Methodology Development for Cycle Packaging

Creating a method and corresponding software for a logistical problem within VDL ETG Almelo

By Laurens J.M. Post
Student number: s1752979

Supervised by
Msc. M. Koot
prof.dr.ir. E.W. Hans
Mr. N. Machiels

UNIVERSITY OF TWENTE.

Table of Contents

Preface

The report in front is the final version of my bachelor thesis on creating a method and corresponding software for a logistical problem. The hosting company, VDL ETG Almelo allowed me to do my research throughout from 2019 to 2021.

At the start of my research, I was given excellent guidance by Mr. N Machiels, allowing me to roll up my sleeves and get to work fixing the logistical process described in this thesis. All those at VDL showed nothing but sincere interest and were willing to invest time and resources to help me. I want to thank everyone involved who helped me during this research.

I would like to take the opportunity to thank my supervisors N. Machiels and M. Koot specifically. Mr. N Machiels for allowing me to operate independently, for your valuable feedback and your dedication to let me see the process improvement through from start to finish at VDL.

MScs. M. Koot for being an indispensable supervisor for the duration of this thesis, for remaining supportive and providing useful feedback throughout the notably extended period of time this bachelor thesis took to complete. Your guidance alongside prof.dr.ir. E.W. Hans made the completion of this report reality.

Finally, I am immensely grateful to my friends and family, without whom none of this would have been possible. My parents Jan and Alie for their undying support. Jasper, Patrick, Wouter and many more for helping me finish this report. I hope this final report was worth the wait.

With kind regards,

Laurens Post

30-06-2021

Executive Summary

The troublesome logistics of purchased large products at VDL ETG Almelo Parts Manufacturing have led to frequent disorganization and notable cost. This disorganization is caused by a lack of methodology around custom made packaging that VDL reuses to deliver and receive complex parts, this packaging will be referred to in this report as "cycle packaging".

The need for emergency shipments to deliver the cycle packaging to suppliers and time-consuming searches for packaging throughout VDL's Almelo location are clear indications of a fundamental core problem:

"*The present cycle packaging process is insufficiently organized to be traceable or reliable.*"

The objective was to understand the process as it was being performed (to be called "current process"), to identify the flaws, and use this information to create an improved process with stakeholders.

Creating improved processes is a well-documented field of research, this field soundly indicates the clearest path to creating process order is business process mapping (BPM). The industry 4.0 compliant version of the Value Stream Mapping method was chosen as ideal BPM for this situation. VSM was chosen because it is a proven method for MTO, because of the methods capacity for rapid systematic improvement, and specifically the 4.0 variant because it exceeds in the provision of traceability (a key variable in VDL's process improvement), as data is tracked meticulously.

The current process relied heavily on interpersonal communication and physics searching, The overview of the current process presented a set of problems:

- Data regarding the process was incomplete (packaging and product number not linked) or not being used (64% of data points are not used, 55% of data not digital).
- Responsibilities were not clearly assigned to stakeholders, inhibiting problem ownership.
- There was no communication about upcoming (urgent) packaging demands to logistics.
- Packaging is lost throughout the factory, requiring extensive searching to recover.

Through interviews, Kaizen Burst sessions, literature regarding modernizing production logistics, ERP system analysis and iterative process mapping the process was reinvented to arrive at an integrated & modernized future process.

Simplified, the new process involves a program that uses data from suppliers and purchasing employees to determine when packaging should ideally be sent. When that date arrives the program automatically informs the logistics department of packaging to be sent. In the event of a packaging shortage, purchasing is informed immediately, allowing them sufficient time to adequately address the problem.

The improved process hinges on connecting the purchasing and logistical departments of VDL ETG Almelo using newly added data points. These data points can be used alongside the existing database to predict and automate necessary communications, which reduces process complexity, and adds more traceability. The new method changes the logistical process from a reactive, to a proactive lean approach.

The new process shows notable performance increases (see table 1) essentially meaning that the information surrounding cycle packaging has gone from limited understanding to full understanding. The indicators clearly show reliability, traceability and process improvement. The improved process has led to a reduction of 0,5 FTE in manual labor by increased efficiency and increased autonomy. meaning the core problem is resolved.

