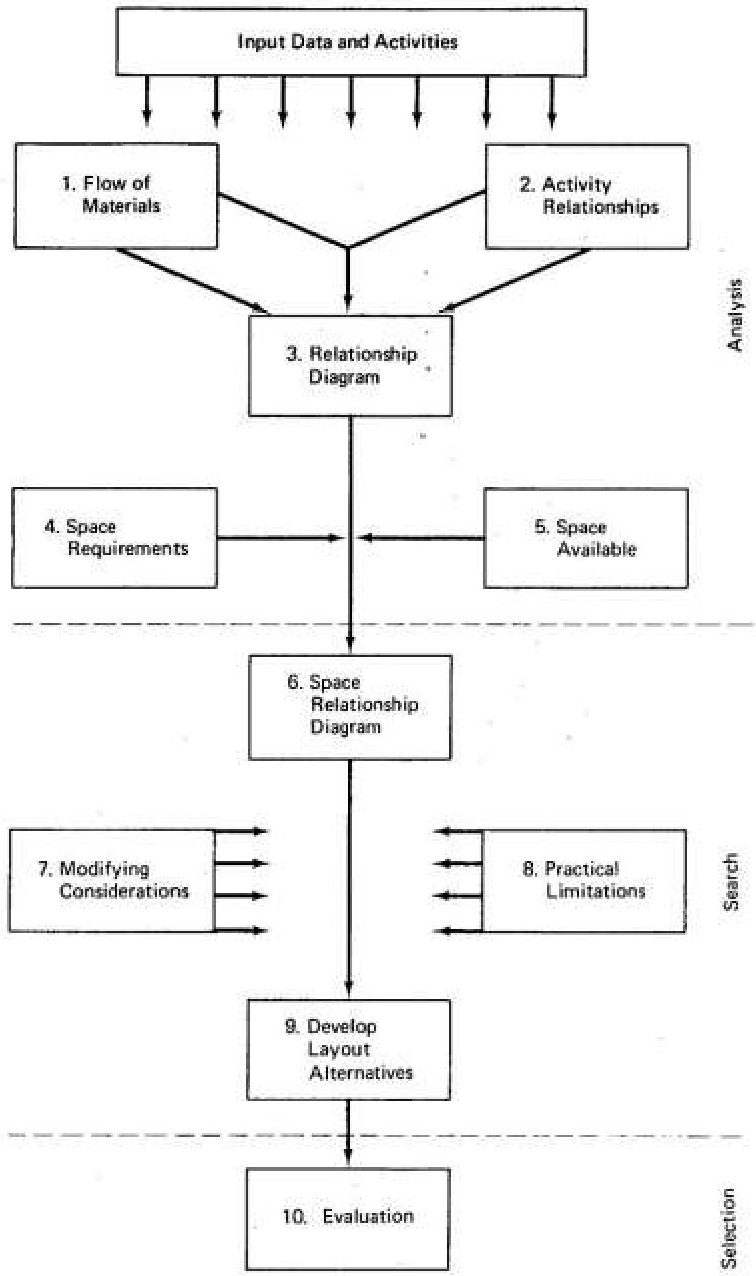


Figure 3.2 Systematic Layout Planning overview (Tompkins, White, Bozer, & Tanchco, 2010)

In both frameworks, the major steps are similar: analysis phase, develop alternatives solutions and evaluation phase. Taylor advices to use his framework only for (real) logistics of supply chain problems (Taylor & Taylor, 1997). The problems that occur at the pallet break down have impact on logistics but their root causes are the bad layout. Improving the layout will also improve the logistical process at the pallet break down. In the framework of Taylor, the focus is mainly on (output) performance, to deal with other issues like ergonomics, the framework is less suitable. After comparing both frameworks and the root cause of the problem, SLP is the most suitable framework for this problem. Therefore, the literature review is continued about the facility layout problem, where SLP provides the framework.

3.2 Facility layout problems (FLP)

Finding, in a systematic way, a plant layout goes back to the industrial revolution (started around 1750) (Scruabin & Vergin, 1975). The facility layout is described as an arrangement of everything needed for production of goods or delivery of services. It can be a department, a warehouse or a machine tool needed (Heragu, 2008). An exact definition does not exist due to disagreement on (Disagreement about is used on other occasions) the definition. Another definition used is that a FLP is an optimisation problem where the partition of a planar region of known dimensions into departments of known area, such that costs are minimised (Tate & Smith, 1995).

This research is about facility layout problems for location departments, similar approached are used in schools and hospitals for designing layouts. For example, the layout of computer chips for minimising required wiring (Singh & Sharma, 2006).

Before the availability of computers, industrial engineers have to rely on visual aids, as scale models, diagrams and graphs, which indicate material flow (Scruabin & Vergin, 1975). In the sixties, aid of the computer became available and new procedures of FLP where designed (Scruabin & Vergin, 1975). With help of the computer, it was possible to find automated solutions for larger and more complex problems.

FLP has significant influence on the total operating costs of a manufacturing facility, between 20 to 50% of the total costs are attributed to material handling (Tompkins, White, Bozer, & Tanchco, 2010). Effective planning could reduce the total operating costs by 10% to 30% (Tompkins, White, Bozer, & Tanchco, 2010). Although FLP and material handling costs are not related on a one to one scale, the layout efficiency is typically measured by the material handling costs (Meller & Gau, 1996). The way of measuring costs is usually the distance based or adjacencies (closeness) ratings of departments. By minimising material movement, multiple optimisation goals are reached simultaneously,

- Lower work-in-progress (WIP);
- Lower throughput times;
- Less congestion of flows.

Therefore, minimising material flow is generally used as a multi objective optimisation (Singh & Sharma, 2006). In the next paragraphs, different ways of calculating costs are explained.

3.2.1 Adjacencies based

Costs based on closeness are based whether department i and j are adjacent (Meller & Gau, 1996). x_{ij} is a Boolean variable that equals 1 if both departments are adjacent and 0 otherwise. The objective value is similar to:

$$\max \sum_{i} \sum_{j} r_{ij} \cdot x_{ij}$$

Where r_{ij} the closeness rating is (a numerical value of closeness). Although, closeness is a visual and intuitive way, solutions with similar results can have very different distances of material flow (Tompkins, White, Bozer, & Tanchco, 2010).

3.2.2 Distance based

Distance based results generally in a more robust solution. The objective of a distance-based method is to minimise the distance that material flow travels between departments. The formulation is as follows:

$$\min \sum_{i} \sum_{j} f_{ij} \cdot c_{ij} \cdot d_{ij}$$

Where f_{ij} denotes the flow between department i and j, d_{ij} is the distance between department i and j and c_{ij} the costs to move a unit of flow one distance unit from department i to department j. c_{ij} is assumed in practice to be independent and constant (linear) over distance, which may often not be the case (Tompkins, White, Bozer, & Tanchco, 2010). If c_{ij} is unknown, it is set to $c_{ij} = 1$. c_{ij} can have multiple values for different ways of transportation, and it is then used as a relative weight for travel within the facility.

Two common approximations are used in practice to determine the I/O points of departments, namely Centroid-to-Centroid (CTC) and Distance between I/O points (Meller & Gau, 1996). The CTC is often used as Centre of Gravity (COG). The CTC is useful when exact layout or positions of input and output points are unknown. This will only work well when departments have rectangular (or circular) shapes (Meller & Gau, 1996). If departments are known exactly, the input and output points are known exactly, then the real point can be used. A major drawback is that often the FLP is solved before detailed plans of departments are known.

To measure the distance between two points four measures are generally used, namely rectilinear distance (also called Manhattan distance), straight-line distance, Chebyshev distance and actual distance (Tompkins, White, Bozer, & Tanchco, 2010). Different ways of measuring distance between two points (x,y) and (a,b) are listed below, where d_{ij} is the distance from department i and j:

Rectilinear distance:

$$d_{ij} = |x - a| + |y - b|$$

Straight-line distance:

$$d_{ij} = \sqrt{(x - a)^2 + (y - b)^2}$$

Chebyshev distance:

$$d_{ij} = \max(|x - a|, |y - b|)$$

Actual distance:

$$d_{ij} = length\ of\ line\ from\ (x, y)\ to\ (a, b)$$

3.3 Department and facility characteristics

Departments are mostly simplified to simple shapes, like a rectangles, squares or circles (Chiang, 2001). There are more properties to consider for layout, for example (Chiang, 2001):

- Size, dimensions and area;
- Orientation, fixed or variable orientation can be changed of a department;
- Aspect ratio, the ratio of height and width can be fixed or variable, with a fixed ratio a department is also called rigid;
- Fixed or movable, also called static or dynamic, can a department be moved within a facility.

Some constraints to consider according to (Chiang, 2001) are:

- A facility must have an orientation and should be either fixed or movable;
- A facility must be placed within the plane;
- An aspect ratio must have a lower and upper bound;
- Overlapping is not allowed.

3.3.1 Equal and unequal area

The areas of departments are either equal or unequal. FLP with equal area departments are often simple to exchange, just by exchanging two departments, without altering other departments (Tate & Smith, 1995). The advantage of equal area departments is that there are a small finite number of possible locations within the plane. With unequal area departments, departments cannot always be exchanged without overlapping other departments. Now, the locations of departments depend on the exact configuration (Tate & Smith, 1995).

3.3.2 Continual or discrete plane

The total area available for departments is a discrete layout or continual layout problem. In the discrete layout problem the total area is divided in a rectangular grid, in each cell of the grid a department can be placed (Chwif, Barretto, & Moscato, 1998). Irregular shapes are created in a discrete plane, by assigning blocks to a department. This is done by dividing the plane in small cells; all areas are equal in shape and area (Chwif, Barretto, & Moscato, 1998). With continual planes, the number of possible locations are infinite. Continual planes are mostly used for MIP formulation where variables are continuous.

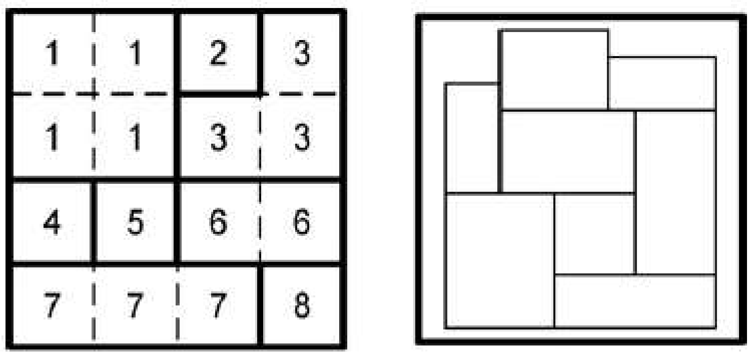


Figure 3.3 Discrete and continual layouts (Drira, Pierreval, & Hajri-Gabouj, 2007)

3.3.3 Regular or irregular shapes

Mostly departments are represented by rectangles, which makes finding a solution easier. Irregular shaped departments are not widely used in literature (McKendall, Noble, & Klein, 1999). Other irregular shapes than in the picture below are L-shaped, O-shaped or U-shaped (McKendall, Noble, & Klein, 1999). Due to irregular shapes and measuring distance from the COG, the distances can be measured wrong because the COG of an irregular shape can be lying outside the department (McKendall, Noble, & Klein, 1999).

Figure 3.4 Regular and irregular shapes (Drira, Pierreval, & Hajri-Gabouj, 2007)

3.3.4 Aspect ratio

If a department has no fixed dimensions, the aspect ratio is variable (Chiang, 2001). Then the height and width can be changed, within a lower and upper bound, the aspect ratio can be defined as follow (Chwif, Barretto, & Moscato, 1998):

$$a_i = \frac{height\ of\ facility\ i}{width\ of\ facility\ i} = \frac{h_i}{w_i}$$

For the lower and upper bound, two conditions have to be satisfied: $a_{il} \leq a_i \leq a_{iu}$ and $\frac{1}{a_{iu}} \leq a_i \leq \frac{1}{a_{il}}$.

3.4 Problem formulation

To solve the FLP several approaches and mathematical formulations are possible. The approaches and formulations that are discussed in the next sections have some general assumptions (Francis, McGinnis, & White, 1983):

1. A plane is an adequate approximation of a sphere;
2. Any point in the place can be considered as a valid location;
3. The facilities to be located may be idealised, therefore can have zero area;
4. Distance to travel between facilities between a located facility and a to be located facility can be represented by a 'planar' distance;
5. Travel costs are proportional with the distance, and travel costs are independent of the distances;
6. Fixed costs can be ignored;
7. Location models are not used for distribution problems.

As can be seen in the list some relevant practical issues are ignored. For example, an area of zero is unlikely for a department and does not provide a feasible solution. Ignoring fixed costs is no problem when the fixed costs per location do not differ much. An alternative reason to ignore fixed costs is because in the long-term, fixed costs are negligible compared to the transportation costs, and the transportation costs remain equal over time (Chwif, Barretto, & Moscato, 1998). However, in an improving approach of an existing facility, moving and construction costs are not included. Costs for changing an existing layout can have significant influences depending on the proposed changes. In practice, travel costs are not proportional with the distance that is to be travelled.

3.4.1 QAP

The Quadratic Assignment Problem (QAP) is introduced by Koopmans and Beckman (1957), to formulate the FLP problem (Koopmans & Beckman, 1957). As QAP suggests, QAP solves an assignment problem, to be precise with help of binary variables. The QAP objective can be minimising (Singh & Sharma, 2006):

- Time;
- Costs;
- Travel distance;
- Flow between departments.

QAP is only usable for discrete layouts (Drira, Pierreval, & Hajri-Gabouj, 2007). Because QAP is NP-complete (Garey & Johnson, 1979), only small instances can be solved to optimality, for large instances a heuristic is required to find a solution for the problem. The optimal solution can be found with Branch and Bound or Cutting plane algorithms.

QAP is later used a base to formulate LP and MIP problems. Montreuil formulated the FLP as a MIP problem with a distance-based objective; by using continuous variables with MIP, the layout is also in the continuous plane (Montreuil, 1990).

3.4.2 Graph-Based Method

A visual technique to generate a layout is the graph-based method. Often based on maximising the adjacency between departments (Tompkins, White, Bozer, & Tanchco, 2010). In Figure 3.5 an example, a graph G, where the solid dots represents nodes (departments), adjacency between departments is represented by a line (Foulds, 1983). By arranging the lines such that the lines are not crossing each other, nodes can be arranged such that adjacency is maximised without crossing flows. With the final layout, blocks can be drawn which represents the departments (Welgama & Gibson, 1995).

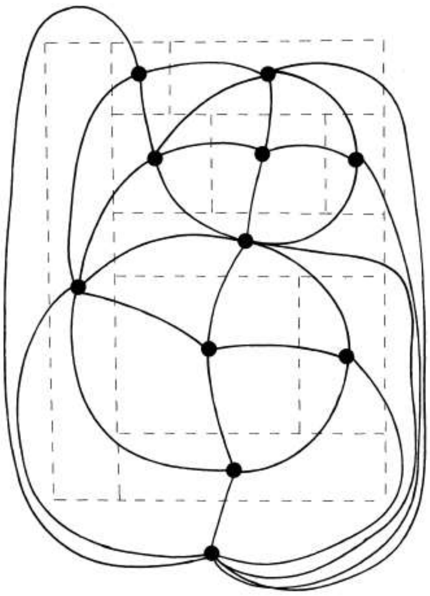


Figure 3.5 An example of a planar graph (Foulds, 1983)

3.4.3 Construction and improvement algorithms

Heuristic algorithms are divided into 2 types, namely construction and improvement algorithms. Improvement algorithms are based on an initial or existing layout in which systematically departments are exchanged and results are compared (Welgama & Gibson, 1995). An improvement algorithm makes a small change in the layout, the new situation is evaluated and the best solution is saved, this is continued until no further improvement can be made. (Kusiak & Heragu, 1987). Therefore, the initial layout has large impact on the resulting layout (Welgama & Gibson, 1995) (Kusiak & Heragu, 1987).

Improvement algorithms are often started with a random initial solution, to change and improve the initial solution (Kusiak & Heragu, 1987). A popular improvement algorithm is for example: CRAFT (Computerised Relative allocation of Facilities), published by Gordon Armour and Elwood Buffa in 1963. In essence, it calculates the initial layout costs, and starts exchanging pairs of departments until no improvements can be made (Armour & Buffa, 1963). A major downside of CRAFT is that it cannot handle unequal area departments. Hassan, Hogg and Smith stated that due to the impact of the initial layout a good initial layout should be constructed for an improvement algorithm (Hassan, Hogg, & Smith, SHAPE: A construction algorithm for area placement evaluation, 1986).

A construction algorithm starts with an empty layout, and during the procedure, departments are added systematically, until a complete layout is made (Scruabin & Vergin, 1975) (Drira, Pierreval, & Hajri-Gabouj, 2007). Construction algorithms are generally easier to apply, and historically founded earlier (Singh & Sharma, 2006).

Studies showed that constructions algorithms create less optimal solutions than improvement algorithms (Scruabin & Vergin, 1975). To overcome this, a combination of a construction and an improvement algorithm can be made; this is then called a hybrid algorithm. An example of a hybrid algorithm is a combination of branch and bound, as construction algorithm, the solution is then improved by exchanging pairwise or triple exchanges until no improvements are found (Burkard & Stratman, 1978).

3.4.4 Meta-heuristics

In this section, principles of meta-heuristics are discussed that are commonly used in the FLP. For solving larger NP-complete problems, heuristics are required to solve problems in reasonable amount of time.

Tabu Search (TS)

Tabu search is an improvement heuristic. In every iteration, TS swaps a pair of departments and evaluates the difference (Chiang, 2001). Therefore, TS is seen as a neighbourhood optimiser (Liang & Chao, 2008). TS works as follows, it starts with a feasible solution, a change is made, all solutions in the neighbour are calculated, and the best solution is chosen. To prevent that TS get stuck in a local optimum TS works with a list. Namely, the Tabu list that records founded solutions (Chiang, 2001). With the Tabu list the algorithm can go back and chose another solution, by declaring the initial way 'Tabu' (Liang & Chao, 2008).

Simulated annealing (SA)

Simulated annealing is derived from theory of statistical mechanics, and based on the annealing of metals (melting metals and controlled cooling afterwards) (Kirkpatrick, Gelatt, & Vecchi, 1983). Simulated annealing is also known as Monte Carlo Annealing (El-Gafy, Abdelhamid, & Ghanem). Simulated annealing starts as a random search and ends as a local optimization algorithm therefore SA could come up with a local solution far from the optimum (Souilah, 1993). Simulated Annealing has proved to solve a wide variety of complex problems (Sexton, Dorsey, & Johnson, 1999). In essence, SA is an improvement heuristic that starts with an initial layout, in every iteration a change is being (present continuous) made. In every iteration, a random selected department is moved to a random location in the plane. Every time a neighbour objective value is calculated and compared with the current solution, if the neighbour solution is better it will be accepted as the current solution (Souilah, 1993). To be able to escape from a local optimum, there is a probability that a worse solution is accepted, this is called the "Metropolis acceptance rule" (Souilah, 1993). The probability of accepting a non-improving solution is initially high, and decreases during time (McKendall, Shanga, & Kuppusamy, 2006). The starting temperature has significant influence on the result; the starting temperature should be such that there is a large probability that a non-improving neighbour solution is accepted (Meller & Bozer, 1996). A rule of thumb is that the start temperature has to be around $t_0 = \frac{z_0}{40}$ (Meller & Bozer, 1996). Due to the nature of SA, SA assigns blocks to random locations in the plane, which can results in block overlapping (Chwif, Barretto, & Moscato, 1998). To prevent this, a penalty function is used besides the transportation costs (Chwif, Barretto, & Moscato, 1998). The penalty is used to prevent overlapping and thus infeasible solutions (Kulturel-Konak & Konak, 2015).

Genetic Algorithm (GA)

Genetic Algorithm is growing rapidly and becomes a widely used algorithm (Singh & Sharma, 2006). GA is a global search heuristic that searches from one population of points to another (Sexton, Dorsey, & Johnson, 1999). This search is done without enumerating the entire solution space, from the initial solution; random new solutions are created (Singh & Sharma, 2006). GA can also escapes from a local optimum, by moving to random point in the solution space, this new point is called a new population (Sexton, Dorsey, & Johnson, 1999). By simultaneously searching in many locations in the solution space, finding a global optimum is more likely (Sexton, Dorsey, & Johnson, 1999). Non-promising populations will die out, and promising populations will survive (Sexton, Dorsey, & Johnson, 1999). Compared to SA and TS, GA is able to produce superior results in optimisation (Sexton, Dorsey, & Johnson, 1999). A major advantage is that GA is also able to achieve global solutions for difficult non-linear problems (Sexton, Dorsey, & Johnson, 1999).

Hybrid algorithms

Hybrid algorithms can be found in several kinds; in this research, two common approaches are discussed of hybrid algorithms. In both approaches the known downsides of starting method is compensated to continue during the optimisation process with another method.

Most algorithms are classified to have optimal and sub optimal characteristics; a third algorithm combines the first two algorithms (Kusiak & Heragu, 1987). For example, Burkard and Stratman suggested an algorithm that uses branch and bound, to create an initial solution and an improvement algorithm (Burkard & Stratman, 1978). After a predefined time the branch and bound algorithm is stopped and continued by an improvement algorithm (Burkard & Stratman, 1978).

The second approach uses Tabu Search and Simulated Annealing; both heuristics are good in finding an optimum, much faster than Genetic Algorithm (Lee & Lee, 2002). GA is more powerful in finding a global optimal solution, but requires more time to find a starting solution (Lee & Lee, 2002). By combining both heuristics, better solutions are reachable in less time, only a predefined number of iterations is (a number is singular needed to change from TS and SA to GA (Lee & Lee, 2002).

Fuzzy logic

Fuzzy logic is based on decision making on imprecise, incomplete, vague or qualitative data (Taylor G. D., 2007) (Evans, Wilhelm, & Karawowski, 1987). In other words, when data is absence, not accurate or not quantifiable fuzzy logic can be applied. Fuzzy can be used instead of QAP, if the input data is difficult to quantify (Evans, Wilhelm, & Karawowski, 1987). In Boolean logic a variable is true or false (1 or 0), in fuzzy the variable is a real number on the interval [0, 1] (Deb & Bhattacharyya, 2004), for example a variable can have the value 1/3. Linguistic variables are used for complex systems to characterise variables, like low, medium, high, very high (Deb & Bhattacharyya, 2004). A common case of vague data is the Activity Relationship diagram, which uses qualitative data, for example, there is no hard distinction between essential and important. At high level, a fuzzy decision-making system (FDMS) has four components (Deb & Bhattacharyya, 2004):

1. Fuzzification, input and output variables are converted to linguistic variables;
2. Knowledge base; membership relations are stored in this block;
3. Decisions rules, the Boolean operators are converted to fuzzy operators, most rules are in the form IF-THEN;
4. Defuzzification, the fuzzy output values are converted back to real (non-fuzzy) values.

