Improving the Waste Supply Chain at the Ford Automotive Company South Africa

Tanya Venter

September 27, 2018

Project report submitted in partial fulfilment of the requirements for the module
BPJ 410 Project
at the
Department Industrial and Systems Engineering

University of Pretoria

DECLARATION OF ORIGINALITY

Full names: Tanya Venter
Student number: u15007482

Declaration

1. I understand what plagiarism is and I am aware of the University's policy in this regard.
2. I declare that this is my own original work.
3. Where other people's work has been used (either from a printed source, internet or any other source) this has been carefully acknowledged and referenced in accordance with departmental requirements.
4. I have not used another student's past work to hand in as my own.
5. I have not allowed, and will not allow, anyone to copy my work with the intention of handing it in as his/her own work.

Signature: Tanya Venter
(By typing my name, I pledge that I signed this declaration.)

Abstract

DHL Supply Chain is a logistics company with various specialities. One of these specialities is in the manufacturing automotive sector. Ford Motor Company South Africa is one of the manufacturing companies making use of the DHL Supply Chain logistical expertise. DHL Supply Chain managers have identified areas needing improvement within the Ford Motor Company South Africa waste supply chain. This supply chain is divided into two processes in this report - the first process being the recyclable waste supply chain process and the second the returnable TrenStar bin waste supply chain process.

The packaging waste restricts the flow of the assembly process and any other movement in the facility. There is a need to improve the flow of the waste materials through the facility as well as to ensure that the waste is not on the floor for extended periods of time. Managing the waste currently requires more resources than necessary. The aim of this project is therefore to optimize the flow of the packaging waste materials through the facility to save resources and increase space.

Each process was individually analysed using process flow mapping, and the problematic process steps identified. Using the 5W1H method, the root causes of the problem areas were pinpointed. The problem areas as well as the root causes were used to establish possible solutions.

In the literature review, industrial engineering areas such as quantifying measurements, material handling, supplier relationships and 5s were researched. Each engineering area has relevant techniques and tools to establish solutions for the identified problems. These techniques and tools were used to develop a research approach which was followed throughout the solution determination process.

A quantification model was developed to quantify the waste generation amount. From there the material flow solutions with regards to the facility layout and material handling equipment were narrowed down. Possible solutions for each problematic process step were constructed within the chosen sections. The solutions were categorized according to the industrial engineering areas and the techniques used to establish the solution. The solutions were then compared to determine the optimal interim corrective actions as well as the permanent corrective actions.

Ten corrective actions have been recommended in the conclusion to expedite the flow of the waste materials through the facility as well as to decrease the resources required to handle the waste materials. The recommendations would also decrease the time waste packaging materials would spend obstructing horizontal space.

Contents

List of Figures

List of Tables

Abbreviations

3PL Third party logistics

I2M Inbound-to-manufacturing

ICA Interim corrective action

MF Material flow

MH Material handler

MHE Material handling equipment

MS Milkrun and Sequencing

P2L Pick-to-light

PCA Permanent corrective action

POU Point-of-use

SCI Supply chain intergation

SR Supplier relationship

VM Visual management

WFM Waste flow mapping

1 Introduction

Although waste management is sometimes regarded as unimportant, it is an intricate part of a supply chain. Companies should focus on the flow of waste because waste management is an important requirement for ecological sustainable development [11]. Many resources are required to move and sort waste [26]. By efficiently moving and disposing of waste, the excessive resources required can be minimized and utilized in a different section.

DHL managers have identified improvement opportunities in the waste supply chain at the Ford Motor Company SA automotive assembly line.

1.1 Company background

DHL is a leading contract logistics provider. They provide high quality customized solutions based on standardised modular components. Some of these components include warehousing, transportation and value-added services. DHL Supply Chain (SC) is a DHL branch that solves business challenges and integrates solutions.

DHL SC has multiple sectors and automotive is one of them, with a specialised area known as Component Manufacturers. With this specific expertise DHL provides the manufacturer with the necessary logistics support to keep the assembly line flowing. The continuous flow is accomplished by supplying the assembly line with the needed parts as well as a wide range of inbound-to-manufacturing (I2M) and value-added services. One of the DHL customers making use of this expertise is Ford Motor Company SA.

The Ford vehicles are assembled on a continuously moving conveyor. This method means that each station needs the required materials at point-of-use (POU) to avoid stoppages in the process or disrupting the movement of the employees [3]. DHL ensures that the materials are at the workstation when needed. As a part of the manufacturing component logistics, it is the responsibility of DHL to move the waste materials (the component packaging) to the dedicated waste areas. With this responsibility, problem areas along with some improvement opportunities were identified. These problem areas are discussed in the project background.

1.2 Project background

Each Ford vehicle consists of multiple parts from various suppliers. These parts are then moved from the warehouses to their workstations via picking methods dedicated to the area. Each supplier has different packaging techniques to protect their products. The general packaging method is to use cardboard boxes with plastic and polystyrene or TrenStar bins. Some of the components are unpacked/unwrapped before being transported to the workstation, others are unpacked/unwrapped at the workstation for protection. The packaging is regarded as waste since it does not add value to the vehicles [18].

Numerous areas on the plant floor are obstructed with packaging waste materials as the components are unpacked and unwrapped. The obstruction is caused by the size of the waste that utilizes a lot of space. Waste obstructing the pathways is dangerous to the employees and hinders efficiency. The cardboard boxes and other recyclable waste is discarded into dedicated trolleys in each area. Sometimes the waste trolleys are full or unavailable, and the employee must travel a longer distance to dispose of the waste in a different area or the waste is placed on the floor. A third logistics party, SuperCare, collects the waste from these collection points and disposes of it. Empty TrenStar bins (also regarded as waste as they add no value) are stacked in a waiting area or a carton flow rack. The empty bins are transported to the TrenStar facility on the Ford Motor

Company site. SuperCare and TrenStar have relationships with Ford Motor Company SA only, and consequently they have no clear supplier relationship with DHL. A process overview is given in the next section.

1.3 Process overview

The waste supply chain is split into two processes - the first process being the recyclable waste supply chain and the second process the TrenStar waste supply chain.

There are four companies involved in the immediate recyclable waste supply chain on the Ford facility grounds. These companies are Ford Motor Company South Africa, DHL Supply Chain, SuperCare and The Reclamation Group. Ford is the process owner and the other three companies are suppliers. DHL handles the manufacturing logistics to ensure that the stock is at the assembly line in time and that the waste is removed to make space for new parts. SuperCare is the cleaning company on the Ford facility grounds and the Reclamation group owns the scrapyard.

Figure 1 illustrates a high-level overview of the renewable waste supply chain.

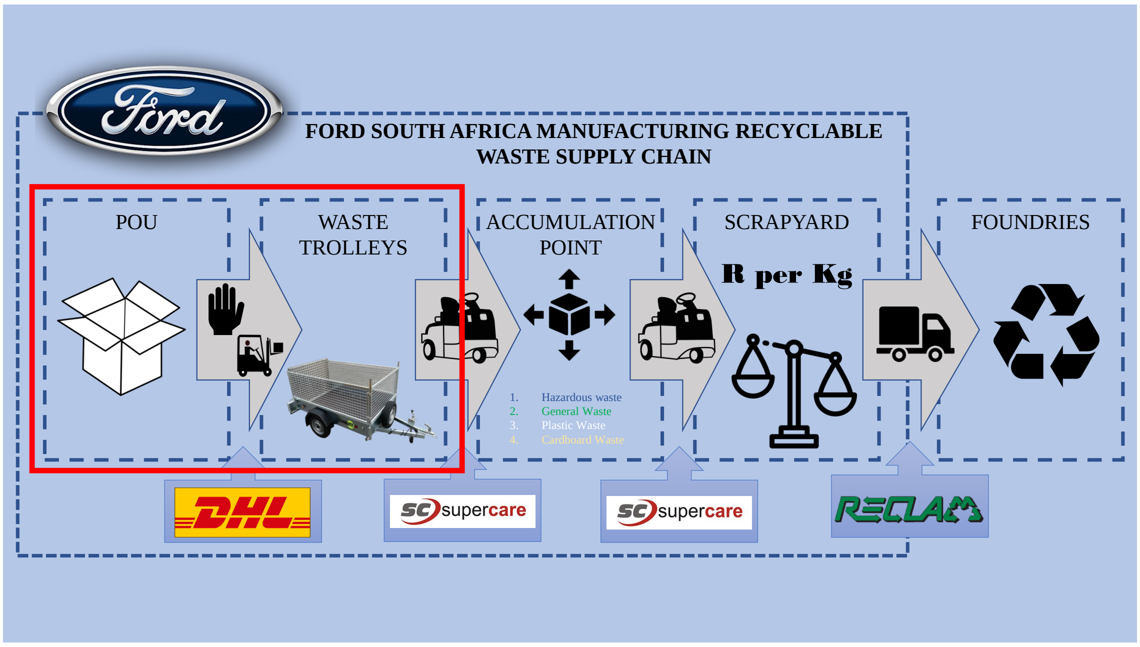


Figure 1: Recyclable waste supply chain process overview

The waste is collected from the workstations by DHL and thrown into waste trolleys in dedicated areas. There are four trolley colours. Each colour represents a specific waste type. They are:

- Blue trolley - Hazardous waste
- Green trolley - General waste
- Yellow trolley - Cardboard waste
- White trolley - Plastic waste

SuperCare moves the general and recyclable waste from the allocated areas in the plant to an accumulation spot where the rest of the waste is sorted. After sorting the waste, SuperCare transports the waste to the scrapyard. Lastly, The Reclamation Group purchases the waste per weight from Ford and then, in turn, transports the various waste types to their particular foundries.

A lot of the parts from local suppliers are delivered in returnable TrenStar bins. Figure 2 illustrates a high-level overview of the TrenStar returnable supply chain. Once the bins are emptied at the workstations, they are collected and then returned to the TrenStar facility (on the Ford Motor Company SA grounds). TrenStar employees offload the bins from the DHL tow motor flat beds, wash the bins and return the bins to the suppliers.

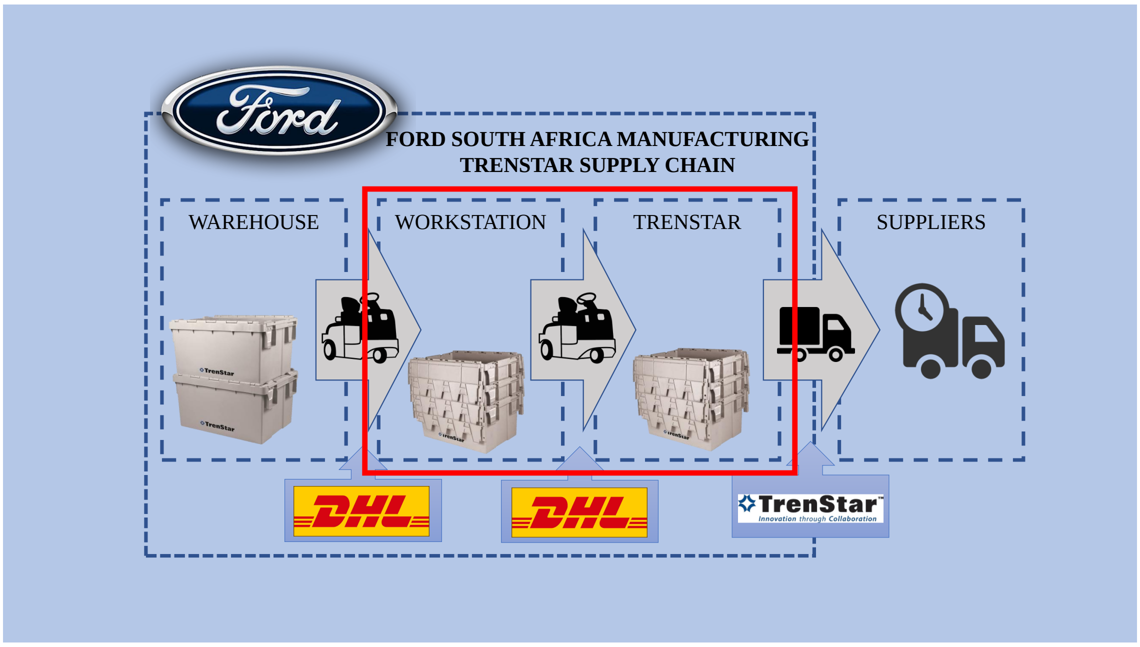


Figure 2: TrenStar waste supply chain process overview

This project is focused on the handling of the waste material between the assembly line and the allocated waste areas within the plant as well as the returning of the TrenStar bins to TrenStar. Section 1.4 outlines the problem within the process.

1.4 Problem statement

The packaging waste restricts the flow of the assembly process and any other movement in the facility. There is a need to improve the flow of the waste materials through the facility as well as to ensure that the waste is not on the floor for extended periods of time. Managing the waste currently requires more resources than necessary.

Waste plays a big role in the Ford Motor Company's daily logistical processes. The waste can be observed in multiple areas of the facility. There are demarcated waste areas for the waste trolleys, but the waste trolleys are not always in their designated spots or are too full to be used. The empty TrenStar bins utilize a lot of unnecessary space. One of DHL's roles is to dispose of the waste in the waste trolleys as well as to return the TrenStar bins to the TrenStar facility.

Each car requires many components. Each component is packaged with materials that need to be discarded or returned to the suppliers. Each cardboard box must be flattened. In some cases it is not flattened, adding to the number of cycles SuperCare needs to perform to remove the waste. The TrenStar bins should also be collapsed when empty. If the bins are not collapsed it occupies more space than necessary. By not collapsing the cardboard boxes or TrenStar bins, manufacturing parts end up at the scrapyard which results in the parts being damaged or lost. This is a financial loss for DHL if the parts are not recovered since DHL carries losses for all the damage done to parts during the picking phases. Collapsing the TrenStar bins or the cardboard boxes is time-consuming. This is time that the material handlers could rather spend on picking parts to ensure that the assembly line does not stand still.

The next section expands on the project aim.

1.5 Project aim and rationale

The aim of this project is to optimize the flow of the packaging waste materials through the facility to save resources and increase space.

The primary objective of the project is to improve the flow of the waste materials through the facility. The waste flow includes the staging, collection, and movement of the waste. Once the component packages are emptied, they occupy space and interrupt the flow of the process.

The second objective of the project is to improve the recyclable waste collection. The number of waste trolleys and the waste collection points are taken into consideration. Ergonomics also plays a role as the boxes are supposed to be flattened before being placed in the waste trolley. The cardboard and plastic are also supposed to be separated into separate trolleys. The empty TrenStar bins should be collapsed as well and are allocated to their own collection point.

The last objective of the project is to briefly examine supplier relationships within the supply chain. Collaboration between suppliers is necessary for efficiency and resource utilization.

The Ford Motor Company SA automotive assembly line is capable of producing 36 units (cars) per hour. Currently, an average of 275 units are assembled in each 8-hour shift (550 units per day). If any component is missing the production line stands still and the company loses production time. For every 1.5 minutes delay, Ford Motor Company SA has a potential to lose one unit (one vehicle of +- R500 000) once the buffer zones have been utilized. This results in a chargeback to DHL. The waste generation rate is proportional to the unit assembly rate. This, in turn, means that the waste flow, waste collections, and waste supply chain relationships have an impact on all processes.

The project scope is outlined, and the approach discussed in the next section.

1.6 Project approach and scope

Waste has multiple definitions and can involve many materials. In the scope of this project, the waste consists of the renewable packaging materials as well as the empty TrenStar bins. The general and hazardous waste is excluded from the project. The recyclable packaging materials and TrenStar bins are regarded as waste as soon as the packaging is empty. This means that the waste starts at the workstations, not in the demarcated waste areas. The project focus areas of the facility are the areas where DHL is involved. The packaged materials are used at various points within the facility. For some processes, the packages are emptied in the warehouse, while others are only emptied at the sequencing areas or even only at the workstations.

For this project, recyclable materials and the TrenStar bins processes are split into two separate processes. The processes are split because they have two different end destinations. The recyclable materials are removed by the cleaning company whereas the

TrenStar bins work on a rotational schedule. The project scope only entails DHL's role within the waste supply chain as illustrated in the process overview in section 1.3.

A process flow map was constructed to track the flow of the materials through the facility. The process flow was analysed and the root causes of the delays as well as the supplier relationship collaboration problems were identified and investigated. The process was thoroughly documented, and improvement opportunities identified. Keeping the improvement opportunities in mind, possible solutions were established.

It is important for a growing manufacturing company to utilize their resources effectively. A quantification model was developed to calculate the amount of waste in the system. The quantification model was then used to narrow the focus down to the areas that generate the most waste. Using the improvement analysis along with the quantification model, the best solutions were isolated. The quantification model was used as a basis to establish the optimal solutions. In the future, the quantification model can be used to reduce the waste in the facility instead of improving the flow of the waste through the facility.

Figure 3 depicts the method that was followed to determine the best solution for waste supply chain improvement opportunities. The figure represents a summary of phases that were completed along with the industrial engineering techniques that were used. Since the two supply chains are split (TrenStar bins and Recyclable waste) there were deviations within the phases for each supply chain.

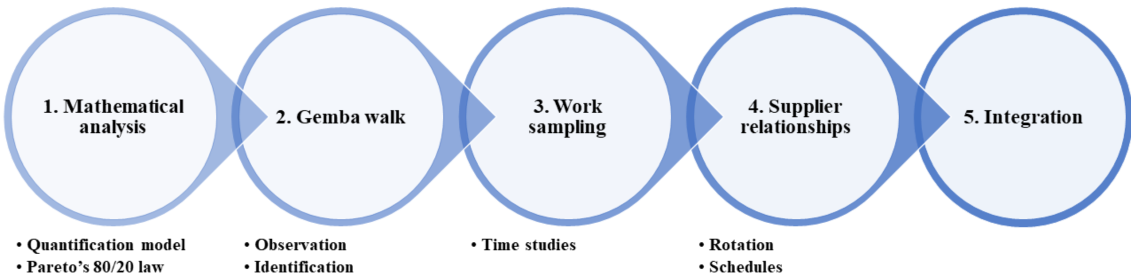


Figure 3: Research approach

The results were compared and the best solutions identified. From the identified solutions, the optimal interim corrective actions (ICA), as well as the permanent corrective actions (PCA), were established.

The rest of the report is structured as follows: A literature review is conducted in section 2 discussing the relevant industrial engineering techniques and how they will be applied to the project. Section 3 is a thorough investigation of the as-is processes identifying the problem areas along with the root causes. Section 4 analysis the data and utilizes a quantification model. The solutions developed in section 5 are discussed in section 6 with a comparative analysis and recommendations following in the rest of the section. The recommendations are validated in section 7 and lastly a conclusion is drawn in section 8. Appendix B is a waste catalogue to produce an overview of the waste and waste handling equipment in the waste supply chain process.

2 Literature review and case studies

The literature review is to support the project approach and plan. Four areas will be discussed: a quantification model, the waste material flow, supplier relationships and lastly the 5s method with regards to visual management.

2.1 Quantification Model

In the construction industry waste is a major problem and a big environmental threat. In 2011, the global generation of industrial waste (including construction waste) was on average 9.2 billion tons. Approximately 1.74 tons/year of industrial waste per capita are generated in the world [27]. The quantification of the amount of waste generated during a construction development is an invaluable tool in the industry. A quantification model can be used as a tool to support mitigating actions [17]. The implementation of such a model can be rolled out to the automotive manufacturing sector.

The objective and use of the model must be determined before it can be designed and implemented. Numerous studies have shown that multiple linear regressions should be used to investigate the waste generated [13]. By using a quantification model, the amount of waste generated for each shift in the automotive industry can be calculated and used in multiple improvement techniques.

Quantifying the waste generation in construction is regarded as a prerequisite for successful waste management. Three waste quantification methodology categories of construction and demolition have been identified namely [32]:

1. Site visit method.
2. Waste generation rate method.
3. Variables modelling method.

For this project, the waste generation rate method was used to determine the amount of waste generated per shift based on the average demand for each part per shift.

The rate at which units are assembled within the facility is increasing and with the increased rate, the waste generation rate is also increasing. Developing a waste generation quantification model will aid in keeping track of the waste generation rate. Using the information from the quantification model, the amount of waste in each department or the whole facility can be determined. This information will help to determine the optimal positions for the waste trolleys. The model can also be used to assess whether there are enough trolleys to keep up with the waste generation. This will be discussed in the material flow section under facility layout. The model can be utilized in the future to decrease waste in areas.

Case Study: Estimation of construction and demolition waste using waste generation rates in Chennai, India [22]. As India urbanizes, the construction and demolition waste generation is increasing. A study was conducted in Chennai city, using the waste generation rates to estimate the construction and demolition waste generation. Chennai City was chosen as it is the fourth largest city in India and still growing.

The rapid urbanization in India means that the infrastructure needs to keep up. To create an infrastructure that can handle an urban area the construction and demolition waste generation increases at an immense rate. To manage the waste generation a waste generation model is needed to estimate the waste quantities. By 2016 it was estimated that about 70 percent of the buildings that would be in India in 2030 have not yet been built. Without being able to estimate the waste generation, the waste is improperly managed and ends up at unauthorised landfills which poses a health threat.