The data points in Table 1 further imply a notable increase in process performance after full implementation.

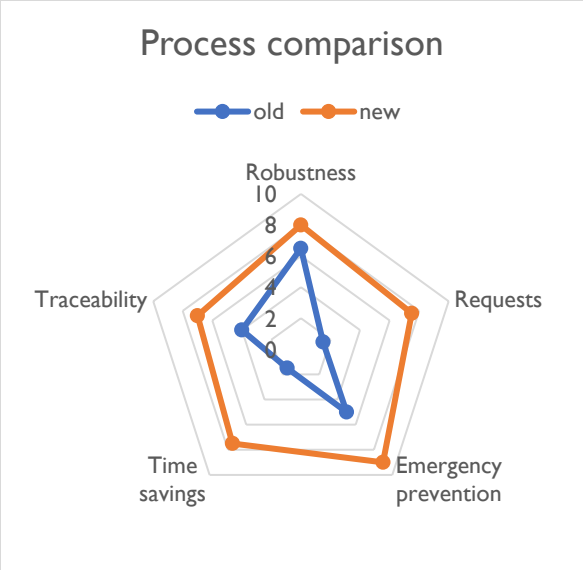


Figure 1 Process comparison

	"past" process	"new" process
Average mails/calls daily	1.70	1.17
Data usage	36	89
Digitization rate	45	95
Monthly emergency shipments	2	0
Average process breakdown duration in days	3.33	1.50

Table 1 Past and new process performance

1. Introduction

This chapter serves to create context and introduces the why and what of the problem tackled in this research. This chapter starts by introducing VDL and the Almelo branches' specific activities(1.1). Secondly it provides the stakeholders' perspective on the matter(1.2). Lastly, the present situation of the cycle packaging is briefly addressed(1.3).

1.1 About VDL

Van Der Leegte Enabling Technologies Group (VDL ETG) Almelo outlines/presents itself as a design & contract manufacturing partner. In more practical terms VDL Almelo occupies itself with developing and manufacturing high-tech systems/components for its customers. To illustrate what part VDL ETG Almelo plays in VDL itself, a brief description of VDL

1.1.1 VDL group

VDL is a large group of high-tech organizations that operates in various industries from car manufacturing to solar panels to constructing components for ASML's chip machines. VDL operates in the manufacturing and high-tech design industry exclusively. Though operations vary notably, the size of VDL means the conclusions of this research also have applications outside of VDL ETG Almelo.

1.1.2 VDL ETG Almelo

VDL ETG designs and manufactures high tech equipment. The primary example being: building the casing and some of the components around ASML's chip making machines. ASML creates the core tech used in the chip making machines to be able to produce 7 nanometer chip threads. Many parts in this chip making machine are constructed and/or assembled at VDL ETG. Almelo plays a part in this, along with ETG Eindhoven, the only other Dutch branch of VDL ETG.

Which part exactly is created by whom is a report of its own, but the casing, in addition to complex electronics and motors are made by VDL ETG Almelo. Another example of what VDL ETG Almelo produces is a mechanical arm for Philips' healthcare departments, allowing for a whole range of movements yet also leaving room for Philips' hardware inside of a compact yet durable shell.

VDL ETG Almelo, a 600 man company, orders hundreds of products at varying frequencies. VDL purchases and uses what is referred to as "Cycle packaging" to safely transport expensive products. This packaging is used in two processes:

- In product transport from suppliers to VDL, providing safe and a potentially cleanroom secured method of transportation (non-VDL made products)
- In transport to and from outsourced production steps, providing the same benefits

When discussing with head of logistics N. Machiels, he illustrated that taking on both of these logistical issues would be too expansive of a task for a bachelor thesis. As such, for a logistical assignment, taking one of these applications on and solving its problems would fit best. The second stated process is currently being optimized by VDL internally. This process is in development and is thus not the aim of this project. This project focusses on the first stated purpose, to ensure well-orchestrated transport from suppliers to VDL.