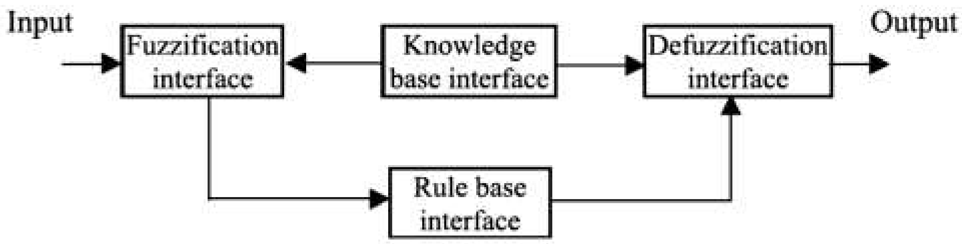


Figure 3.6 Fuzzy system (Deb & Bhattacharyya, 2004)

3.5 Choice of solution

Now that the literature review for this research is conducted, it is applied to our research. First, the direction and assumptions for the research is chosen. Although the problem size is not too large for an exact method, a heuristic is chosen to find alternative solutions. In this way, in little time solutions can be found that are reasonably good. The departments at the pallet break down are unequal area departments and have irregular shapes. The irregular shapes are solved by dividing departments into smaller blocks. For example, the pallet break down is a large U-shape, but can be modelled as three separate rectangular blocks with different sizes. In our research, we use fixed dimensions of departments, so the aspect ratio can be neglected. Because departments are moved, the current I/O points can be changed. Therefore, in the model the COG of departments is used to determine the distance between department flows. As method of measuring distance the rectilinear distance is used. Due to the availability of research, Tabu search and Simulated annealing are more documented than Genetic algorithm and Fuzzy logic, a choice is made between the first two. For the unequal areas, TS is less suitable than for example SA. The plane, in our case the hall is modelled as a discrete plane, divided in square meters. Because SA randomly places departments in the plane, a penalty function is needed to prevent SA to find optimal solutions where large overlaps occurs. Due to possible changes, a complete new layout can be required. Therefore, a construction algorithm is used. The algorithm can be compared with the existing layout whether the algorithm can find solutions at least as good as the current solution.

3.6 Approach for our research

The applied simulated annealing heuristic is a construction algorithm. We have written in Excel VBA the heuristic and a program, primarily to draw results graphically in a spreadsheet, and easy input of flow and department area. At the initialisation, all departments are initialised at the origin of the hall. In other words, all departments are overlapping each other. In terms of transportation costs, this is the best feasible solution. All COG are positioned on each other, thus there is no transportation costs between departments. The SA algorithms works with making incremental changes. The changes made consist out selecting a random department and selected a random new coordinate for the department. This change is then evaluated and compared with the previous layout costs, an improvement is accepted and a worse solution is accepted with a decreasing probability over the run time of the algorithm.

After the last iteration of SA, the best-founded layout is drawn graphically in a worksheet together with the settings, parameters and results.

3.6.1 Future layouts

It is possible that in the near future a department is outsourced. In the settings for the heuristic, it has to be flexible to take out a department by changing or removing the material flow and remove the required area for the department.

3.6.2 Acceptance probability of a solution

The probability whether a solution is accepted depends on the objective value that is calculated for the neighbour solution. When a solution is better than the current solution it will be accepted definitely. A neighbour solution, which is worse than the current solution, is accepted with a probability. During the run time of the heuristic the acceptance probability decreases. In other words, at the beginning a worse solution will be accepted more likely than after many iterations. This is accomplished by taking the negative difference between the solutions divided by the current temperature value, and take the natural exponential of that number. This number should be smaller than a uniform random value between 0 and 1, then the solution is accepted, otherwise the solution is rejected and swapped back. In formula form, the acceptance probability is given by:

$$\mathbb{P}(accept\ solution) = \begin{cases} neighbour\ solution < current\ solution\ , & 1 \\ neighbour\ solution > current\ solution, & x \sim U(0,1) < e^{\frac{current\ solution - neighbour\ solution}{current\ temperature}} \end{cases}$$

3.6.3 Calculation of objective value

The objective value is calculated by summing up all costs of the current layout. The objective value consists of the following:

- Transportation costs of the units between the departments;
- Penalty costs of overlapping departments;
- Penalty costs for departments having area outside the hall area;
- A department that requires direct connection to the I/O point, but is not located near the I/O point.

The applied penalty can be either a static penalty or a dynamic penalty. A static penalty does not change during the cooling process. The dynamic penalty is initially negligible on the objective value and the influence of the penalty increases during the cooling process. For a static penalty it is more work to find a good value that results in a good final solution. Whereas with a dynamic penalty the penalty can simply have the value $\frac{1}{current\ temperature}$.

During this research, we have used a static penalty because a usable static penalty is quickly found. Therefore, the objective function is equal to:

$$\begin{aligned} Total\ cost\ of\ solution &= transportation\ costs + hall\ overlap + department\ overlap \\ &+ No\ connection\ to\ I/O\ point \end{aligned}$$

3.6.4 Transportation costs

The transportation costs are calculated as the rectilinear based distance function. This is simply summing the absolute difference between the centres of gravity of two departments in X and Y direction in a 2D plane. The centre of gravity is the midpoint of two diagonal lines that are connected in the corners of a rectangle. This distance is multiplied with the flow between the departments i and j multiplied by the transportation costs between the departments i and j.

$$Transportation\ costs = d_{ij} \cdot f_{ij} \cdot c_{ij}$$

$$d_{ij} = |X_i - X_j| + |Y_i - Y_j|$$

Were

(X_i, Y_i) and (X_j, Y_j) represent the coordinates of the centre of gravity of department i and j.

d_{ij} The distance between two centres of gravity of department i and j.

f_{ij} The flow from department i to department j.

c_{ij} The cost to transport 1 unit for 1 metre from department i to department j.

3.6.5 Hall overlap and department overlap

Both functions are almost equal, where department overlap is between two departments and hall overlap between overlap of a department outside the hall. The overlap is calculated as the cross section of two rectangles (departments). The overlap costs are then calculated as the overlap is multiplied by the penalty for overlap per m².

$$Overlap = \max(0, min\ XA2, XB2 - max\ XA1, XB1) \cdot \max(0, \min YA2, YB2 - \max YA1, YB1)$$

$$Overlap = \max(0, min\{XA2, XB2\} - max\ \{XA1, XB1\}) \cdot \max(0, \min\{YA2, YB2\} - \max\{YA1, YB1\})$$

$$Overlap\ costs = overlap\ [m^2] * penalty\ for\ overlap\ [per\ m^2]$$

Where

A and B are two different departments.

X1, Y1 are the left down coordinates of a department.

X2, Y2 are the right upper coordinates of a department.

Graphically the overall of two departments can be illustrated like the following picture:

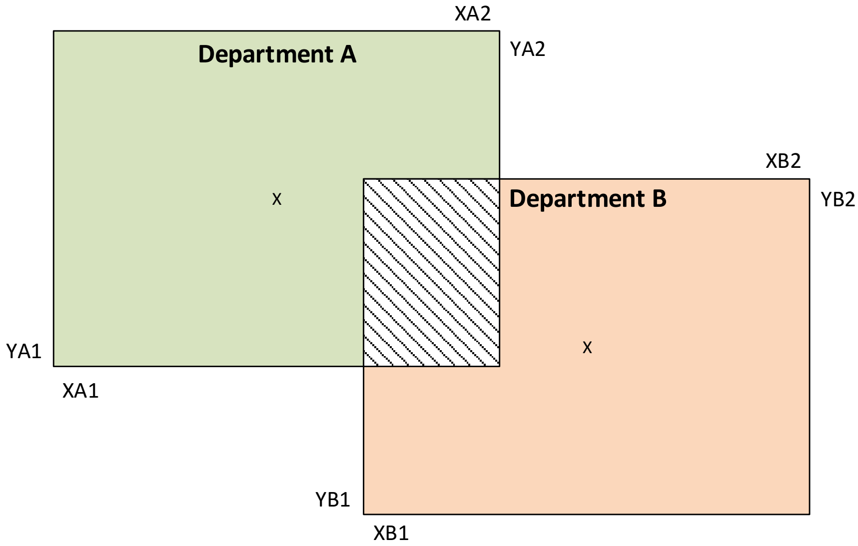


Figure 3.7 Overlapping departments

Where the dashed area represents the overlap.

For the overlap of the hall and a department, a minor change is made. Here the overlap is the area of a department that does not overlap the hall. In the picture below this is shown as follows. The penalty must be applied to the area of department B that does not overlap the hall. This represents the dashed area.

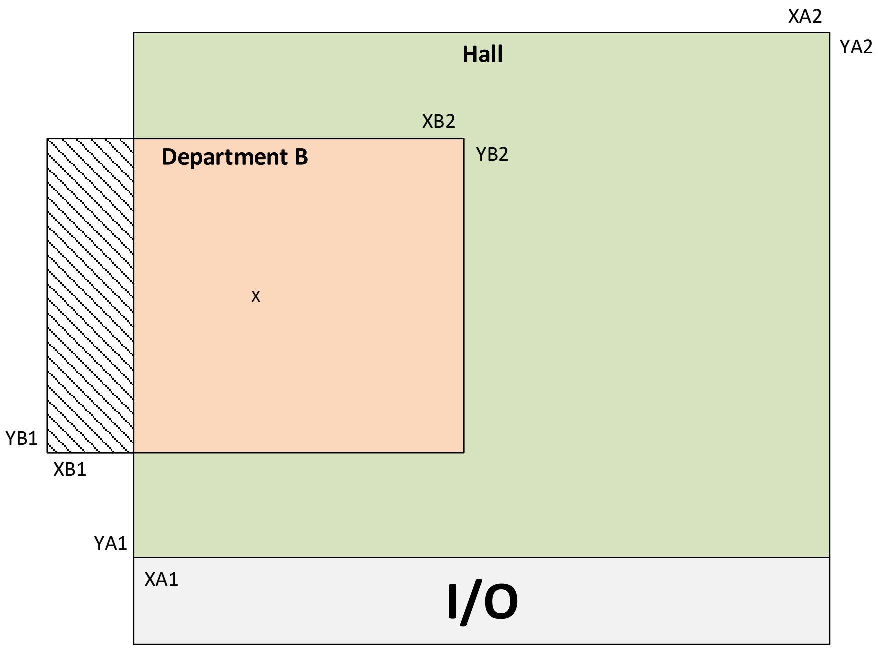


Figure 3.8 Department overlapping outside of the hall

3.6.6 No connection to or from I/O to department

To stimulate the heuristic explicitly, to place departments that require to be connected to the I/O point a penalty is given when a department is placed not near the I/O side of the hall. Although a better layout can be found by placing a department far away in practice this situation is unwanted. Due to regulations for safety forklift trucks are not allowed to drive (far) in the hall. Therefore, a penalty is applied in the heuristic when a department is placed at an unrealistic place.

The penalty is determined for departments that have flow from or towards the I/O point. A penalty is applied when the centre of gravity is further away from the I/O point than the half height of the department. Otherwise, no penalty is applied.

$$Distance\ penalty\ from\ I/O\ point = \begin{cases} COG_i - \frac{Y_i}{2} > 0, & COG_i - \frac{Y_i}{2} \cdot penalty \\ COG_i - \frac{Y_i}{2} < 0, & 0 \end{cases}$$

Where

COG_i Centre Of Gravity of department i.

Y_i is the height of department i.

In the picture below an example is given. The assumption is that both department A and B should be connected to the I/O plane. Because the rectilinear distance is taken from the Centre Of Gravity, all distances are calculated from the COG. In the picture below, department A is placed too far away from the I/O point (in vertical direction), the location of the COG is placed further away than half of the department height from the I/O plane. Whereas department B is placed correctly. In this example, the location of department A is penalised.

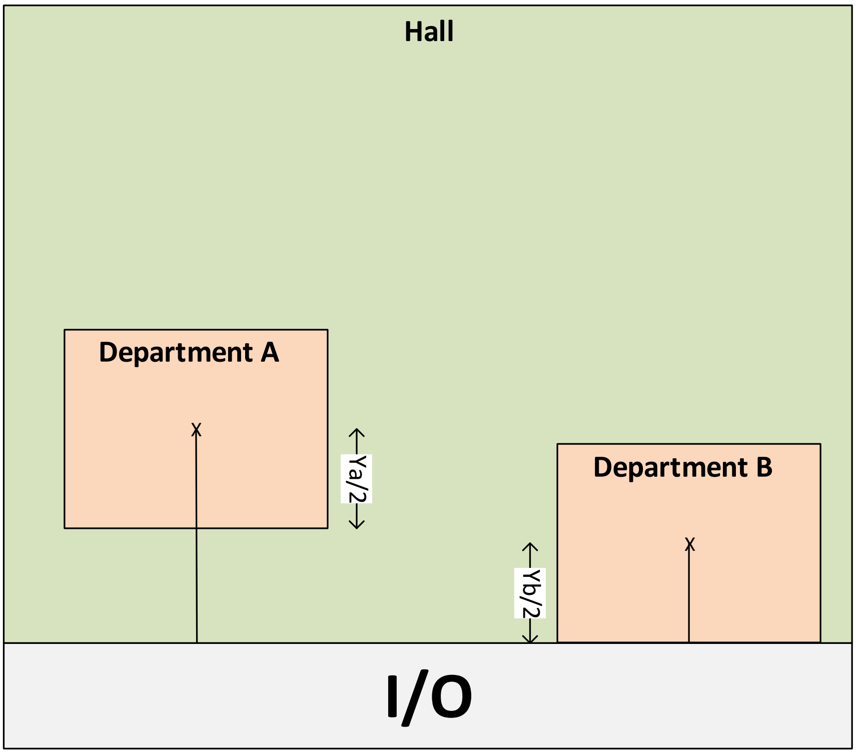


Figure 3.9 Department A placed too far from I/O

In Appendix: H, the constructed pseudo code that is used during the research can be found.

3.6.7 Reusability

For usage of heuristic in the future, we have made the heuristic such that changes in flow and dimensions can easily be done by the user. Furthermore, all simulated annealing settings can be adjusted by the user. The program that runs the heuristic automatically draws a graphical layout of the founded layout at the end of all calculations. To start the heuristic a simple click on the start button is required.

3.6.8 Multiple runs

To ensure that our construction heuristic finds a good solution the heuristic is executed multiple times. In every run, the seed value for random numbers is increased. This results in every run different steps and thus different results. This will prevent that a solution in a local optimum is found. After all runs the user selects the most promising solution to use.

3.7 Conclusion

At the start of this research, we determined what kind of problem occurred at the pallet break down. One of these problems is a layout problem. For this reason, SLP is a suitable framework for this research. A literature review was conducted on relevant literature on the facilities layout problem. Moreover, the reviewed literature is used during the research within the SLP framework. With the literature, a heuristic is created to generate a layout in limited time to simulate changes in the layout of flows at the pallet break down. In the next chapter, the constructed heuristic is applied to generate alternative layouts, and deal with possible changes in the requirements of departments and thus layouts of the pallet break down.

4 Facility layout

In the previous chapters, the current situation was analysed at the pallet break down and a literature review has been conducted. As expected, the current situation is not optimal, the processes have multiple bottlenecks, and the layout or processes can be improved. The findings of chapter one are used in this chapter to set out possible improvements at the current location with the current activities by applying the literature review. The Systematic Layout Planning (SLP) framework is used to structure the search for improved situations. To generate alternative layouts we put our heuristic that we have created in chapter 3 to work. The heuristic is used to generate new layouts.

4.1 Input data and activities

The SLP framework begins with gathering input data and activities. Most of the input data and activities have already been presented in the previous chapter and are therefore not mentioned again. In the first step, the analysis, the flow of materials and relations between the activities are clarified. To give insight, which actions and handlings are performed, within the departments, in Appendix: D, flow charts depict these activities and show the decisions that are made in de departments.

4.1.1 Types of layout per department present

Apart from the Special department, all production departments have a product layout. Materials flow through the departments, in a specific path from one workstation to the next workstation. Only at the pallet break down, strapping and the inner units departments, a conveyor system is used for the transportation of materials. At the box processing, the flow is also predefined but there are no transportation systems for individual parts. A worker moves processed units to the pickup point with a pallet jack. Special departments have a layout that can be compared with a fixed product layout. A special is lifted and disassembled by hand; there is no real movement of the product through the department. The removed parts are sorted by the worker by taking it from for example the crate and place it at the appropriate place.

Department	Type of layout
Pallet break down	Product layout (flow shop)
Inner units	Product layout (flow shop)
Box processing	Product layout (flow shop)
Special department	Fixed product layout
Strapping machine	Product layout (flow shop)

Table 4.1 Department layout types

4.1.2 Step 1: flow of materials

SLP starts with the flow of materials between the departments. In the table below an overview is given of the units that are transported between the departments. Because real units do not arrive at the receiving area, the crates, pallets and boxes that arrive are taken into account as units by calculating the future amount of resulting units. There is no backtrack in the material flow, materials are only moving ‘forward’ to the next department. Due to this choice, units that are not strapped (well) are moved to the Special department instead of the shipping area. This is a large travel distance, just for rework and adds no value to the product. Therefore, rework have to be eliminated in a future state. Furthermore, there is a small flow from the Receiving to the inner units; this flow will be ignored because it does not concern a final product, just transportation material.

		To						
		Receiving	Pallet break down	Inner units	boxes	Strapping machine	Special department	Shipping
From	Receiving	-	300	0	270	0	600	0
	Pallet break down	0	-	100	0	200	0	0
	Inner units	0	0	-	0	110	0	0
	Box processing	0	0	0	-	0	0	270
	Strapping machine	0	0	0	0	-	20	290
	Special department	0	0	0	0	0	-	620
	Shipping	0	0	0	0	0	0	-

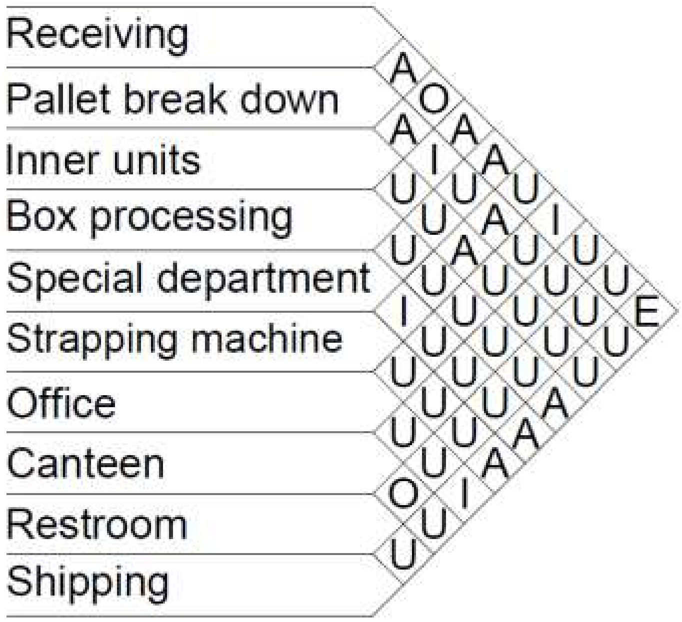
Table 4.2 Material flow chart (in units)

All receiving and shipping activities are performed at this side. Therefore, the receiving and shipping department is essentially one large department. This also requires that most departments need to have the I/O point at the opening of the hall.

4.1.3 Step 2: activity relationships

Although the activity relationship diagram is qualitative, it is included to support a possible decision. For the activity relationships, also the non-production departments are taken into account. Although no material flow is present in these departments, personnel is visiting these departments during the break, in the case of problems or just for a toilet visit. Putting these departments far away or ignoring them will causes delays during production time. For example, for the forklift drivers to hand in the count lists they filled in. This is not possible to express in the 'flow of materials', and has no direct influence in the costs or efficiency of material handling, but the quantitative side should also be considered in a future state.

As can be seen, the receiving and shipping departments interact with almost all production departments. The pallet break down, inner units and strapping are essentially to each other, and can be seen in practice as one large department. The Special department and box department are individual departments that do not interact. Only in case of a break down or no supply of the pallet break down, workers of the pallet break down help out at the box department.



Value	Closeness
A	Absolutely necessary
E	Especially important
I	Important
O	Ordinary
U	Unimportant
X	Undesirable

Figure 4.1 Activity relationship diagram

4.1.4 Step 3: relationship diagram

Combining the previous steps into one diagram, the relationship diagram is made. At first sight, a strong relationship is visible at the right side of the image. The pallet break down, inner units and strapping are strongly connected, and a large amount of the materials are moved and processed through these departments. The box processing department is an individual department that has no direct connections with other departments outside shipping and receiving. Although, the Special department is an individual department with no interaction between other processing departments, due to strapping rework, material flow is present between strapping and special department. In a future state, this flow is preferably eliminated, because it is no direct goal of SLP to change the action it is taken into account for the relationship diagram.

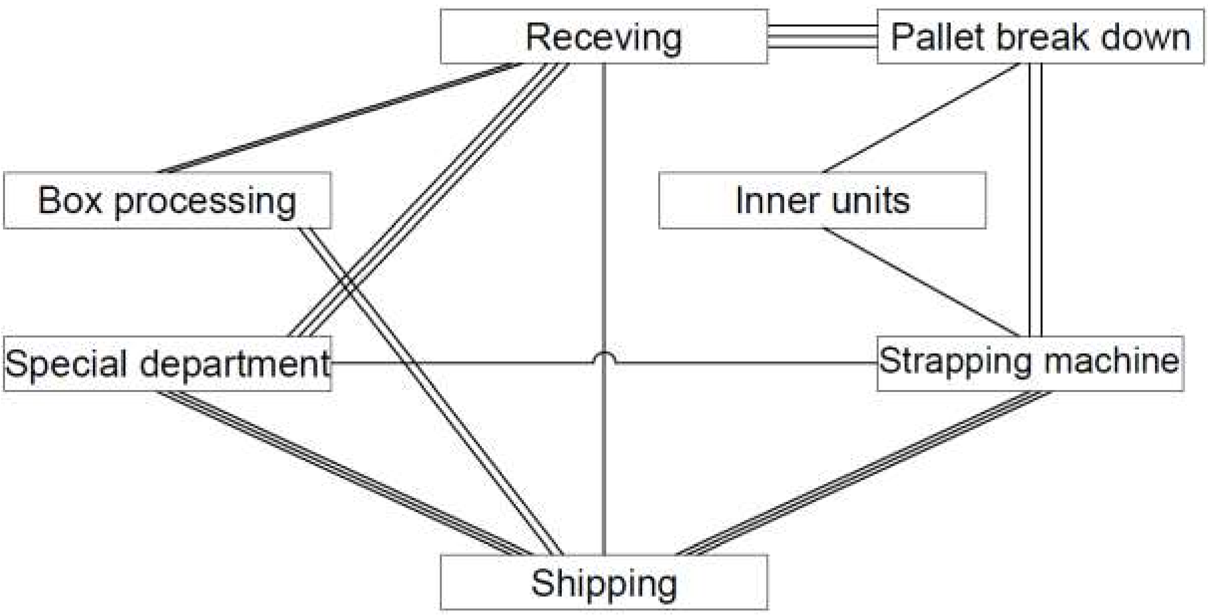


Figure 4.2 Relationship diagram

4.1.5 Step 4: space requirements

To determine the department space requirements, the dimensions of the departments are measured. Because the departments already exist, it is easy to measure. The pallet break down is a large U-shaped department. Because this department is difficult to model, the department is simplified in to three departments. The conveyor system in and out are shown in the table as individual departments. Omitting the conveyor system will have practical issues because the conveyor system is used as a buffer between departments. Leaving the departments out, will also discard the buffers of WIP and finished materials. Without the buffers, the pallet break down will result in excessive handling in the receiving and shipping area. By splitting the U-shape in three separate departments, the layout alternatives that will be developed, have to result in solutions that are more feasible.