The solution to the waste estimation problem was to create a waste estimation model using the waste generation rates. The research methodology used to collect the data for the waste estimation model was conducted in four steps namely:

1. Quantifying the floor area of construction and demolition activity.
2. Estimating the proportion of various types of buildings.
3. Establishing waste generation rates.
4. Integrating the data to get the total estimate.

The integrated data was then used to estimate the total demolition and construction waste. To verify the model, the estimated rate was compared to the rate values of several other countries. It was found that Chennai has a lower waste generation rate than other countries, but the rate is expected to increase as Chennai is still growing.

Using the waste generation rate to estimate the construction and demolition waste quantities in Chennai city proved to be a reliable methodology. This model could be used by urban planners and researchers to estimate construction waste generation. Similar challenges in other countries can be overcome with this model.

Unfortunately for this study, the waste generation data in India was not available. The model can be used on a simple level with minimal data, but it is preferable to use as much data as possible. An estimation will be more accurate the more dependable the input data is. No model can precisely predict waste generation. Collecting waste load movement records from waste transportation is another method to predict the future waste generation. To increase the reliability of the waste generation estimation, it is best to rather combine the two methodologies than just use the one. These two methodologies would be the waste generation model along with historical transportation data.

Using waste generation rates to calculate waste quantities can be used in a diverse number of theories and analyses. Having the methodology at hand to estimate the waste generation can significantly improve the waste management involved. This methodology is an invaluable tool but should not be used in isolation.

2.1.1 Pareto 80/20 rule

In a lot of situations, it becomes quite apparent that 80 percent of the work is done by 20 percent of the people involved. With regards to projects, 20 percent of the project efforts yield 80 percent of the results. This principle is known as Pareto's 80/20 law [31]. An extension of the Pareto 80/20 law is the ABC-analysis which many businesses use for optimization [15]. The idea is to focus on the 20 percent of the processes that yields 80 percent of the outcome (dependent on the chosen topic). In the case of the Ford Waste Supply Chain, this principle was used to determine on which areas to focus the waste management improvement techniques. The results of the quantification model waste generation per facility area were used to identify the 20 percent of the facility that generates 80 percent of the packaging waste. By improving the waste staging, collection and movement in these areas, 80 percent of the waste will be managed more efficiently.

2.2 Material flow

At times the waste is delayed at the workstations in the Ford Motor Company SA automotive assembly line. This hold up causes a delay in the waste material flow. By mapping the processes, the material flow was taken into consideration. Two aspects became apparent namely facility layout and material handling functions. Material handling system design and facility layout design are inseparable [30]. Separation of the two aspects will result in continuous problems with each step made towards improvement. In this section, the two aspects are discussed separately but the solutions involve both aspects.

2.2.1 Facility layout

A material flow system is the flow of materials, parts, and supplies [30]. The flow of materials in a facility is dependent on the facility layout. The layout of a facility can obstruct the flow, or the travelling distance can be too lengthy. It is important to visualise the current state and improvements of the waste flow [5].

Waste does not add value to the assembly process which means that the facility might have to undergo a few changes to accommodate the waste flow. In this project, in order to accommodate the waste flow, the waste trolley locations are under investigation. The waste flow through a facility can be analysed by mapping the flow of the waste from the various workstations. Along with the flow, the distance of the travelling needs to be taken into consideration. After mapping the flow of the waste materials, flow system analysis techniques along with the quantitative model can be used to determine the heavy traffic flow areas. An example of one of these techniques is activity relationships using quantitative flow measurement [30]. Using the data gathered from the various facility analysis techniques, the optimal location for the waste trolleys can be determined. To optimize the flow through the facility the flow planning should occur in hierarchical form as depicted in figure 4.

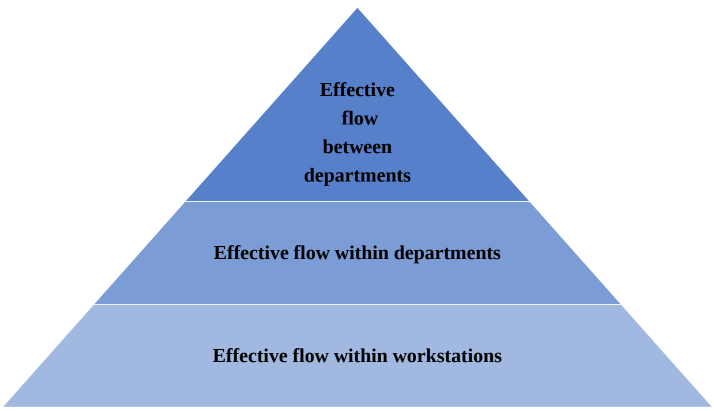


Figure 4: Flow planning hierarchy [30]

Waste flow mapping (WFM) is a combination of lean manufacturing tools (e.g. value stream mapping) and production and material flow cost accounting strategies [18]. By implementing the WFM method at various manufacturing sites, it was determined that there is potential in reducing inefficiencies in the handling of waste. WFM requires analysis of material flow, facility layouts, supplier relationships (the supply chain) as well as the quantification of the materials. The quantification assists the identification of problem areas within the waste flow. The WFM technique is therefore a mixture of the other techniques in this section.

Case Study: Volvo Waste Flow Mapping [18]. The Swedish Volvo Group experienced material losses and inefficiency in their waste management.

In 2010 and 2011 the WFM technique was performed on 16 Swedish Volvo Group sites. This WFM multi-site mapping project focused on the procurement of waste management services as well as on waste management itself. For the sake of this project scope, only the waste management is taken into consideration and not the procurement thereof. The WFM technique was chosen as it is an attempt at a combination of lean management and operational management. Data were collected with regards to the problem on two levels. The first level was quantitative data on the system's performance, characteristics, and behaviour. The second level was qualitative methodological data on the method's functionality, characteristics, and usability. The quantitative data were used for the WFM method whereas the qualitative data were used to assess the outcomes of the WFM method. The WFM method was implemented through a 7-step procedure presented in figure 5:

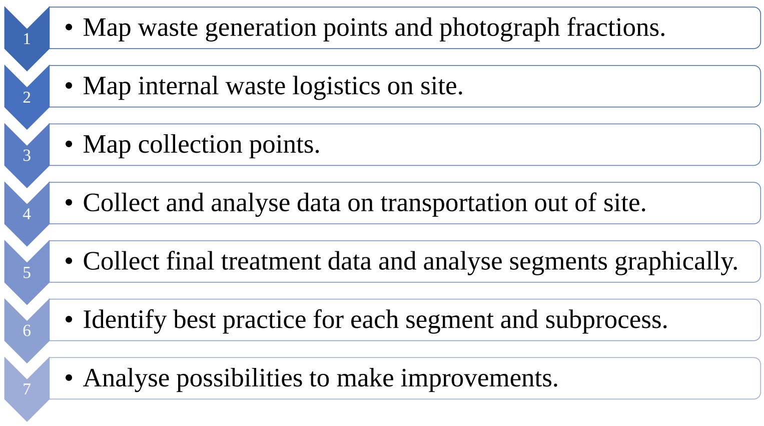


Figure 5: 7 Waste flow mapping steps

The waste management activities were analysed as systems because a system view of waste management is a useful way to gain effectiveness and efficiency. A system view involves the waste collection, transportation, and storage operations [25]. The waste system was subdivided into 5 sub-processes namely:

1. Workplace bins/signs.
2. Internal handling.
3. Collection points.
4. Transport.
5. Final treatment.

Swedish Volvo Group plants have historical data for waste sorting rates as well as average prices for the sorting rate. With the sorting data available and the WFM calculations at hand, the performance measurements were used to identify potential improvements. Some of the improvements identified within the sub-processes included:

- Underused bins.
- Lack of bins for some waste fractions.
- Inefficiencies in handling and internal logistics.
- Container and equipment inefficiency.

In the end, the WFM results concluded that sorting waste materials (steel and plastics) increased the revenue returned when the materials were sent to foundries.

Unfortunately, for the WFM technique to work, a lot of data need to be gathered. Not all data was available or accessible to fully complete the technique. In the Volvo case, the general cost for each load of incoming material was not available, thus a material lost cost could not accurately be calculated. The WFM technique does not provide the necessary support with performance data in all the cases. The performance data can be used to analyse the improvements from a qualitative point of view.

There are advantages and disadvantages to the technique. It is a starting point to identify potential improvement opportunities as waste flow mapping provides a framework in which to analyse the waste management process and reveal valuable losses. Although the framework is a guide to best practice, the implementation of best practice within the process is not covered by this technique.

2.2.2 Material handling functions

The packaging waste does not undergo any changes within the system. The packaging is merely for the protection of the components during storage and handling. Thus, the waste is handled along the way but does not add value. The handling of these materials is non-value-adding but the expenditure still influences the operation costs [14]. To decrease the waste handling expenditure, waste handling should be minimized.

Forklifts and tow motors are used to transfer the components from the warehouse to the workstations as well as to move the waste from the workstations or warehouses to the waste trolleys. Each of these transportation methods requires a person to operate the equipment. The boxes are flattened manually before being placed in the trolleys. The employees bend over and flatten the boxes with their hands or feet which means that ergonomics also plays a role in the process. The design of a working environment to fit human capabilities is defined as physical ergonomics [2]. Thus, physical ergonomics can be considered along with the product handling functions.

The handling of the waste material products results in three of the seven deadly wastes [19]:

- waiting
- transport
- motion

These wastes can be reduced by identifying improvement opportunities with regards to the material handling functions. The four primary functions of material handling are [8]:

1. Transportation.
2. Positioning.
3. Unit formation.
4. Storage.

The function relevant to this project is transportation. Transportation material handling equipment (MHE) includes conveyors, industrial vehicles, trucks, and tractors [8]. There are multiple tools and systems to determine the optimal MHE for a system.

Case: A framework for selection of material handling equipment in manufacturing and logistics systems [12]. A new pharmaceutical company needed to design a material handling system for its new facility. To design the material handling system and choose the best material handling equipment, a material handling framework was selected. The framework is based on system engineering concepts. These concepts take the equipment roles, functions, objectives and requirements into account. The framework used is divided into three phases with a total of 10 steps:

1. Conceptual design
   (a) Specify and prioritize requirements.
   (b) Set objectives.
   (c) Establish performance measures.
   (d) Functional decomposition.
   (e) Determine candidate equipment class.
   (f) Design subsystem.
2. Preliminary design
   (a) Select equipment type from candidate class.
   (b) Determine the number of units of equipment type.
3. Detailed design
   (a) Determine specifications of the selected equipment.
   (b) Evaluate the design.

The framework categories are based on the user objectives and requirements. In this case, the requirements of the managers were used to validate the selection of the MHE. This specific framework produces a wide variety of material handling equipment. This MHE selection framework supports cooperation between designers and manufacturers, facility managers, and logistics. The framework also takes the entire system into consideration (within scope) and does not isolate one material handling event.

Unfortunately, not all the steps within the framework in this case study can be applied directly. Some of the steps require more research and investigation. Material handling equipment was only prioritized for some functions. There is also no guideline on preparing the final specifications of the equipment.

The waste supply chain requires a lot of material handling. By using this framework, the best material handling equipment can be selected. There are multiple methods that can be used to handle the waste. A conveyor can be stretched from waste traffic areas to a central location for sorting. EffiBots (automated guided vehicles) can follow waste collection routes past the workstations to collect the waste. Official housekeeping tow motors and forklifts can be appointed. The material handling selection framework should be used to identify the optimal MHE.

2.3 Supplier relationships

Organizational success requires that the entire supply chain is aligned in terms of strategies, plans, and functioning. There are three relationship perspectives: transactional (vendor), collaborative (partner) and strategic (alliance) [9]. To successfully collaborate within the waste supply chain, a strategic alliance between the third party logistics (3PL) involved should be considered. 3PL in logistics and SC management is an organizations use of a third-party company to outsource elements of a process. Usually some of these elements include the organizations distribution and fulfilment services. For the waste supply chain in question, the relationship between TrenStar and DHL as well as the relationship between SuperCare and DHL should be aligned.

Supply chain researchers have explored the differences between 'smallest unit of network' triads and buyer-supplier relationships. The researchers preferred the 'smallest unit of network' approach to the buyer-supplier relationship approach. The 'smallest unit of network' approach considers all the relationships within the supply chain whereas the buyer-supplier relationship approach only considers the buyer and the supplier. The network perspective was therefore developed based on this approach [7]. A network perspective is important to expand the view of the consequences before making a decision.

Supply chain integration (SCI) includes governance, organization structure, systems, relationship management, business strategy, process design, and performance management [28]. The foundation of SCI is built on the relationship between internal, supplier and customer integration [10]. In this case, only the relationship management will be considered as it is the first step towards SCI. The relationship between DHL and TrenStar and the relationship between DHL and SuperCare are analysed as two separate entities.

Waste management requires the waste supply chain to collaborate. A method applicable to this need is the allocation of responsibility [18]. Without allocating specific responsibilities, problems occur within the supply chain and the difficulty of solving the problems is increased without a responsible party.

Case Study: The role of collaboration in supply chain resilience [23]. Due to globalisation, the business world has become more complex every day. Businesses are required to be lean and flexible within this intricate system which makes the supply chain vulnerable and increases all risks [6].

Any disruption within a supply chain can cause an enormous financial loss which results in supply chain resilience as a strategy for the company to recover and improve. To test the role of collaboration in supply chain resilience in the food industry, a case study of eight buyer-supplier relationships was conducted. In the past, the resilience theory was only tested on an individual company perspective. In this investigation, the theory was tested on a focal company level and expanded to an empirical supply chain level.

By researching these case studies it was found that specific collaborative activities can increase supply chain resilience. Some of these activities include collaborative communication, information-sharing, and joint relationship efforts. The resilience was increased via flexibility, velocity, and visibility.

For a supply chain to reach the level of resilience aimed at, a lot of underlying mechanisms and interdependencies are created within the supply chain network. Interdependencies can prevent a company's independent decision making. Although interdependent networks can be regarded as a risk, supply chain resilience eliminates some of the risks posed in the fast-paced global business world.

By estimating the waste in each area, a relationship with SuperCare can be established to align the waste collection rotations with the waste generation rate. The same concept can be rolled out to TrenStar to align the availability of employees to offload the flat beds. As seen in the case study, collaborative communication is important when integrating a supply chain.

2.4 5s - Visual management

The word 'housekeeping' is a common definition of the 5s method [4]. 5s is a Japanese goal alignment technique used to support lean implementation. The practice of this technique is to embed values into the workplace. These values include organization, neatness, cleaning, standardization, and discipline [21]. There are 5 steps to implement 5s [20]:

1. *Seiri (Sort):* Removal of unnecessary items in the workplace.
2. *Seiton (Stabilize):* Visual organization and arrangement of items in the workplace. The items are placed at point-of-use where it is necessary.
3. *Seiso (Shine):* Cleaning the work environment and maintaining the cleanliness to avoid contamination.
4. *Seiketsu (Standardize):* Implementation of standards and setting rules in the workplace.
5. *Shitsuke (Sustain):* Ensuring implementation and building self-disciple within the work environment.

Various tools can be used to implement the 5s method where visual management (VM) is one of the tools. In this project, the visual management aspect will be considered as it falls within each of the 5s steps but has the biggest influence on step 2 (seiton, stabilize). The main aim of the tool will be to stabilize the waste flow, but standardization will always be kept in mind.

VM is a management system to improve organisational performance by directly addressing one of the five human senses. By addressing one of the senses, quality information can be communicated to help people make sense of an organisational situation [29].

Case: Implementation of 5s methodology in the small-scale industry [1]. V.M. Auto Pvt. Ltd. situated at Satpur (M.I.D.C.), Nasik, is a small-scale industry manufacturing company with a need to improve efficiency in a continuously changing global market. Being a small-scale industry, the company does not necessarily have the capital to invest in changing the business. The business must adopt techniques that lower costs.

Lean implementation focusses on cost reduction through waste elimination. One of the methods that lean implementation uses to achieve waste elimination is the 5s method. The 5s method can be implemented without spending a lot of money.

By implementing the 5s method, V.M. Auto Pvt. Ltd. manufacturing company increased storage space by 30 percent. Standards were created, and unproductive time was reduced by 10 percent.

Many advantages of the 5s method were identified in this case. Within 1s, process development reduces costs, the workplace is better utilized, and tool loss is prevented. 2s increases efficiency as well as aids process growth. 3s improves employee working conditions and maintenance costs are reduced. 4s brings company standards to the next level and improves safety. Lastly, 5s increases awareness and morale and decreases absenteeism.

Unfortunately, 5s requires a lot of changes. In some cases, changes can cause a negative atmosphere in the work environment and the workforce will then rebel against the improvements. The changes required when implementing 5s should be monitored closely and change management should be prioritized throughout the process.

The second s has a very popular saying connected to it: 'A place for everything and everything in its place.' In this step of the 5s method, the items are placed at the workstations according to their use. The trolleys/flat beds are necessary items near a workstation to ensure an orderly workstation. According to the case study, the items were placed in the following manner:

- Items frequently used: Placed at POU.
- Items sometimes used: Placed further away.
- Items not used (must be kept): Stored with identification.

Since the trolleys are frequently used to dispose of the packaging materials, the trolleys are required to be located at the POU. Because of a space constraint, this is impossible in some areas. The trolleys are placed further away but still within reach. The 5s method should be used to determine locations where the trolleys are needed the most. The trolley should be placed closest to the area with the most waste generation. To keep track of the trolleys and to aid waste separation, basic visual management can be implemented. Visually controlling the trolley locations and waste separation methods will aid the employees. By marking the demarcated areas for the trolleys on the floor, a missing trolley can immediately be spotted. Labelling the trolleys and not relying on the colour only will aid new employees in the waste separation guidelines.

The waste supply chain with regards to the recyclable waste process, as well as the TrenStar bin returnable process, is analysed in the next section.

3 Process and problem analysis

In this section, the waste supply chain is analysed and the problems within the supply chain are identified. The waste supply chain is split into two processes. The first process analysed is the recyclable waste process. The second process analysed is the empty TrenStar bin waste process.

3.1 Waste supply chain process

Figure 6 and figure 7 illustrates the current waste processes for the recyclable waste and the TrenStar bins respectively.

This project is divided into three picking processes that all materials follow within the facility: milkrun direct supply (lineside in this project), milkrun repack (milkrun and sequencing in this project), and pick-to-light.

Milkrun direct supply is where the products are taken directly to the assembly line where they are used. The products are placed at point-of-use (POU) still inside the packaging. The general unit parts usually use this method of distribution. An example of these general unit parts are parts that all units require no matter what kind of unit it is, for example, some panels.

Milkrun repack is where the bigger product parts specific to each unit are organized in a sequence aligned with the unit sequence and placed next to the assembly line at the POU. Examples of these parts are window panes or door rubber trimming.

Pick-to-light (P2L) is where the smaller parts specific to each unit are picked into a crate or bag which travels with the unit. The picking method involves racks with lights shining under the parts needed for a unit and once the part is picked, the picker switches off the light under the part. When the unit parts are picked, the material handler presses a button to switch on the next unit's part sequencing lights.

The recyclable waste process starts at the workstations where the parts are used. At the workstation the packaging is emptied and staged at a spot nearby. The waste spot is dependent on the process area.

Generally, the P2L locations have a carton flow racking system where the full packages are placed on the top racks and the empty packages discarded onto the bottom racks. The milkrun repack and direct supply employees usually create waste piles with the discarded packaging in an open area.

With regards to the recyclable waste process, there is no method or rule as to when the packaging is removed from the workstations and discarded in the trolley areas. The material handlers are each responsible for the discarding of their own waste packaging. In the case where the trolley is full, the material handlers (MH) will either place the packaging next to the trolleys or move to a different trolley. It is unclear who has the responsibility to flatten the boxes before discarding them into the cardboard trolley. The majority of the time it is the responsibility of the MH to flatten the boxes to check for parts. In six areas (at six trolleys) of the facility, there are SuperCare employees who have been assigned to collapse the cardboard boxes and separate the waste. The larger corrugated cardboard boxes that are too heavy to be carried manually, are collected and disposed of by a forklift driver.

The TrenStar bin process works a bit differently from the recyclable waste process. Although the waste locations are still determined by the process area, the bins are collapsed by the MH employees. The bins are then collected by the tow motor driver who brings a refill of the product. The full bin is exchanged for the empty bin. Once all the empty bins are loaded and the full bins are offloaded, the tow motor takes the empty bins to the TrenStar facility on the Ford grounds.

The red process blocks in figure 6 and 7 indicate steps within the process where DHL managers, SuperCare supervisors, and the Reclamation Group manager have identified problems. In the next section, the identified problem areas are investigated.