1.1.3 Cycle Packaging

Cycle packaging is used typically for each product that needs packaging too expensive for single time use, which in recent days is most of VDL's packaging. Cycle packaging is therefore the product that has to be available for almost every transportation outside of VDL. This packaging may be cleanroom iso

class 7 approved packaging, or it may simply be a large bin with soft materials on the inside to prevent damages. Below are three pictures to illustrate what packaging can look like.

Figure 2 Purchasing cycle packaging

Figure 3 Cleanroom product with packaging

Figure 4 Various pieces of in-house cycle packaging

1.2 Stakeholders' perspective

The primary stakeholder is my direct supervisor for this bachelor assignment Mr. N. Machiels. With VDL ETG Almelo set to grow notably in the coming period, the importance of introducing methodology into every aspect of day to day activities is essential in ensuring order and preventing unnecessary work. Mr. Machiels is working on ensuring in-house cycle packaging is traceable, effectively used, and quality controlled. The step to solve the problem for purchasing cycle packaging however proves difficult, as ERP system changes are required and the in-house cycle packaging solutions cannot be applied to the purchasing cycle packaging problem.

Further stakeholders are the purchasers and logistical employees, as an aspect their work may change depending on the outcome of this study. Though the full extent of the interests of further stakeholders is unknown at this point in time, as interviews must still be conducted to find the exact problems they encounter, The stakeholders and their interests are described in the table below:

Stakeholder name	Stakeholder goal	Stakeholder interests
Purchasing	Purchase products that enter VDL ETG Almelo for the first time (no outsourcing)	Increasing supplier satisfaction with our delivery of packaging. Preventing increase in workload for Purchasing employees.
Logistics department	Outsourcing matters and helping in packaging departure / arrival (searching)	Decreasing lead time and / or transport costs. Obtain clarity about what to do with packaging.
Supply chain department	Determine supply chain performance, monitor logistical processes, sign / modify contracts with suppliers	Increasing transparency in packaging, clarify how many of each packaging is currently still in circulation.
Materials Handling Expedition (Dutch = expeditie)	Physically move packaging from A to B, Quality control incoming and outgoing goods	Increasing clarity as to what to do with what packaging. Moving away from the blind "send it back" or follow email commands. Prevent having to search for or allocate space for packaging.
Suppliers	Supply VDL ETG Almelo with goods	Encounter fewer instances of being unable to deliver a product due to lack of packaging.

Table 2 Stakeholder interests

2. Problem identification

In order to most adequately address the assignment, the Managerial Problem Solving Method(MPSM) (Heerkens & van Winden, 2017)methodology is adopted, the first step of which is problem identification. The choice of MPSM is the first matter discussed in this chapter (2.1) after which a brief clarification is given as to the scope of this bachelor assignment (2.2). The "current" situation and the challenges the process faces are discussed in the section Current situation(2.3)

After stating the relevant problems, these problems are be linked, causal relations are found to ultimately arrive at the problem cluster (2.5). Following this step, a choice is made regarding which of the various found problems is the core problem (2.6).

Norm and reality is then established (2.7). Variables to reach said norm will be discussed directly after the norm section in non-numerical values (2.8), the numerical values i.e. indicators are introduced in sub-chapter 4.3.

2.1 Research methodology

The MPSM methodology allows for a robust and scientific approach despite the somewhat ambiguous task of developing a methodology for cycle packaging. This straightforward methodology involves 7 phases from start to finish to arrive at a sound resolution of any core problem. These phases are as follows:

1. The Problem identification
2. D3: Do, Discover, Decide
3. The problem analysis
4. The formulation of alternative solutions
5. The decision
6. The implementation
7. The evaluation

These phases were followed in chronological order during the execution of this research. These seven phases are in broad terms be represented in this report, with each chapter being a phase.

2.2 Research scope

The scope of this research is for all intents and purposes VDL ETG Almelo Parts Manufacturing wide. Due to the aforementioned time limitation of 10 weeks, enhancing this scope may not be realistic, depending on time required to assure successful development and theoretical implementation at the Almelo location.