Furthermore, all non-production departments are included. In the material flow diagram and relationship diagram, the non-production departments are not required. However, to determine the required space all departments in the hall are included. For example, the battery station has no unit passing through the department, but the battery station is placed inside the hall and therefore requires space.

Department	**Dimensions [m]**	**Required space [m²]**
Conveyor in	12 x 3	36
Pallet break down	30 x 12	360
Inner units	20 x 6	120
Box processing	20 x 6	120
Strapping machine	4 x 3	12
Special department	24 x 13	312
Conveyor out	1 x 14 + 1 x 12	26
Canteen	12 x 10	120
Battery station	12 x 6	72
Buffer	12 x 11	132

Table 4.3 Space requirements and dimensions table

4.1.6 Step 5: space available

The hall where all work is done is a hall that is open at one side. The part of the hall that is used by SUEZ is 25 metres deep and 60 metres wide, in Figure 4.3; the hall is expressed by the dashed line. During the research, Scania moved the KD department in the other side of the hall away, and the space that came free results in extra space available for the departments by approximately 12 metres in width that could be used. In total 300m² of extra space that can be used by the departments. If the extra space is not needed, it will be used by SUEZ as extra storage space. In the picture below a sketch is given of the current used space and the extra space that came available.

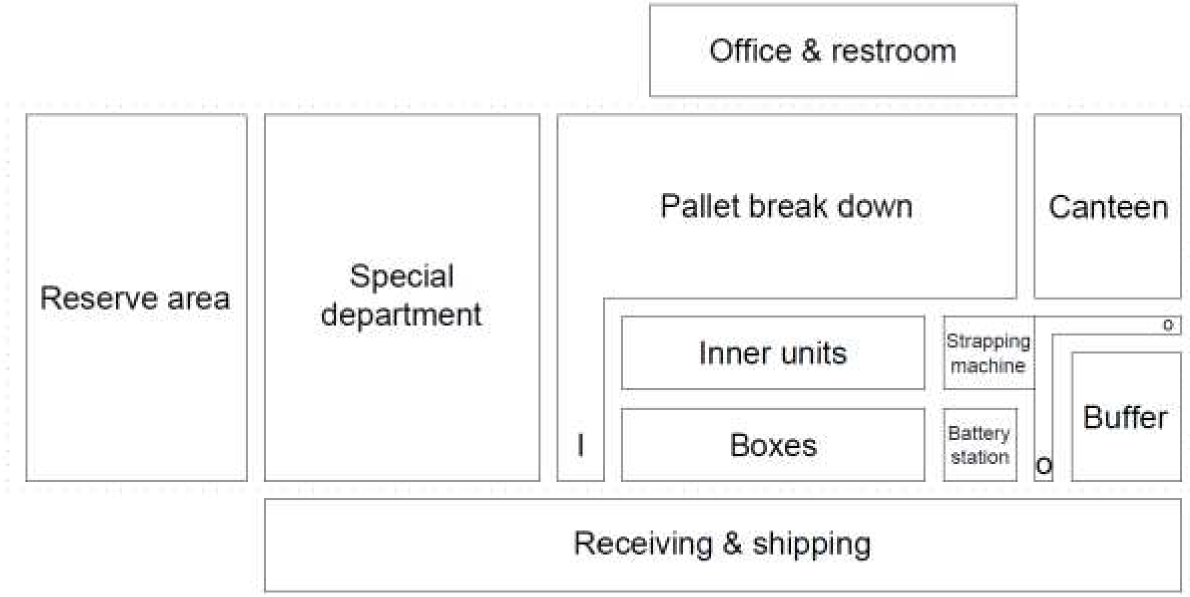


Figure 4.3 Current block layout

4.1.7 Step 6: space relationship diagram

Combining the previous steps into in diagram, results in the space relationship diagram.

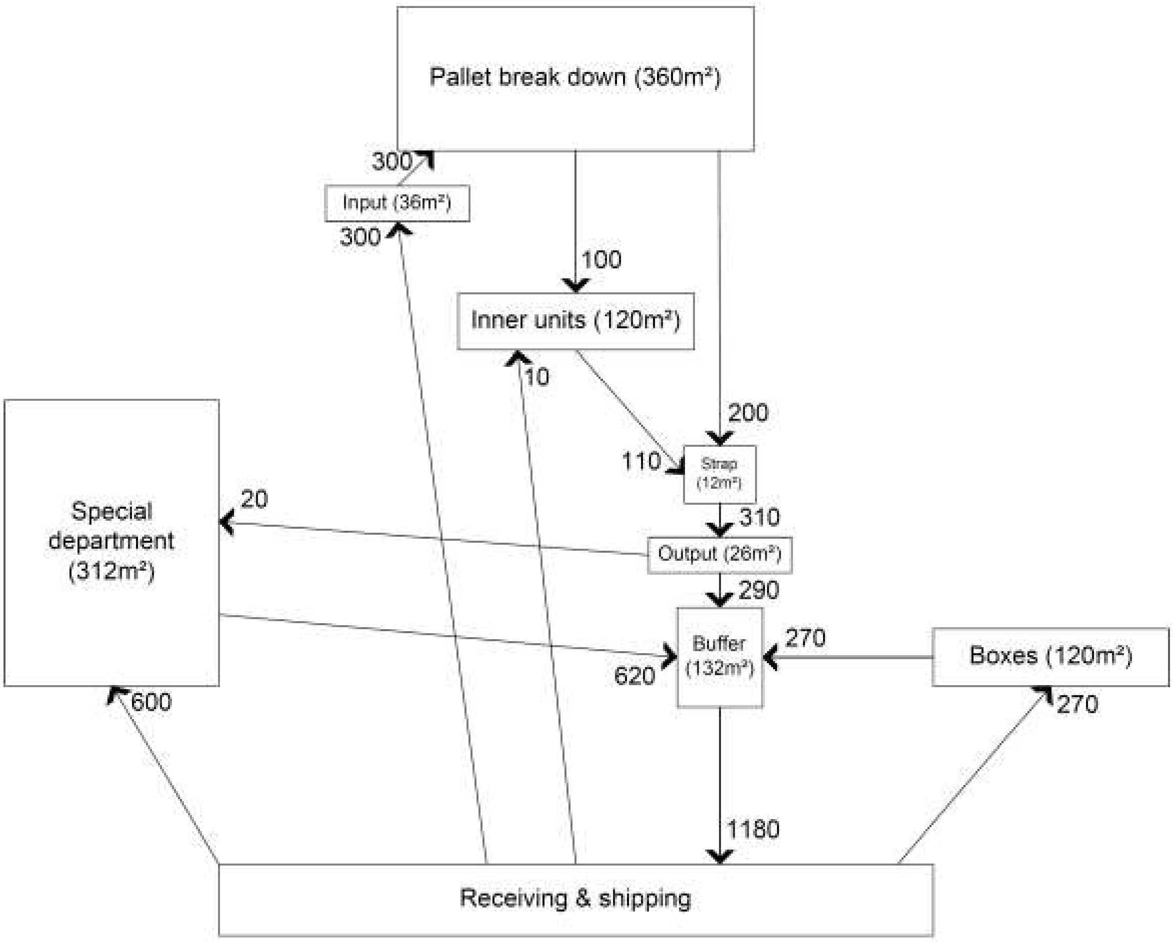


Figure 4.4 Space relationship diagram

4.1.8 Step 7 & 8: modifying considerations & practical limitations

Steps 7 and 8 are combined into one paragraph, because the considerations and limitations have similar results.

Most general limitations and boundaries are mentioned in paragraph 1.7.5, in the scope of the research. There are some extra limitations for changing or swapping the departments in the hall that have to be taken into account during the development of alternative layouts. For example, the opening of the hall cannot be changed without permission of Scania. In practice, the location of the shipping and receiving area cannot be changed. It is also very costly to move some departments, especially the pallet break down and the strapping department. The machines of these departments are fixed on the ground and cannot easily be moved. Furthermore, placing the electrical machines closer to the opening of the hall results in more breakdowns, due to weather effects on the machines.

It is also not recommended to place input and output points of departments close to each other, as forklift trucks will hinder each other. As a safety regulation, forklift trucks cannot come in to the workstations themselves, that is why the I/O points have to be located in a forklift area, away from the workers. For example, to stimulate the location of the forklift battery station nearby the opening of the hall we add artificial flow to the battery station. The heuristic places in this way the battery station nearby the opening of the hall to reduce total transportation costs.

4.1.9 Step 9: develop layout alternatives

In the remainder of this paragraph, changes to layout and flows are made, to see what alternatives will be achieved in addition to the current situation. All improvement are compared to the actual layout.

Current layout

To relate all changes and to quantify the theoretical improvements. First, the current layout and flow is processed by our heuristic from chapter 3 to generate a starting point.

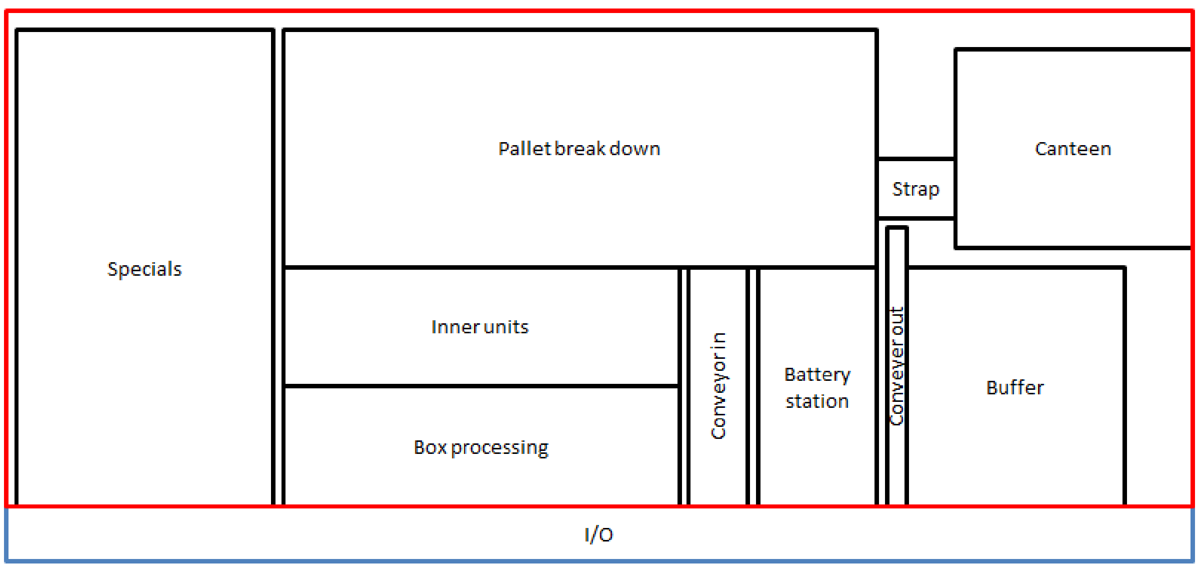


Figure 4.5 Current layout (objective value of 77,150)

In the picture above, a layout of the created algorithm. This layout is nearly equal to the current layout, only the ‘conveyor in’ should be located between the ‘specials’ and ‘box processing’, simply by swapping positions. The total transportation costs in this layout are 77,150. This value is used in the remainder of this chapter to calculate improvements on the layout.

For all layouts that are generated, the same transportation costs and penalties are used. The transportation costs are equal to one. The penalty for department overlap is 5,000, hall overlap is 10,000 and departments that are located to far from the I/O point is 5,000.

Preventing rework (flow from output conveyor out to special department)

The simplest change is to stop unwanted flows of manual rework after the strapping machine has failed to strap a unit. This improvement does not change the layout, but reduces the total flow, and consequently transportation costs. This improvement is not a large improvement of the transportation costs; however, the personnel costs also decrease. The objective value of the total transportation costs will decrease from 77,150 to 75,290, which is a decrease of 2.4%. On average, the strapping time is 45 seconds, on a yearly basis, 20 units per day for 246 days this will save besides transportation costs 61.5 hour of labour per year.

Layout wit only production departments

In the current layout, the non-production departments are also located at the pallet break down. Of course, a canteen and battery station should be located somewhere because personnel needs to rest and eat, and forklift trucks need to charge their batteries. With the heuristic model, we can easily remove these departments, and look how the total transportation costs changes due to absence of these departments.

The total transportation costs decrease to 50,910, which is a decrease of 34% compared to the original layout. In other words, the presence of non-production departments results in about 34% extra transportation costs. This is caused mainly by the battery station, which is now positioned between the special department and the buffer, causing extra travel distance.

It can be argued, whether the layout is more practical. Concentrating more traffic on a smaller area will cause in the current situation more congestion and will further increase the probability of accidents between forklift trucks.

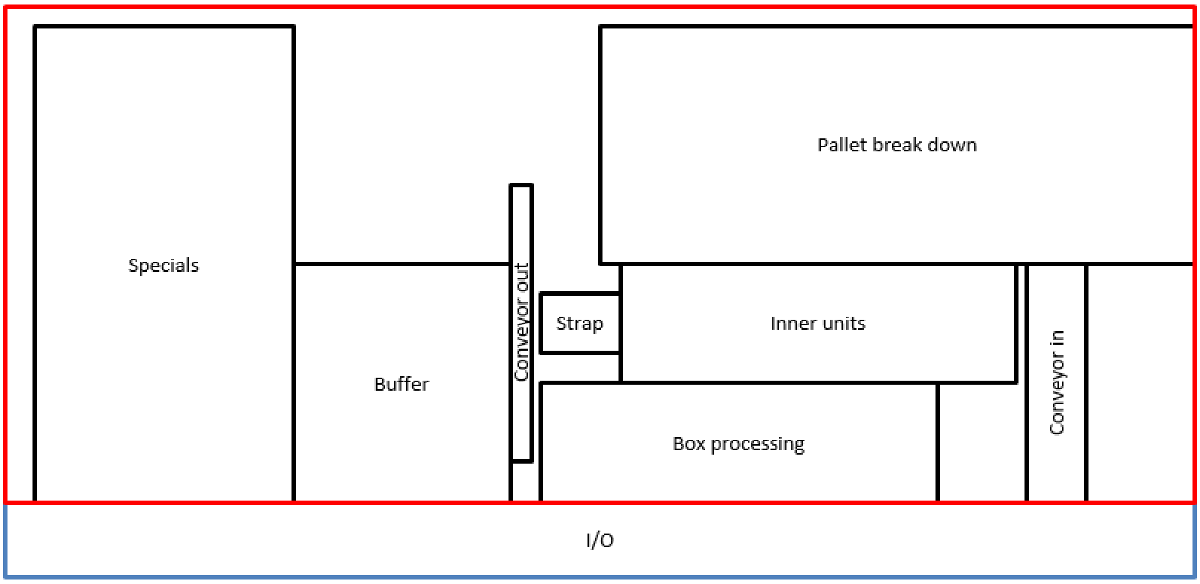


Figure 4.6 alternative layout without non-production (canteen & battery station) departments, objective value of 50,910, 34% improvement

Outsource the box-processing department

A direction during this research is; what if we outsource the box processing to an external partner. If the department is outsourced, a large amount of area is free, which can be used for other purposes. The algorithm shows that with one change a large improvement in the layout can be made. By moving the pallet break down to the right, and the buffer (and canteen) to the left, the buffer is positioned in the middle of the departments that supply the buffer. The transportation costs to the buffer decrease with over 60% in this layout. The total layout costs decrease to 45,970, this is an improvement of 39.8%, compared to the current situation where the flow (and thus transportation costs, c=810) of boxes is removed.

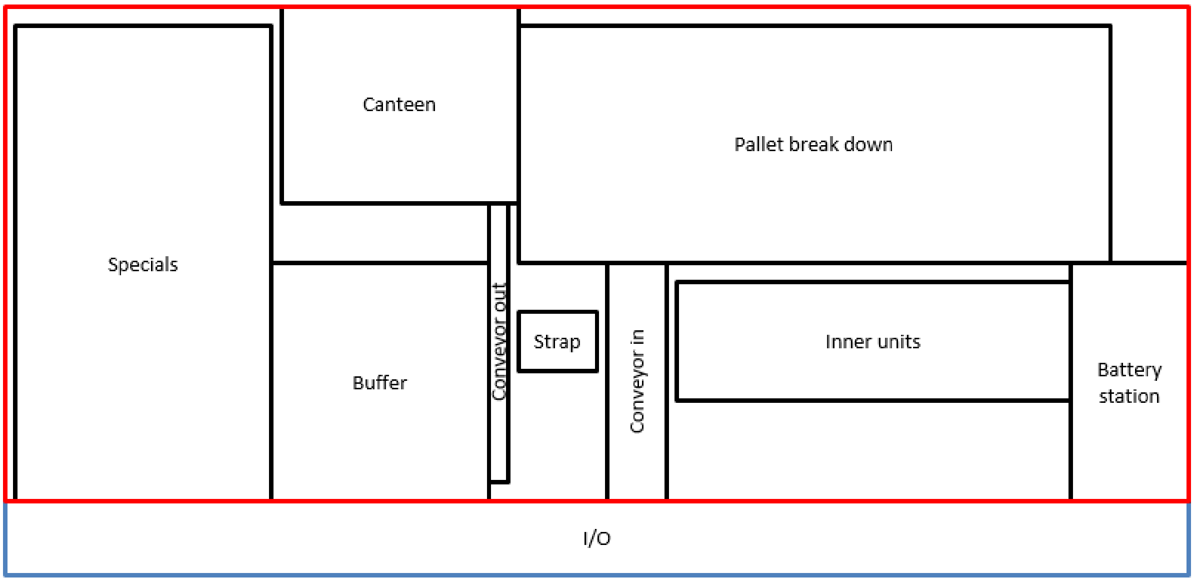


Figure 4.7 Alternative layout, by outsource box processing, objective value of 45,970, 39.8% improvement

To make the layout feasible, some changes are required. The conveyor in should be positioned opposite of output conveyor, and the strapping department has flow from the pallet break down and inner units to the output conveyor, positioning the strapping department better would further reduce transportation costs.

Separate shipping and receiving location

A suggestion is to move the shipping area. Currently the hall is open on one side, on this side all shipping and receiving is done. At this moment, flows of incoming and outgoing materials are crossing each other. Due to the small space and crossing flows, the forklift trucks are waiting for each other and are in each other's way. The current side is also a major path for other vehicles. Like Scania's, own internal transport vehicles, trucks, contractors, the garbage collection and the cleaning service. The improvement will be that the shipping area will be moved to the backside, by creating a new shipping area. This way less traffic is present at the backside, and the forklift trucks are not in each other's way, only problem is that of the presence of the truck storage. Changing the location and number of I/O points will have impact on throughput, travel distances, time and congestion (Hassan, A framework for the design of warehouse layout, 2002). In the proposed layout, more I/O points will be created. A simple way to determine the required number of points is by counting the number of destinations (Bartholdi & Gue, 2004); in this case, it will be the number of forklift trucks that bring or take the materials to or from the destination. This change will have an impact on the layout and will require a redesign of the department layouts and material flows. In Figure 4.8, a visualisation of the possible forklift truck paths is illustrated. This will decrease the amount of congestion. For the relationship diagram and algorithm, the shipping and receiving area will be split into separate departments. The incoming goods arrive at the south side, and the goods that are shipped leave via the north side.

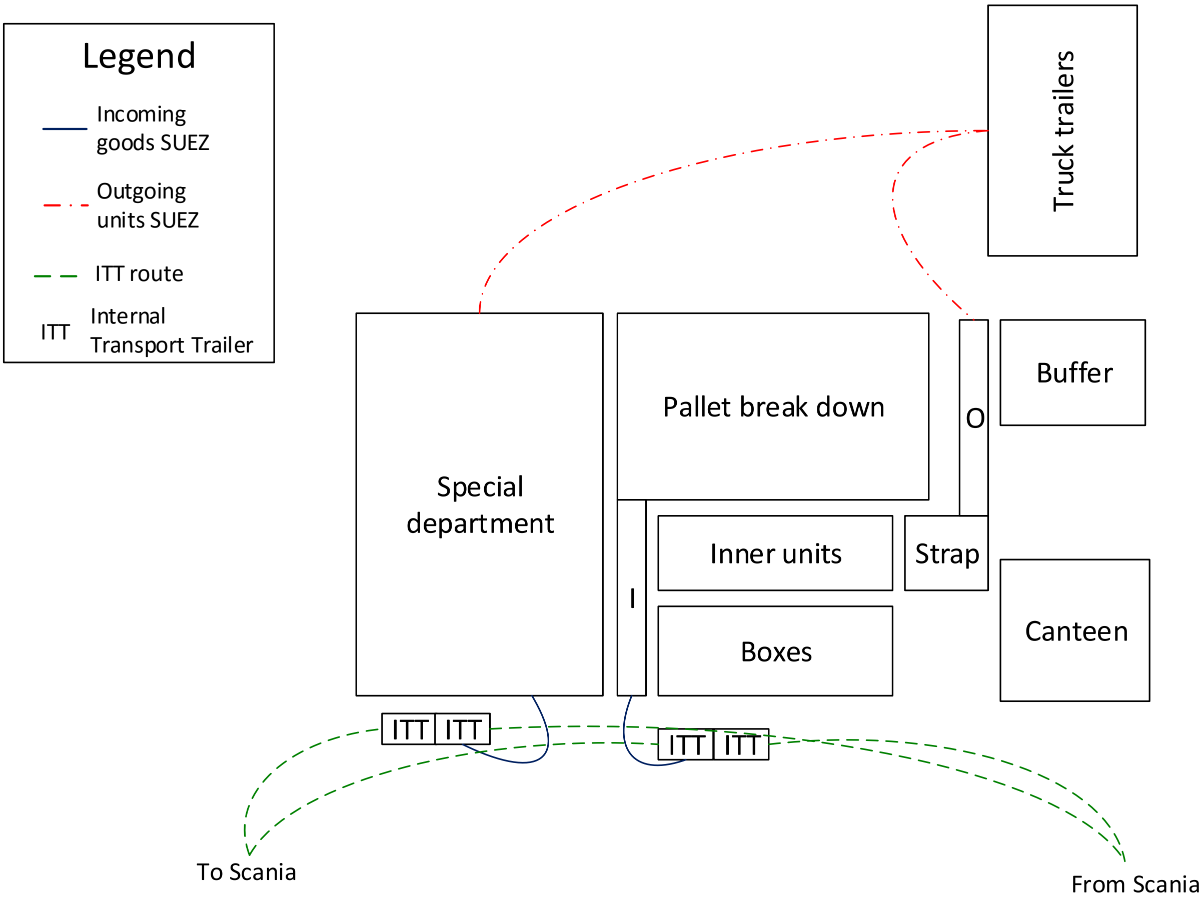


Figure 4.8 Solving congestion by separate I/O points

Due to the department shapes, for this layout, the canteen and battery station are taken out in order to get a feasible solution quickly. It is now no longer a problem to allocate the battery station department, as forklifts of SUEZ are now traveling at both the north and south side of the hall. The canteen requires also no fixed location. Both departments have no influence on the transportation costs of unit flow, for the calculations it have no effect.