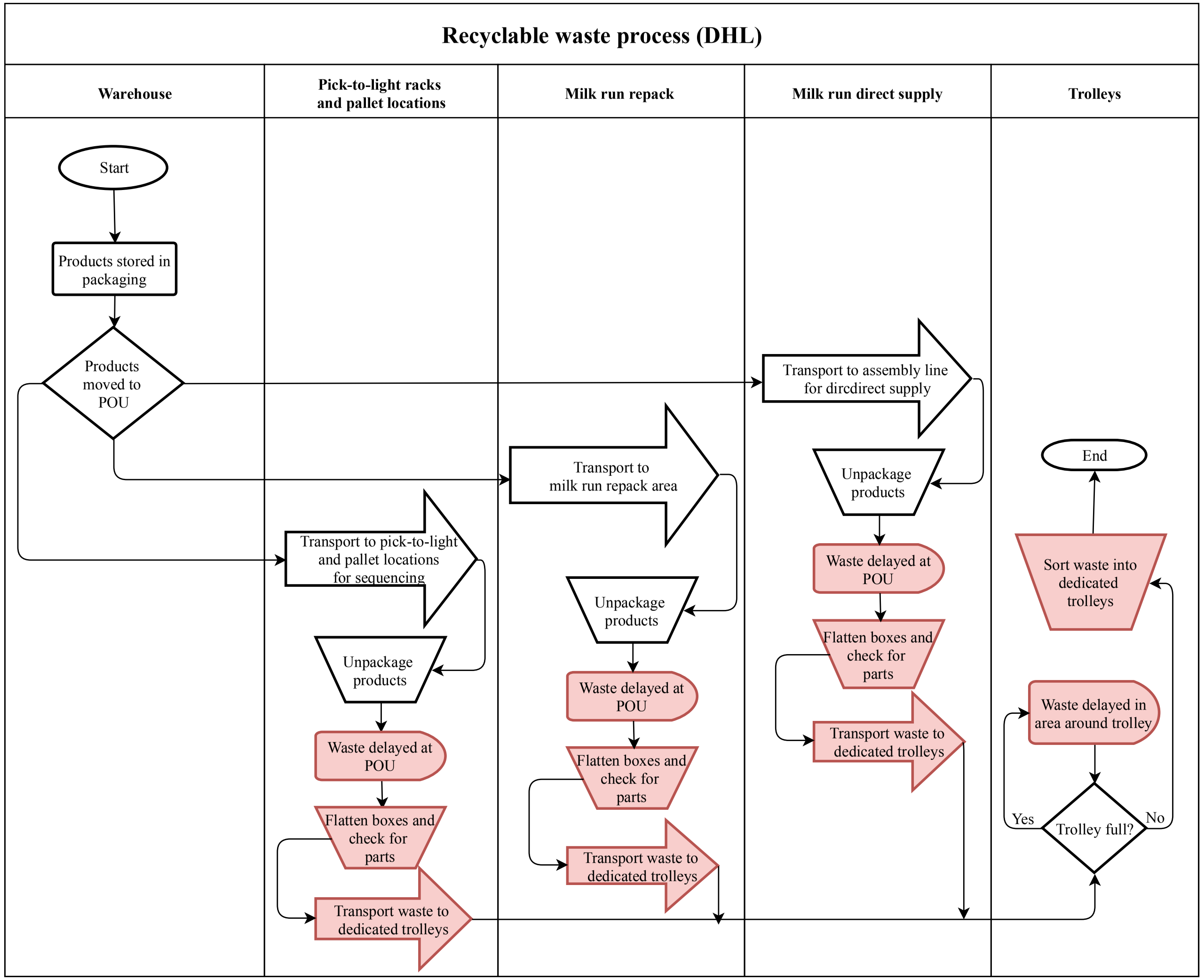


Figure 6: Recyclable waste process

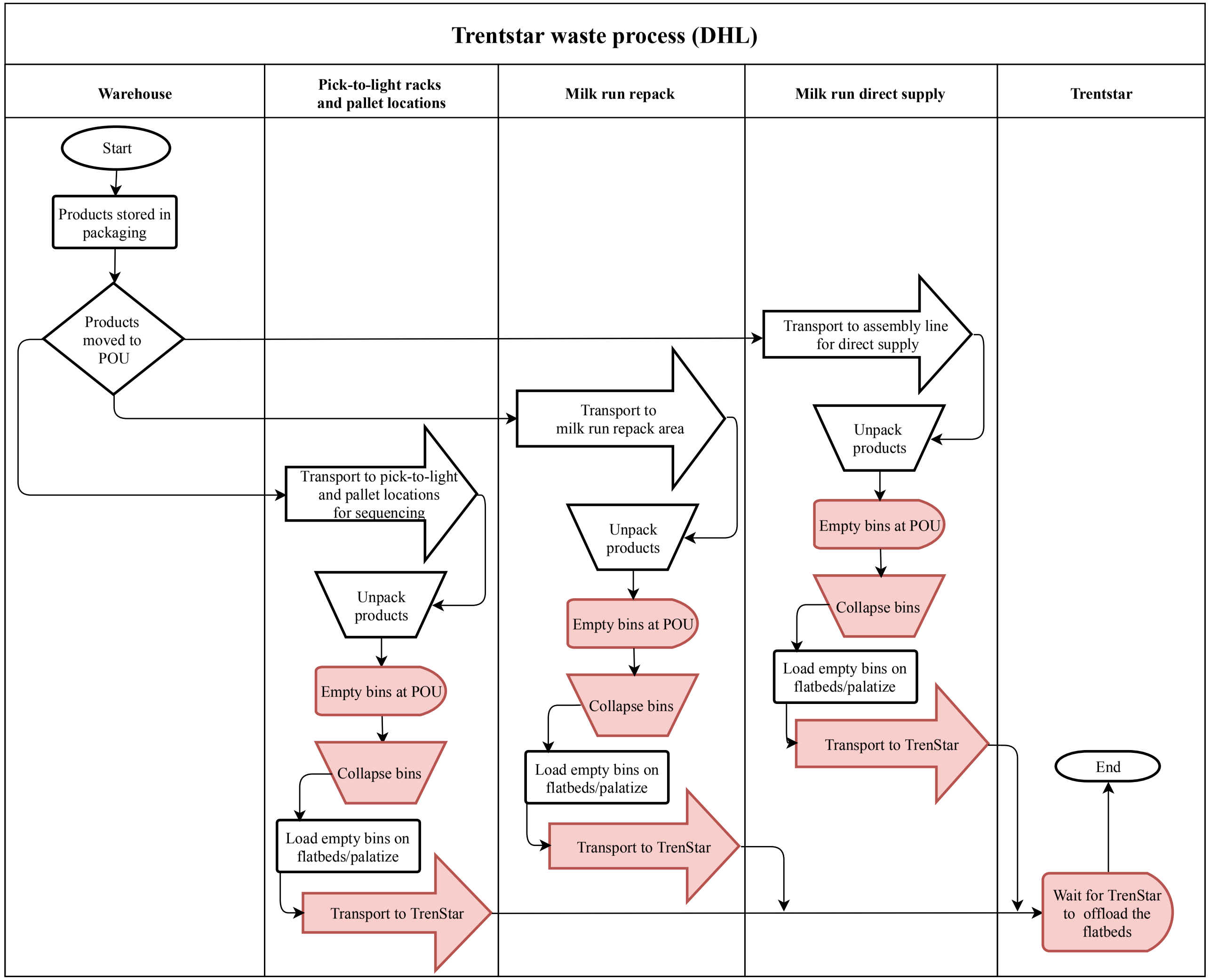


Figure 7: TrenStar waste process

3.2 Problem investigation

DHL management has identified problem areas within the waste supply chain processes discussed in section 3.1. The identified areas are indicated in red in figure 6 and figure 7 respectively.

To analyse a process flow, specific questions need to be asked. The 5W1H method is used to ask and answer the analytical questions as this method is a framework of questions to analyse a process. The questions consist of the 5 W words (what, when, where, who and why) and the H represents the 1 H word used (how). Table 1 represents the questions along with descriptions of what the question queries [24].

Table 1: 5W1H process analysis questions.

Question	**Description**
What?	What does the client need? What should be done? What is currently being done?
Who?	Who is performing this part of the process? Who should be performing this part of the process?
When?	When is this step of the process performed? When should this step of the process be performed?
Where?	Where is this step of the process completed? Where should this step be completed?
Why?	Why is this step necessary? Why was a problem identified?
How?	How is the process step completed? How can the step be changed?

The clients for the recyclable waste process are SuperCare and Ford Motor Company SA. The recyclable waste process is analysed with the red process steps (figure 6) in mind namely:

- Waste is delayed at the workstations.
- Boxes should be flattened
- Waste is delayed at trolley locations.
- Waste is not separated into specific waste bins.
- Waste is transported manually to trolleys.

The TrenStar waste process is analysed with the red process steps (figure 7) in mind. The client in this process is TrenStar. The process steps are:

- Empty bins delayed at the workstations.
- Bins not always collapsed.
- Transportation to TrenStar.
- Prolonged waiting periods at TrenStar.

The next section is a summary of the problems that were identified by analysing the process.

3.3 Identified problems

The following problems are identified within the supply chain with regards to DHL. Table 2 is a summary of the problems within the recyclable waste supply chain. Table 3 is a summary of the problems within the TrenStar waste supply chain.

Table 2: Recyclable waste supply chain problem summary.

Process step	**Problems**
Waste is delayed at the workstations.	Waste piles up at the workstations. No schedule for waste collection. Trolleys are located too far from waste generation point in some areas.
Boxes should be flattened	Unit parts end at the scrapyard and DHL carries the losses. Boxes that are not collapsed requires a lot of space in the trolleys.
Waste is delayed at trolley locations.	Trolley areas are not marked everywhere, thus the trolleys are not always replaced correctly. There are not enough trolleys in each area. SuperCare trolley collection schedule does not align with the waste generation rate.
Waste is not separated into specific waste bins.	There is not a specified responsible party for waste separation.
Waste is transported manually to trolleys.	There is not always time to transport waste and waste heaps at the workstations. Waste is left behind when it falls as employees carry the waste to the trolleys.

Table 3: TrenStar waste supply chain problem summary.

Process step	**Problems**
Empty bins delayed at the workstations.	Empty bins at the workstations utilize space. A hiring fee is paid for each bin on the premises, empty bins add no value. (Hiring fee falls outside of the scope of this study).
Bins not always collapsed.	Bins that are not collapsed utilizes a lot of space. When bins are not collapsed it might cause a delay in identifying empty bins.
Transportation to TrenStar and prolonged waiting periods at TrenStar.	Flat beds are underutilized. Waiting is one of the 7 deadly wastes.

4 Data analysis

Two data analysis techniques were used to investigate the waste supply chain within the facility. The first was the waste quantification model in conjunction with the Pareto 80/20 law to determine how much waste is generated in each section of the facility. The second was time studies to determine the waste handling efficiency.

4.1 Quantification model and Pareto 80/20 law

The quantification model was used to determine the number of packaging boxes, as well as the volume occupied, in all the sections of the facility where DHL is involved. The Pareto 80/20 law was used to determine the areas that should be focused on in the rest of the study.

4.1.1 Method

Three sets of data were used to complete the quantification model, namely the:

1. Master process for each part data.
2. Part demand data.
3. Packaging types and sizes for each part.

The following method was used to approach the quantification of the waste materials:

1. Division of the facility into the three main material stream types.
   - P2L
   - Milkrun and sequencing (MS)
   - Lineside
2. Division of the parts into their respective material stream type.
3. Each material stream type consists of multiple sections within the facility. Each part was assigned to its dedicated section within the material stream type.
4. The average demand for each part was calculated over a 50-day period.
5. The number of packages in each facility section was calculated in relation to the part demand in the corresponding section.
6. Using the packaging external measurement, the occupied space per cubic meter of packaging waste was calculated in accordance with the number of packages.
7. The packaging was separated into four main categories:
   - Cardboard boxes
   - Mesh cages (TrenStar)
   - Plastic bins (TrenStar)
   - Other - Includes all other stillages and packaging that falls outside of the scope of this study.
8. Within each material stream type, the amount of packaging, as well as its volume, was compared via the Pareto 80/20 law.
9. The top 20 percent of waste areas for each material stream type was selected.
10. The selected sections were also compared to a detailed Pareto analysis of the facility to distinguish where these sections fit into the whole facility's waste generation.

4.1.2 Results

Two Pareto graphs were constructed for each material stream type. The first graph analyses the average packaging materials generated per area. This number of packages per area per shift is a result of the part demand in each area and the number of parts in each of their respective packages. The second graph analyses the volume space (cubic meter) occupied by the waste packaging during a shift.

P2L Sections: There are 15 P2L lines in the Ford Facility that fall within the scope of the project. As a result of the quantification model and Pareto law, it became clear that the Engine dress, Doorline, Instrument panel and Trim 2 P2L results in 80 percent of the boxes used per shift as seen in figure 8. The Instrument panel, Engine dress, and Doorline P2L sections are responsible for 80 percent of the volume waste generated in these sections as seen in figure 9. Through observation, it has been determined that the P2L sections struggle with waste in general (especially cardboard boxes) which means the study will focus on all four sections identified in the average waste graph.

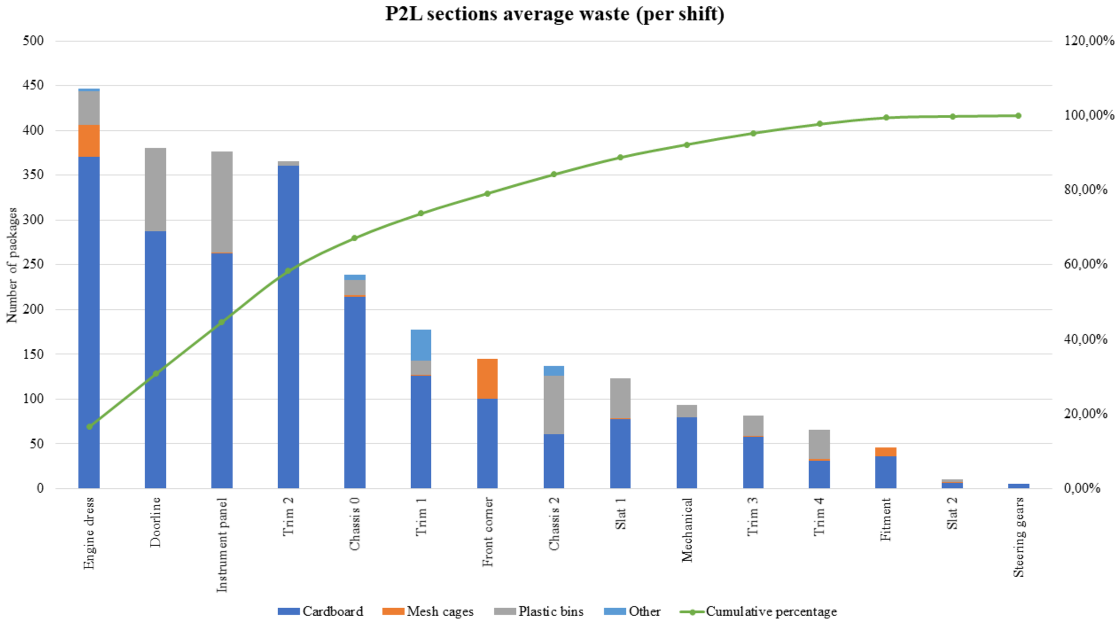


Figure 8: Pareto results - P2L average waste

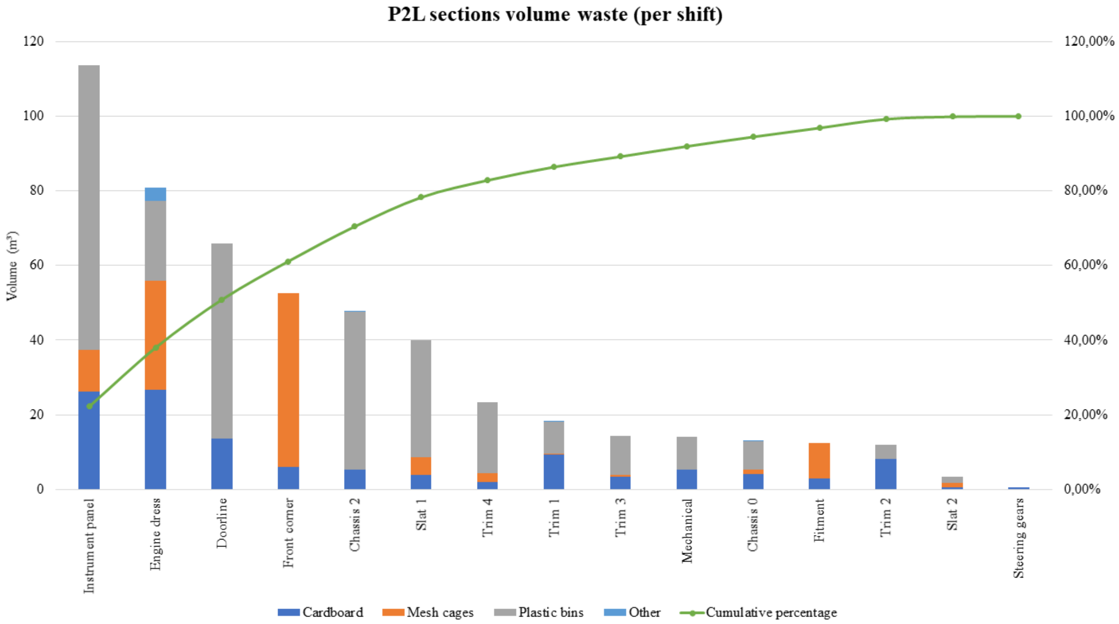


Figure 9: Pareto results - P2L volume waste

Milkrun and sequencing sections: The milkrun process and sequencing processes are two separate material handling processes. For this analysis, they were combined since some of the parts are used in the same sections within the facility regardless of the material handling process the part is following. Figure 10 indicates that the FREE IS-SU (parts required on demand) and JCI (seat suppliers) sections generate 80 percent of the waste. It also indicates that the majority of the waste is defined as 'other' which is because external companies work with these parts in these sections of the facility. That means that the FREE IS-SU and JCI sections fall outside of the scope of DHLs project. The lockup section follows the FREE IS-SU and JCI sections but still has a very high percentage of other waste. The next three sections are PL10-Seq (Plant 10 Sequencing), PL1-SU-M1 (Plant 1, Suma 1) and Body 2 (Bodyshop 2). According to Figure 11, these three sections are also the sections that generate the most waste based on the space that they occupy. The TrenStar mesh cages play a large role within the milkrun and sequencing sections which is a large waste of space.

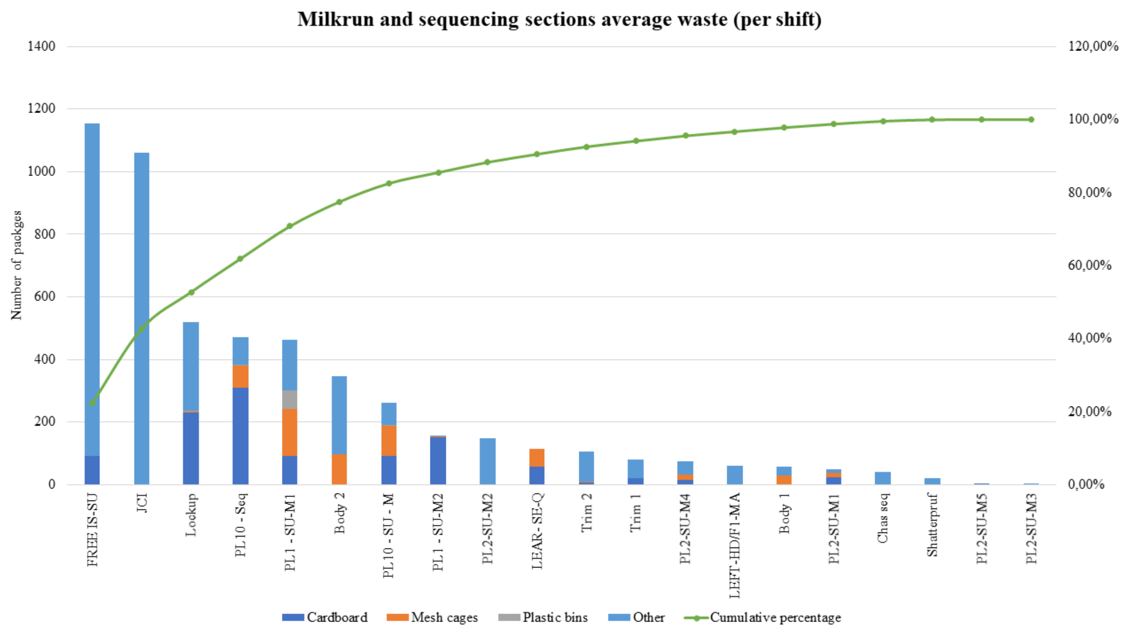


Figure 10: Pareto results - Milkrun and sequencing average waste

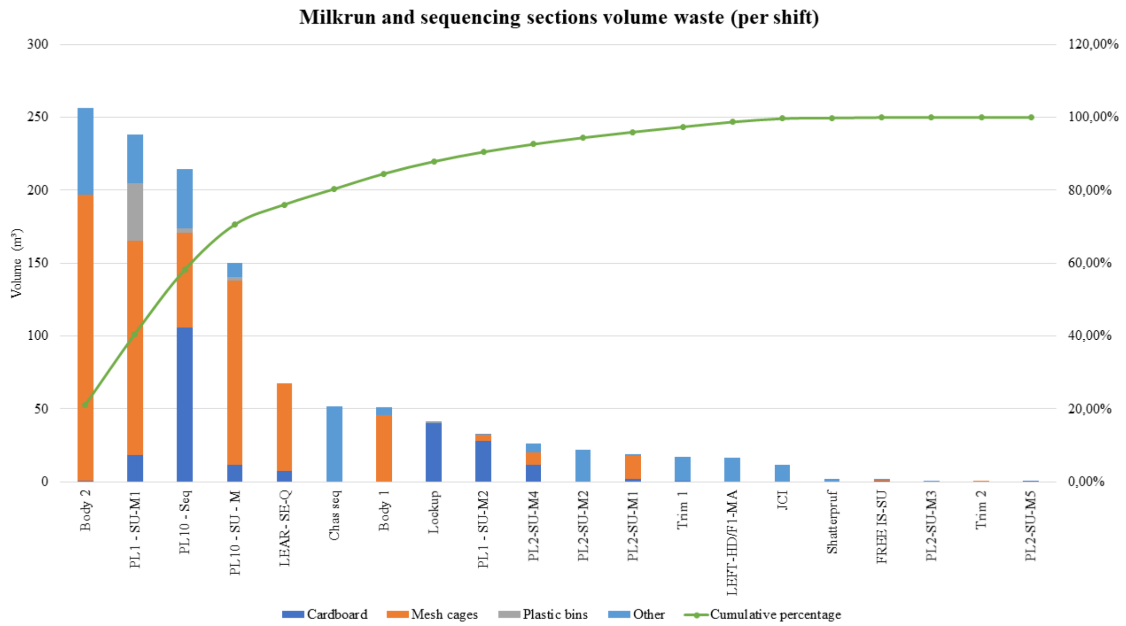


Figure 11: Pareto results - Milkrun and sequencing waste volume

Lineside sections: The lineside sections are the sections where the boxes are taken directly to the assembly line and removed/replaced once they are emptied. Empty boxes in these sections can be dangerous for the assembly line workers as they cannot move freely around the moving unit on the assembly line conveyor. In Figure 12 Trim 1, Trim 3 and Trim 4 are the lineside sections generating 80 percent of the waste. Although a large amount of the waste consists of packaging other than cardboard boxes or TrenStar bins, the number of cardboard boxes plays a large role in waste accumulation along the assembly lines. Figure 13 clearly indicates that Trim 1 and Trim 4 contributes to the most space occupied by packaging per shift, with Trim 1 the main contributor.