The smallest realistic scale is a developed solution for the core problem with a limited implementation plan, the most ambitious scale is a developed solution, with a complete expansive implementation plan in addition to indications to multiple other branches of the ETG group as to the adaptation and implementation of this solution to their facility. A solution to Parts Manufacturing is a must, this solution should largely apply to ETG Almelo as a whole, with recommendation at the end of this paper for implementation to other branches of VDL ETG Almelo.

Adaptation of this solution to other locations entirely may belong to the realm of optimism, as other facilities are not "Copy Exact" versions of ETG Almelo. Select parts are however, meaning this solution may have use in other locations as well. See Figure 5 for what VDL ETG Almelo Parts Manufacturing means:

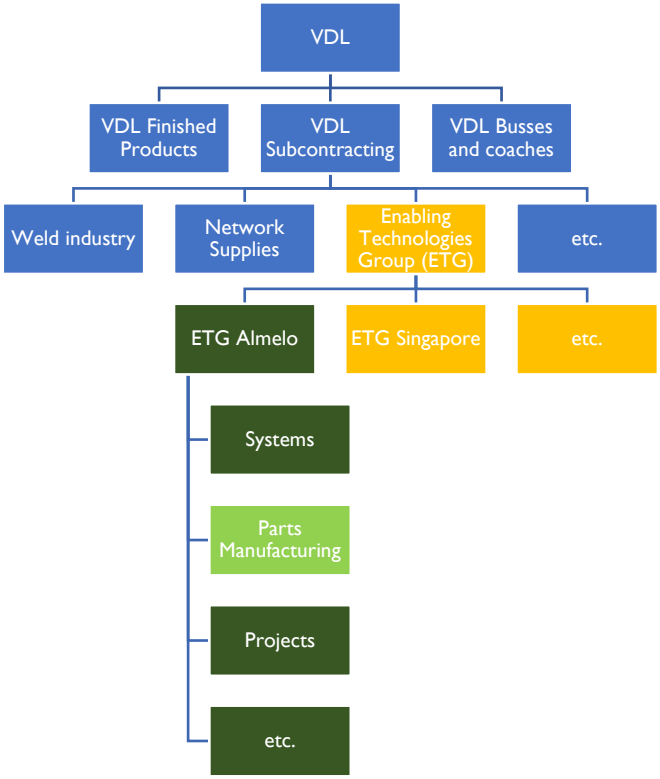


Figure 5 Organigram of VDL and scope indication (VDL, 2019)

2.3 Current situation

In the original "current" process, VDL manages cycle packages by a large amount of communication and manual labor. What this means is that email communication regarding purchasing cycle packaging is frequent and rather inefficient. Furthermore, mistakes occur causing last moment orders for trucks to be placed at a significant premium due to the urgency of the order, these shipments will be referred to as emergency shipments. N. Machiels estimates in the year 2019, on average twice a week an emergency shipment was needed to supply packaging.

In the current situation a major challenge is the IT ecosystem. Within VDL ETG Almelo the ERP system BaaN is used, this ERP system is at end of life, this means that in the current situation the choices of IT are limited.

The majority of purchasing cycle packaging (estimated at over 80%) is in ownership of VDL, and part is in ownership of the suppliers that provide the purchased parts. In the "current state" (state as originally observed) various employees around VDL ETG Almelo have fractional knowledge of what is being done or needs to be done, universal information regarding when what purchasing cycle packaging should be where is entirely absent.

In sub-chapter 2.3.1, the primary problems initially found when investigating the cycle packaging process are stated, this to provide some background on how the Problem cluster is created. The full list of relevant problems in the "current" cycle packaging process can be found in the appendix ii alongside any explanation necessary to clear up the details of each problem.