With separate I/O, the total transportation costs descend to 54,340. This is an improvement of 29.6%, which can be mainly explained by the placement of the buffer location between the 'Specials' and 'Pallet break down'. Assumption is that the trailer positions are not placed further away than their current positions.

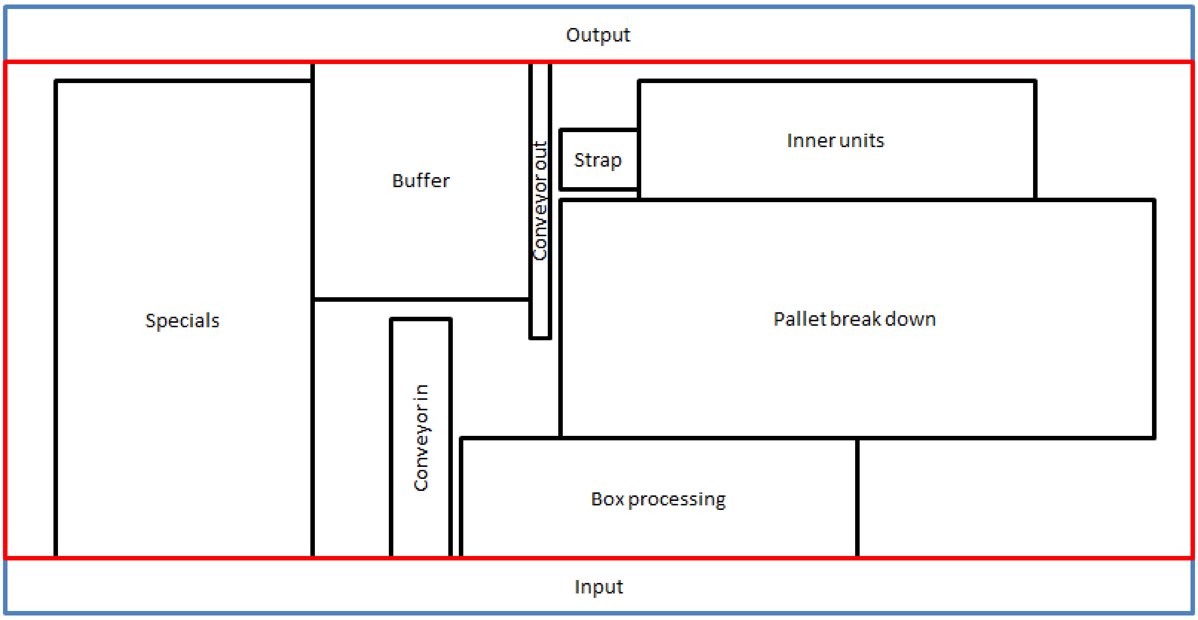


Figure 4.9 Alternative layout with separate input and output point, objective value of 54,340 improvement of 29.6%

Strap boxes automatically

At this time, all boxes are strapped manually by the workers. On average per day, 240 units of boxes are created and thus strapped by hand. This causes time delay and is not ergonomic. The flow from box processing is redirected from the buffer to the strapping machine. Sending materials from the box processing to the strapping machine, to the output conveyor and then to the buffer results in extra material movement. However, the heuristic is able to generate a layout that is better than the current layout. The total transportation costs descend to 60,600. This is an improvement compared to the current layout of 21.5%.

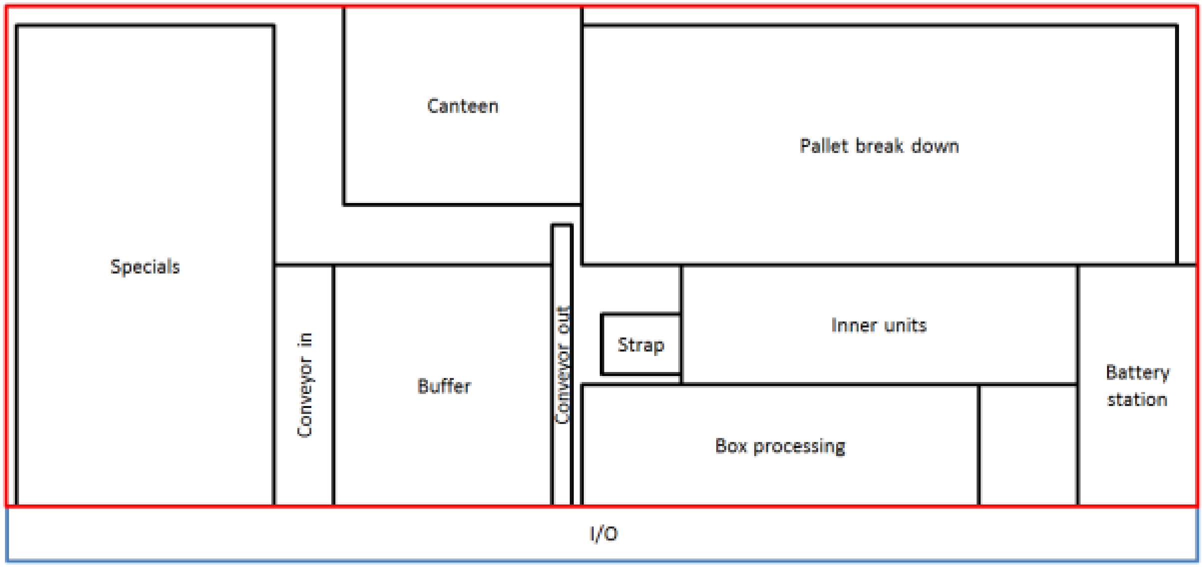


Figure 4.10 Processed boxes are send to strapper, objective value of 60,600 improvement of 21.5%

4.2 Conclusion

The SLP framework is applied in this chapter on the available data and information, and improved layouts are realised with our heuristic.

As result of this improved layout transportation costs can be reduced theoretically up to 37.2%. this change required the larges investment costs to realise. There are partners within Scania that have interest in these specific changes. It might be beneficial to work together with these partners within Scania, and to make a plan that includes all the other advantages created by these change(s). For example, a separate I/O point drastically improves the safety, which is an important factor for Scania. Moreover, it reduces the traffic nearby the Scania factory.

By leaving out the canteen and battery station, only the production departments remain in the hall. This improved layout decreases the total transportation costs by 34%. In other words, due to the current layout the efficiency is decreased by at least 34%.

The sub questions about which alternative layouts can now be made can now be answered. The sub questions about the layout were the following:

Which feasible alternative layouts can be made to improve the current performance of the pallet break down?

What do these alternatives cost and how do they perform compared to the current situation?

In the remainder of the conclusion the alternative layouts are summarised, and answer to the sub questions are given.

Preventing rework will decrease the transportation costs by 2.4%, rework is unnecessary and non-value adding work. The yearly savings on extra transportation costs can better be invested in machine improvements to tackle the underlying cause of the rework. The savings of this change are in practice equal to the required costs to prevent rework.

By completely outsourcing the box processing the previously occupied space has been released. There are no depreciation costs because there is no machinery placed. There is only a challenge for the transportation of boxes to the external location; the possible location where the outsourcing will be done should be closely located to Scania Logistics, if the transport can be combined with Scania transport, transportation costs will not be significant. The freed area can be used as a buffer storage; this will decrease the transportation costs of the special department to the buffer significantly, up to 39.8% of the total transportation costs.

When the receiving and shipping area are split up into two different locations, a change in transportation costs of 29.6% can be realised. Additional savings like fewer collisions with forklift trucks are neglected, implying that the total costs reductions can be even greater. Investment costs for SUEZ will be caused by moving the output conveyor, and material flows going into the opposite direction. For the special department no large change is required, by splitting the input and output more buffer capacity on the receiving and shipping area can be created. Only the box-processing department needs an additional change that completed units can be transported to the new shipping area.

Currently all boxes are strapped by hand. This is not ergonomic and requires extra tools. If the box processing department starts to strap boxes by using a strapping machine, this will result in a 21,5% reduction of transportation costs is, when compared to the current layout. Investments in machinery are relatively low, however the strapping machine variations have to be decreased to be able to handle the increased unit flow.

5 Process & logistics improvements

Besides the Systematic Layout Planning, improvements at a lower level, within the departmental improvements are possible. By improving the processes and logistics within department's higher efficiency and lower costs can be achieved. With a prognosis of increasing production rates a more optimised process and material flow is needed to deal with the increase of materials. In this chapter, improvements in the departments are discussed. Improvements that can be realised without changing the layout of the departments.

5.1 Pallet break down system

In the current process, the strapping machine is the largest bottleneck. Although the current utilisation of 0.77 is not extremely high, the variability is high. This high variability is mostly caused due to delays in successor and predecessors stations, which make the utilisation of the strapping machine unnecessarily high. Reducing variability is a key issue in order to improve performance (Hopp & Spearman, 2008). The only way to achieve high throughput and high utilisation of resources is to reduce variability (Slack, Chambers, & Johnston, 2010). Causes that the variability is high at the strapping machine are not only breakdowns, but also because the supply of materials is fluctuating or because materials are misaligned. Delays due to the output side are for example the processed materials are not taken away quickly enough which causes the machine to stop or cause a unit to be stuck on the conveyor. The strapping machine can be compared by a G/G/1 queue, in formula form; the average time at the strapping machine is approximated by:

$$\mathbb{E}W_{strapping} = \underbrace{\frac{{C_a}^2 + {C_e}^2}{2}}_{variability} \times \underbrace{\frac{\rho}{1-\rho}}_{utilisation} \times \underbrace{t_e}_{processing\ time}$$

The expected average number of units at the strapping is given by:

$$\mathbb{E}L_{strapper} = \frac{{C_a}^2 + {C_e}^2}{2} \times \frac{\rho^2}{1-\rho} + \rho$$

Where C_a^2 is the squared coefficient of variation of the inter arrival times, C_e^2 the squared coefficient of variation of the processing times, ρ the utilisation and t_e the effective processing time.

The mean effective processing time, is fixed and cannot be changed. By lowering the first part of the equation, the variability, the queue time and therefore queue length is decreased. On the other hand, increasing the capacity is also possible, by decreasing the variability; the utilisation can be increased without longer queue times and queue length, which result in congestion. In this way, lowering variability and increasing the utilisation expansions or replacements of current installations can be postponed. In Factory Physics, this is called 'pay me now or pay me later' (Hopp & Spearman, 2008). In other words, the idea is you can invest now to improve your process or pay later to deal with lower throughput and wasted capacity. In general, the relation between utilisation and queue length can be seen in Figure 5.1. The initial process is in point X, by reducing the process variability the process can end up in point Z, which gives a more stable situation.

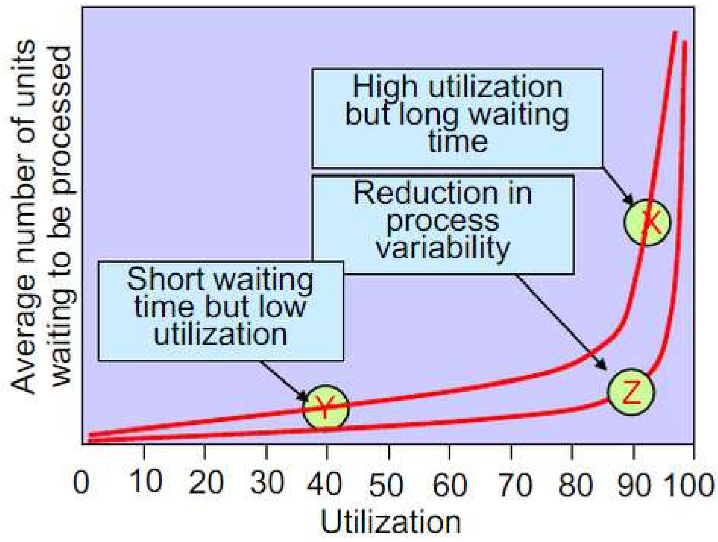


Figure 5.1 Influence of process variability (Slack, Chambers, & Johnston, 2010)

5.2 Arrival variation

As mentioned in the previous paragraph, at the pallet break down workstations and further in the line there is much variation. Some variation is natural, but too much variation is not good. Root cause of the variation is variation in the supply by Scania.

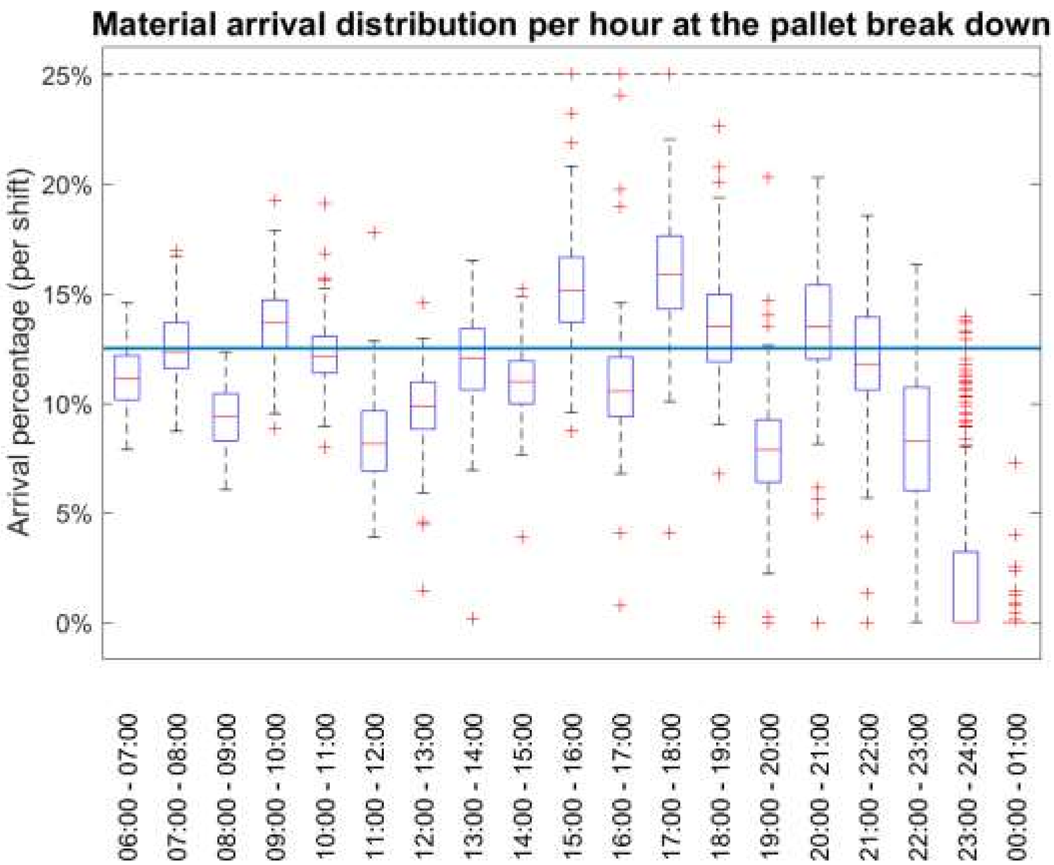


Figure 5.2 Arrival percentages per hour and per shift (based on firth 10 months of 2015)

Due to the variations, that can be seen in Figure 5.2, some times per day the pallet break down cannot handle the flow of incoming goods. Moreover, the time before the large flow of incoming materials at SUEZ, an unwanted effect arises for SUEZ. Workers are forced to start working slower or to stop working due to less material arrival and are not used effectively. Half an hour later, they have to overwork to keep up the tempo.

SUEZ has designed employment based on peak levels. Therefore, only for 1 or 2 hours employees are needed to handle the peaks. If, by reducing variations for a workstation less employment is needed per day, this can saves 2 persons per day. On a yearly basis, this saves around €80,000.

It is recommended that Scania's forklift drivers follow their given instructions and planning and work until the end of shift, as they should on paper. The late shift should take their break when it is scheduled, or drink beverages before work. This results in a more uniform arrival and constant workflow. Moreover, the forklift traffic within the factory will be more constant without a rush hour. Due to variations, SUEZ has to plan present personnel in such a way that the peaks can be processed. If the variation is lower, Scania could benefit from lower personnel costs in the future unit price.

5.2.1 Conveyor improvements

After a week of breakdown measurement on the conveyor systems, the calculated availability is good with 93%. This is because many stops can easily be solved, on average within 3 minutes. However, according to this measurement on average 23 breakdowns occur each day. This requires that the team leader has to focus several times per hour on breakdowns. Two repeating errors cause over 65% of the total amount of breakdowns during the measurement. It is advisable to fix these errors with a long-term solution. This will significantly reduce the number of errors and delays in the system. The firefighting way of working is causing to stay in a viscous circle of returning problems. Further, there are three main causes of variations and delays in the conveyor system that SUEZ can directly influence:

- By design, the conveyor system is not fully suitable for half-euro pallets. This causes several times per day that crates get misaligned which results in falls in between the conveyor system that causes the system to stop. By improving the design, such that crates cannot fall in between the conveyor system these delays will not occur.
- Another issue is that due to mostly gliding materials on a pallet, materials stick out and hit and bend or even damages photo reflectors sensors, fences and the strapping machine. The needed repair time is over fifteen minutes, this result in a major build-up of materials that are blocked.
- To help the forklift driver, an alert can help him to indicate that his attendance at the output conveyor system is needed. There is some buffer space; therefore, it is not necessary to continuously empty the conveyor system. However, due to piles at the buffer inventory near the output conveyor, it is hard to see whether he can focus on emptying the conveyor or not, which could result in congestion further back in the system. If he could be alerted when the conveyor is nearly full, meanwhile he can focus on his other tasks.

Improvements that can be realised are mostly the reduction of variation in the service time and inter arrival times. Currently the SCV[1] of the service times is 0.65, after a quick field-test, the reached SCV can be as low as 0.03. A similar situation for the SCV of inter arrival times is possible. Currently the SCV

[1] The SCV is used to show the degree of variation in relation to the mean

is around 1.32. Which is more difficult to manage, and the SCV on inter arrival times can reduced to a value less than one.

5.2.2 Expansion

The designer of the pallet break down system has provided the option to place a 4th workstation to increase throughput. It seems a reasonable option for increasing capacity; more workstations equal more throughput. In the ideal situation, it is true, however as stated in the previous paragraph only an extra workstation will not help. At this moment, the utilisation fluctuates around 0.77. Looking at the historically throughput during 95 per cent of the time (ignoring the seldom 5 per cent high arrival rate) and linearly extrapolate this arrival rate from three to four workstations will result to an utilisation of over one. The queue before the strapping machine will explode if the variability is not decreased. Reducing the variability in the system with four workstations will result in an expected utilisation of around 0.79. This will result in practice to almost no increase of service time or utilisation of the strapping machine. Indirectly this will give more advantages. Not only will direct adding activities improve. Non-added value activities like waiting, moving and inspection will reduce (Fullerton & McWatters, 2001). Lower variability will contribute to improved productivity and higher reliability to deliver (Mapes, Szwejczewski, & New, 2000).

5.3 Scrap, repairs and truck parts

At this time, 10% of all handled materials at the pallet break down are sent to repair. Materials that have to be repaired are taken out, and placed on dedicated positions. For each part, a single position is available. A similar position is available for materials that are broken too much and will thus be scrapped. Compared to good parts, extra handling is required, primarily in the form of extra walking distances. Founded truck parts are handled similarly. The worker needs to bring the founded parts to a single position that is appointed for founded truck parts. In total to handle collars, pallets, lids and truck parts per day on average 2.04 hours are lost (0.13 FTE). Currently there is no drive for Scania to decrease the number of repairs, although all repairs are repaired paid by Scania. If the percentage of repairs decreases both the repair costs and the extra handling costs for repairs decrease. To decrease the percentage of damages, it is most likely to solve with more careful handling of materials primarily at Scania.

5.4 Extra strapping machine

A potential expansion is to place an extra strapping machine with a dedicated output buffer. This expansion will not directly reduce the variability. However, by dividing the work over two machines queues before and after the strapping machines are reduced, and it will take more time before the output buffer is full and blocks the strapping machine. Currently the strapping machine causes 47% of all reported delays in the conveyor systems. These delays mostly do not completely stop work, but require a lot of attention. Often distortions at the strapping machine results in more rework at the special department. Moreover, an extra strapping machine is a potential insurance. The strapping machine is a bottleneck, but also a critical machine in the process that has the potential to break down. When the machine severely breaks down, chaos will arise. All strapping has to be done by hand, which is not feasible to obtain the same throughputs of the machine. In case of this expansion, one strapping machine can handle most of the work. Another advantage will be that the strapping machine could do the strapping work that is now done by hand at the boxes department automatically. This only requires a point where the pallets of boxes could be placed on the conveyor belt. This will reduce the work, improve the ergonomics and reduce the number of equipment needed at the boxes department.

5.5 Wezo

In the past, with help of subsidies, a few workers for social employment were stationed at the shop floor. Due to changes of these subsidies, other workers with other handicaps came in place, but where unsuitable for the environment at SUEZ. This caused the program to stop. During this research, the question came back whether under the right conditions and settings this program could be re enabled. In practice the question would be "could the box processing be outsourced to the social employment workshop?" The box processing is very simple work, after selection, remove the labels and clean it from the inside with a wipe. In an initial contact, the Wezo is pleased to work out a case in which they would be the subcontractor to perform the box cleaning for SUEZ. Although corporate social responsibility is not an objective in this research, it can be an unexpected addition. For operations at the location, it will have additional benefits. There is need for extra space and moving a department to an external location will give more room. Although extra transportation will be involved, the changes will be low. The social employment workshop is located only a few hundredth metres away from Scania Logistics where almost half of the blue boxes are shipped to. Additional advantages are that less personnel needs to be managed, less company clothing is needed, less equipment for making a unit is needed and less fork lift movements on the terrain. Only on the direct measurable costs (clothing and equipment), a saving of just over €10,000 on a yearly basis is possible. Unfortunately, the personnel costs to do the box processing externally are larger than the current personnel costs, excluding transportation and extra variable costs. Therefore, outsourcing seems not an attractive option.

5.6 No more manual strapping

At the box processing department and all packaging material units at the special department are strapped by hand. This is both a labour intensive process and a non-ergonomic activity. The required time to strap is about 60 seconds, which is equal to around 4.4 hours of continuous manual strapping per day (0.28 FTE). This is, based on 246 working days almost 27 working weeks of strapping. By automatizing the strapping, a potential saving of €22,000 can be achieved. This saving is only on labour costs, extra saving are made on fewer manual strapping machines on the shop floor. For the ergonomics the saving are 1,100 times bending per day onto the floor. For both financial and ergonomics savings can be achieved by automatizing the strapping of completed boxes on the conveyor line. This will require an entry point for the units to be strapped on the conveyor line, at the box processing and special department. Prerequisite is that the strapping machine has the capacity available to strap at least 350 extra units per day. Otherwise, this improvement will create more problems than it can potentially save.

For this solution, the relationship diagram and thus material flow diagram will need some changes. A new relationship will be introduced between material flow from the box-processing and special department to the strapping department. The relationships from box processing to shipping disappear. The material flow from special department to shipping will decrease as well.

5.7 Excessive strapping

According to Scania's own standards, most units have to be strapped with a single strap, due to technical limitations of the strapping machine all units are strapped twice. This results in more effort than is necessary. This is contradictory with the definition of material handling which demands among others: right conditions, right costs (Tompkins, White, Bozer, & Tanchco, 2010). Scania as a customer desires products with just a single strap in most cases. Due to the double straps being applied, the material costs of a unit are higher than under the right conditions.