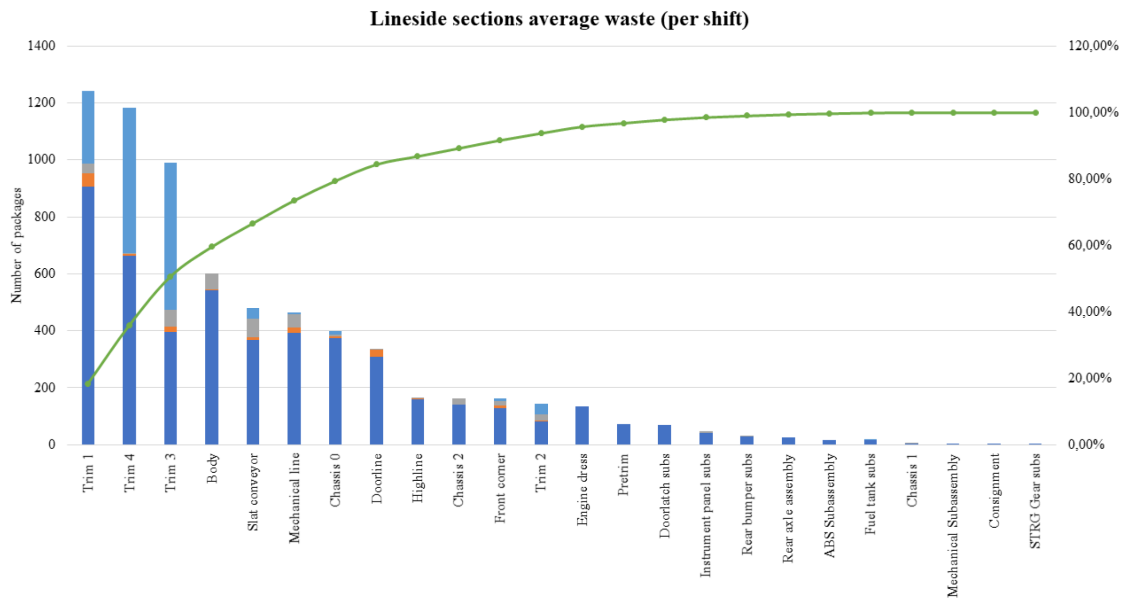


Figure 12: Pareto results - Lineside average waste

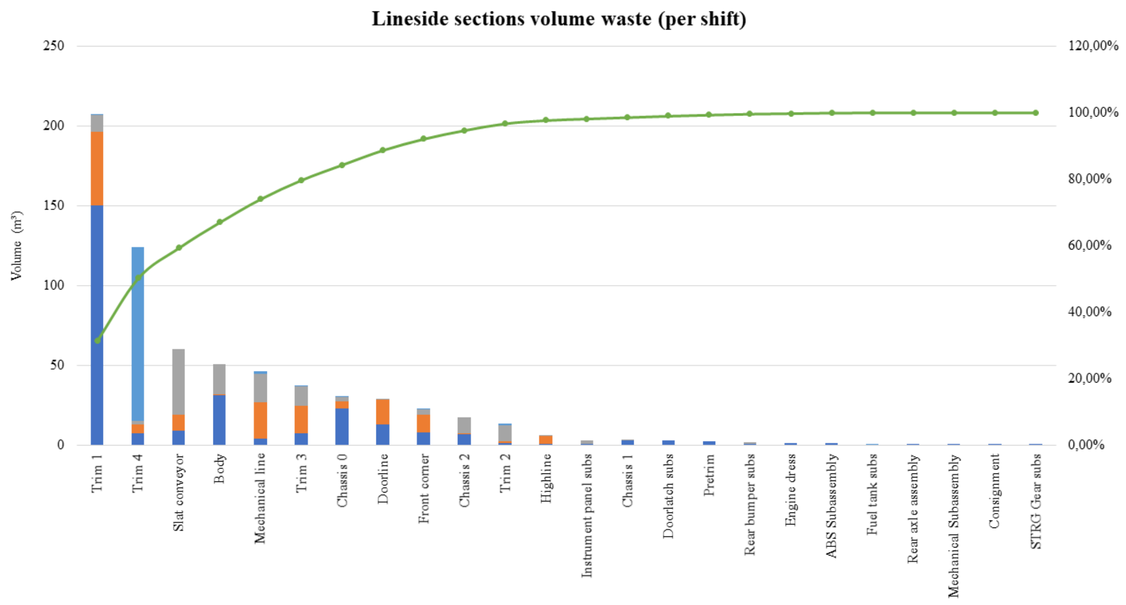


Figure 13: Pareto results - Lineside waste volume

Section summary: From the Pareto law the following sections have been chosen as the focus of this study:

1. P2L

   - Engine dress

- Doorline
- Instrument Panel
- Trim 2

2. Milkrun and sequencing

- PL10-Seq
- PL1-SU-M1
- Body 2

3. Lineside

- Trim 1
- Trim 3
- Trim 4

Figure 14 and Figure 15 is a summary of all the sections identified within the facility and the amount of waste each section generates.

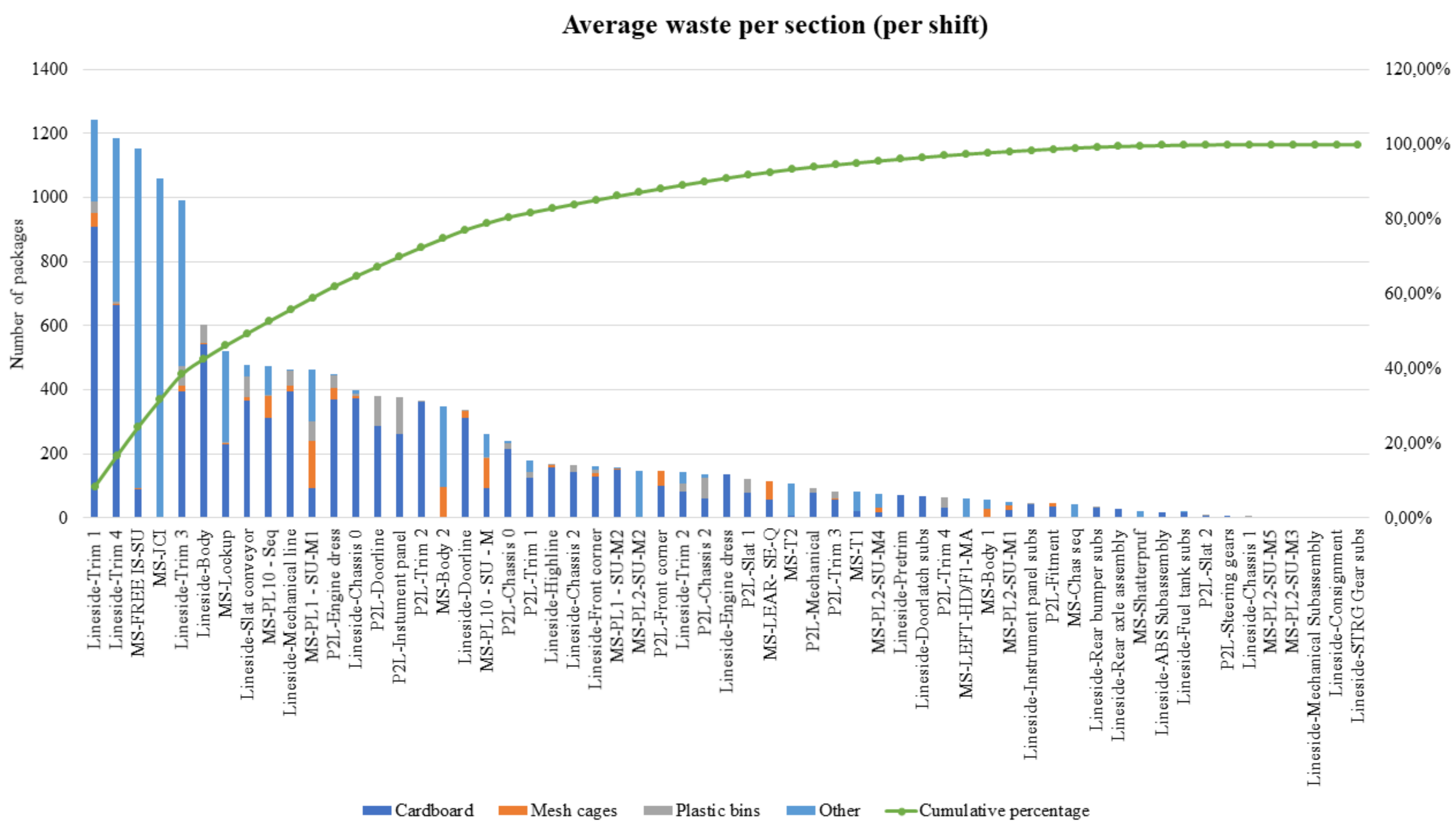


Figure 14: Pareto results - Average waste in Ford facility

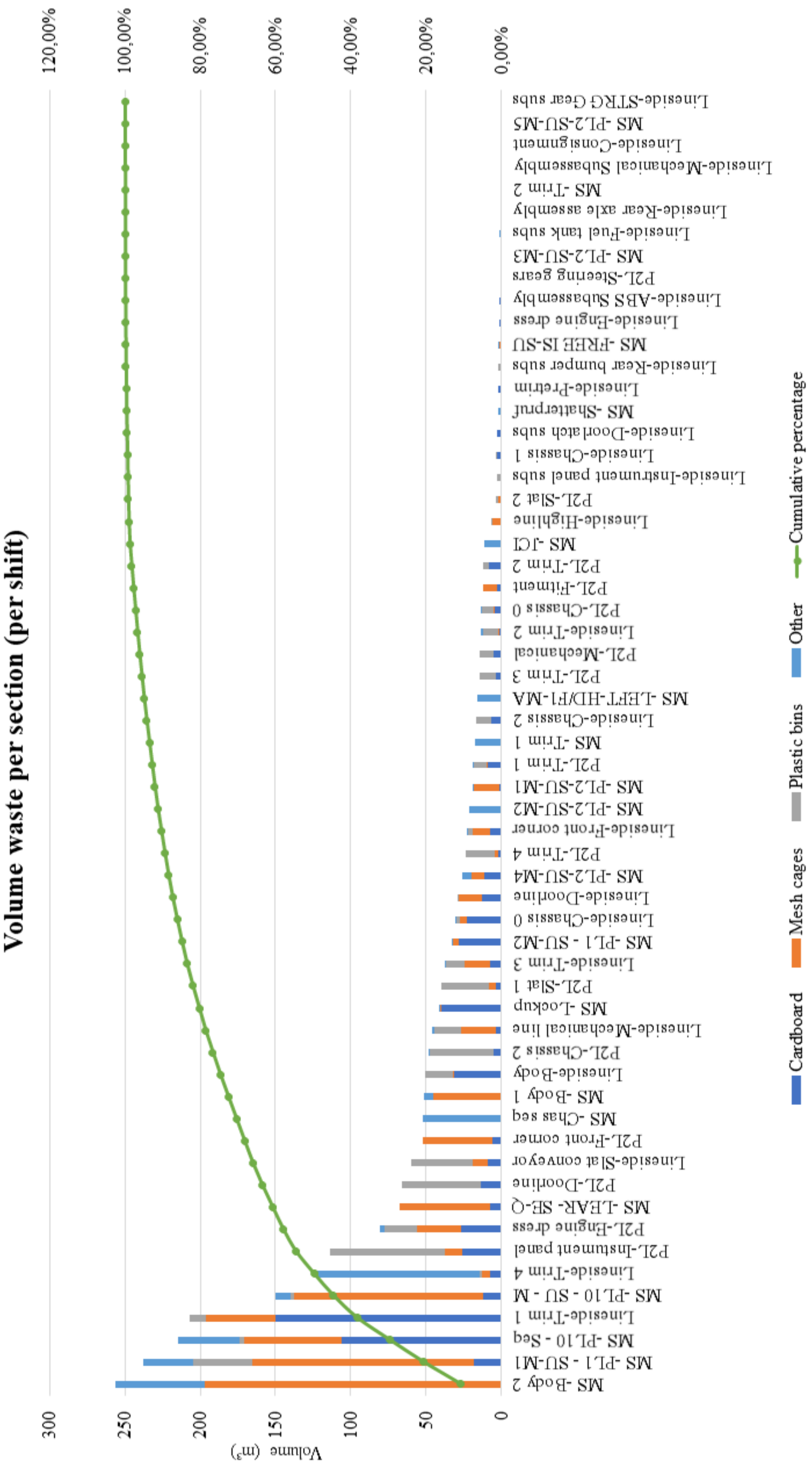


Figure 15: Pareto results - Volume waste in Ford facility

Once the areas with the most waste have been identified, time studies were conducted to determine how much time and resources are utilized to handle waste.

4.2 Time studies

Several time studies were conducted to determine the amount of time spent on waste during a shift. The amount of time spent on waste is time wasted that could have been spent on value-adding activities.

The following time studies have been conducted:

1. Time it takes for a material handler to collapse a cardboard box and how much time the process utilizes in a shift.

2. Time it takes to fill a trolley with waste.

3. Time it takes SuperCare tow motors to move the trolleys around the facility.

Using the quantification model, Figure 16 was generated to determine the amount of cardboard waste in each section.

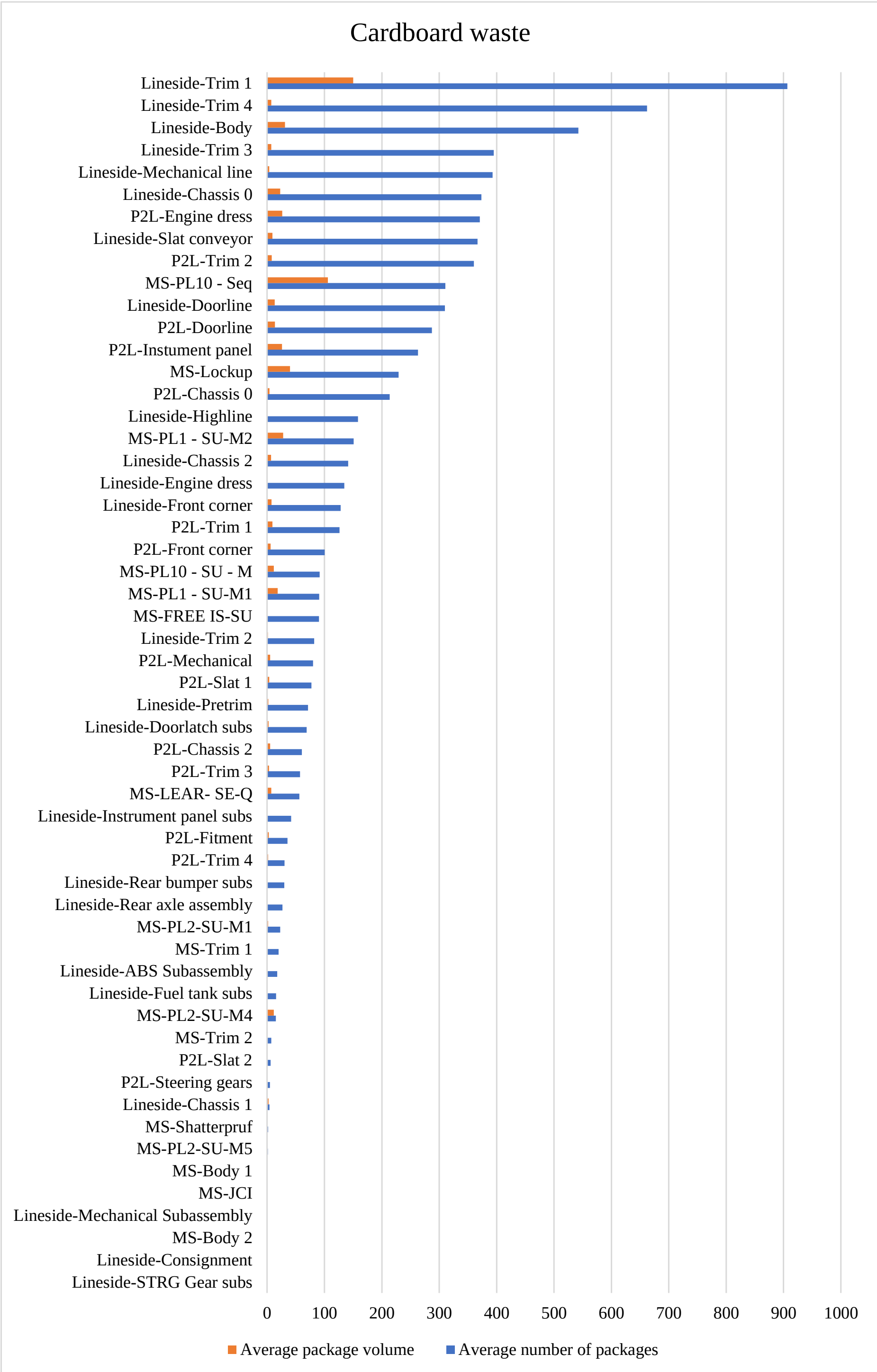


Figure 16: Cardboard waste in each section of the facility

There are 6 areas that have SuperCare employees dedicated to collapsing boxes. These areas are:

- Mechanical P2L
- Mechanical lineside
- Slat P2L
- Trim 1 lineside and P2L
- Instrument panel P2L and lineside
- Chassis 0 P2L

4.2.1 Cardboard box collapsing process

Table 4 indicates the average time spent to collapse a cardboard box. There are several activities included in collapsing a box. Each activity was timed, and a total collapsing time was calculated. The time varies for smaller boxes and bigger boxes. The smaller boxes are easier to collapse whereas some of the bigger boxes cannot be collapsed without the use of tools.

Table 4: Time study: Time spent to collapse one box.

Activity	**Average time (s) for one box**
Remove plastic or dividers inside the box	26.29
Tear the tape sealing the box	22.55
Collapse the boxes	27.83
Throw box inside the trolley	3.08
TOTAL TIME:	**79.75**

Referring to Figure 16, Table 5 is a summary of the average time the top five sections that generate the most cardboard waste spent on collapsing cardboard boxes. The table was generated with the assumption that the linefeeders collapse the boxes and not the pickers. A linefeeder is the employee who removes and replaces the empty boxes with full boxes.

Table 5: Time study: Average time spent on collapsing boxes in 5 sections of the facility.