2.3.1 Problem identification

In order to properly identify the problems surrounding this packaging process, an interview was conducted with various parties. Mr. N. Machiels already had a firm understanding that the cycle packaging process had an elaborate cloud of problems, interviewing him alongside individuals from every stakeholder group defined in 1.2 allowed for preliminary understanding of challenges stakeholders were facing daily, though the connection between these problems was still to come. The most relevant issues mentioned by stakeholders are the following:

1. The process for purchasing cycle packaging is chaotic.
2. The process for purchasing cycle packaging is time consuming.
3. The process for purchasing cycle packaging is expensive.
4. There is no analysis regarding whether or not the purchasing demand is cyclical.
5. ERP system presently does not support any cycle packaging options.
6. Some suppliers lack a clear delivery method.
7. No uniform clarity towards suppliers what VDL wants.
8. Different departments all arrange transport differently.
9. A new order starts a new process of uncoordinated requests to arrange packaging.
10. There is no clarity of does what or oversees what in the purchasing cycle packaging process.

2.4 Problem cluster

The understanding of the individual problems led to an improved sight into how these problems interrelate. Deliberation with N. Machiels on the relation between the various problems in addition to mapping out the causes behind problems stated by stakeholders, the following problem cluster came to light:

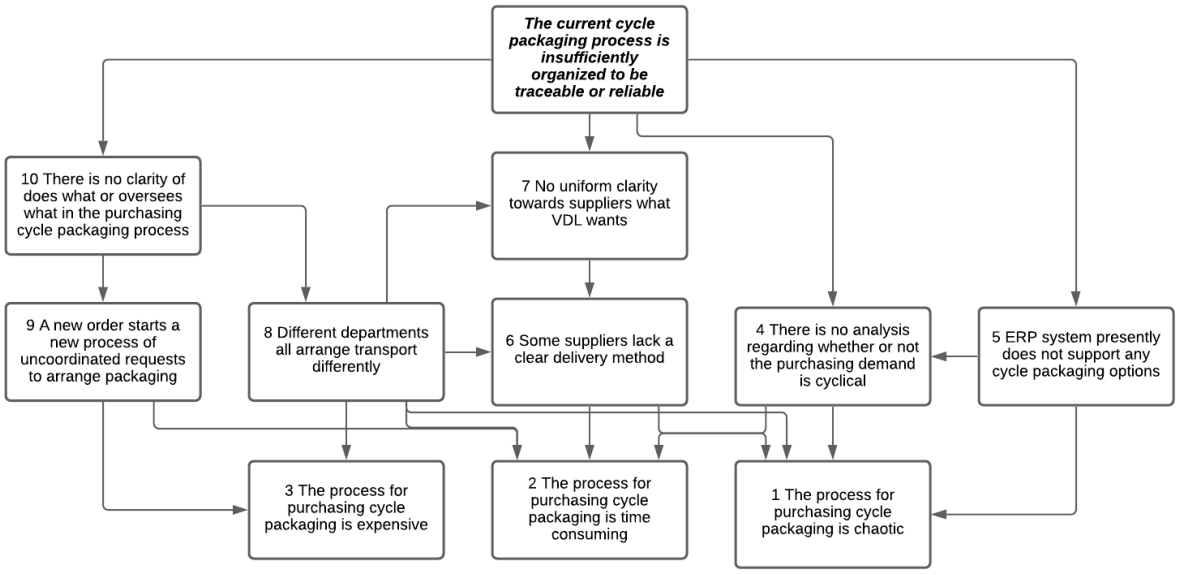


Figure 6 The problem cluster

2.5 Core problem

Considering VDL is occupied with solving a similar problem internally, One must conclude it is not due to an incorrect company culture that the cycle packaging problem is yet to be combatted. investigating the evident primary shortcoming of the current process leads us to the following core problem:

"The current cycle packaging process is insufficiently organized to be traceable or reliable"

Arriving at this conclusion came forth when a helicopter-view perspective showed that the purchasing cycle packaging process was showing general disorganization and lack of clear guidelines. When starting the search from the chaotic process for cycle packaging in place today, initially discovered issues like an ERP system not showing functionality seemed individual problems that when solved would lead to a solution of this problem. Solving these problems with a problem by problem approach however would lead to temporarily solving the issues at hand, but not tackling the underlying cause of these difficulties, each of these problems could not be the core problem I sought after as they all had a common cause: a lack of systematic approach towards effectively handling this process.