5.8 Robot(s)

At an initial visit of Cofely, in early 2015, the idea was raised that robots can do most of the crate disassembly. With the outcomes during the analysis during this research and the more detailed process description in Appendix: D. It was clear that simply placing one or more robots is not the solution to improve efficiency at the pallet break down. The handling and work that is now done by men is more complex than was estimated at first sight. Moreover, due to the short contract periods of two years, the payback period of a robot is very short, additional agreements have to be made with Scania to arrange a long-term contract. In the worst case, Scania's production will decrease, and in that situation, the fixed costs of the robots are higher than temporary labour that is sent home, or even not called to come. Placing a robot will also give some practical challenges. First, at this moment there is no space to place a robot. A precondition at the current location will be the movement of the canteen outside the hall. Secondly, the required speed is fast. At this time, on average 95 crates per hour are collapsed. This is equal to 38 crates per hour per workstation with on average 2.5 workstations in use. To replace two manual workstations with a robot station, the disassembly time have to be less than a minute.

In order to keep the costs in control of automation and control a selection which crates can be processed has to be made. It will be impossible to process all types and possible configurations of crates and to automate them all. This choice requires a selection procedure, early in the process. A human has to do a selection which crate is standard and has no visual breakdowns. Applying robots becomes interesting when Scania can supply materials in a more standardised way. Cofely estimated the investment for a robot installation between €300,000 and €500,000.

5.9 Indirect activities

The indirect activities for the pallet break down can be largely improved by lowering the number of administration systems. All invoice activities should only be performed in the SUEZ SAP system. In the current way of working, all invoices are delayed for a day because the information has to be collected in Excel at the site office. Next, that information is sent to the regional head office where the invoice is made and sent back to the site office for control. Staff on the site office can better make the invoice themselves. Another issue is that currently default information about agreements, contracts and other information is stored in SAP, changes in contracts, agreements and information are not always known in SAP. However, it is known at the site office, with the current way of working this information is not updated consequently. Sending the right invoice is more critical than in other businesses because Scania is the only source of income. Moreover, by skipping the current chain, the lead-time for sending an order will be decreased which causes earlier payment. Some other improvements can be made, for example, no more turnover calculations in Excel, SAP can present the information automatically and more accurate than is being done at this moment.

5.10 Continuous improvement techniques

At this time, there is no structural form of continuous improvement program at the SUEZ site. An improvement program is recommend. Not only because Scania requires such programs from it contractors. Although the business looks to be very efficient, it is often a perception (Melton, 2005). Moreover, for SUEZ itself such programs gives advantages. Implementing techniques like continuous improvement, waste reductions all in JIT philosophy can improve the firm's competitiveness (Fullerton & McWatters, The production performance benefits from JIT implementation, 2001). Introducing and maintaining these improvement programs will improve sustainable financial performance (Fullerton, McWatters, & Fawsonc, 2003). Melton states that apart from financial benefits also cultural benefits are realised (Melton, 2005). It may all sound as the solution for everything, but for success, employee altitude have to change to 'improve quality' (Powell, Alfnes, Strandhagen, & Dreyer, 2013).

"Lean" maybe known for improving and changing operations, and is used to improve operations. However, "Lean" does far more than only improving operations. Although it can be hard to quantify all costs and benefits that "Lean" will bring with it. For a long-term vision, SUEZ have to consider starting a program to gain sustainable and long-term advantages, on at least operational and financial level.

Figure 5.3 Typical benefits of Lean (Melton, 2005)

5.11 Conclusion

Besides the layout improvements, improvements on processes and logistics are possible at the SUEZ pallet break down. A wide variety of possible improvements exists to change the current processes and material flows. To answer the 5th sub question

Which improvements can be made on logistics and organisational level to improve the performance of the pallet break down?

On organisational level, the most important recommendation is to implement a lean program, which gives structural and continuous improvements. "Lean" can be used on both the shop floor and office to improve processes, reduce waste and increase efficiency. Applying robotisation is only useful in the future when the crates that are provided in a more standardised way. Under the current process robotisation is not feasible.

A surprisingly 10% of materials arriving at the pallet break down of SUEZ are damaged. Although SUEZ is paid for a damaged unit, it costs extra effort to handle repairs, to be scrapped and left over truck parts. Furthermore on average 32 units are scrapped every day, SUEZ has to process the material which costs effort but does not result in more income. Scania have to be stimulated to decrease the amount of repairs, scrap and truck parts.

Outsourcing the box processing to Wezo looks promising at first sight, however the costs at Wezo are more expensive when taking labour and transport costs into account. Due to the Scania pricing model where is paid per unit, outsourcing will costs SUEZ only money.

On logistic side, most significant improvements require cooperation of Scania. The current flow of arriving materials is not organised well, peaks in arrival rate occurs which causes congestion at SUEZ and employment of personnel only to handle peak levels. It is estimated that two workers are only planned to handle the peak levels.

Combining smoother arrival rates of materials and improving internal flows of materials will reduce the variation at SUEZ. Lower variation postpones the need for extra equipment if the truck production rate will increase even further.

6 Green field

In this chapter, a side step is made. Previous chapters focused on the existing location, and mostly on the current constraints and limitations. In this chapter, all active constraints, limitations and the current location are ignored. Just like a green field, we start all over again, with the only assumption that the same work and results have to be delivered in terms of units, speed and quality of work. The location of the pallet break down in this chapter is outside but close to Scania Production Zwolle.

The chapter starts with ideas such as what to consider at the green field. Which logistical improvements can be made? Finally, an alternative layout for the green field location will be presented that gives an idea for an alternative layout.

6.1 Old constraints

In the old situation, some constraints limit the work severely. Scania dictates the workflow; on the green field, enough buffer space is present to decouple Scania's material flow. Eventually this could even result in quitting the two-shift program. Only a few persons are needed to take the flow of materials from Scania to transport it to Scania. Stopping with two-shifts (completely) saves just over €8,000 per month on shift fee of 8.75% of the salary. Estimated yearly savings are €6,000 x 11 months = €66,000. Transportation costs of materials from Scania to SUEZ is not arranged, but could be paid from the shift fees that will not have to be paid for. Furthermore, the workflow can be improved; there is a more continuous flow and less variation in incoming material flow. Therefore, workers can work continuously, and do not need to wait for work.

In the current situation, the working climate in the current hall completely depends on the weather. The hall is open; gives rarely protection during extreme weather. Although there is no reason for the hall to be completely open at one side. At the green field, the working conditions can be improved. In a closed hall, working is more comfortable due to a more constant climate. Extreme heat and cold will influence working speed that is why in a controlled environment efficiency will increase. Additional saving is on working cloths, currently SUEZ spends for €18,000 yearly on working clothing, just for the pallet break down. By working indoor, winter clothing is not required anymore. An indoor location for working will also save costs on company clothing. In ideal form following the ideas of William McDonough and Michael Braungart, the promotors of Cradle2Cradle (C2C), a well-equipped working location will result in even more efficiency improvement. Natural lighting, plants will create a positive atmosphere and attitude to work and result in higher efficiency and better work quality per employee (Afval = voedsel (deel I), 2007).

Moreover, a very interesting constraint can be dropped. There is now a possibility to perform a complete overhaul, all processes; departments and working methods can be redesigned. A key improvement is that manual handling, material handling and transportation should be minimised as far as possible. Further, a goal must be to make a stable and robust system. This can be realised by controlling the amount of work in progress.

6.2 Arrival of materials

In the current situation, all inbound crates, boxes and pallets have to be processed immediately. It is not allowed to create a buffer outdoor on the Scania terrain, mostly due to fire prevention rules. Secondly, the packaging materials have to stay dry. On a green field, only the last constraints remains, the materials may not become wet. Temporary storage of materials in a hall is sufficient, this way a first sorting can be performed. Alternatively, even early before transport to the green field. By sorting, all special sized materials can be grouped, and all (half) euro-pallet materials can be grouped. When the materials are processed, there can simply be pick piles already sorted on department and destination. An extra advantage is that the forklift driver can fully load his forklift truck, which is of course more efficient than less than full truckloads.

6.3 Box processing

For example, the cleaning of the boxes can be completely automated and can be cleaned with an industrial washer. Now all work is performed indoors, a washer can be placed, because there is no more frost. The six to eight persons required at the box-department can be decreased. Simple pick and place work can be done by robotisation. Only the visual inspection on box quality and the removing of staples out of boxes needs to be done manually. To make the detection of staples 100% a metal detector can be used, like in the food industry. This saves both time to check for staples and insures that every box with staples is detected. Strapping is not done manually anymore; all strapping is automated.

6.4 Specials

The special department material flow should be redesigned, with the philosophy “handling less is best” (Compton, 1988). An I-shaped flow will result in fast material flows from receiving to shipping (Bartholdi & Gue, 2004). This will also guarantee that the input-point and output-point of the department are separated. Which give the benefit that material flows will not cross or make turns and result in improved faster product flows. An ABC analysis needs to be performed, such that those fast-moving units are placed close to the input-point, and slow moving units placed further away from the input-point. For all packaging material units that are released in the special department automated strapping have to be possible. Extra advantage is that all (half) euro-pallets are flowing to a single point, and all materials larger than a euro-pallet are concentrated to another output-point.

6.5 Pallet break down

Although the design of the pallet break down is not bad, some improvements can be made. By splitting, the material flows from and to the workstation, fewer collisions will occur with incoming and outgoing products. In addition, a second strapping machine will be present. In this way, all materials that have the dimensions or (half) euro-pallet are strapped automatically. Currently, rejected pallet collars are placed on a pallet, only one location is present where these rejected collars can be placed. This causes a large average walking distance for rejected collars. In total 10% of all units, consist of rejected material, therefore decreasing the average walking distance for rejected materials will have a great influence on saving transportation costs. Solving the problem by its root cause will decrease the amount of repairs, if this is not feasible, the average walking distance have to be minimised.

From an ergonomics point of view, a solution has to found for lifting a euro-pallet. One or two stations can be dedicated to euro-pallet sizes, at these workstations then a pallet lifting and rotating support system is present that can lift and rotate the euro-pallet. At the other workstations, only half euro-pallets are then handled, which could be handled by hand. Forcing personnel to lift a euro-pallet in pairs will not be a realistic solution, because rotating a euro-pallet and place it on a pile will result in practical struggle, and after all it will be a done by a single person.

An alternative solution is to make a transportation system near all workstations, where all euro pallets will be placed on. The pallets are then transported to a central location where an automated pallet rotator and stapling machine will be placed.

6.6 Inner units

At this moment, both inner units from the special department and the pallet break down are processed separately. Processing inner units at multiple locations is eliminated in the green field. The transportation system or layout is designed in such a way that all inner units are moved to a central processing point. This will save for every unit two positions (good and scrap materials).

6.7 Robots and automation

Besides, the manual workstations, robots are placed to handle all standard crates. A worker stationed early in the line will check all crates on quality and remove waste, brackets and labels, and then the worker decides whether the crate can be disassembled by robots or workers.

6.8 Layout

At the green field, an important issue is the layout. The flows of materials should be well organised and materials may not cross each other. This means that arriving materials are stored in an inbound buffer or directly placed on the line for processing. All finished units have to leave the building at another side where the outbound flow is organised. A separate buffer for outgoing flow and no other crossing activities with the inbound flow. In Figure 6.1 two examples of how separate flows can be organised. The left example is preferable, because no bends in material flow are required. In the right example, at least two bends are present.

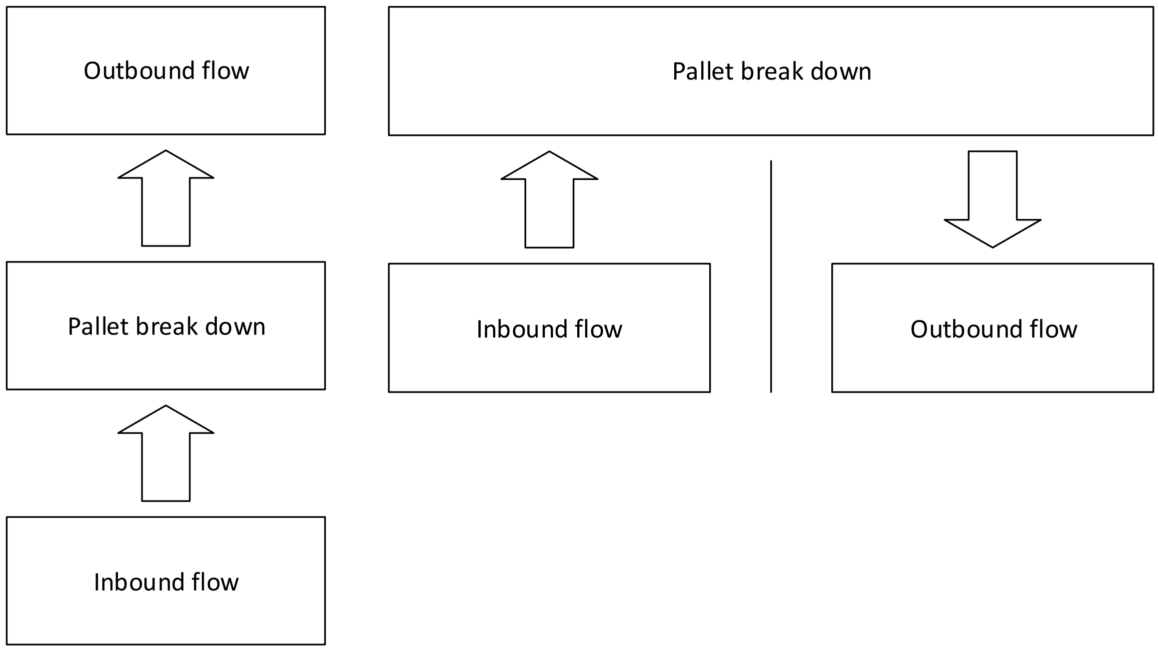


Figure 6.1 Examples of seperate in and out bound flow

Trailers should be positioned such that they can be loaded quickly and nearby. The used trailer are loaded from one side. The angle of the trailer in relation to the output flow of units also influences the speed of loading; every sharp angle slows the forklift down. The best situation is obtained by placing a trailer perpendicular to the conveyor. In Figure 6.2 this is the red trailer. Only one 90° angle is made by the forklift truck, for the purple trailer two 90° angles are needed (with time between the turns) and for the blue trailer one 180° angle is made.

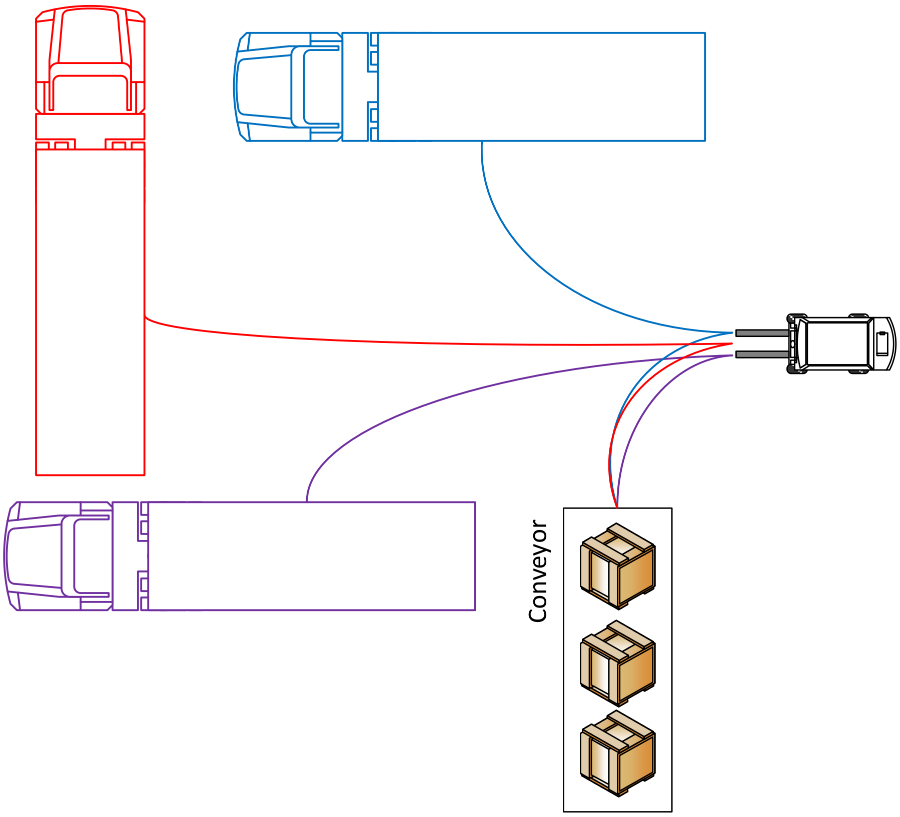


Figure 6.2 Trailer orientation, red position is preferable

6.8.1 Department block and flow layout

A block layout is designed for the pallet break down. Arrows are used to indicate the material flow through the departments. The layout is essentially a large cross-dock. Materials arrive at one side and processed units at the opposite side. In the next paragraphs, the different departments are described. To end this section, a block layout is presented for the green field. In this layout, ideas are implemented from this chapter to generate the layout.

Box processing

Arriving boxes are first checked on staples. To detect staples in boxes, a metal detector performs this check. Secondly, a quality check combined with the decision whether a box needs to be cleaned is performed. At the green field, boxes can be washed at SUEZ. This eliminates transportation flows to and back from Eschweiler just for cleaning. At the end of the department, a palletising machine is present that automatically makes the units. Competed units are sent to a strapping machine, there will be no more manual strapping.

Specials

At the special department, there is only one change compared to the current situation. All inner units are processed centrally at the inner units department. Therefore, a transportation system is present to transport inner units to the central department. Only special units are strapped by hand.

Pallet break down

The pallet break down between the input conveyors and workstations a quality and label removal station is positioned. The activities are centralised at the pre-processing station and are no longer performed at the workstations. At the station a worker checks if a crate can be disassembled by a robot or needs to be manually disassembled. All non-damaged crates are sent to the robot system. All broken crates and non-standard crates are sent to a manual workstation. Workers do not need to lift pallets anymore by hand. A pallet stacker will make the pallet units. In this way, a workstation can be operated by one worker if necessary.

At the robot cell a robot disassemble the crate automatically, and can continue during the break.

Inner units

The inner unit department does not change, only addition is that the inner units present in special pallets are processed at the inner units.

Strapping machines

Two strapping machines are present at the green field for two reasons. First, manual strapping of units does no longer occur. All units in half and euro size pallets are strapped automatically according to the Scania guidelines. Secondly, because all work is done in one shift, the amount of units that have be strapped in a working hour increases.

Proposed layout

In Figure 6.3, an example depicted of a possible block layout at the green field. The pallet break down is essentially a large cross-dock. The input and output flows are separated, all E and H units are sent through the strapping machines. In Figure 6.4, we worked out in more detail the material flows and sub processing stations of Figure 6.3.

Required area

The brownfield currently has an area of 1,500m² for the departments. In a new layout, extra layout is required for the extra workstations, strapping machine and conveyor. The estimated area for the new layout is 2,000m² to 2,500m² for the departments. At the green field, a buffer of around 1,000m² is required for incoming materials, primarily for the materials that arrive overnight.