Section	**Average time (min) per shift**	**Average time per linefeeder**	**Percentage time of shift spent on waste collapsing**
Lineside - Trim 1	1205.219	3 linefeeders: 401.740 1 SuperCare employee: 1205.219	N/A - SuperCare employee dedicated to collapse the waste 262.01
Lineside - Trim 4	880.148	3 linefeeders : 293.383	63.77
Lineside - Body	721.340	6 linefeeders: 120.223	26.14
Lineside - Trim 3	525.305	1 linefeeder: 525.305	114.20
Lineside - Mechanical line	522.387	3 linefeeders: 174.129 1 SuperCare employee: 522.387	N/A - SuperCare employee dedicated to collapse the waste 113.56

From the time studies and analyses, it is clear that the box collapsing process requires a lot of resources. In some of the processes, most of the waste handling process is spent on the box collapsing process instead of on value-adding activities.

4.2.2 Trolley fill rate

Various factors play a role in filling the trolleys during the shift. Material handlers and linefeeders only take the boxes to the trolleys when they have time. This results in peak times of trolley usage around the shift end as the employees starts their own housekeeping process. This poses two main problems, the first being that the trolleys fill up quickly and a lot of boxes end up next to the trolleys. The second problem affects the SuperCare employees who must collapse the boxes at the dedicated trolleys. The sudden wave of boxes cannot be collapsed before the end of their shift. This results in the workload being transferred to the next shift which creates a negative mentality among the workforce.

Table 6 portrays the time it takes to fill a trolley during a shift along with the rotations needed to ensure that the trolleys do not overflow during a shift.

Table 6: Time study: Average time it takes for a trolley to be filled during a shift.

Sections utilizing the same trolleys	**Trolleys in section**	**Average time (min) to fill trolley per shift**	**Rotations required to empty trolley**
PL10-Seq	1	43.39	10
Body lineside	1	148.14	4
Trim 1 lineside Trim 1 P2L	2	57	8
Pretrim Trim 2 lineside Trim 2 P2L Fitment P2L Doorline P2L Mechanical P2L Slat 1 and 2 P2L	2	121	4
PL1-SU-M1 Instrument panel P2L Instrument panel lineside	1	101	5
Trim 3 lineside Slat lineside Doorline	1	140	4
Trim 4 lineside Fuel tank subs Mechanical highline Bumper subs Mechanical lineside	1	345.28	2
Engine dress P2L Engine dress lineside Steering subs Chassis 0 lineside Chassis 2 lineside	2	139.03	4

In the above time study, it becomes apparent that the current rotations through the facility are not enough. There are also not enough trolleys to handle the waste generated per shift.

4.2.3 SuperCare tow motor time studies

The SuperCare tow motor follows a predetermined route through the Ford facility to collect the trolleys, tow them to a specified point, unhook or unload the trolleys and move to the next trolley.

Table 7 is a summary of the SuperCare tow motor activities and time it requires.

Table 7: Time study: Time spent to collapse one box.

Activity	**Average time (min)**
Drive to trolley destination	7.62
Hook trolley	4.21
Drive to waste separation area	6.32
Unhook trolley	4.65
Hook trolley	4.39
Drive to scrapyard	8.36
Wait for the trolley to be emptied	23.26
Drive to trolley location	11.76
Unhook trolley	3.65
TOTAL TIME:	**74.22**

The table provides evidence that a lot of time is required for a SuperCare tow motor to manoeuvre through the facility and move the trolleys to the correct locations. A lot of time is also wasted when the trolleys are emptied at the scrapyard.

In the next section, each engineering technique identified in section 2 is analysed and solutions developed in conjunction with the data analysed in this section.

5 Solution development

5.1 Material flow

The recyclable waste should be separated into the allocated waste trolleys dedicated to each section within the facility. Some of the sections within the facility share trolleys.

SuperCare has a facility layout with marked trolley spots according to which their trolley runs are scheduled. This facility layout and trolley locations were used as a basis along with repetitive walks through the facility to determine the actual trolley locations. The actual trolley locations are a clear indication of where the workers prefer the trolleys to stand, where there is space, and where SuperCare employees feel comfortable to hook and unhook the trolleys.

5.1.1 Facility layout - Waste trolleys

There are waste trolleys scattered across the Ford facility. These trolleys started at strategic points, but as the facility changed and expanded the trolleys were moved. Some trolleys moved to better strategic points whereas others moved according to available space.

The number of trolleys on site:

1. White - 7
2. Yellow - 27
3. Green - 6

TOTAL TROLLEYS: 40

Table 8 is a summary of the available trolleys for the recyclable cardboard waste in each chosen section along with the requirements per shift. The trolleys were custom made by Ford years ago (before SuperCare was appointed), and no two trolleys are the same size. Thus, an average trolley size of $10m^3$ will be used in this project. The calculations were done with the assumption that the cardboard boxes are not flattened before they are discarded into the waste trolley. This assumption was made due to observation.

Table 8: Trolley requirements per section.

Section	**Available trolleys** (m^3)	**Required trolley space**(m^3)	**Comments**
PL1-SU-M1 P2L instrument panel	10	18,41 26,23 **TOTAL**: 44.64	Trolley located far from PL1-SU-M1 area and closer to P2L Instrument panel area SuperCare does not rotate enough during a shift to justify only one trolley.
Trim 1 lineside	20	149,94	Trim 1 lineside generates too much cardboard waste to justify only two trolleys.
P2L - Doorline P2L - Trim 2	10	13,57 8,14 **TOTAL**: 21.71	There are trolleys enough to handle the amount of waste for these two sections since SuperCare rotates to empty the trolleys during the shift. Unfortunately, the two trolleys are shared with seven more areas which results in a shortage of trolleys.
P2L - Engine dress Trim 3 Lineside Trim 4 Lineside Body 2	10 10 10 10	26,61 7,54 7,40 0,56	One trolley is sufficient for the amount of cardboard waste, but the trolley is shared with various other sections which results in insufficiency.
PL10-Seq	10	106,01	One trolley cannot handle the volume of waste generated in this section. More trolleys are located too far away for efficient waste material handling. A lot of time is wasted in moving the waste from this area to any other area within the facility.

Three things can be observed from the above table:

1. There are not enough trolleys.
2. The boxes should be flattened before being disposed of to decrease the volume re-

quired.

3. SuperCare might need to change their rotation cycles to accommodate the waste.

Since the trolleys are shared by several sections at a time, the other sections need to be considered when the optimal position for the trolleys is determined. To determine the optimal position for the waste collection points, the chosen sections were used as a base point. All the sections that share a waste collection with the chosen section were identified. Once the areas involved were identified, the percentage cardboard each section generates per shift was calculated with regards to the other sections. These percentages were then used as weights to establish to which side of the facility area the waste trolley should be located.

Figures 17- 24 are simple block layouts (not to scale) of the areas indicating the current waste collection point in each area versus the proposed waste collection points. The top percentage is the number of boxes, and the bottom percentage the volume of boxes that the specific area generates with regards to the specific waste accumulation point. The required number of trolleys is also taken into consideration.

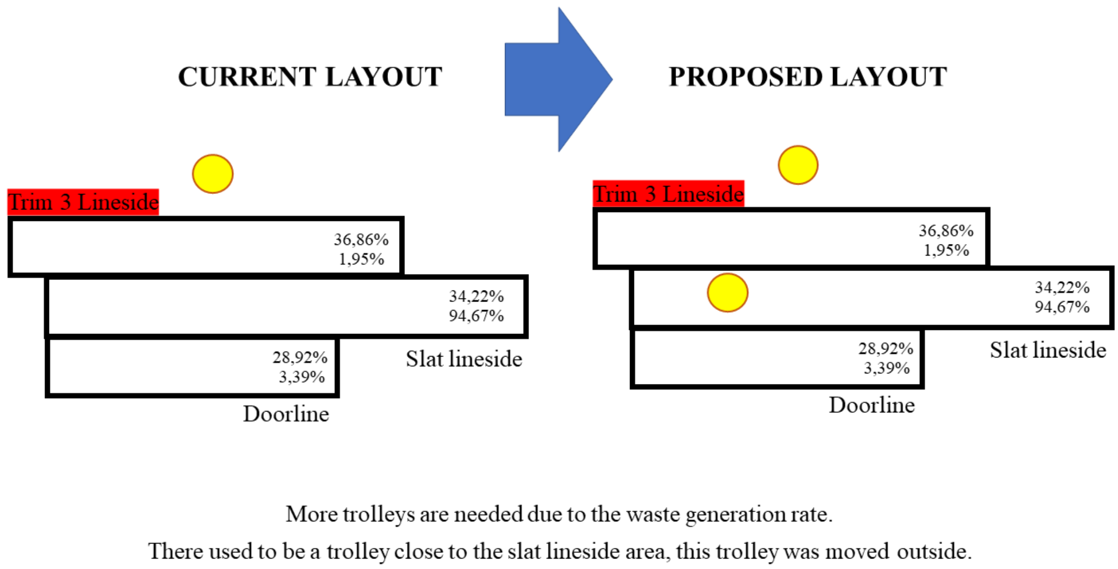


Figure 17: Trolley locations block layout - Trim 3 lineside

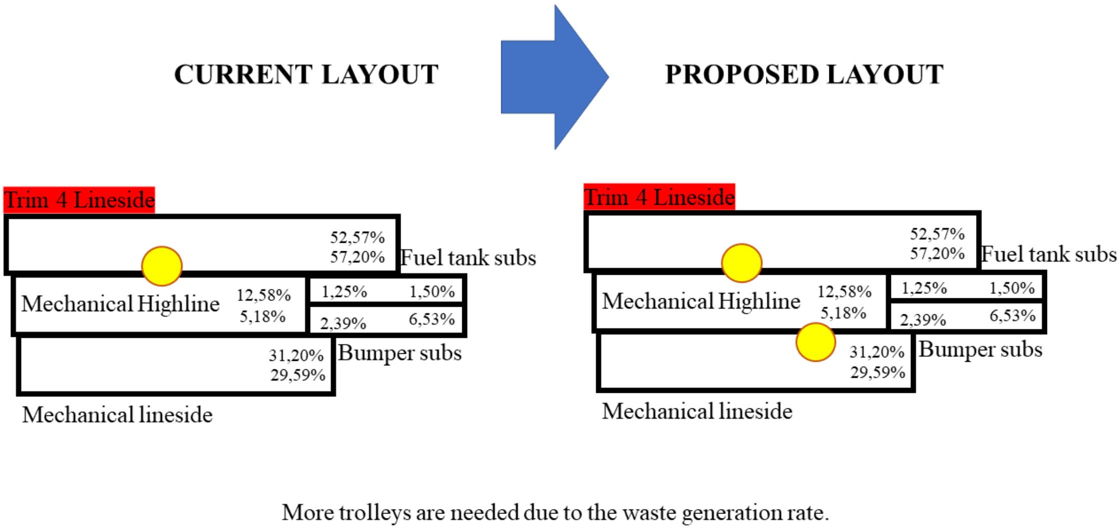


Figure 18: Trolley locations block layout - Trim 4 lineside

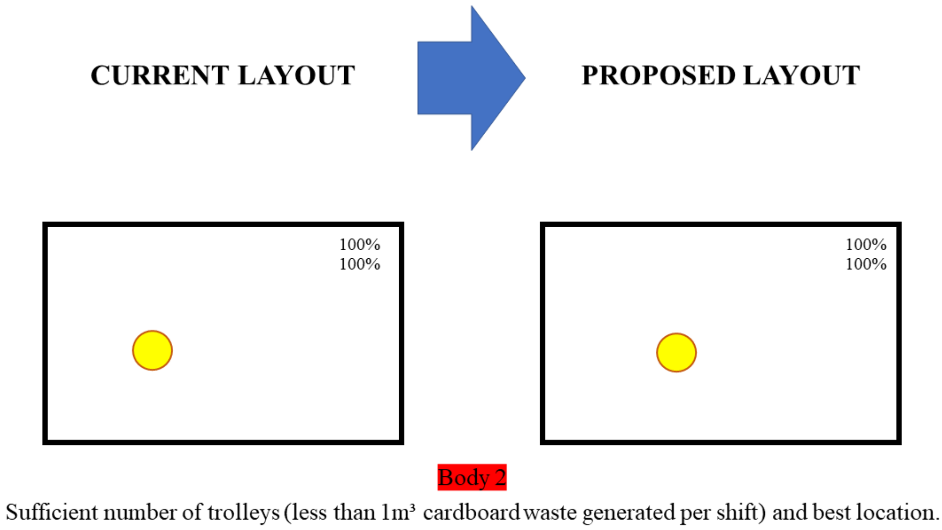


Figure 19: Trolley locations block layout - Body 2

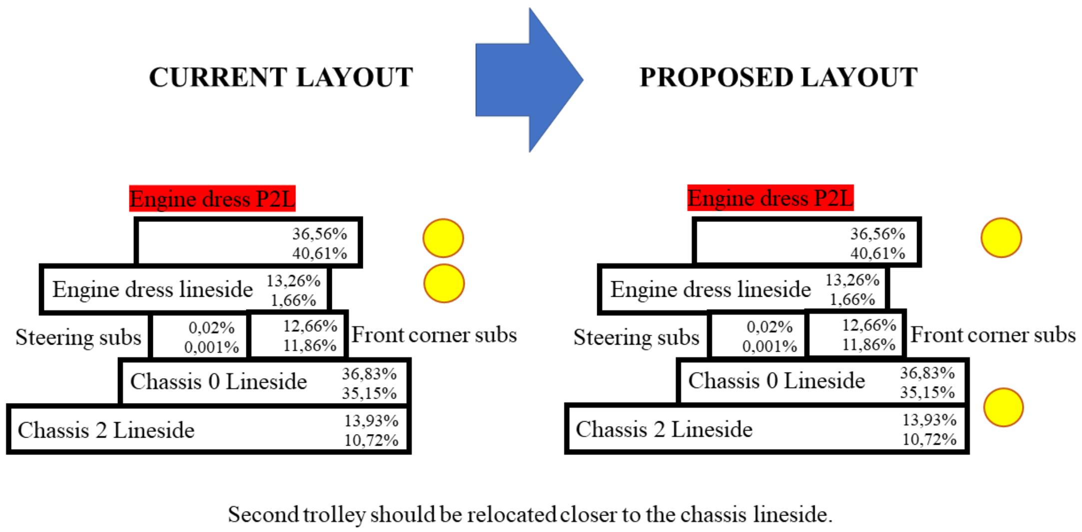


Figure 20: Trolley locations block layout - Engine dress P2L

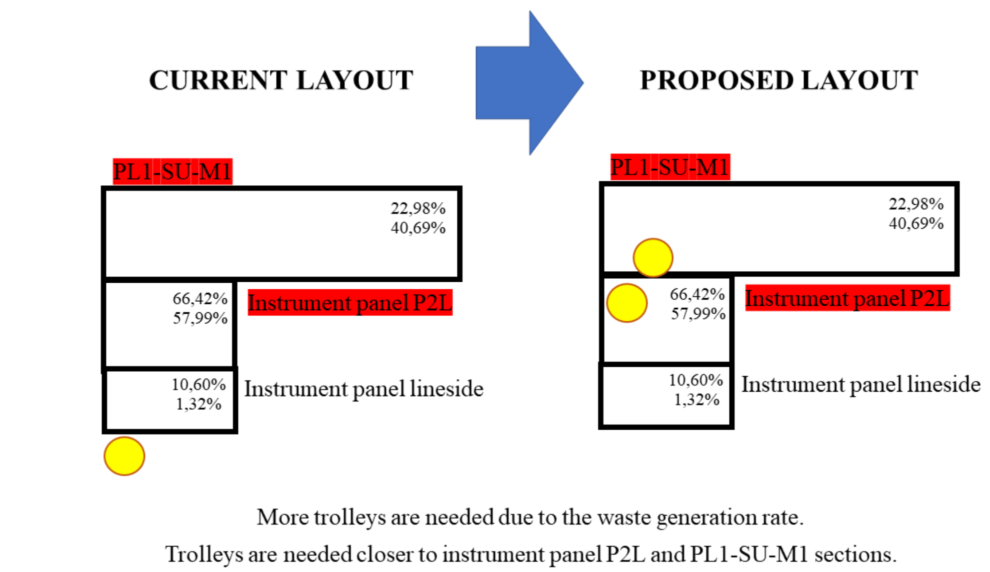


Figure 21: Trolley locations block layout - PL1-SU-M1 and instrument panel P2L

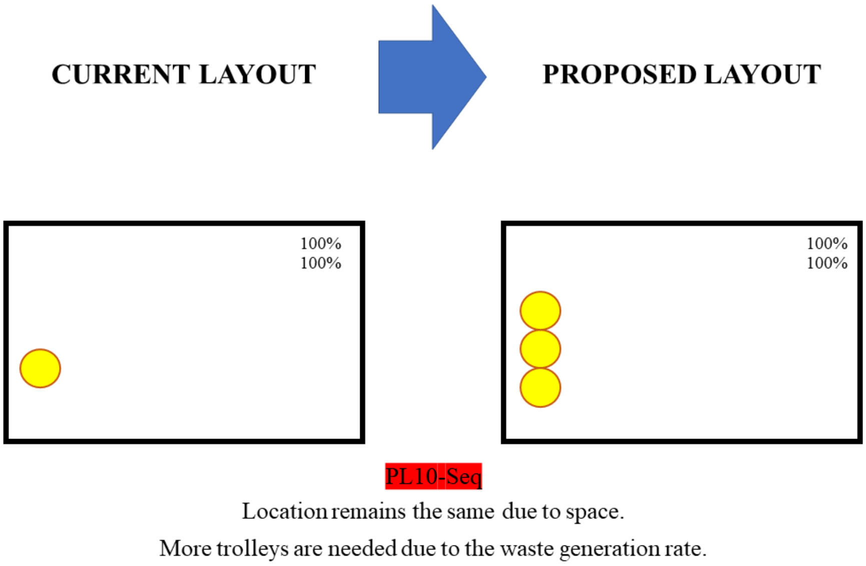


Figure 22: Trolley locations block layout - PL10-Seq

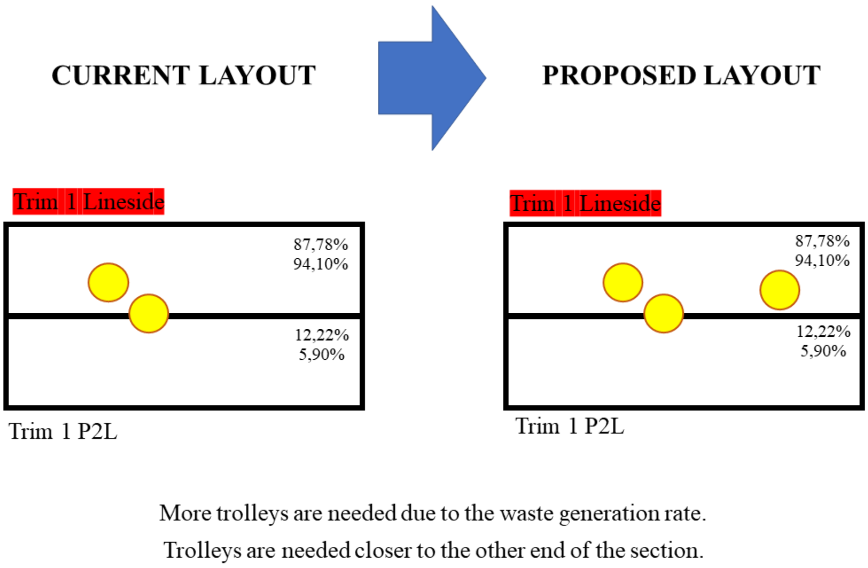


Figure 23: Trolley locations block layout - T1 lineside

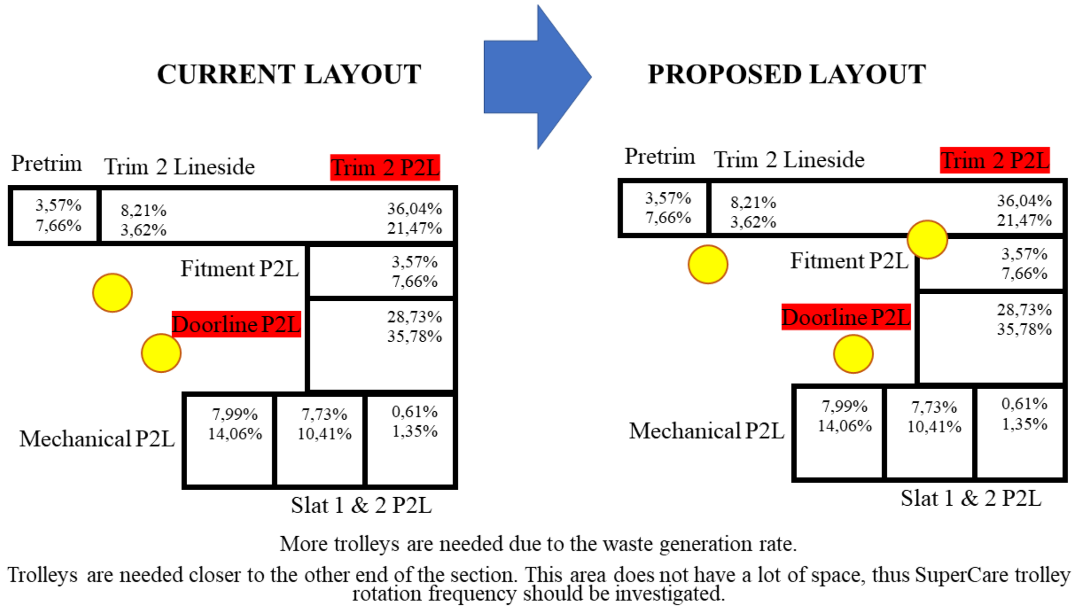


Figure 24: Trolley locations block layout - Trim 2 P2L and doorline P2L

In addition to more trolleys for cardboard, more trolleys for the other recyclable wastes should be considered. In some sections, the recyclable waste is not separated as there is nowhere to put the other waste e.g. plastic and polystyrene.