There are four primary problems that are caused directly by the absence of a systematic approach. Firstly the lack of responsibility, no clear appointment meaning no clarity who does what. Secondly the insufficient clarity from VDL to suppliers how they desire communication and requests for new packaging. Thirdly opportunities for automation are left unseized due to a lack of analysis. Lastly the ERP systems abilities to assist in this process are unutilized as modifications or upgrades to the ERP systems may be required to allow this to function.

The core problems has many aspects and is thus in some sense rather general, making the obtainment of a definite executable plan and solution a more numerous task. Considering the time frame of ten weeks, problems will have to be addressed efficiently. Measuring the core problem will have to be done primarily by means of checking the present level of traceability (near none) and reliability (possible through a managers estimate if data is lacking) and then attempting to improve on these 2 aspects, while of course managing best as possible to keep the process accessible and intuitive. More on measuring the results in 2.7 indicators.

Concluding, the absence of a methodology to approach purchasing cycle packaging is the core problem for it causes a range of problems, which ultimately results in a chaotic purchasing cycle packaging process.

2.6 Research goals

The primary objective of this assignment is the organizing of the purchasing cycle packaging process for VDL ETG (Almelo), and as a result, solving the core problem. Organizing is an umbrella term for various improvements such as minimizing communication required for a seamless process, minimizing risk factors in the process, minimizing work being required per purchase order and optimizing data gathering surrounding this issue. In sub-chapter 2.8 more details about improvement metrics.

2.6.1 Deliverables for VDL

The deliverables are the following:

- Methodology to streamline and standardize cycle packaging.

Methodology again being an umbrella term for whatever software and work instructions are part of the proper functioning of this methodology. Proper functioning in turn means a method that better maps the process (what is where till when), requires less human interaction using software and assures the

process runs smoothly. In section 5.4.2 more specific requirements regarding this deliverable are detailed

- Implementation plan on how to create the proposed solution and maintain it.

This plan should be as straightforward as possible, allowing for simple allocations of tasks to individuals which can then read work instructions to engage in the activities required for this process to run smoothly. Software implementation is a part of this implementation plan and will be the first aspect that needs to be addressed before workplace adaptation.

- Advice on scope of implementation within VDL ETG (local / global implementation)

This deliverable is VDL's desire for this thesis to look beyond the scope of just VDL ETG Almelo, giving VDL ETG an estimation of added value of the solution of this bachelor assignment to the other branches, as well as indication of work required to get this solution operational in the other branches as far as that is possible. This is addressed in sub-chapter 7.3 Recommendations.

2.6.2 Methodology solution requirements

Below are the two requirements placed upon the methodological solution, at special request from VDL ETG Almelo:

Fit

It is important that the proposed solution aligns with VDL, this means its culture, its present contracts with suppliers and customers, it's ERP system and the present workflow of employees that may end up having an increased or decreased workload depending on the solution.

ERP system takes center stage in this requirement, as integrating any potential solution into the ERP system is undeniable, and a large amount of the true functionality of the solution may be limited or enhanced by its ability to cooperate with software presently in place at VDL.

Futureproof

A last aspect is perhaps the most difficult to measure is the extent to which this proposed solution is futureproof. With this aspect the solutions ability to tackle change is mapped, which is another vital requirement for a system that is set to work in an environment as rapidly developing and changing as VDL ETG Almelo, these are the two main challenges addressed in this performance requirement:

- The solutions ability to handle new cycle packaging in an efficient manner
- The solutions ability to adapt to changing situations like new warehousing or workforce change

The ideal solution should entirely resolve the issues stated above regarding who does what in the cycle packaging process. This means the ideal solution should work not only to those instructed on this methodology, but rather as an intuitive process that is understood simply by seeing the other players in the chain execute their function, with when necessary well documented additions to which function within VDL has which responsibilities within this process.