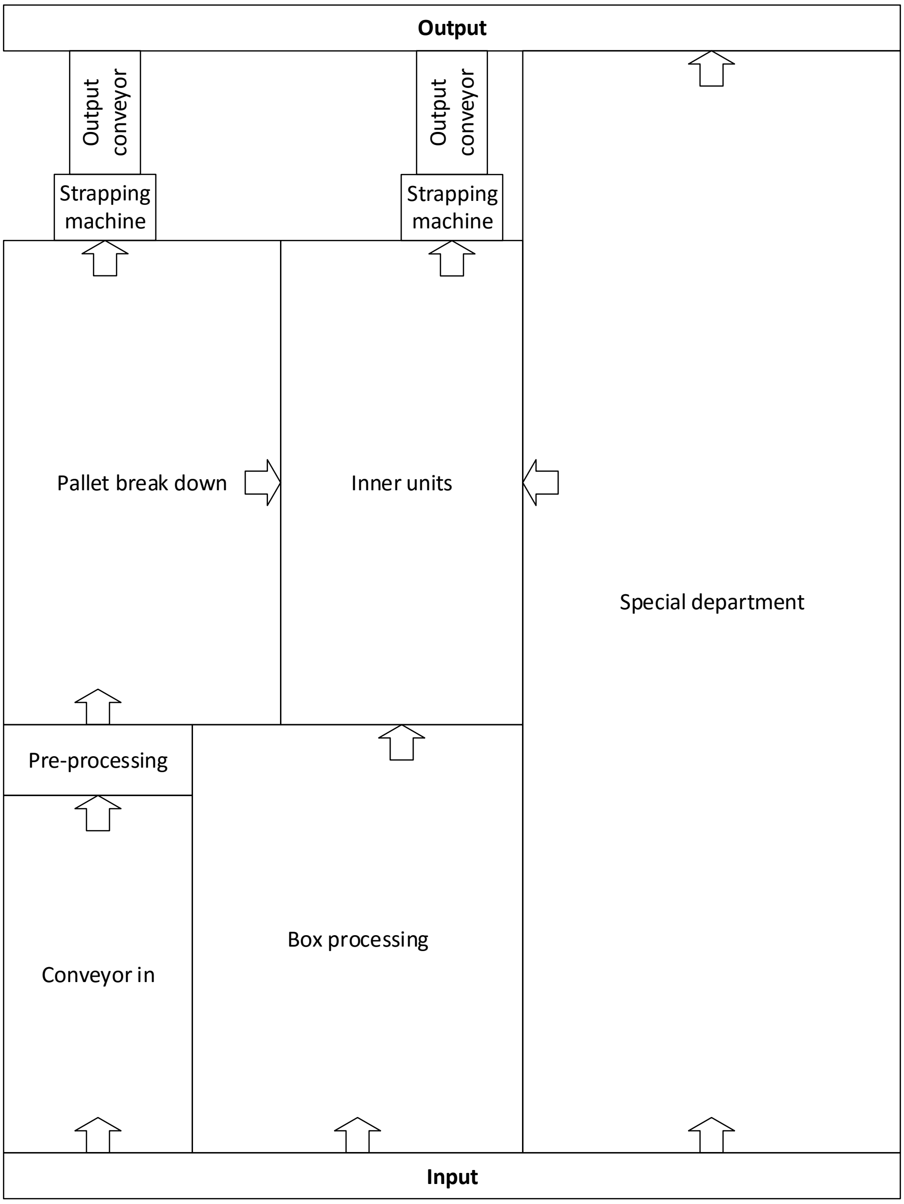


Figure 6.3 Possible block layout green field

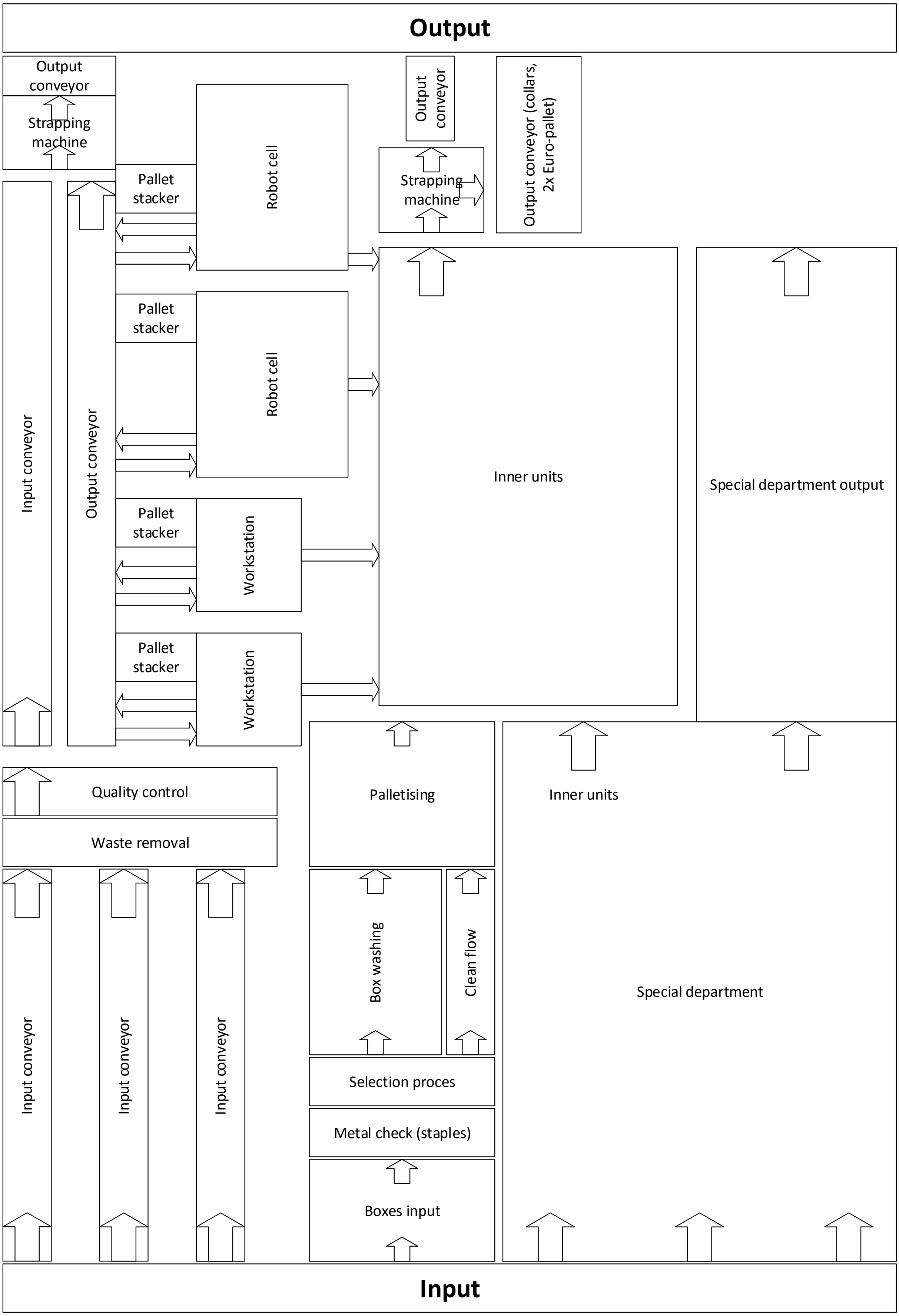


Figure 6.4 more detailed block layout

6.9 Conclusion

In this chapter the advantages and disadvantages are viewed what would happen when the pallet break down is moved to an external location, where a complete new plant is realised. In this green field, everything is possible, what may currently be taboo. Although the green field is not realistic, the green field can be compared with the brown field (current situation). The brown field is shaped with 'old knowledge', in a hurry back in 2011 and with a Scania view and restrictions. Currently, even Angers could be seen as a green field, which even exists. In Angers, some improvements already exists.

Major downside to move to an external location is that road transport have to be organised between the SUEZ location and Scania. Outside office hours, some employees are needed to fill trailers. Currently, Scania pays for example for buildings and electricity these advantages will disappear.

Advantages with a green field are yearly saving of €80,000 euros is possible, only looking at shift fee and clothing. Moreover, higher efficiency and throughput are possible. Finally, the SUEZ process is completely decoupled from the Scania production process.

A green field is only realistic if two conditions are satisfied. The savings on its own are lost with the extra transportation and building costs. Therefore, two conditions have to be satisfied for a profitable green field:

- A long-term relationship with Scania, such that investments can be made;
- Significant efficiency improvements that are only possible on a green field.

7 Future changes

Within Scania, different research and projects are going on over the future of Scania Production B.V. changes regarding the production rates, or ways of transportation will all have influence on the pallet break down. Therefore, the last question during this research is “What are possible changes in the future of the production plant of Scania, and how do these changes influence the current process?” In this chapter, some major changes are addressed that are influencing the way of working of SUEZ.

7.1 Maximum truck production

The production lines Castor and Pollux are calculated for a maximum truck production rate. Although the maximum is not yet achieved, it is reasonable to start the preparations for the maximum production rate. During this research, it became clear that the current available capacity would not be sufficient to deal with a production rate of 200 trucks per day. The Castor production line is calculated at a maximum of 150 trucks per day in two shifts and the Pollux line is calculated at a maximum of 50 trucks per day. Currently although Scania could produce this amount of trucks, the assembly station near by the production lines would have to be improved in order to be able to deal with the higher production rate. Scania is active with preparation projects to remove these bottlenecks and to be able to increase the truck production rate to 200 trucks per day.

Although the trend in truck production is rising. If for example, a new economic crisis arises, the production rate could also collapse in a very short time. This will mean that there will be periods where the production plant will be shut down and all investments for increased capacity will have been for nothing.

7.1.1 Over the maximum

As mentioned in the scope of this research, Scania dictates the production. In the current working week of 80 hours, the physical maximum is 200 trucks per day. It is unlikely to extend the two shifts working day to three shifts. With a 24 hours operation for 5 days per week, there is no possibility to perform maintenance on the production line, nor to clean the production line during the night. Only in the weekend. Besides that, equipment will degrade much faster when it will be operated for more hours per week. In addition, very practical things will cause problems. Overnight charging of forklift batteries is not possible anymore, and more batteries are required. An advantage in a 24 hours production schedule will be that overtime costs will vanish. Full day production may be not a large problem for hours and costs. However, backlog of crates, boxes and pallets cannot be done in SUEZ’s own overtime. In other words, the flexibility at the end of the day is gone.

7.2 Internal transport

The project department within Scania is currently preparing the plan to start changing the collection of empty (half) euro pallet crates. In the near future, the crates will be placed on a trolley, by using this trolley no forklift traffic or pallet jacks are required to move these crates within the factory. The delivery of full crates and the collection of empty crates will be done by a small train. This train will not be unloaded in front of the SUEZ site, but will be unloaded in a logistics hall nearby. In the same hall where the internal transport trailers are currently loaded with full crates. In this hall, the empty crates will be loaded into the old internal transport trailer. This will result in extra handling, but reduced traffic within the factory. An opportunity for SUEZ is to unload the trolleys and load the trailer to the SUEZ site. An advantage is that SUEZ has more control to level out the arrival flow and reduce the arrival variability. For example, the current variability or arrival of crates just after the shift changes can be controlled better. In addition, the arrival for the different departments will be separated. This means that the special sized parts are loaded in a dedicated trailer and the (half) euro sized crates in a different trailer. By positioning the trailers in an optimal place per department, the trailers can be unloaded even more efficiently. In the new setup, SUEZ can load all trailers completely full. SUEZ have also large interest in the outcome of this project, and if SUEZ is proactive in participating in the project and get a position within the project. SUEZ can get an optimal result out of the project.

It is currently a wish of the project department. With help of the ERP systems at Scania it can be predicted when a crate or pallet is empty. This information can be used to schedule the transportation systems for collecting empty crates and pallets, and placing full crates and pallets. The advantage will be that the predefined schedules of collection can be replaced by driving only when a crate or pallet is empty. This will reduce variation in arrival of crates and pallets even more, because there will be more small deliveries. Management is currently not convinced that this is a safe system to replace the current predefined schedules for collection of empty crates and pallets.

7.3 Unit transport

Currently, Scania is investigating whether a regional packaging pool can be established. In the old situation, all units were sent to Voith in Germany, and from there units were sent to the customer that orders packaging materials. In the past years, SUEZ has suggested to improve that situation by also sending trailers directly to customers and the left over units to Voith. A down side to this solution is that on average more trailers are needed to fulfil the orders of all customers during a day now about 17 trailers are filled during the day. With the new plan, all units will be sent to a regional location. This makes work easy, because there are no orders anymore. All units are sent immediately to the regional pool. The forklift drivers only have to count the number of units that he or she loads in to a trailer. It also do not matter anymore which trailer is loaded. By reducing the number of destinations to one location, the average number of trucks will also decrease on the parking lot of Scania. This will help to decrease the traffic in the parking lot in front of the SUEZ site. All units are sent to the same location this will also result in less paperwork at the office. SUEZ will also have to deal with the special orders, because the specials orders are sent from the regional pool. Therefore, SUEZ does not need to have any units in stock anymore. Mathematically speaking SUEZ can minimize inventory up to zero units.

Combining the ideas of the previous two paragraphs will result graphically in the unit flows as in Figure 7.1. Compared to Figure 1.2, there is no more congestion and crossing forklift traffic.

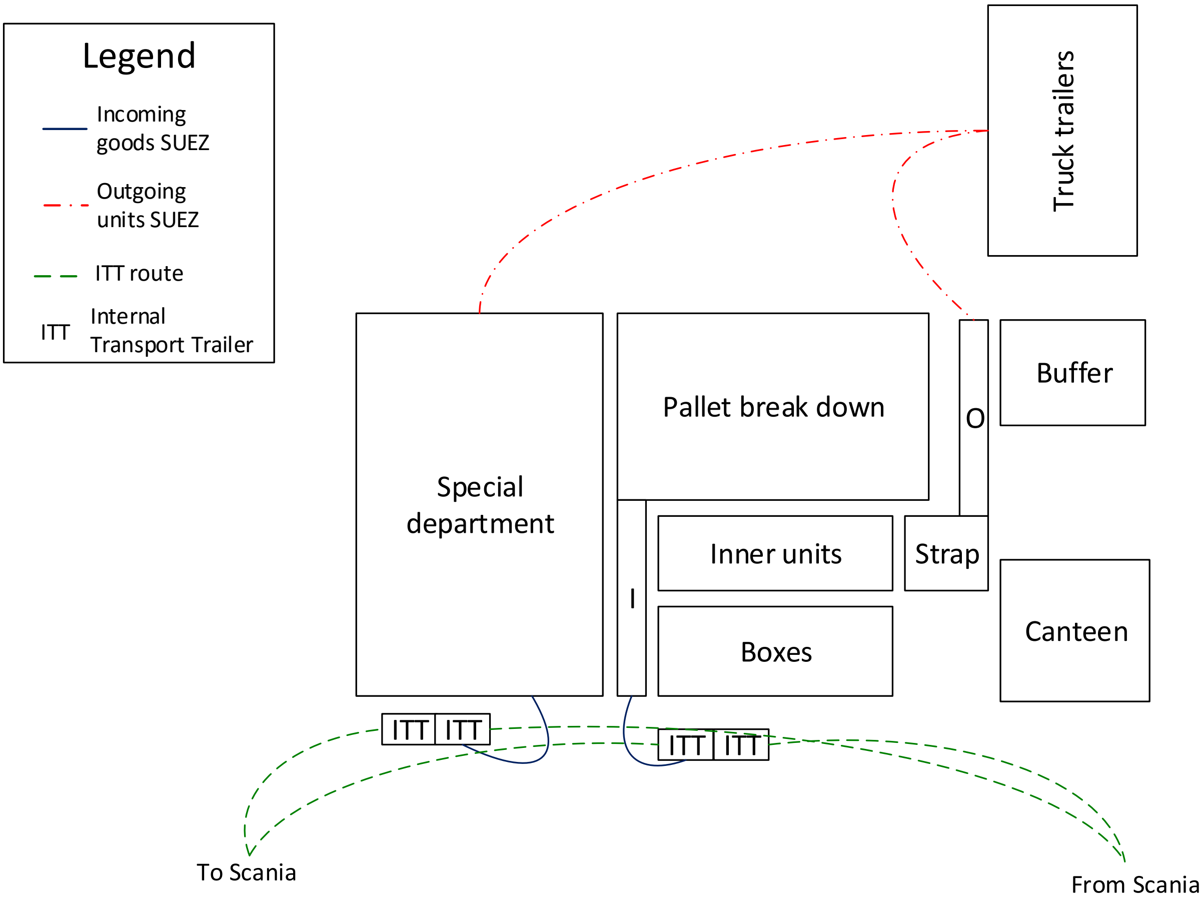


Figure 7.1 Combining new internal transport and unit transport

7.4 Conclusion

As became clear during different visits at the different departments at Scania a few major changes are investigated and are prepared at Scania. We propose SUEZ to follow these projects and to stay up to date. Moreover, to have a voice within the project to get the best out of the research and changes that will affect the processes at SUEZ.

The answer to the sub question in this chapter is the following; it is very likely that changes in the near future will be introduced that will affect the delivery of crates, boxes and pallets, the output process of shipping units and the volumes will likely increase. Changes in the receiving and shipping process will have (in the right way) opportunities both in extra work for SUEZ, but also more simplicity which will enhance the efficiency of the workers and processes. If the truck production will increase until or over the limits this will have a significant impact on the processes and way of working. If the truck production will start tomorrow to increase close to 200 trucks per day, SUEZ will not be able to deal with the increase of work. Therefore, the truck production plan will be the most important to follow, although SUEZ cannot influence the truck production plan. We recommend SUEZ to follow the production rates closely and be in time to invest and improve processes.

8 Conclusion and recommendations

In this chapter, the conclusion and recommendations of this research are provided. Moreover, we will propose a direction for further research. In the next paragraph, also the answer is given to the main question of this research.

8.1 Conclusions and recommendations

The main question of this research is:

How can the current process at the pallet break down of SUEZ Zwolle be improved by reducing operational costs and increasing throughput by changing the pallet break down?

To answer the main question current activities, performance and the costs and incomes of the pallet break down have been analysed. We applied the Systematic Layout Planning framework to develop layout alternatives. Based on a literature review we created a simulated annealing construction heuristic that creates alternative facility layouts. The objective value of the heuristic is to find a layout such that the total transportation costs are minimised. The heuristic is made such that it can be easily changed in the future and can be reused. In addition, the advantages and disadvantages of moving the pallet break down to a green field location outside the Scania terrain have been studied. Finally, we have investigated at Scania which changes are likely to occur in the near future at Scania that influences the pallet break down process of SUEZ.

This has led to the following results, conclusions and recommendations in the areas of layout, logistics and processes:

1. Material arrival at the pallet break down varies during the day. By far the largest peak for SUEZ occurs during the shift change of Scania. This peak is once a day and lasts for one hour. The cause for this peak is that Scania employees on average stop a quarter before the end of the shift. Since SUEZ equipment and personnel planning is based on peak levels, avoiding this peak can save 2 FTE. In addition reducing this peak may avoid investments by SUEZ in additional capacity of the conveyor system required when Scania would increase their production level to 180 trucks per day. Avoiding these peaks for SUEZ will require at Scania a culture change to work until the end of the shift.
2. Both SUEZ Zwolle and SUEZ Angers face similar problems. At SUEZ Angers, many processes are structured better. SUEZ Zwolle can learn and adopt from SUEZ Angers. It is recommended to cooperate more with SUEZ Angers to innovate and improve and to help each other.
3. Activities of SUEZ are not completely documented. Start defining all activities on paper, for all activities define: what is the scope, objective, safety issues, who is the problem owner and who pays for it. Periodically check whether these activities are still in line with agreements. This to prevent that activities change uncontrolled and that the scope of work increases.
4. The current KPIs are demanded by Scania and are not suitable for SUEZ. To gain insight in processes and to trigger improvements, we recommend SUEZ to define and introduce its own KPIs and PIs, like personnel absenteeism, machine availability or personnel efficiency. The KPIs and PIs can be used to measure the effects of lean and warn when changes occur in processes.

5. Both SUEZ and Scania are unaware of many losses in production. It is recommended to start investigating losses and quantifying them. Make clear to Scania what (product) losses SUEZ detects, or even come with a proposal to stop the (product) losses. As long as Scania is unaware of losses and possible improvements Scania will not change or facilitate improvements. Suggestions for improvement made by SUEZ will also contribute to a long-term relationship with Scania.

6. On crates Scania attaches multiple labels. This differs from Scania's guidelines that mention only one label per crate and from the practice in Angers. All extra labels, on multiple sides cause extra work for SUEZ in removing the excessive labels. We propose to Scania that they follow their own guidelines better.

7. The non-production departments cause the total transportation costs to be 34% higher at the pallet break down. Moving the non-production departments away will reduces the total transportation costs.

8. Due to failures at the strapping machine of SUEZ rework is performed. This rework causes 2.4% of the total transportation costs. Improving the strapping machine can eliminate rework.

9. Scania is investigating whether the inbound and outbound flow can be separated. This is an opportunity for SUEZ. This change will require a redesign of the flow at SUEZ. Separating the flow will decrease the total transportation costs by 29.6% assuming that the trailers are not positioned further away.

10. The box-cleaning standard in Zwolle is higher than for other pallet breakdowns and Scania guidelines. Following the Scania standard of box cleaning, like in Angers, will save at least 2-3 employees, which saves over €80,000 to €120,000 yearly. Nevertheless, when Scania requires a higher cleaning standard, a suitable higher price can be asked by SUEZ.

11. 10% of materials that arrive at SUEZ are taken out for repair externally. Moreover, on average 32 units per day are scrapped because the materials are broken too much. To take out broken materials for repair requires 0.13 FTE extra handling time. 32 units that are scrapped equals loss of income of about €65,000 yearly. We propose Scania to check incoming materials better on quality and handle materials with more caution in warehouses, factory and during transport. This will result in less broken materials, increased efficiency, and lower costs for both SUEZ and Scania.

12. Outsourcing the box processing needs further negotiations between Wezo and SUEZ. Wezo is able to fulfil the work; the price per unit makes outsourcing not beneficial. SUEZ can take into account that outsourcing the box-processing department saves additional costs. For example, relocation of the buffer saves 39.8% of the total transportation costs. Less required company clothing and manual strapping machines can save up to €10,000 per year.

13. All units of plastic boxes are strapped by hand. This causes a lot of manual labour and is ergonomically irresponsible. By automating this process 0.28 FTE can be saved. An entry point have to be realised at the conveyor system. The strapping machine feature have to be enabled to strap these units with a lower tension.

14. Applying robots in the current process is not recommended. First, the process needs to be improved and have to be more stable at SUEZ. When the improvements are implemented and the process is stable, applying robots or more automation may become interesting for SUEZ.

15. Scania is preparing to increase its production rate to 200 trucks per day. SUEZ believes that when the production rate becomes higher than 180 trucks per day a 4th workplace is required for handling extra units. However implementing recommendation 1 (reducing peaks in the arrival flow) is a more attractive solution.

16. At this moment, there is no structural process improvement program at SUEZ. A lean program is required to structure continuous improvement. Many improvements are possible, and workers see dozens of improvements. We recommend SUEZ to facilitate and structure improvements. Lean will provide a way to:

    - Preventing rework;
    - Improving the conveyor system;
    - Using more visual indicators in the process.

17. A green field at an external location is investigated in this research and is worked out with all advantages and disadvantages in chapter 6. However, a green field is currently not feasible. Two conditions are required for a green field:

    - A long-term relationship between SUEZ and Scania
    - Significant efficiency improvements that are only possible on a green field

18. Scania is busy with investigating changes in the material flows. Both in material flow to SUEZ as from SUEZ in the form of a regional packaging pool. SUEZ have to anticipate on changes of Scania and cooperate with Scania to elaborate the plans to gain advantages in future changes.

As became clear during this research, many activities are deployed at the pallet break down to fulfil both the contractual obligations as well as servicing additional demands from different Scania departments. However without thinking about the impact on the business and performance of SUEZ itself. As a result, SUEZ may have lost sight of its own business. Financially speaking SUEZ is making a small profit but when all overhead costs are taken into account it is questionable whether the current operation is profitable. Extra work and income is of course not bad provided that there are proper arrangements.

To reduce costs and to improve throughput, we propose more cooperation between Scania and SUEZ to improve the arrival of materials to the pallet break down. We recommended Scania to focus more on following their own guidelines. In addition, SUEZ have to make its process more transparent. Implementation of a structural lean improvement program is recommended, to trigger continuous improvement of processes and performance. SUEZ Zwolle also can learn a lot from SUEZ Anger by sharing knowledge.

The following table once more summarises the conclusions and recommendations sorted on implementability and on involved parties:

	SUEZ	Scania & SUEZ
“Quick win”	2, 3, 4, 8	1, 6
More difficult	7, 12, 13, 15, 16	5, 10, 11
Long term	14, 17	9, 18

Table 8.1 conclusions sorted on complexity and stakekeholders

In the implementation of these improvements, the extensive experience of Scania in the area of process improvement can be helpful.

8.2 Further research

This research was the first research on the pallet break down activities of SUEZ Zwolle. This research showed that many improvements in different directions are possible.

The initial wish for this research was applying robots with fewer personnel at the pallet break down. This is an interesting improvement in the future when the pallet break down is better organised and there is a strictly organised process. At that time, further research on implementation of robots is recommended. We recommend further expanding the research since there are more ways to handle crates by machine. Which leads to the following future research question:

How can SUEZ implement mechanical disassembly of crates?

In further research, we propose to use the knowledge of Scania. Scania has build-up extensive knowledge in the field of process improvements that may be useful for SUEZ and in the best interest of Scania.