To force material handlers to separate the waste, check inside the boxes for forgotten parts and to flatten the boxes, the waste trolleys can be renovated to add a roof and create a slit for the cardboard boxes to be slid into.

The facility layout and flow of materials through the facility are closely related to the material handling methods. The next section analyses the current material handling methods and material handling equipment.

5.1.2 Material handling - Transportation

The material handling of the waste materials is a time-consuming job. By expediting the waste material flow, more time will be available for material handlers to pick items. By reducing the picking time, more unit materials can be picked per shift. By increasing the number of materials picked, the assembly line can speed up and more units can be assembled per shift. For this scenario, different material handling equipment was investigated. By using the material handling system framework identified in section 2 as a basis in conjunction with a material handling system equation (equation 1 and figure 25) the recommended material handling system was identified.

$$Materials + Moves + Methods = RecommendedSystem \quad (1)$$

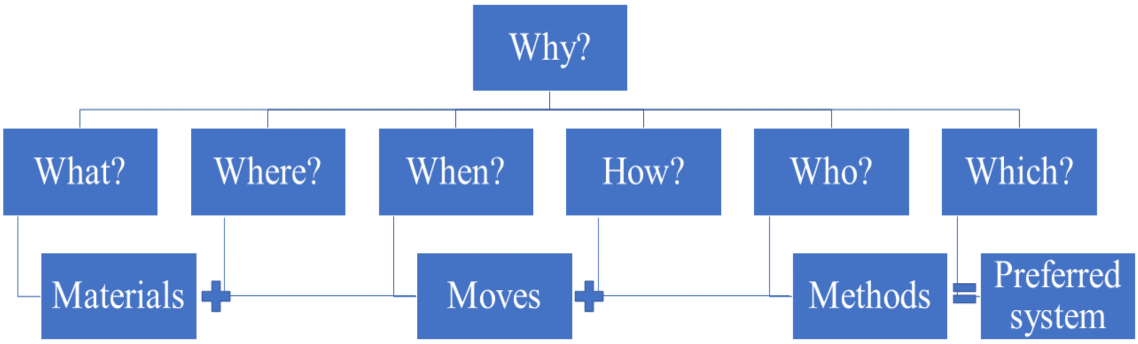


Figure 25: Material handling system equation [30]

Why?

- Waste materials are currently occupying a lot of space in each facility section.
- Material handlers handling their own waste is very time-consuming.

What?

- Types: Cardboard boxes, TrenStar mesh cages, and TrenStar plastic bins should be removed from the facility sections.
- Characteristics: Cardboard boxes can range from very light to extremely heavy, depending on their purpose. These boxes also vary extremely in size. The mesh cages are very heavy and material handlers cannot move them by themselves. There is an average of 8 different mesh cage sizes. The plastic bins are light and mostly the same size.
- Amounts moved and stored: The amounts moved and stored are dependent on each section. These results can be found in section 4.1.

Where?

- Point of origin: The materials come from their respective workstations within the facility sections.
- Point of delivery: The cardboard boxes should be delivered to the waste trolleys and the TrenStar cages and bins to the TrenStar facility.

- Storage: There are no storage requirements for waste materials. The TrenStar bins are, however, stored next to the TrenStar facility if no TrenStar employees are available to empty the flat beds.
- Material handling process steps that can be changed: The cardboard boxes should not have to be flattened by hand and the TrenStar bins should not over utilize the flat beds.
- Mechanization and automation: The flow of cardboard boxes to the trolley can be mechanized or automatized.

When?

- Time needed: The waste materials should always be cleared.
- Time to mechanize and automate: The waste material movement between process stages.

How?

- Current material movement: The materials are moved by hand, forklifts and flat beds. Further analysis of the movements is in section 3.
- Inventory: None.
- Material tracking: The TrenStar bins should be tracked from the workshop to the TrenStar facility to ensure that no additional time of the TrenStar units is spent on the Ford facility site.
- Analysis of the problem: The problem should be analysed with space utilization in mind. Vertical space is available, but the aim of the project is to clear the horizontal space.

Who?

- Waste material handlers: Material handlers and pickers.
- Skills required: None.
- Required people for system design: Industrial engineer (DHL), required Ford managers and employee inputs.

Which?

- Necessary material handling operations: Collapsing of all boxes and stacking of TrenStar bins. Transportation of TrenStar bins to the TrenStar facility.
- Types of material handling equipment to consider: (Refer to figure 26) Waste materials run a variable path in restricted areas.
    1. High frequency: Industrial trucks cannot navigate the narrow aisles of the facility. In this case forklifts, EffiBots and flat bed tow motors should be considered.

2. Low frequency: Cranes can be considered in low-frequency areas as the horizontal space utilization will be shifted to vertical space utilization. Cranes under consideration are bridge cranes and gantry cranes.

Path	Fixed			Variable		
Area	Restricted			Restricted		Unrestricted
Frequency	High	Low		High	Low	-
Adjacent	-	Yes	No	-	-	-
Equipment category	Conveyor	Conveyor	Industrial Truck/Crane	Industrial truck	Crane	Industrial Truck

Figure 26: Transport equipment characteristics [16]

Each of the material handling equipment ideas have been investigated according to usage, advantages, disadvantages, and impact. The overall impact of mechanization and automation would be to decrease picking time, increase picking efficiency and in the end increase number of units assembled per shift.

Forklifts: Using forklifts to transport the waste materials to the section waste point would require a material handler with experience to load the materials and drive to the closest waste collection point.

An advantage of forklifts is that they can navigate in smaller spaces and can be utilized in other departments as well. Forklifts can travel over various surfaces and will be able to handle the large mesh cages.

Unfortunately, forklifts have limited space to carry the necessary waste materials.

Currently, the larger waste materials are removed by forklifts that have time and see an opportunity of housekeeping. To employ a forklift to focus on housekeeping would increase the waste flow and if a trolley is too full, the driver can drive to the next trolley without causing a delay further down the process. This means forklifts would have a positive impact on the process and workforce as job creation would be involved.

EffiBots: EffiBots are automated robots that follow a predetermined route. The EffiBots are a DHL initiative and can save a lot of money and resources. The robots can be used to drive past designated spots and load the empty boxes. These boxes should then be taken to the dedicated waste area. Another way to use the EffiBots would be to program them to replace the SuperCare tow motors. A hook-in system could be installed for the EffiBots to collect the trolley, move the trolley to the waste separation area and then return the trolley to the designated spot once emptied.

On the other hand, the EffiBots cannot think for themselves which could be problematic in moments when the waste supply chain is most variable. The EffiBots predetermined route would also utilize horizontal space instead of vertical space. These machines would also require extra resources to be able to handle the TrenStar mesh cages.

Thus, depending on the view, EffiBots could have a positive or negative impact on the waste supply chain. With regards to the flow of waste materials and the utilization of trolleys, the EffiBots would have a positive impact on the system.

Flat bed tow motors: Flat beds and tow motors can be utilized even more by appointing a dedicated tow motor and flat bed to collect cardboard waste, as well as TrenStar bins.

An advantage of this material handling transport method is that the tow motors and flat beds are already in use and most of the drivers know how to operate the equipment.

Manual labour is needed to load and unload the flat beds. Forklifts are also needed to load the heavier waste onto and off the flat bed.

The use of tow motors would not necessarily have an impact on the section environment, only on the waste supply chain itself.

Conveyor: The P2L areas use flow racks in some sections to increase the flow of the picking process. The full cartons are slid into the top rack which then slides to the picker. The picker slides the empty cartons onto the bottom rack which then slides away towards the back of the rack to be collected again.

The empty cartons must be collected from each individual rack at random locations. A conveyor (return chute) can be added to the bottom layer of the flow rack that would move the empty cartons to the end of the picking line. The cartons would accumulate in one central area to ease housekeeping duties.

An advantage would be that the waste is accumulated at one point without human resources. A disadvantage would be the renovations the areas would have to undergo to install the conveyor system.

Bridge crane: Bridge cranes are cranes mounted on bridges stretched between opposite walls of a facility. The crane can be used to collect the waste from the specified sections and take it to the waste collection area. In the waste collection area, a waste employee would separate the recyclable waste into dedicated trolleys, and stack the TrenStar bins to be collected for TrenStar. The same employee could be used to do TrenStar runs.

An advantage of a crane system would be that the manual labour required to handle the waste materials would be reduced. Bridge cranes can handle three-dimensional handling and TrenStar bins, as well as cardboard, could be handled.

A crane system is very expensive which would make it an inviable option. It would also require downtime to be installed.

The impact of a crane can be positive or negative. In the long run, the crane system can be used to distribute parts in the facility sections and collect the empty containers. The positive impact would be that there would be an immense increase in picking speed as the need for a tow motor to deliver the parts would be eliminated. The negative impact would be that the tow motor drivers would then not be necessary, although luckily if the picking speeds increased more pickers would be required so with some reshuffling in the workforce everyone could keep their jobs. If the system could be used both ways (distribution of parts as well as the collection of empty boxes) it could enhance the chance of a better return on investment.

Gantry crane: A gantry crane is also a railway crane utilizing vertical space, but the crane is supported with one or two legs on the floor. The crane could be used to gather the empty waste materials from the selected sections and place them in the waste collection area. Same as bridge crane techniques, the waste would be separated and the TrenStar bins collected from the waste are.

Gantry cranes can be supported by fixed floor supports or on travel runways.

A bridge crane would be preferred to a gantry crane as a bridge crane utilizes wall space and a gantry crane floor space. This also means that a gantry crane spans a smaller portion of the area.

A gantry crane would have the same impact as a bridge crane. The difference would be that a gantry crane would not necessarily be able to span across the entire warehouse, thus the picking speeds would not be able to increase as much.

Along with material handling transportation methods, material handling operation methods should be considered.

5.1.3 Material handling - Operations

During the material handling analysis, it was determined that one of the most important handling operations is the collapsing of the boxes. This is due to the space occupation difference between the box erected and collapsed.

The TrenStar plastic bin lids have hinges which enables the lids to be placed outwards and the bins can be stacked neatly inside each other. The TrenStar mesh cages can collapse into smaller cages which can be stacked on top of each other for storage and transportation. These steps, the collapsing and stacking, require manual labour. Some of the mesh cages are too heavy to stack on top of one another without additional help.

Currently, forklifts are used to lift the mesh cages onto the flat beds. There are two other options namely:

1. Magnet lift.
   Advantage: A forklift will not be necessary which would be beneficial as the forklifts are utilized in other sections of the facility.
   Disadvantage: The equipment will be fixed in place and utilizes a lot of space. A magnet would not be able to lift the plastic crates.

2. Vacuum lift.
   Advantage: A forklift will not be necessary which would be beneficial as the forklifts are utilized in other sections of the facility.
   Disadvantage: The equipment will be fixed in place and utilizes a lot of space. In some cases, the vacuum will struggle to find suction area on the cages.

If the boxes are collapsed into the smallest possible size, more space can be utilized within the waste trolleys. The biggest problem for a MH to collapse a cardboard box is the strength of the corrugated boxes. These boxes are designed to withstand multiple external factors that could harm the parts inside. In most cases, the MH does not collapse the box. This means that they do not check inside the box for forgotten parts. In other cases, some material handlers jump on the boxes which could have many health and safety repercussions.

Several tools have been identified to expedite the collapsing process of cardboard boxes. Using power tools, the process can be done quickly and efficiently. Two power tools were identified to investigate, namely:

1. Power saw.
   Usage: A power saw can be used to cut the edges of the cardboard box to ease collapsibility. The saw is then easy to use if any other parts need cutting.
   Advantage: The power saw is easily accessible and can be used in variable methods and processes.
   Disadvantage: Power saws need specific training and only trained employees will be able to use the equipment.

2. Hydraulic press.
   Usage: A hydraulic press can be used in sections where the cardboard waste generation is the highest. In some instances, the number of empty cardboard packages generated per shift cannot be collapsed fast enough to keep areas free of clutter. The hydraulic press can be used to place a box under the press and in one swift movement, the box will be pressured into a flat object.
   Advantage: Using a hydraulic press is a quick movement that would save a lot of resources. The amount of space would increase, and the time spent on packaging would decrease.
   Disadvantage: A hydraulic press is expensive and usually fixed. The press would require a lot of training and if an employee forgets to check the box for forgotten parts it could result in a lot of damage.

To expedite the material flow through the process, the supplier relationships within this supply chain plays an important role. In the next section, the current supplier relationships are analysed.

5.2 Supplier relationships

Supplier relationships are important in a supply chain to ensure that the flow of materials is continuous. This means that DHL should build a strategic relationship with TrenStar and SuperCare respectively to balance the flow of the waste materials through the facility.

The Ford production teams work in 9-hour shifts with 15 minutes of team talk and 30 minutes lunch. These shift times are:

1. 06:00 - 14:15

2. 15:15 - 23:30

TrenStar and SuperCare operate on the same cycle times. Unfortunately, operating the same time as production is the only link between Ford and DHL with TrenStar and SuperCare respectively.

5.2.1 SuperCare supplier relationship

SuperCare has a working relationship with Ford. This means that there is a missing link between DHL and SuperCare. This link is important since DHL must provide the assembly line with the necessary unit parts, which means that DHL generates the waste.

SuperCare has been working for Ford for a number of years. The employees emptying the trolleys and bins work on a specific route laid out through the facility. A total of three employees walk around with push trolleys to empty the plastic bins. Five tow motors are used to empty the trolleys. Each tow motor can only empty one trolley at a time. The scrapyard is at the end of the facility which means that some of the tow motors have a long distance to cover to empty one trolley. The scrapyard, as well as the SuperCare waste collection point, has limited space for movement which results in the tow motors queueing at some points waiting to empty a trolley.

The five tow motors are utilized as follow:

- 1 x tow motor to take the outside trolleys to the scrapyard.
- 1 x tow motor to take trolleys from Plant 10 to the waste collection point.
- 2 x tow motors to take all other trolleys within the plant to the waste collection point or scrapyard (depending on the distance).
- 1 x tow motor to take the trolleys from the waste collection point to the scrapyard.

Since some of the trolleys are taken from the plant to the waste collection point before being emptied at the scrapyard, the trolleys tend to pile up at the collection point which results in no trolleys in the plant.

To compare the efficiency of each tow motor, the number of trolleys were compared to the number of tow motors assigned to the section.

$$Trolleys : TowMotors \tag{2}$$

The results are as follow:

- Plant 10 - 5:1
- Rest of plant - 11:2 (5.5:1)
- Outside - 16:1
- SuperCare waste collection area (theoretical) - 8:1 (undefined, since trolleys rotate through this area)

It is clear that the SuperCare resources are not distributed evenly throughout the facility. A rotational schedule for each tow motor driver would be able to distribute the resources evenly as well as prevent flow bottlenecks at the scrapyard or the waste collection point. The schedule should also be aligned with the waste generation rate throughout the facility.

In section 4.2 Figure 16 represents cardboard waste generated per shift in each section. With the waste amount in each section, the tow motor routes can be aligned with the waste generation to prevent waste accumulation at the workstations or trolleys. The graph was constructed according to the average number of boxes emptied per shift as this would play a large role in the number of rotations SuperCare would have to make.

ABC analysis can be applied to prioritize the rotation frequency in each section. Table 9 shows the section classification as well as the plan of action. This should be aligned with a practical element of ways to navigate around the facility.

The classifications were calculated as follow:

1. Class A: Sections that generate 80 percent of the waste.
2. Class B: Sections that generate 15 percent of the waste.

3. Class C: Sections that generate 5 percent of the waste.

Table 9: Potential impact of improvement opportunities: Combination.

Criteria	**Class A**	**Class B**	**Class C**
Number of sections	18	12	25
Percentage of the total amount of sections	32.7	21.8	45.5
Percentage cardboard waste generated per shift	80.06	14.21	5.73
Priority level	1	2	3
Plan of action	Frequent rotations.	Moderate number of rotations.	Low number of rotations.

The formation of a rotational schedule for the SuperCare tow motors falls outside of the scope of the project. However, the separation of the recyclable waste materials does fall within the scope. DHL is at the start of the waste supply chain. By splitting the waste into respective categories at the start, the waste can be handled more easily and unit parts will not end at the scrapyard. The TrenStar supplier relationship is also important to consider as the empty TrenStar bins should not be on site for extended periods of time.

5.2.2 TrenStar supplier relationship

DHL is responsible for taking the empty TrenStar bins to the TrenStar facility. TrenStar is responsible for unloading the tow motor flat beds. The bottleneck within this part of the waste supply chain process is linked to the availability of TrenStar employees to unload the tow motor flat beds. The material handlers handling the TrenStar bins, collect the empty bins from the workstations while dropping off full bins. Once the tow motor is filled with empty bins the tow motor driver takes the bins to the TrenStar facility. The driver works on a schedule to keep the parts flowing on time to the right places along the assembly line. This schedule would be useful to integrate the DHL process with the TrenStar process. The DHL part distribution schedule and time studies could indicate what times the TrenStar employees should be available to unload the flat beds.

To establish a strategic alliance a 6-step model for forming logistic relationships can be followed [9]. However, to expand on this relationship forming process falls outside of the scope of the project.

The steps for DHL to form and sustain a strategic alliance with TrenStar should be as follows:

1. Perform strategic assessment.
   An audit of the current supply chain relationship revealed the following:
   - DHL objective: Minimize the time the TrenStar bins spend on the facility grounds under Ford's care.
   - Relationship need: Collaboration and communication between both entities.
2. Decision to form relationship.
   To satisfy DHL and Ford's needs, the decision was made to form a relationship.

Each relationship has drivers and facilitators. The following drivers and facilitators should be present in the relationship:
Drivers:

- Cost efficiency.
- Asset efficiency.
- Turnover increase.

Facilitators:

- Management philosophy.
- Mutual commitment to forming a relationship.

3. Evaluate alternatives.
   Due to the nature of the project as well as TrenStars relationship with Ford, alternative suppliers were not be considered/evaluated.

4. Select partners.
   Since no alternatives where evaluated, TrenStar is already the partner DHL should establish a strategic alliance with. The aim is for TrenStar and DHL to reach a consensus on how to collaborate about TrenStar bin deliveries.

5. Structure operating model.
   To structure the operating model some key components are necessary:

   - Planning.
   - Joint operation control.
   - Communication.
   - Trust and commitment.

6. Implementation and continuous improvement.
   To implement the model to establish a relationship, a planning horizon is required. The schedules would have to be continually adapted to the changes within the facility until the optimum schedule has been established. Specific measures must be agreed upon by both parties to satisfy all stakeholders' needs.

Once the optimal material flow process and supplier relationships have been established the best way for standardization would include visual management techniques.

5.3 Visual management

Housekeeping plays an important role in any facility. A simple change in housekeeping can affect a process in more ways than one. Housekeeping is a time-consuming task. The DHL material handlers do housekeeping duties when there is time, or after the shift. By improving the housekeeping techniques, the spare time can be utilized for other tasks.

This project is focused on the second s (stabilize) of the 5s methodology. It is the visual organization and arrangement of items in the workplace. The items are placed at POU where it is necessary.

Currently, the waste supply chain visual aids consist of coloured waste trolleys. These trolleys are for recyclable and general waste. The TrenStar bin process has no visual aid mechanisms. One key objective of VM is to aid external people of the process in understanding the correct actions at first glance. VM is an aid to housekeeping to ensure everything will be kept in its place as well as to guide the responsible people in knowing when something is missing.

In the case of the trolleys, VM could be applied by outlining the trolley areas or waste areas on the floor. By providing dedicated areas for the trolleys, they cannot be moved to sections where they are less necessary and the SuperCare employees would also know where to replace the trolleys after emptying them. Some employees do not know what the different trolley colours mean. A solution to this would be to label the trolleys clearly as well as indicate the process to be followed on the trolley. An example would be an illustrative picture flow chart of waste separation and cardboard box collapsing.

In section 6 the solutions that were identified in this section are summarised and compared to distinguish the preferred solution from the rest.

6 Solutions

In this section, the possible solutions identified to improve the problem areas are discussed. The alternatives are analysed and prioritised to determine the preferred short-term and long-term solutions.

6.1 Possible solutions

All the identified possible solutions were summarized and categorized within each engineering area. The solutions are applicable to either the recyclable waste process, the returnable TrenStar bin process or a combination of the processes.

6.1.1 Material flow

The following solutions were determined in section 5.1.

1. More trolleys.
   Some areas have more waste than others. The areas with more waste have a need for more trolleys. With more trolleys in the areas, it would not affect the waste flow if SuperCare collected one trolley at a time to empty it.

2. Change trolley locations.
   Trolleys are located where there is space. The trolleys should be located closest to the points with the highest waste generation rates depending on space for the trolleys.