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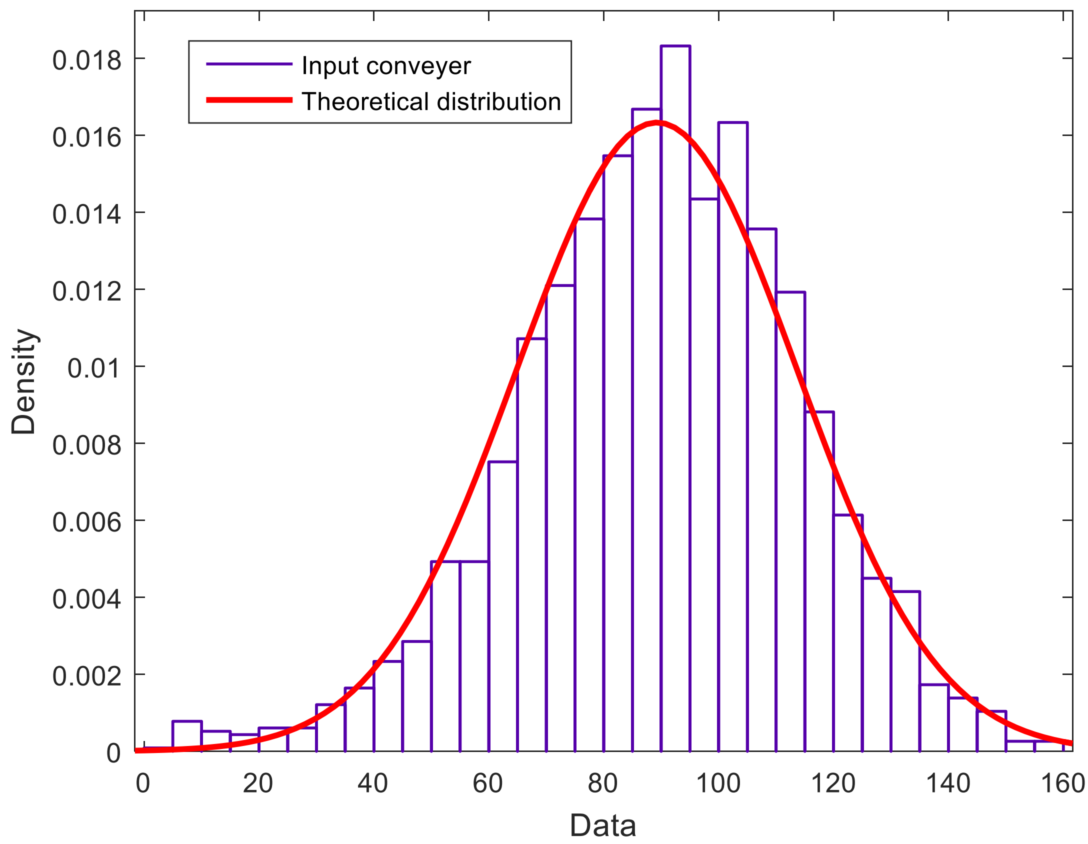
Appendix: A Process statistics

Conveyor input per hour

Conveyor input per hour	
Mean	89.24373379
Standard Error	0.507698919
Median	90
Mode	90
Standard Deviation	24.42237616
Sample Variance	596.4524575
Kurtosis	0.39700121
Skewness	-0.33880317
Range	156
Minimum	4
Maximum	160
Sum	206510
Count	2314
Confidence Level (95.0%)	0.995592573



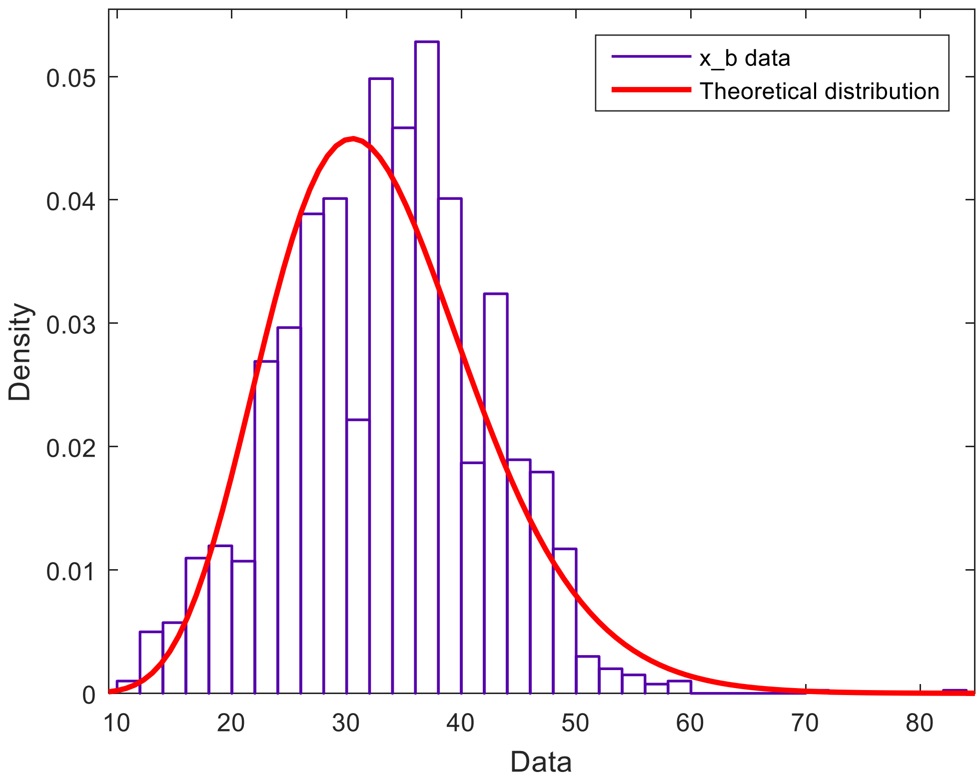
Distribution: Normal
Log likelihood: -10677.3
Domain: -Inf < y < Inf
Mean: 89.2437
Variance: 596.452

Parameter Estimate Std. Err.
mu 89.2437 0.507699
sigma 24.4224 0.359114

Estimated covariance of parameter estimates:
mu sigma
mu 0.257758 -6.528e-16
sigma -6.528e-16 0.128963

Output conveyor per hour

Units output per hour	
Mean	33.04285002
Standard Error	0.195295332
Median	33
Mode	37
Standard Deviation	8.749143667
Sample Variance	76.5475149
Kurtosis	0.309415709
Skewness	0.068494427
Range	73
Minimum	11
Maximum	84
Sum	66317
Count	2007
Confidence Level (95.0%)	0.383002907



Distribution: Gamma
Log likelihood: -7242.74
Domain: 0 < y < Inf
Mean: 33.0429
Variance: 84.0954

Parameter Estimate Std. Err.
a 12.9832 0.404693
b 2.54504 0.0808816

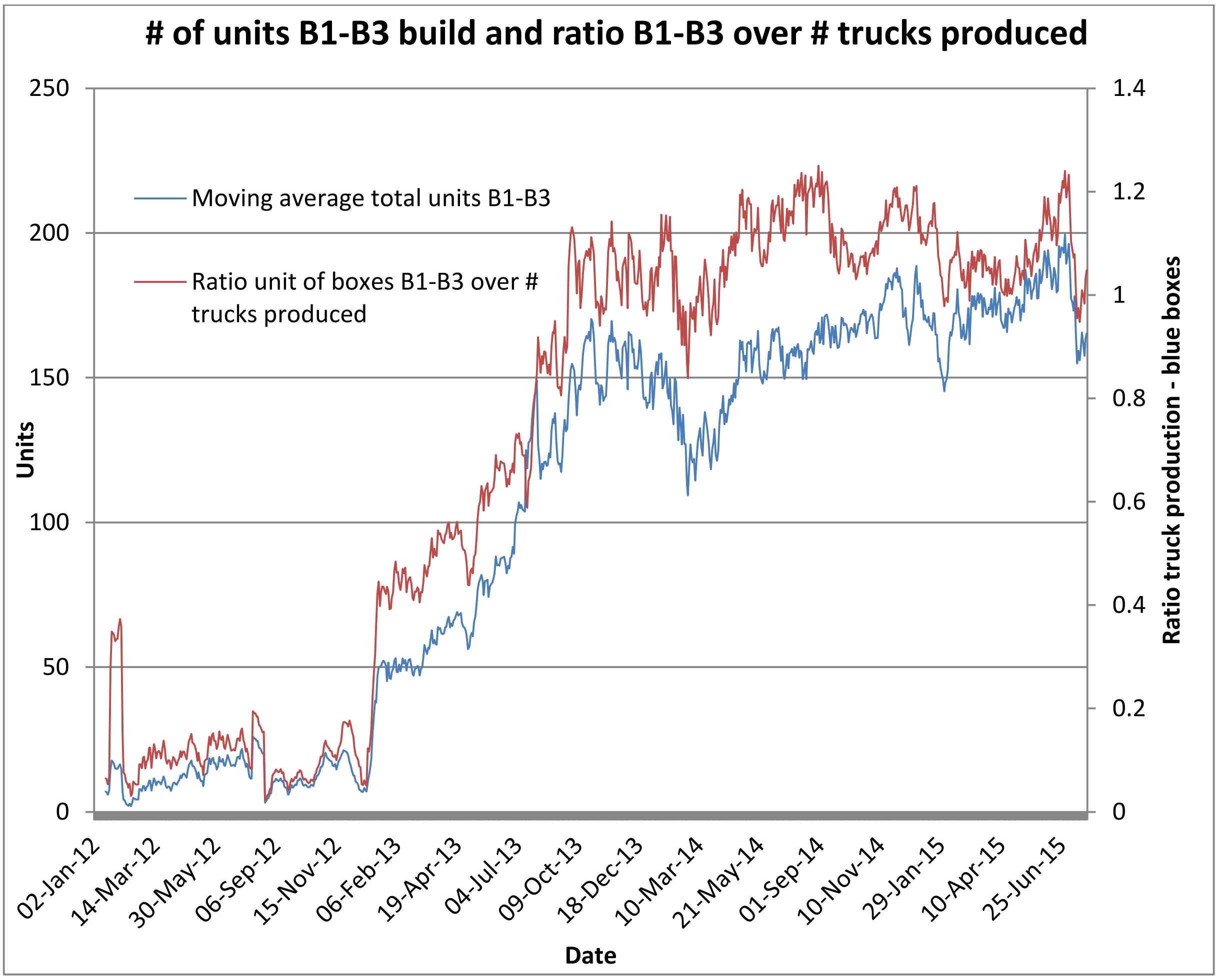
Estimated covariance of parameter estimates:
a b
a 0.163776 -0.0321043
b -0.0321043 0.00654184

Appendix: B Plastic boxes comparison Zwolle, Netherlands – Angers, France

Units B1-B3 produced in Angers France									
Description		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
MH-3147	B1 box	284	316	408	284	296	238	244	224
MH-4147	B2 box	188	218	242	164	182	154	160	130
MH-6147	B3 box	133	135	157	111	127	96	94	89
Trucks per month produced		788	863	950	987	761	1050	568	497
	Average	808							
Units B1,B2,B3 per truck		0.77	0.78	0.85	0.57	0.80	0.46	0.88	0.89
	Average	0.75							

Average Zwolle 1.08 Units B1,B2,B3 per truck

Difference 44%



Appendix: C Statistical test truck production

In advance, a truck production schedule is created for a week ($\mu_{schedule}$); the number of trucks produced per week may differ from schedule (μ_{build}).

The question is whether the number of trucks produced per week is different from the number of trucks scheduled to build per week.

To test $H_0 : \mu_{schedule} = \mu_{build}$ against $H_1 : \mu_{schedule} \neq \mu_{build}$

$T = \frac{\mu_{schedule} - \mu_{build}}{S\sqrt{\frac{1}{27}+\frac{1}{27}}}$ with $\mu_{schedule} = \frac{1}{27}\sum_{i=1}^{27}\mu_i$, $\mu_{build} = \frac{1}{27}\sum_{i=1}^{27}\mu_i$

$$S = \sqrt{\frac{1}{52}\left\{\sum_{i=1}^{27}(\mu_i - \mu_{schedule})^2 + \sum_{i=1}^{27}(\mu_i - \mu_{build})^2\right\}}$$

Under H_0 has a T student distribution with 52 degrees of freedom.

Observed value for T = 0.019

Critical range: $-2.01 < T < 2.01$

Do not reject H_0

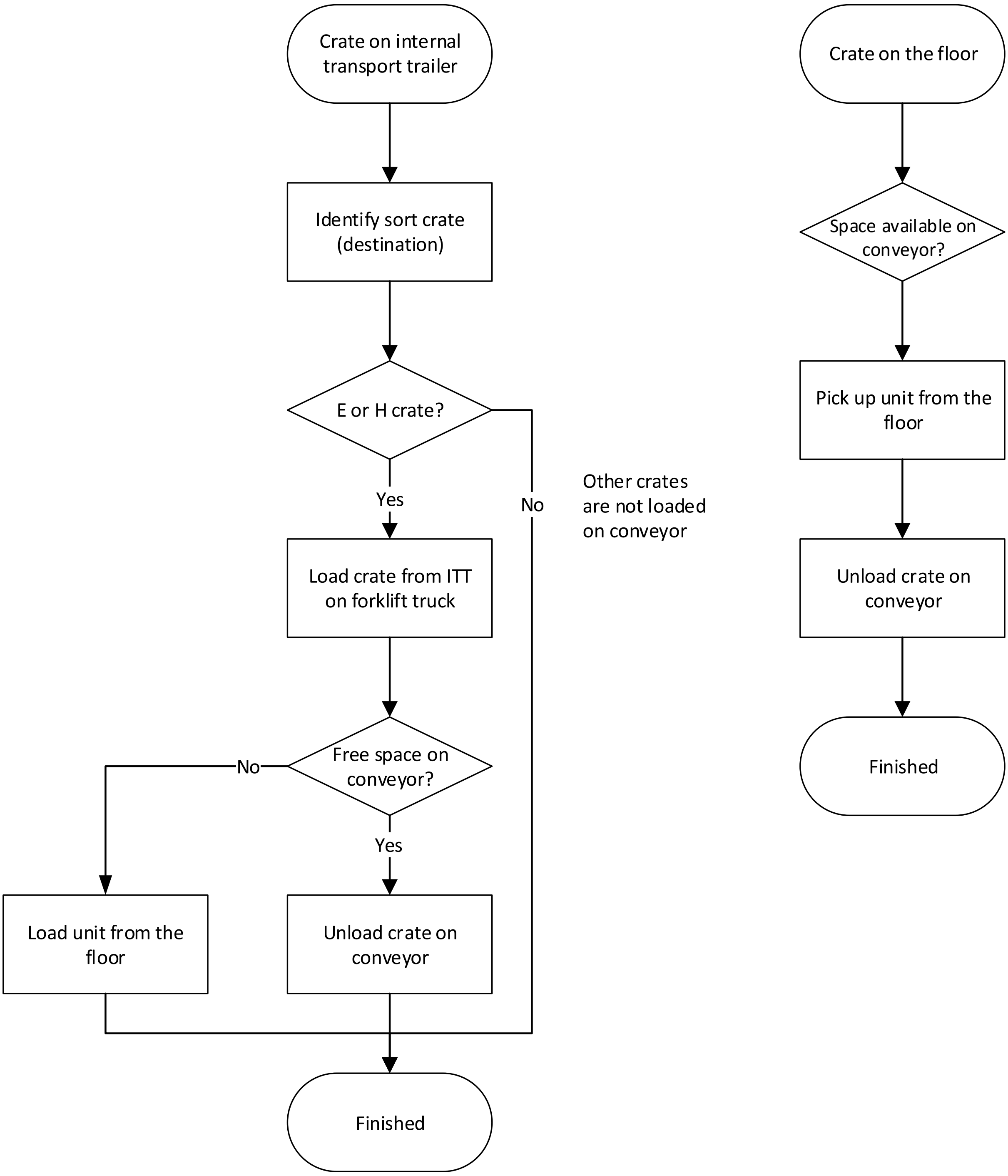
Conclusion: the observed value is not larger than the value from the table. Therefore, do not reject H_0, there is no evidence that the production schedule differs from the number of trucks build.

t-Test: Two-Sample Assuming Equal Variances

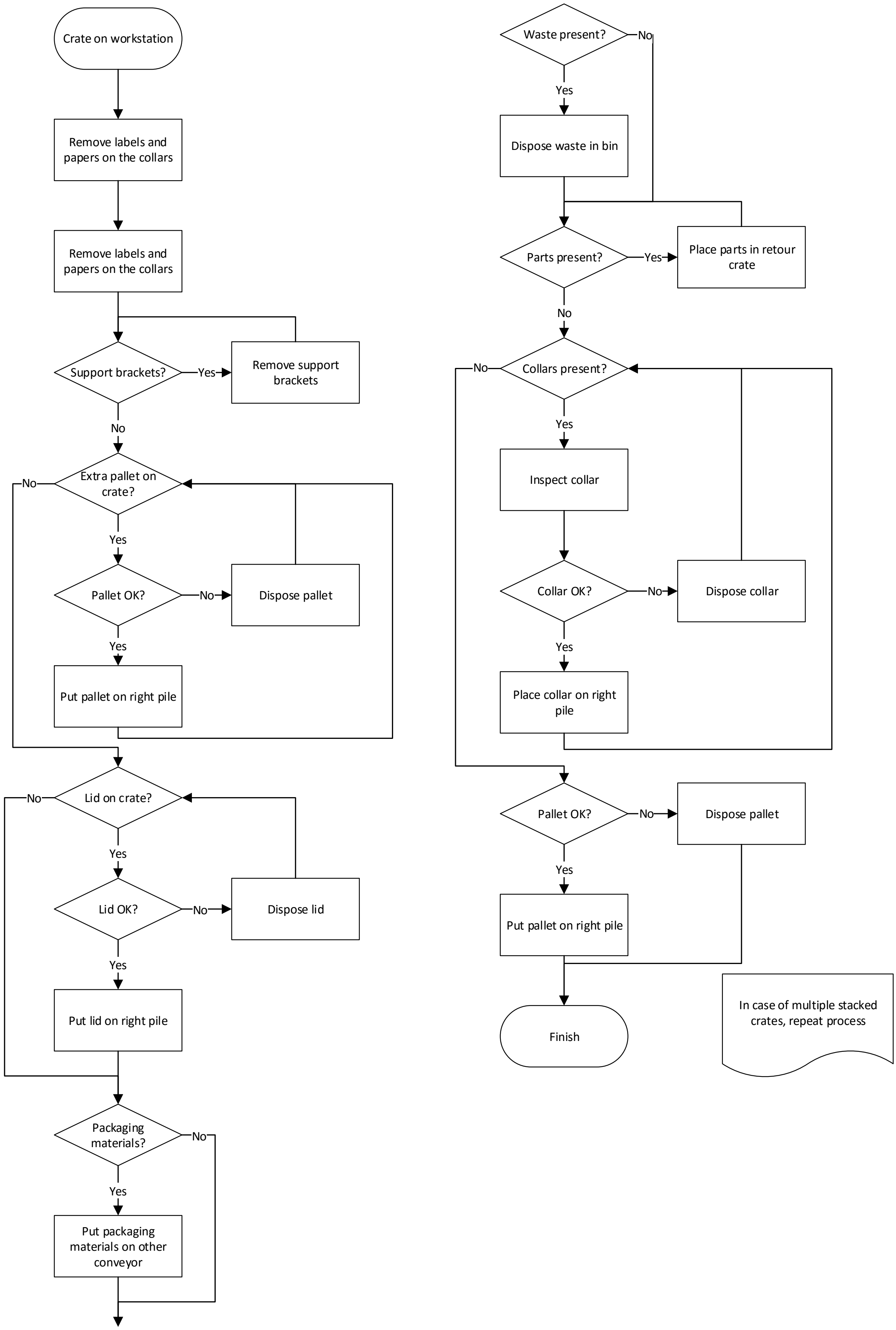
	Plan	*Realised*
Mean	779.9259259	780.3333333
Variance	5952.45584	6703.769231
Observations	27	27
Pooled Variance	6328.112536	
Hypothesized Mean Difference	0	
df	52	
t Stat	-0.018817361	
P(T<=t) one-tail	0.492529411	
t Critical one-tail	1.674689154	
P(T<=t) two-tail	0.985058823	
t Critical two-tail	2.006646805	

Appendix: D Flow charts processes

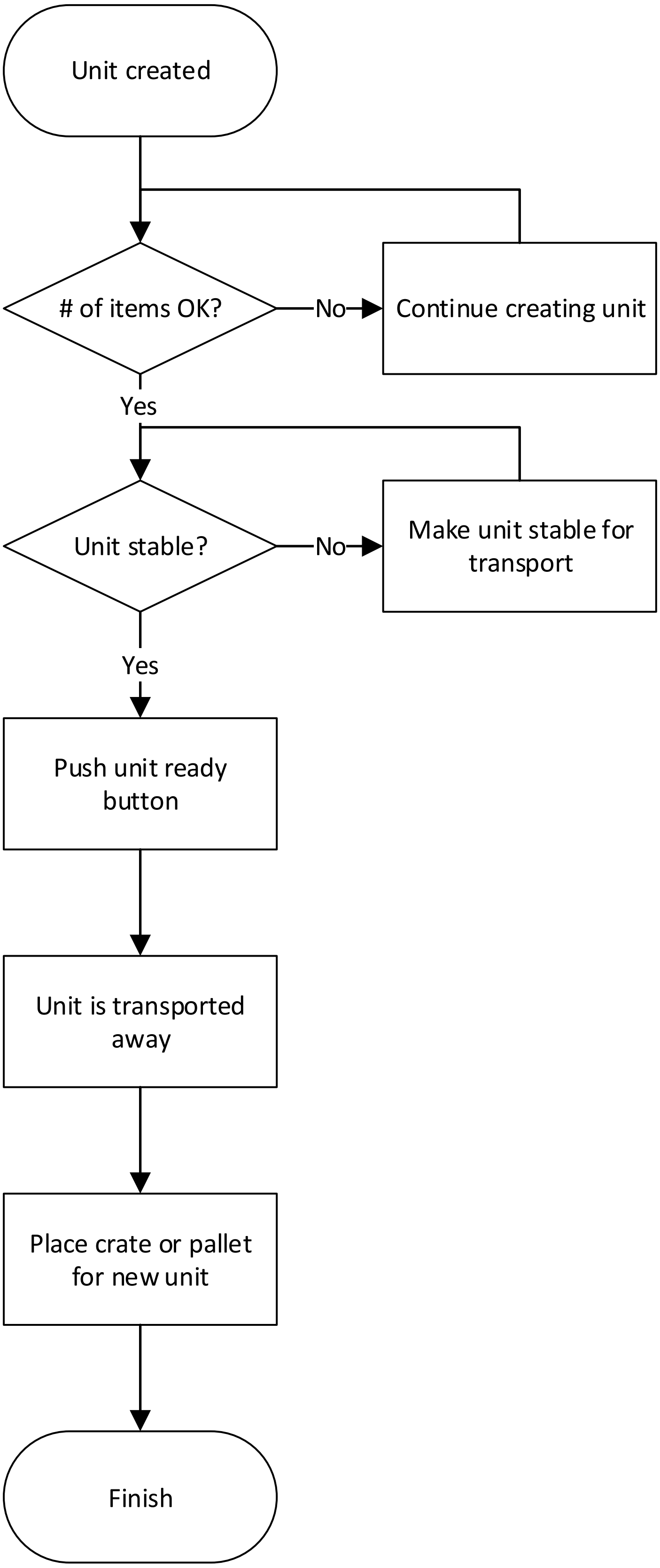
Unload Internal Transport Trailer (ITT)



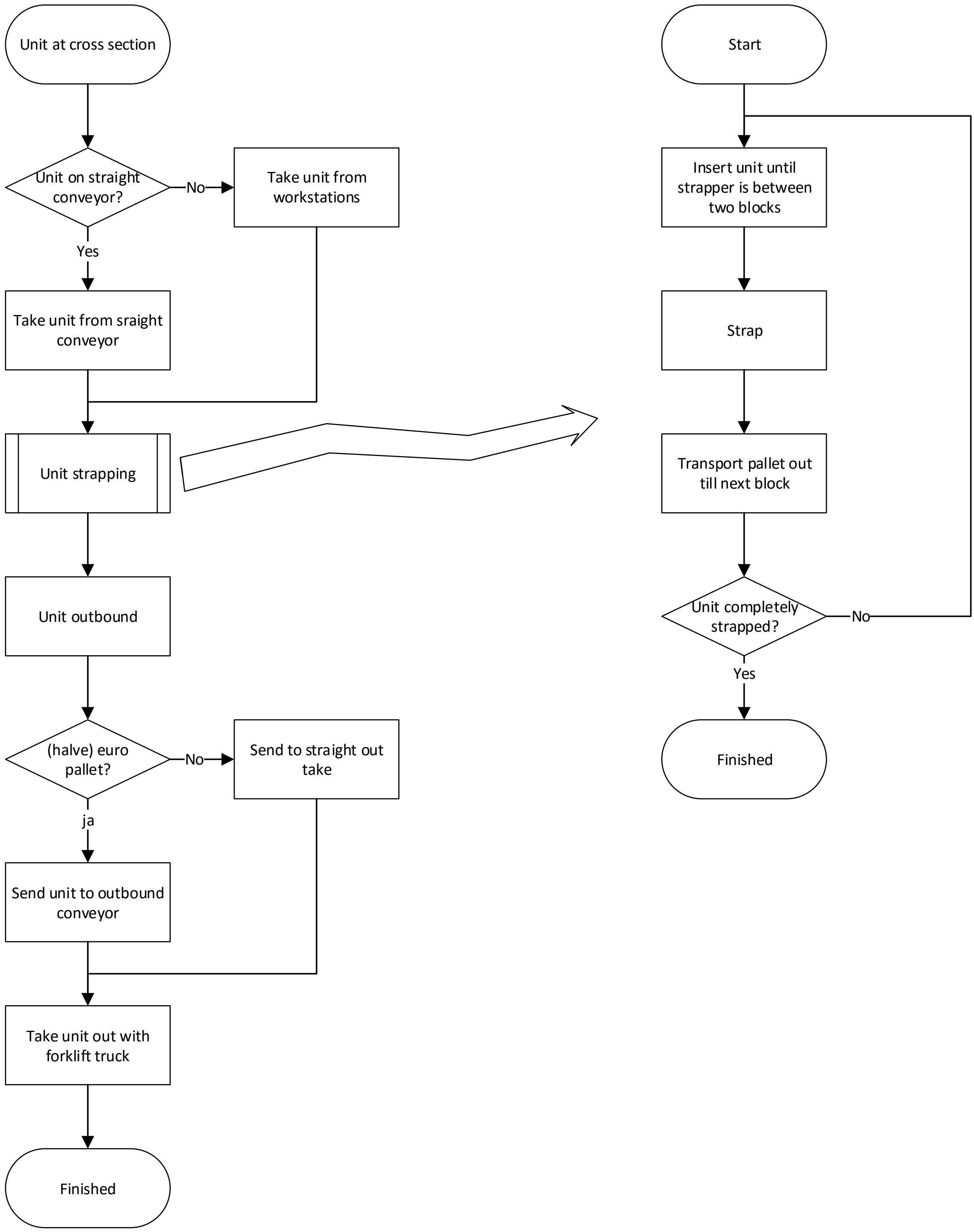
Disassemble crates



Unit created



Strapping process



Appendix: E ABC analysis units created

MH Description	Percentage	Cumulatieve
T-pallet x15	10.82%	10.82%
Mixed / defect	10.33%	21.15%
S-pallet x15	9.75%	30.90%
E-pallet	7.00%	37.91%
B1 Box, blue	6.97%	44.88%
E-collar (rand)	4.56%	49.44%
E-spacer, foam plate	4.31%	53.75%
B2 Box, blue	3.45%	57.20%
H-spacer, foam plate	3.32%	60.52%
E-lid (deksel)	3.05%	63.56%
H-pallet	2.67%	66.23%
T-collar (rand)	2.56%	68.79%
H-lid (deksel)	2.44%	71.23%
SB-spacer, foam	2.27%	73.50%
B3 Box, blue	2.23%	75.73%
L-pallet x15	2.13%	77.86%
Mixed Box, blue (dirty)	1.67%	79.53%
Mini Box/lid, green	1.60%	81.13%
X-pallet x15	1.58%	82.71%
H-collar (rand)	1.48%	84.19%
Spacer, PE-plastic	1.37%	85.55%
Small Box/lid, green	1.14%	86.70%
E-spacer, HDPE	0.95%	87.65%
Plywoodbox	0.87%	88.52%
S-collar (rand)	0.85%	89.37%
H-spacer, HDPE	0.82%	90.19%
E-insert, EPP	0.70%	90.89%
Mixed Box/lid, green (dirty)	0.60%	91.49%
E-Spacer, plywood	0.53%	92.02%
Spacer B2, PP	0.46%	92.49%
T-lid (deksel)	0.46%	92.95%
S-lid (deksel)	0.41%	93.36%
Spacer, plastic for gearboxes	0.38%	93.74%
Support Fuel TA (Katwijk)	0.36%	94.10%
Foam SB-spacer	0.36%	94.46%
Insert white (Zwolle U6)	0.35%	94.81%
X-collar (rand)	0.33%	95.13%
Divider for bumpers	0.32%	95.45%
H-insert, EPP	0.29%	95.74%
Stand, left	0.26%	96.00%
Stand, right	0.26%	96.26%
Lid B1/B2, black (deksel B1/B2)	0.24%	96.50%
Canvasbag	0.22%	96.72%

Support Fuel TA (Katwijk)	0.19%	96.91%
Canvasbag	0.18%	97.09%
Spacer, plastic	0.18%	97.27%
Foam strip 15, LDPE	0.17%	97.45%
Insert, EPP (Meppel)	0.17%	97.62%
Spaces for wheels	0.17%	97.78%
Stand, PE-plastic	0.16%	97.95%
Spacer B1, PP	0.14%	98.08%
Spacer, wood/plastic	0.13%	98.21%
Spacer B3, PP	0.13%	98.34%
Divider, EPP	0.11%	98.45%
Spacer, plastic	0.11%	98.56%
Foam strip 30, LDPE	0.11%	98.68%
Stand, middle	0.10%	98.78%
Fixing bult (Zwolle U7)	0.09%	98.87%
Bosch, plastic box (grey)	0.09%	98.96%
L-collar (rand)	0.08%	99.04%
Various / diversen	0.08%	99.12%
Insert red (Zwolle U6)	0.08%	99.21%
Tray, plastic plate	0.08%	99.28%
X-lid (deksel)	0.08%	99.36%
Spacer, wood	0.08%	99.44%
B4 Box, green	0.07%	99.50%
Collar retainer	0.06%	99.56%
Spacer, wood	0.05%	99.61%
L-lid (deksel)	0.05%	99.66%
H-spacer, board	0.04%	99.70%
Spacer, wood	0.04%	99.75%
M-pallet x15	0.04%	99.79%
Spacer, wood	0.04%	99.82%
Spacer, wood	0.03%	99.85%
Canvasbag	0.03%	99.88%
Tray, plastic plate	0.02%	99.90%
Insert green (Zwolle U6)	0.02%	99.92%
Spacer, wood	0.01%	99.94%
E-spacer, board	0.01%	99.95%
Spacer, wood	0.01%	99.96%
Spacer, plastic	0.01%	99.97%
Spacer, ABS-plastic	0.01%	99.98%
Collar retainer	0.01%	99.99%
M-collar (rand)	0.00%	99.99%
Bosch, plastic box (blue)	0.00%	99.99%
Spacer, board	0.00%	100.00%
M-lid (deksel)	0.00%	100.00%
Collar retainer	0.00%	100.00%
Insert blue (Zwolle U6)	0.00%	100.00%

Appendix: F Regression analysis temporary labour

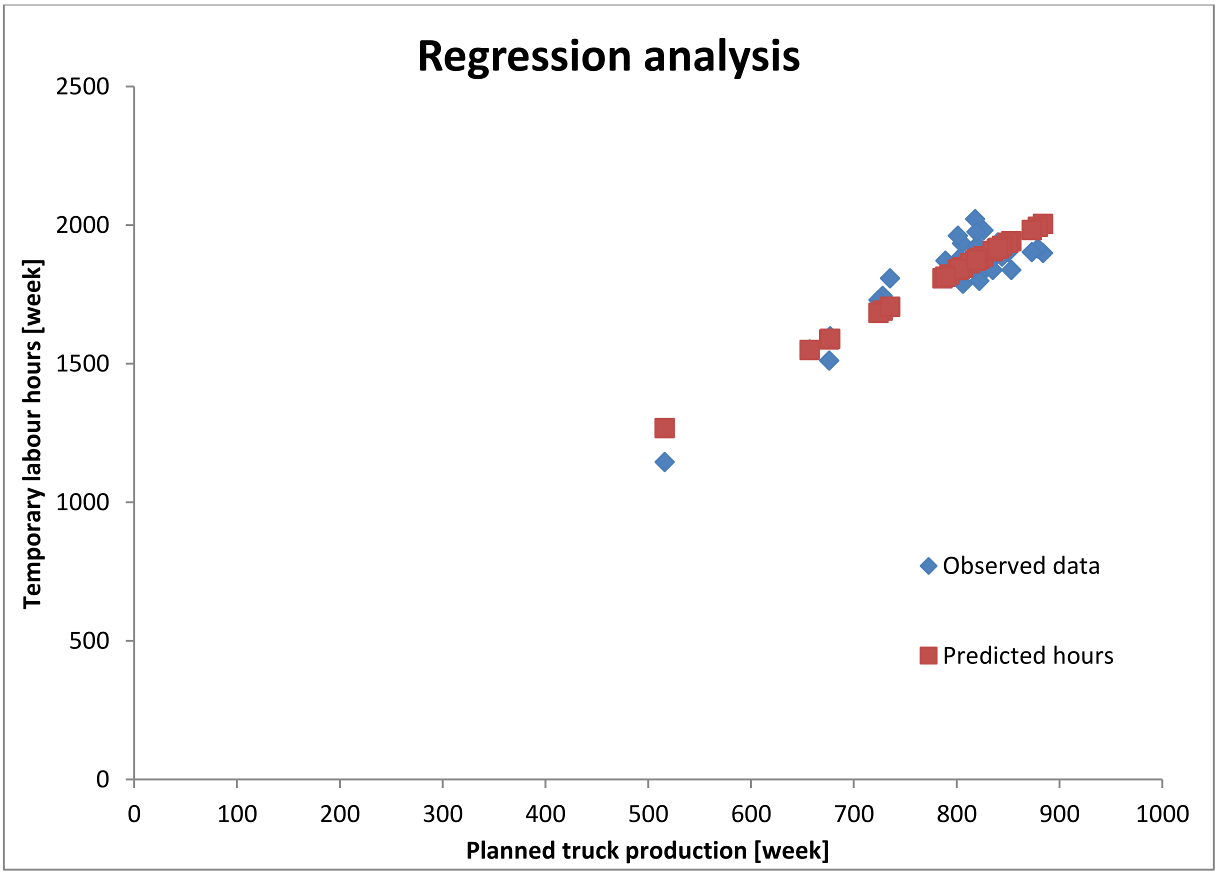
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.9040
R Square	0.8173
Adjusted R Square	0.8121
Standard Error	69.3646
Observations	37

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	753268	753268	156.6	1.77412E-14
Residual	35	168401	4811		
Total	36	921668			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	234.275	127.688	1.835	0.075	-24.9452	493.4955
X Variable 1	2.003	0.160	12.512	1.77412E-14	1.6780	2.3280



Appendix: G Regression analysis units produced

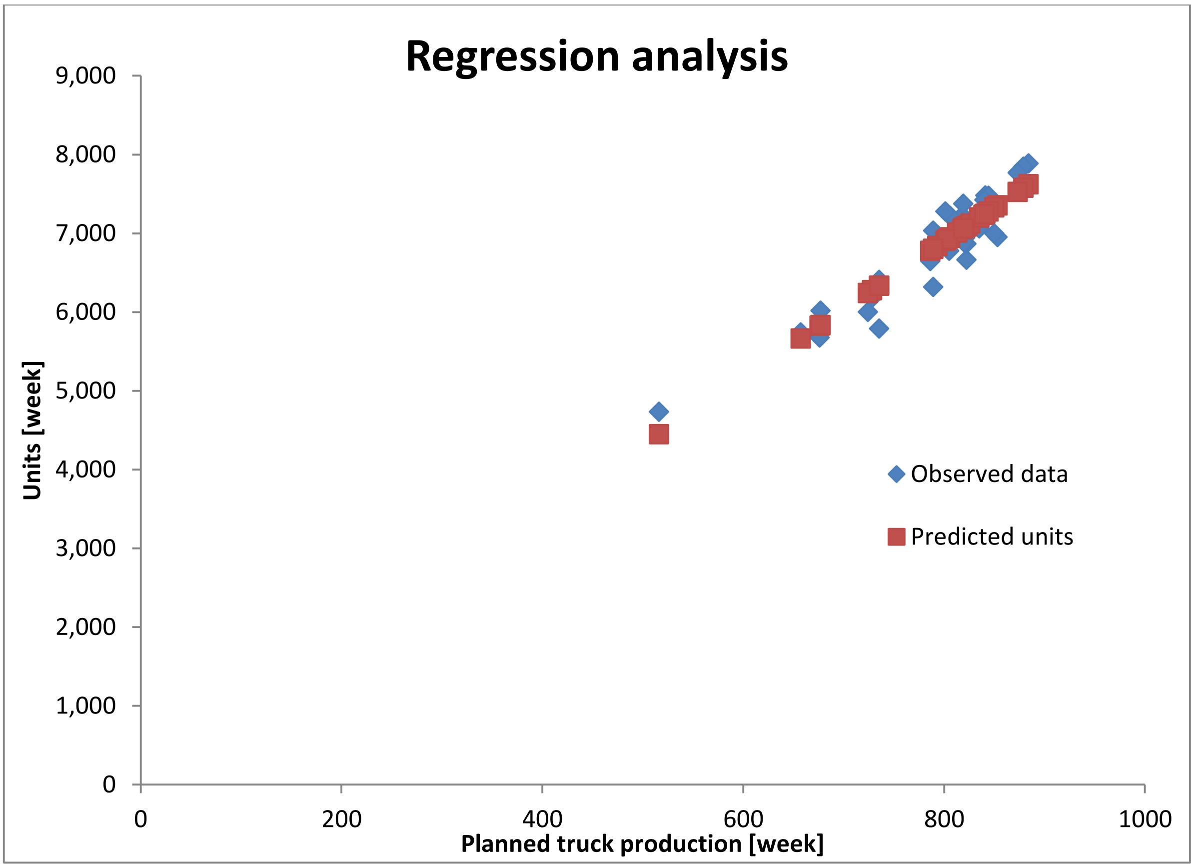
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.9313
R Square	0.8674
Adjusted R Square	0.8636
Standard Error	247.0231
Observations	37

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	13970567.0	13970567.0	228.9	6.31692E-17
Residual	35	2135714.2	61020.4		
Total	36	16106281.2			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-2.455	454.726	-0.005	0.996	-925.598	920.688
X Variable 1	8.626	0.570	15.131	6.31692E-17	7.469	9.783



Appendix: H Pseudocode heuristic

```
Start of function
Initialise all variables, parameters and random number generator
Current temperature is start temperature
Start with all departments on coordinates (0,0)
Calculate current solution as starting solution
Best solution is current solution
Do while NOT STOP (temperature lower bound)
    For 0 to length of Markov chain
        Pick a random department from list of departments
        Store current coordinates X and Y of chosen department
        Pick a random new coordinates X and Y for chosen department
        Calculate neighbour solution
        If neighbour solution is lower than current solution
            Current solution = neighbour solution
            If neighbour solution is lower than best solution
                Store current objective and coordinates as new best solution
            Else
                Calculate acceptance ratio
                If acceptance ratio is larger than a random number U(0,1)
                    Current solution = neighbour solution
                Else
                    Swap back to previous layout (deny change)
                End if
            End if
        End if
    Next
```

Current temperature = current temperature * decrease factor

Loop

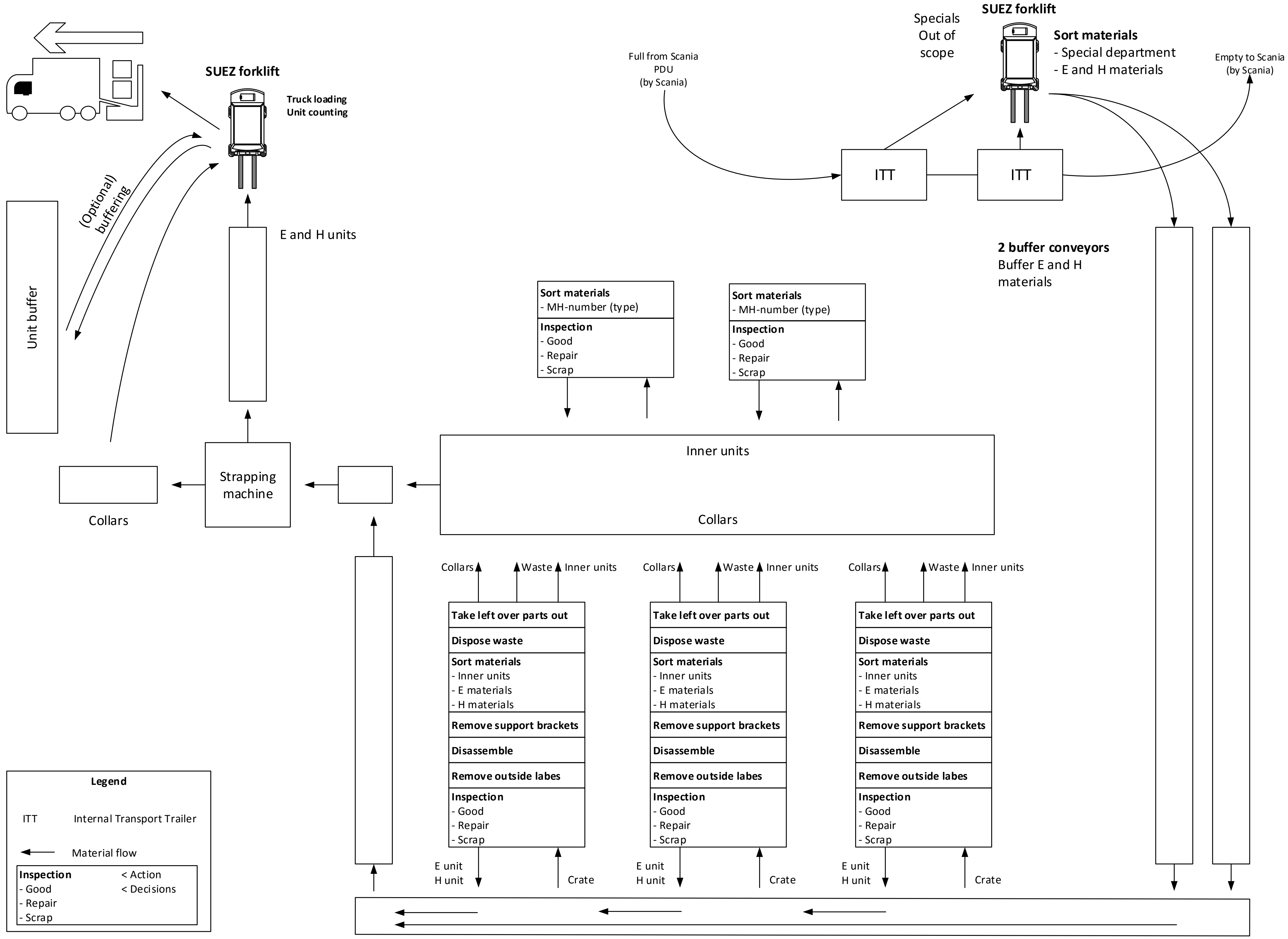
Restore best solution found

Draw best solution in picture

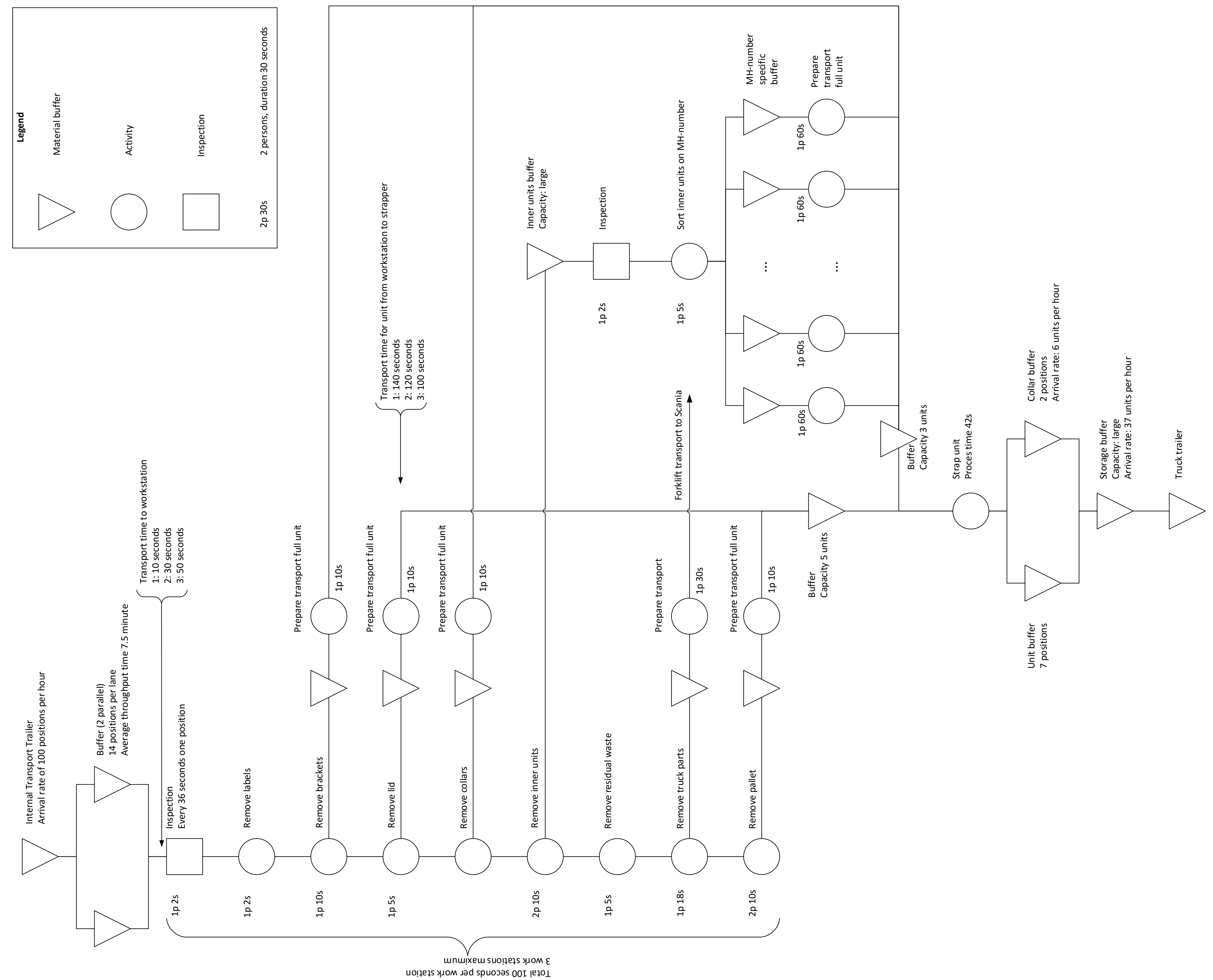
End function

Appendix: I Process schemes

Pallet break down



Process times



Special department