3. Trolley renovations.
   Renovate the trolleys to create a slit into which a flattened cardboard box can be slid. This would force the material handlers to separate the waste and to check for lost parts.

4. Assign responsibility for waste separation.
   Assign waste separation to DHL, as DHL is at the start of the waste supply chain to improve material handling. At the points where SuperCare employees are employed to separate the waste, the waste separation responsibility would fall on these employees.

5. Alternative recyclable box collapsing method - power saw or hydraulic press.
   Using power tools such as a power saw, the box could be collapsed quicker. Another method would be to crush the boxes under a hydraulic press. In the case of the hydraulic press, it would be very important to check for parts inside the boxes.

6. Alternative waste transportation methods - Forklifts, EffiBots, conveyors, flat bed tow motors, bridge cranes or gantry cranes.
   Forklifts and tow motors can be used to collect the waste from dedicated points and travel to the next point. Cranes can be installed at a central waste collection area where an employee can collapse the boxes and separate the waste. To prevent waste build up at the workstations, an EffiBot (automated guided vehicle) can follow a route through the facility to collect waste from workstations and take it to the waste trolleys. Conveyors can be used in the flow racks to accumulate the waste at one point.

7. Alternative mesh cage lifting methods - Magnet, vacuum or forklift.
   All three options would be applicable to loading the mesh cages onto a tow motor to be transported to the TrenStar facility. The magnetic and vacuum lifts are infeasible due to facility restrictions.

6.1.2 Supplier relationships

The following solutions were determined in section 5.2.

1. Waste collection schedule (DHL and SuperCare).
   SuperCare and DHL can use the waste quantification model to calculate the waste generation in each area. DHL and SuperCare can then collaborate on a waste collection schedule that ensures that the SuperCare rotations align with the waste generated.

2. Waste collection schedules (DHL and TrenStar).
   To reduce the delay time at the TrenStar facility, TrenStar and DHL can collaborate on a bin return schedule. The schedule should align with the train schedules to deliver the new parts at each workstation.

3. Assign responsibility.
   To successfully collaborate, it is important to assign responsibilities and ensure that both parties fulfil their obligations.

6.1.3 Visual management

The following solutions were determined in section 5.3.

1. Mark trolleys.
   The trolleys are identified by colour. Each colour means that the trolley is for a specific kind of waste. Marking the trolleys with names will aid new employees to identify which colour means what type of waste.

2. Mark trolley areas.
   Marking the trolley areas can give a clear indication as to where the trolley should always be. Marked areas aids in seeing if trolleys are missing. It also aids the employees to know where to take the waste in case a trolley is not present.

3. Illustrative process flows.
   Illustrative waste process flows will aid any member on the facility to understand the process an empty package should follow.

6.1.4 Composite

The following solution was determined by combining the requirements of DHL, SuperCare, and TrenStar.

1. Housekeeping employees.
   Hire employees to focus on housekeeping. The employees would collect the waste, flatten and collapse the boxes, separate the waste and take the waste to the dedicated areas. These employees can also transport bins to TrenStar if needed.

The next step was to categorise the possible solutions and determine which solution would be the most appropriate.

6.2 Comparative analysis

To determine the optimal solution all the identified options need to be compared. In this section, each option is analysed according to the impact it would have on the facility and the risks that the implementation would have.

6.2.1 Impact-benefit analysis

Each of the identified solutions will have an impact on the facility and employees. The benefits, as well as the long- and short-term impact, of each improvement opportunity are summarised in Tables 10- 15.

Table 10: Potential impact of improvement opportunities: Material flow - Trolleys.

Improvement opportunity	**Short-term impact**	**Long-term impact**	**Benefits**
More trolleys	Waste would not accumulate next to the trolleys.	In the case where the waste process is changed, in the long run more trolleys would be a waste of space and inefficient.	When a SuperCare employee removes one trolley to empty it, another trolley will be available to ensure good housekeeping.
Change trolley locations	The trolleys would be easier to access by the material handler who needs them.	The facility and operations are changing and expanding continuously. This means the trolley locations would have to change continuously.	By locating the trolleys closest to the point where recyclable waste is generated the fastest, the time spent on housekeeping will be decreased.
Trolley renovations	Employees would take time to get accustomed to the new process as they are forced to flatten the boxes which is time-consuming.	The renovated trailers could not necessarily be utilized in other forms of operations.	The waste would be separated at the start of the waste supply chain and missing and forgotten parts would be caught before being sent to the scrapyard.

Table 11: Potential impact of improvement opportunities: Material flow - Transportation.

Improvement opportunity	**Short-term impact**	**Long-term impact**	**Benefits**
Forklifts	Forklifts are already in use and would have no different impact.	The forklifts can be used in different locations as the waste location area might change with facility expansion.	Forklifts can be used for various operations within the facility. Most of the employees also already know how to navigate a forklift.
EffiBots	The waste would be collected from each individual point which would reduce housekeeping time. EffiBots would, unfortunately, require a lot of space.	EffiBots will result in job loss and would also have to be reprogrammed every time the facility changes.	EffiBots are environmentally friendly.
Conveyor	The conveyors would move the empty cartons to accumulate in one area which would immediately ease housekeeping duties.	The flow racks are individual racks next to each other. If the racks are to be moved in the facility, the conveyor could pose a problem.	The housekeeping would be easier and since the cartons are accumulated in one area, it would increase the chance of housekeeping being completed.
Flat bed tow motors	Flat beds are already in use and would have no different impact.	The flat bed tow motors can be used in different locations as the waste location area might change with facility expansions.	Flat bed tow motors can be used for various operations within the facility. Most of the employees also already know how to navigate a tow motor.

Table 12: Potential impact of improvement opportunities: Material flow - Operations.

Improvement opportunity	**Short-term impact**	**Long-term impact**	**Benefits**
Power saw	Power saws are an inexpensive option which would improve the cardboard collapsing process. Training would be needed, but once the employees are used to the new equipment the working experience would improve.	The power saws would be able to change locations as waste areas change.	Power saws are inexpensive and not a fixed mechanism.
Hydraulic press	A waste area would have to be established and the waste area would have to be shut down while the press is being installed. Intense training would also be required. This is an expensive option.	A hydraulic press is a permanent fixture which would not be beneficial when the facility expands.	The cardboard boxes would be collapsed in one swift movement.

Table 13: Potential impact of improvement opportunities: Supplier relationships.

Improvement opportunity	**Short-term impact**	**Long-term impact**	**Benefits**
SuperCare routes	A relationship would have to be established and a change management plan would have to be put into place. The routes would require training and could upset the employees.	Once the employees are used to the new rotational schedule, the waste would be removed from the areas a lot faster.	With a supply chain relationship, both entities can collaborate to improve the process even further.
TrenStar availability schedule	A relationship would have to be established and a change management plan would have to be put into place. TrenStar runs as an individual company and might not have the time to collaborate.	A collaborative relationship would result in further improvements in the future.	Once the availability schedule has been set up and standardized, the tow motor flat beds utilization can improve.
Assign responsibility	In the short-term, the entities would have to get used to the specific responsibilities and would have to be held accountable.	In the long term, it can be investigated if the assigned responsibilities worked and if changes should occur.	By assigning responsibility to specific entities within the supply chain the process can be standardized, and more improvement opportunities can be identified.

Table 14: Potential impact of improvement opportunities: Visual management

Improvement opportunity	**Short-term impact**	**Long-term impact**	**Benefits**
Demarcate trolley areas	The trolley areas would encourage employees to use the dedicated waste areas.	Marking the waste areas can be permanent which would hinder facility changes. It would also be counter-productive if the waste generation point moves.	Employees would know where to stack the waste materials.
Mark trolleys	Markings on the coloured trolleys would aid new employees in the waste process. It would also remind all employees to separate waste.	The paint would be permanent on the floor but can easily be repainted or covered.	Visual management has been proved to improve process efficiency.
Illustrative process flows	Employees would easily understand the new process.	If the process changes and people are used to the illustrative explanations of the old process it would be hard to change the habits.	Anyone can understand the process.

Table 15: Potential impact of improvement opportunities: Composite.

Improvement opportunity	**Short term impact**	**Long term impact**	**Benefits**
Housekeeping employees	New employees would have to learn the process. All the other employees would have to accept a new process set into place. Change management would be important.	By distinguishing the waste process from the picking process, more improvement opportunities will present themselves in both processes respectively.	Pickers and material handlers would not have to spend time on the waste materials which would mean the picking speed can increase.

Each of these options run it's own risk. In the next section, the impact of the solution is compared to the risk.

6.2.2 Risk-impact analysis

Each of the possible solutions was rated according to the risk as well as according to the impact the solution would have. Figure 27 illustrates the results.

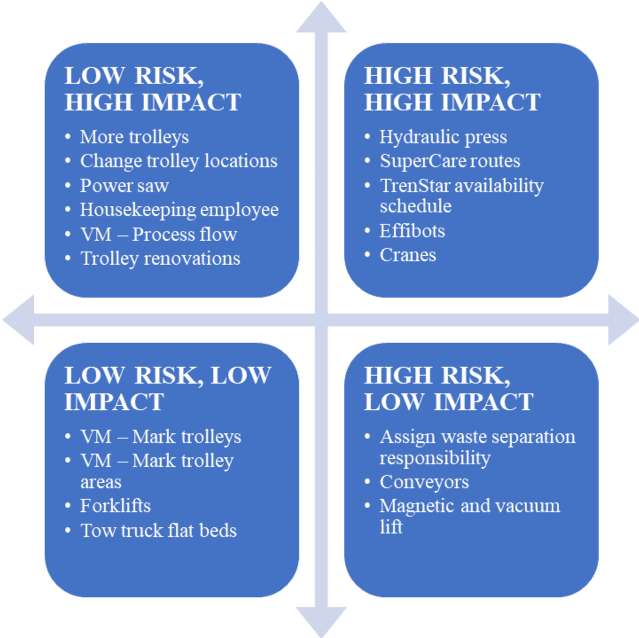


Figure 27: Impact-risk matrix

Low risk, low impact: The items under this classification would not be risky to implement and can thus be changed if the solution does not work. The improvements would have an impact on some aspects of the process, but not all aspects. Forklifts and tow motors are already in use and the VM is easy to implement. If the forklifts and tow motors currently used by DHL are utilized, no extra risk will be involved.

High risk, low impact: The items in this classification would be risky to implement, but the impact would not be big enough to justify the risk. The magnetic or vacuum lifters would be a luxury and were discarded from the solutions due to facility constraints. Installation of these lifting material handling equipment would also pose a risk to the environment around the working area. Assigning the waste separation responsibility would be risky to rely on and the impact low as the scrap yard has its own waste classification system. A conveyor system in the P2L areas poses a high risk as all the carton flow racks would have to be renovated and a smooth waste material flow is not guaranteed. The impact of a conveyor is also quite low as the materials are only moved to the end of the P2L area and not necessarily to a central waste area.

Low risk, high impact: The options in this section should definitely be implemented. The risk is low which means that alternatives can easily be considered if it does not work. The impact would be very high as each step addresses a need of the waste supply chain process. The only risk more trolleys pose is space occupation. The impact would be great as the waste materials would not accumulate on the floor. Changing the trolley locations and renovating the trolleys have a very low risk within the process since the equipment is already on-site and no new process is needed. The impact would be high with regards to parts ending up at the scrapyard. Power saws and housekeeping employees have a low risk to the process with a large impact on the waste handling times. There are risks involved such as the power saw has safety hazards (e.g. cutting off limbs) and new employees should adjust to the process, but these risks can easily be mitigated.

High risk, high impact: These options would be very risky to implement as they would be permanent. The hydraulic press would have a very high impact, but a power saw is a better alternative. Cranes are permanent and would hinder expansion plans of the facility. The supplier relationship solutions are risky because Ford must be the middle link. The integration would have to be very thorough.

In the next section, a cost-benefit analysis was conducted to determine the viability of each recommendation with regards to the costs of implementation and upkeep.

6.2.3 Cost-benefit analysis

A cost benefit analysis was conducted to establish the viability of each improvement opportunity. If the benefit of the recommendation does not exceed the cost, the solution would be scrapped. If the benefit exceeds the cost, the recommendation would be considered.

In Table 16 the cost of each recommendation was calculated before being compared to the benefits in Tables 10 - 15.

The following abbreviations where used in the tables:

- MF - Material flow
- SR - Supplier relationships
- VM - Visual management

Table 16: Cost analysis of recommended solutions

Improvement opportunity	**Cost objects**	**Cost**
More trolleys	Trolleys (7 as determined in section 5.1.1)	R 15 000 x 7 **TOTAL**: R 105 000
Change trolley locations	No purchases	No cost
Trolley renovations	Renovations through external supplier	R 30 000 **TOTAL**: R 30 000
MF Transportation - EffiBots	EffiBots (5 EffiBots to replace the 5 SuperCare tow motor drivers and utilize the drivers in a different section of the facility)	R 350 000 x 5 **TOTAL**: R 1 750 000
MF Transportation - Conveyor	Conveyor including renovations to P2L carton flow racks (3 areas)	R 3 000 x 3 **TOTAL**: R 9 000
MF Transportation - Flat bed tow motors	Tow motor monthly hire (To accommodate the 5 SuperCare tow motors) Drivers	R 9 700 x 5 R 96 000 per annum x 5 **TOTAL**: R 528 500

MF Transportation - Crane system	Crane (4 for each Trim (1, 2, 3, and 4)), including installation and certificates	R 62 000 x 4 **TOTAL**: R 248 000
MF Transportation/ Operations - Forklifts	Forklifts monthly hire (To accommodate the 5 SuperCare tow motors) Drivers	R 9000 x 5 R 96 000 per annum x 5 **TOTAL**: R 565 000
MF Operations - Power saw	Power saws (6 to be utilised at the six stations where the SuperCare employees are dedicated to box collapsing)	R 1 500 x6 **TOTAL**: R 9 000
MF Operations - Hydraulic press	Hydraulic press including installation	R 100 000 - R120 000 **TOTAL**: R 100 000- R120 000
SR - SuperCare routes	-	No cost
SR - TrenStar availability schedule	-	No cost
SR - Assign responsibility	-	No cost
VM - Demarcated trolley areas	Marking paint	No cost (Facility markings are painted weekly)
VM - Mark trolleys	Name boards (40 trolleys, would increase if new trolleys are purchased) Tie wraps	R 250 x 40 R 2 x 160 **TOTAL**: R 10 320
VM - Illustrative process flows	-	No cost
Housekeeping employees	Employees (To accommodate the 5 SuperCare tow motors)	R 60 000 x 5 **TOTAL**: R 300 000 per annum

Table 17 is a summary of the costs of each solution along with the benefits each solution would provide.

Table 17: Cost-benefit analysis of recommended solutions

Improvement opportunity	**Cost**	**Benefit**
More trolleys	R105 000	More trolleys would save time in handling the waste materials. In some cases, the materials are next to an overfull trolley which results in the SuperCare tow motor having to wait for the waste materials to be loaded. This wastes time.
Change trolley locations	No cost	The waste travel time would be decreased.

Trolley renovations	R30 000	Parts valued at R800 000 have been found at the scrapyard in 6 months. The trolley renovations would be paid back by saving on the parts not sent to the scrap yard.
MF Transportation - EffiBots	R 1 750 000	A SuperCare tow motor employee salary results in R96 000 per annum. The return on investment would be within 18 years. One EffiBot would be paid off within 3.75 years.
MF Transportation - Conveyor	R 9 000	The waste travel time would be decreased and the recyclable waste as well as the TrenStar bins would accumulate at one point to ease the collapsing process.
MF Transportation - Flat bed tow motors	R 528 500	No additional cost or time benefit involved.
MF Transportation - Crane system	R 248 000	The crane system would be able to replace the linefeeders. These linefeeders can be utilized in different areas of the facility. This results in a cut back of R 540 000 per annum and a return on investment in less than 1 year.
MF Transportation/ Operations - Forklifts	R 565 000	No additional cost or time benefit involved.
MF Operations - Power saw	R 9 000	The power saws would decrease the cardboard collapsing time which would free resources to collapse and stack TrenStar bins.
MF Operations - Hydraulic press	R 100 000 - R 120 000	The waste collapsing process would be shortened which would decrease the manpower needed to collapse the boxes. 6 trolleys have SuperCare employees collapsing boxes and sorting waste. 1 employee would be able to operate the hydraulic press. Cutbacks would be R 300 000 per annum with a return on investment within less than 1 year.
SR - SuperCare routes	No cost	Routing processes would utilize the tow motors and in turn decrease unnecessary maintenance costs.
SR - TrenStar availability schedule	No cost	A hiring fee is paid for each TrenStar bin for the duration the bin is on the Ford facility. By decreasing the time spent on the facility, Ford would save a lot of money. (Hiring fee falls outside of the scope of the project).

SR - Assign responsibility	No cost	Double material handling would be decreased which frees resource time. The waste separation section can be cut from the process which would mean fewer tow motors are needed. One driver moves the trolleys from the waste separation area to the scrapyard. This would result in a cut back of R 96 000 per annum.
VM - Demarcated trolley areas	No cost	No cost benefit but the material flow would be expedited.
VM - Mark trolleys	R 10 320	On the job training through VM for new employees would also decrease the R 800 000 loss of scrap parts that end up at the scrapyard.
VM - Illustrative process flows	No cost	On the job training through VM for new employees would also decrease the R 800 000 loss of scrap parts that end up at the scrapyard.
Housekeeping employees	R 300 000 per annum	Other resources would be freed to be utilized by various other tasks.

The results of the comparative analysis are discussed in section 6.3.

6.3 Recommendations

After comparing the possible solutions in the previous section, the recommended solutions have been identified. The recommended solutions were discussed with DHL managers to determine the optimal solutions for the facility. The recommended solutions are split into three categories. The discard category consists of all the non-viable options. The ICA (interim corrective actions) category is the short-term solutions, and lastly, the permanent corrective actions (PCA) category consists of all the long-term permanent solutions.

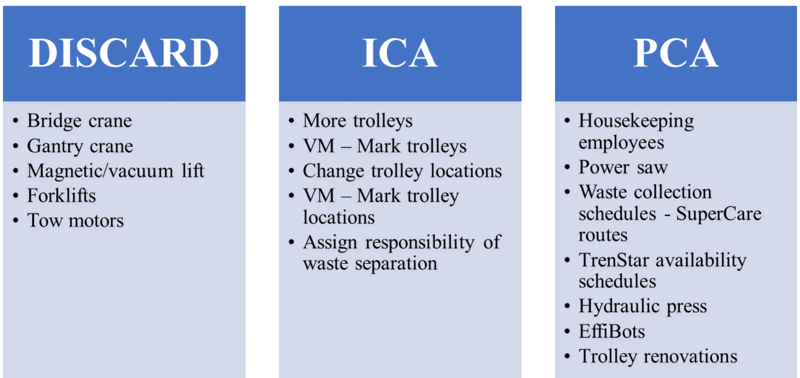


Figure 28: Recommended actions

Discard: The improvement opportunities were discarded as all three alternatives would be a permanent change in the facility. Ford SA will be expanding soon and a permanent change that does not directly affect the assembly process would not be viable in the future. The cranes were rejected due to the permanent fixtures and installation required. The magnetic lift and vacuum lift were rejected and discarded due to the facility constraints. Adding more tow motors and forklifts was discarded as this would add more traffic to the current traffic in the facility.

ICA: The ICA improvement opportunities can be implemented with the current facility layout without requiring a lot of resources. The only permanent improvement would be the demarcation of the waste trolley environments. DHL approves each of the solutions in the ICA category. The only solution in this category that requires time is the procurement of more trolleys and trolley signs.

PCA: The PCA improvement opportunities would require thorough planning as well as multiple resources. These permanent solutions would improve the waste supply chain so that the picking speed could increase and in the end, the unit assembly speed could increase. DHL approves of each of the solutions suggested in the PCA category. Some of the solutions should be investigated a bit more before being considered as an option to implement, e.g. EffiBot procurement.

These solutions will address all the identified problems in both the recyclable waste supply chain process, as well as the TrenStar returnable supply chain process.

7 Validation and verification

The project identified a need to improve the flow of the packaging waste materials through the facility as well as to ensure that the waste is not on the floor for extended periods of time. The aim of this project was to optimize the flow of the packaging waste materials through the facility to save resources and increase space. The flow increase is achieved by implementing waste collection rotation schedules as well as employing housekeeping employees. By defining who the primary waste sorting link is in the supply chain will also improve the flow as the excessive handling of materials will be minimised. Employing a dedicated housekeeping employee that would also use a power saw to collapse cardboard boxes would improve the space utilization of waste materials. The employee would also be responsible for checking for parts missed during the picking process inside of the packaging materials to decrease the number of parts ending up at the scrapyard.

The recommended improvements are based on the quantity of waste in each section of the facility. The quantification model used to determine the amount of waste in each section was based on the demand of each part over a 50-day period. This was to incorporate the reality of broken or misplaced parts. A sensitivity analysis was done to determine if the sections with the most waste would change as a result of change in demand. The assembly line is running at a rate of 36 units per hour moving towards 39 units per hour. To test the sensitivity to the demand, the model was run according to 36-, 39-, 42-, 45- and 48-units per hour. The results (illustrated in figure 29 and 30) show a linear increase in waste, but the facility sections with the most waste remain the same. This is because the parts used in each vehicle stays consistent. The demand is dependent on the units and not on the parts that the unit consists of. Thus, the same amount of packaging waste generated per vehicle stays consistent.

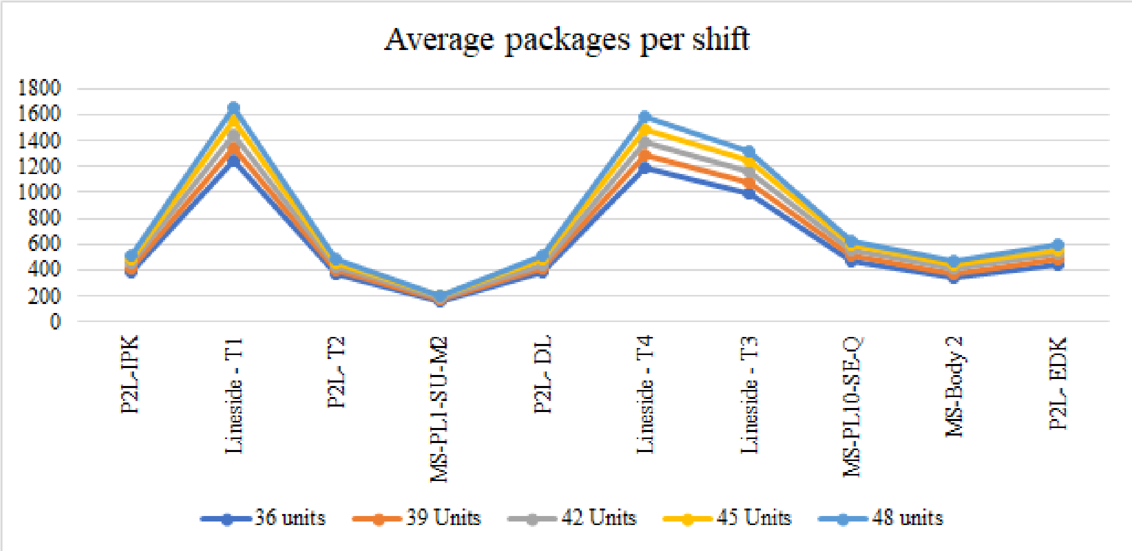


Figure 29: Volume waste generated per shift over 5 demand rates

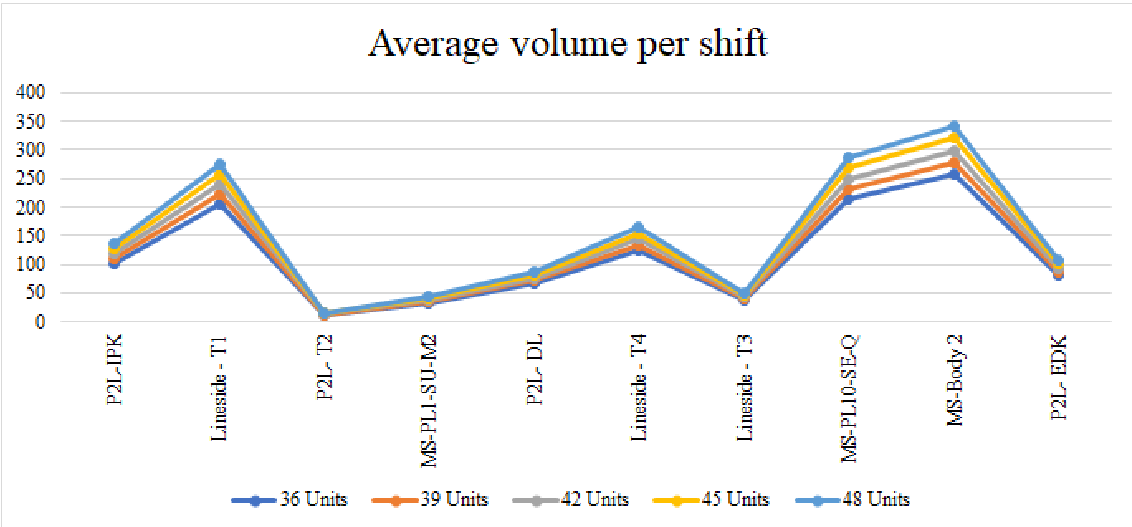


Figure 30: Average waste generated per shift over 5 demand rates

The quantification model was designed with the assumption that the average demand for the Ford Ranger compared to the Ford Everest would remain the same. This assumption was made due to the demand history of the two vehicle types. Even though there is a possibility for the demand to change, each vehicle still has the same basic components which would still generate the same amount of waste in each section.

As discussed in section 6.3, DHL managers are interested in ICA and PCA solutions. From these recommended solutions a conclusion was drawn as to which solutions would be optimal for the facility in its current state. This conclusion is drawn in the next section.

8 Conclusion

To conclude, DHL has identified improvement opportunities in the Ford Motor Company SA automotive assembly line waste supply chain. The waste supply chain is split into two parts, namely the recyclable waste process and the TrenStar bin return process. Both processes pose delay problems, thus the flow of the waste was analysed.

Both processes were individually mapped using process flow charting and analysed via the 5W1H methodology. Problematic process steps, along with the root causes, were identified and investigated.

There were five problematic process steps in the recyclable waste supply chain. They are:

- Waste is delayed at the workstations.
- Boxes should be flattened before being disposed of.
- Waste is delayed at trolley locations.
- Waste is not separated into the specific waste bins.
- Waste is transported manually to trolleys.

In the TrenStar waste supply chain, three problematic process steps were identified as:

- Empty bins are delayed at the workstations.
- Bins are not collapsed after being emptied.
- There are delays in the bins returnable leg.

Each of the problem areas and root causes were considered and solutions were formulated.

Industrial engineering techniques were used to identify the problems as well as possible solutions. Other techniques were used to determine the optimal solution. Four main engineering areas were considered with regards to solving the process problems. The first engineering area considered was a quantification model to quantify the waste generation. The second was the material flow. The facility layout and material handling both fall under that material flow analysis. The quantification model has proved to be useful with regards to analysing possible facility layout changes as well as identifying which material handling equipment to use. Supplier relationships are important building blocks in supply chain integration which resulted in supply chain integration investigations. Waste management which involves multiple entities relies on supply chain integration. The last engineering area considered was visual management. Visual management has multiple tools to aid continuous improvement and standardization.

To solve the problems, multiple solutions were investigated and an integration of the possible solutions was necessary to address the posed improvement opportunities. ICA and PCA are both required for long-term and short-term solutions.

To correct the problems identified in the waste supply chain, the following solutions are recommended (in order of priority, established during section 6):

1. Assign the waste separation responsibility to the DHL employees handling the waste with the exception of the SuperCare employees working at designated trolleys to separate waste and collapse cardboard boxes. Employ the SuperCare employees to collapse the TrenStar bins while they are waiting for the cardboard boxes as well as to collect empty cardboard boxes in the proximity.

2. Change the trolley locations to the areas where the most waste is generated (determined in section 5.1.1).

3. Demarcate the trolley areas.
4. Renovate the current trolleys to force the separation of waste materials.
5. Mark the trolleys to visually manage the waste separation into the correct trolleys.
6. Collaborate with TrenStar to determine an availability schedule for receiving empty TrenStar bins.
7. Collaborate with SuperCare to create a routing model to establish the routes and schedules a SuperCare employee should follow to empty the trolleys and bins.
8. Acquire power saws for the facility areas where the big cardboard boxes are dealt with.
9. Renovate the P2L carton flow racks to include conveyors on the bottom level. Focus on the instrument panel area as this section is in a restricted zone so no unauthorized personnel can collect the waste. The conveyors should move outside of the restricted area.
10. Pilot an EffiBot to collect waste trolleys and move the trolley to the scrap yard.

The aim of this project was to optimize the flow of the packaging waste materials through the facility to save resources and increase space. The integration of these solutions would address each of the problematic steps and areas identified by improving the flow of the waste packaging materials in the Ford Automotive Company South Africa waste supply chain. By implementing the above-mentioned solutions, the flow would be expedited and the resources utilized would be decreased.

References

[1] Agrahari, R., Dangle, P., and Chandratre, K. (2015). Implementation of 5s methodology in the small scale industry: A case study. *International Journal of Scientific & Technology Research*, 4(04):180–187.

[2] Ahram, T. and Jang, R. (2014). Advances in physical ergonomics and human factors: Part i. AHFE Conference.

[3] Barbosa, G., Carvalho, J., et al. (2014). A proper framework for design of aircraft production system based on lean manufacturing principles focusing to automated processes. *The International Journal of Advanced Manufacturing Technology*, 72(9-12):1257–1273.

[4] Becker, J. E. (2001). Implementing 5s: To promote safety & housekeeping. *Professional Safety*, 46(8):29.

[5] Bergmiller G.G., P. M., editor (2009). *Parallel models for lean and Green operations.* Proceedings of the 2009 Industrial Engineering Research Conference, Institute of Industrial Engineers, Miami, Florida.

[6] Blackhurst, J., Dunn, K. S., and Craighead, C. W. (2011). An empirically derived framework of global supply resiliency. *Journal of Business Logistics*, 32(4):374–391.

[7] Carter, C. R., Rogers, D. S., and Choi, T. Y. (2015). Toward the theory of the supply chain. *Journal of Supply Chain Management*, 51(2):89–97.

[8] Chu, H.-K., Egbelu, P., and Wu, C.-T. (1995). Advisor: A computer-aided material handling equipment selection system. *International Journal of Production Research*, 33(12):3311–3329.

[9] Cole J.J., Langley, J. J. N. R. and B.J., G. (2016). *Supply Chain Management, A logistics perspective.* Cengage Learning, 10 edition.

[10] Flynn, B. B., Huo, B., and Zhao, X. (2010). The impact of supply chain integration on performance: A contingency and configuration approach. *Journal of Operations Management*, 28(1):58–71.

[11] Glouche, Y. and Couderc, P. (2013). A smart waste management with self-describing objects. In *The Second International Conference on Smart Systems, Devices and Technologies (SMART'13).*

[12] Hassan, M. D. (2010). A framework for selection of material handling equipment in manufacturing and logistics facilities. *Journal of Manufacturing Technology Management*, 21(2):246–268.

[13] Hassan, S. H., Aziz, H. A., Johari, I., and Adlan, M. N. (2016). Quantification of brick waste generated in housing construction sites via site sampling: development of a linear regression mode. *Journal of Scientific Research and Development 3 (2): 39-44.*

[14] Hogland, W. and Stenis, J. (2000). Assessment and system analysis of industrial waste management. *Waste Management*, 20(7):537 – 543.

[15] Juran J. M, G. A. (1998). *Juran's Quality Handbook.* New York: McGraw Hill.

[16] Kay, M. G. (2012). Material handling equipment. *Fitts Dept. of Industrial and Systems Engineering North Carolina State University*, 65.

[17] Kern, A. P., Dias, M. F., Kulakowski, M. P., and Gomes, L. P. (2015). Waste generated in high-rise buildings construction: A quantification model based on statistical multiple regression. *Waste Management*, 39:35–44.

[18] Kurdve, M., Shahbazi, S., Wendin, M., Bengtsson, C., and Wiktorsson, M. (2015). Waste flow mapping to improve sustainability of waste management: a case study approach. *Journal of Cleaner Production*, 98:304 – 315.

[19] Melton, T. (2005). The benefits of lean manufacturing: what lean thinking has to offer the process industries. *Chemical Engineering Research and Design*, 83(6):662–673.

[20] Mĺkva, M., Prajová, V., Yakimovich, B., Korshunov, A., and Tyurin, I. (2016). Standardization–one of the tools of continuous improvement. *Procedia Engineering*, 149:329–332.

[21] Osada, T. (1991). The 5s's: Five keys to a total quality environment. Tokoyo: Asian Productivity Organisation.

[22] Ram, V. and Kalidindi, S. N. (2017). Estimation of construction and demolition waste using waste generation rates in chennai, india. *Waste Management & Research*, 35(6):610–617.

[23] Scholten, K. and Schilder, S. (2015). The role of collaboration in supply chain resilience. *Supply Chain Management: An International Journal*, 20(4):471–484.

[24] Schroeder (2011). *Introduction to Operations Management*. McGraw-Hill/Irwin, 5th edition.

[25] Seadon, J. K. (2010). Sustainable waste management systems. *Journal of Cleaner Production*, 18(16):1639 – 1651.

[26] Shehu, S. et al. (2017). Separation of plastic waste from mixed waste: Existing and emerging sorting technologies performance and possibilities of increased recycling rate with finland as case study.

[27] Song, Q., Li, J., and Zeng, X. (2015). Minimizing the increasing solid waste through zero waste strategy. *Journal of Cleaner Production*, 104:199–210.

[28] Stevens, G. C. and Johnson, M. (2016). Integrating the supply chain ... 25 years on. *International Journal of Physical Distribution & Logistics Management*, 46(1):19–42.

[29] Tezel, B., Koskela, L., Tzortzopoulos, P., et al. (2009). The functions of visual management.

[30] Tompkins J.A., White J.A., B. Y. and J.M.A., T. (2010). *Facilities Planning*. John Wiley & Sons, Inc,, fourth edition.

[31] Ultsch, A. (2002). Proof of pareto's 80/20 law and precise limits for abc-analysis. *Data Bionics Research Group University of Marburg/Lahn, Germany*, pages 1–11.

[32] Wu, Z., Yu, A. T., Shen, L., and Liu, G. (2014). Quantifying construction and demolition waste: An analytical review. *Waste Management*, 34(9):1683 – 1692.

Appendices

A Gantt chart

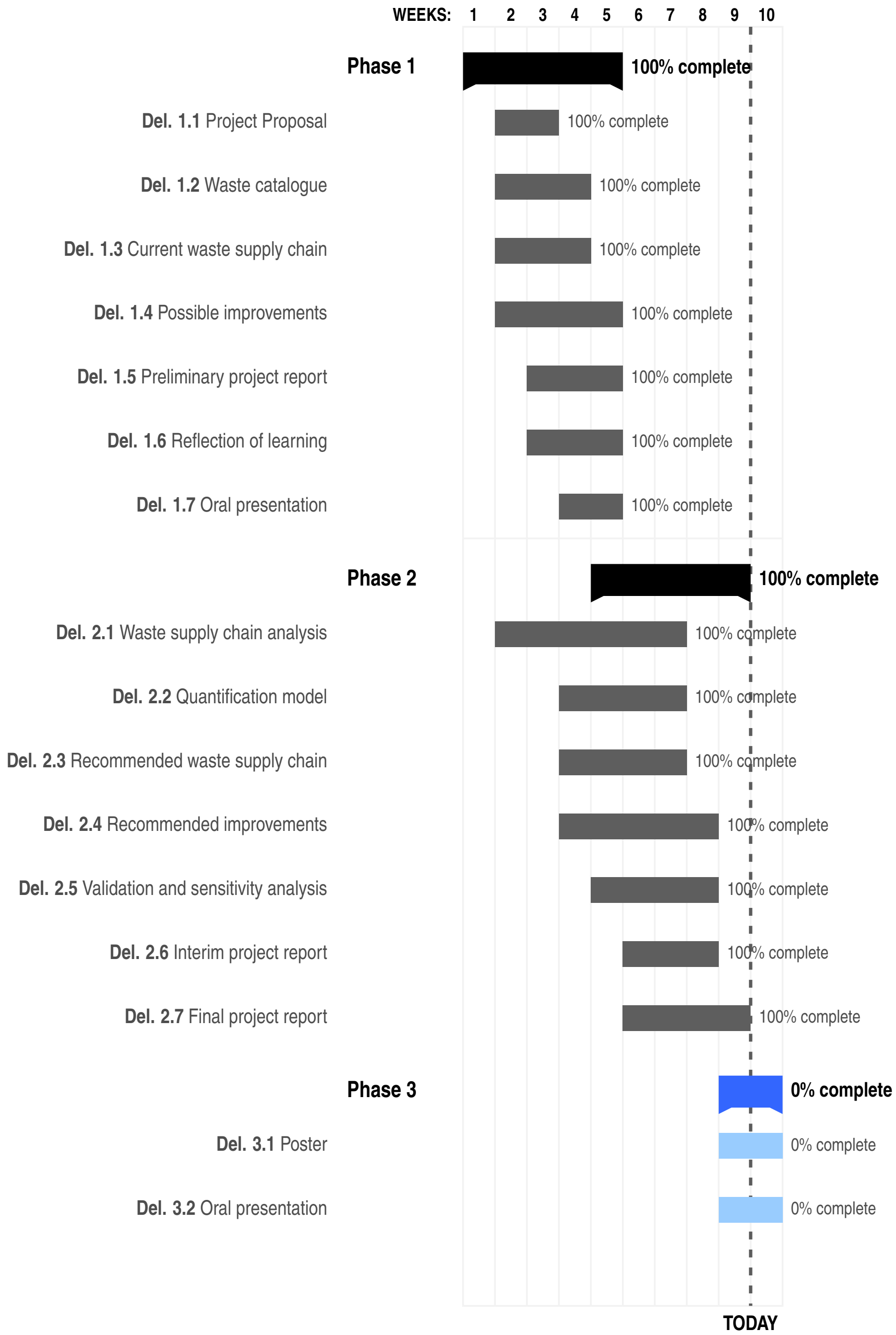


Figure 31: Gantt chart

B Waste catalogue

WASTE MATERIALS

Large cardboard boxes

Large corrugated cardboard boxes. These boxes are too heavy to carry manually.

Small cardboard boxes

Smaller cardboard boxes. These boxes contain very few items, thus generating a lot of waste. The boxes are taken to the trolley manually.

Plastic TrenStar bins

Returnable plastic TrenStar bins. The lids can collapse and the bins can be stacked inside each other.

TrenStar stillages

Large steel framed TrenStar stillages . The stillages can be collapsed and stacked on each other once empty.

Plastic

All the materials in the cardboard boxes are wrapped in plastic.

Recyclable waste heap

The waste is collected in various areas as there are not enough trolleys.

Waste overflow

The waste is collected in various areas as there are not enough trolleys.

TrenStar bin waste heap

The stillages are not returned to TrenStar immediately.

Cardboard waste

A yellow trolley is used to collect cardboard waste.

Plastic waste

A white trolley is used for plastic waste.

General waste

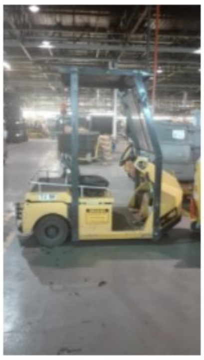
A green trolley is used for general waste.

Hazardous waste

A blue trolley is used for hazardous waste.

Forklift

Forklifts are used to transfer the larger boxes to the trolleys or directly to the scrapyard. This is because the boxes are too big or heavy for a person to carry.



Trolley tow motor

Tow motors move the trolleys around the facility.

Material handling tow motor

Tow motors with flatbeds collect pallets and waste (TrenStar bins) from various locations.

Carton roll racks

Full boxes are placed on the top racks and empty boxes are placed on the lower racks.

C Industry mentorship form

Department of Industrial & Systems Engineering
University of Pretoria

Final Year Project Mentorship Form
2018

Introduction

An industry mentor is the key contact person within a company for a final year project student. The mentor should be the person that could provide the best guidance on the project to the student and is most likely to gain from the success of the project.

The project mentor has the following important responsibilities:

1. To select a suitable student/candidate to conduct the project.
2. To confirm his/her role as project mentor, duly authorised by the company by signing this **Project Mentor Form**. Multiple mentors can be appointed, but is not advised.
3. To ensure that the **Project Definition** adequately describes the project.
4. To review and approve the **Project Proposal**, ensuring that it clearly defines the problem to be investigated by the student and that the project aim, scope, deliverables and approach is acceptable.
5. To review and approve all subsequent project reports, particularly the **Final Project Report** at the end of the second semester, thereby ensuring that information is accurate and the solution addresses the problems and/or design requirements of the defined project.
6. Ensure that sensitive confidential information or intellectual property of the company is not disclosed in the document and/or that the necessary arrangements are made with the Department regarding the handling of the reports.

Project Mentor Details

Company:	DHL SUPPLY CHAIN
Project Description:	The primary objective of the project is to improve the flow of the waste materials through the facility. This includes the staging, collection and movement of the waste. Each product component is received in cardboard boxes or returnable stillages from the supplier. Once these packages are emptied they occupy space and interrupt the flow of the process. A hiring fee is paid per returnable stillage thus, empty stillages on the facility is a financial loss to the company. The secondary objective of the project is to optimise the cardboard waste collection as well as ensure the returnable stillages are returned to the correct supplier as soon as it is emptied. The last objective of the project is to investigate alternative disposal methods and establish the optimum method. Different waste collection companies will be considered as well as alternative disposal solutions of the waste.
Student Name:	Tanya Venter

Student number:	U15007482
Student Signature:	
Mentor Name:	Janine Pieterse
Designation:	Senior Industrial Engineer
E-mail:	Janine.pieterse@dhl.com
Tel No:	
Cell No:	082 868 0019
Fax No:	
Mentor Signature:	