2.7 Reality to norm

One obstacle that presented itself upon discussing what would be the ideal outcome of this thesis is the lack of a clear norm, this due to uncertainties in ERP system upgradeability and compatibility, and uncertainty about what exactly is reachable in terms of potentially drastic change in the purchasing cycle packaging process for VDL ETG.

During early stages of this thesis, clear allocation of responsibility to individual stakeholder was absent, this contributes to the uncertainty of the exact ideal, as different stakeholders envision the ideal solution differently. There is however consensus among stakeholders that the ideal solution should be incorporated into the purchasing order process of the present ERP system, the reason for this being that no stakeholders intend to invest heavily into a new order process and ERP system. The lack of willingness to invest in a new process being primarily due to the ERP system being outdated, and therefor new IT tools are postponed until a new system is adapted. With this constraint in mind, the difference between norm and reality is as follows:

The norm is a packaging order process where manual communication and labour is minimized, and the ERP system (extension) effortlessly handles the packaging related to the purchase placed once a purchasing order has been placed. Quantifying these norms is important to prove significant increase in performance was achieved. In the norm situation every order for a product will lead to packaging being sent to allow for the transport of this product, as presently we are unaware of the amount of packaging at the location we must make the assumption that packaging must still be provided. Thus a norm situation to aim for is that every product purchased means packaging is sent to the suppliers address. In the next section the Key Performance Indicators that show whether or not the norm is reached are explained.

The present reality is a largely provisional high communication and thus time intensive method that leads to frequent mistakes causing occasional last moment truck deliveries at notably higher cost.

2.8 Variables

The ultimate goal of this assignment is to best solve the core problem defined above. In order to prove that the solution sufficiently resolves the core problem, variables must be derived that can function as evidence that a potential solution bring the desired yield. Key Performance Indicators(KPI's) will be used to assess solutions for their ability to resolve the core problem, these indicators will be discussed in the problem analysis (4.3) after initial investigation of the situation will allow for translation of variables to workable indicators.

Naturally whatever solution is to be selected should be cost efficient, however as money does not accurately depict results for this problem, as it is not a direct consequence of the core problem, it will thus not be used as a variable.

The following variables will be used in this research to assess the performance of any proposed solution:

1. **Robustness**

Robustness is the degree to which the solution is capable of preventing and handling disruption or variability. Essential to this assignment is a result that removes as much unnecessary workload (cause of miscommunication) as possible. Furthermore the final process should be of such form that no simple human error can lead to the return of disorganization. This variable presents how frequently the solution can and will fall back to old ways of operation, reintroducing chaos.

For examples think communication between relevant employees, placement of truck order and instruction of forklift employee to move any purchasing cycle packaging at the right location or in the correct truck. This variable can be directly measured by observing the amount of repetitions that occur, the percentage of which does not follow standard procedure, and lastly the odds of consecutive failed, implying a fallback to an unorganized process.

2. Process performance

As much as the solution with the highest potential for automation may appear the clear winner, this alone will not stop the disorganization within the cycle packaging process. Solving the core problem thus needs a different variable that indicates to which extend the actual errors occurring in the process are prevented.

Put concisely, the first variable assures work is done in the way prescribed by the process description, and that any minor hiccup does not lead to desertion of a new process. The second variable serves as an indication of the direct results of the process, does the packaging frequently go missing or need personal attention by logistical employees to get it to the right place? Then despite having automated some tasks and making the process be executed in a consistent manner, the process is still chaotic, meaning this new solution does not actually save on resources. This explains why these two variables together form a strong indication of how well this process runs.

3. Traceability

Indication of how much better the situation is understood. How many packages are required on a cyclical basis? How much operational packaging do we have? When does what packaging need to be where? This last variable serves to make the manual error handling as organized and insightful as possible for the logistical employees, giving them a good idea of what the problem is and how to solve said problem.

3. Problem Solving Approach

This chapter reflects the second step in the Managerial Problem Solving Method(MPSM); the Problem Solving Approach. The steps main is describing in a manner as accurate as possible to arrive at a solution. The activities to be conducted are divided into three categories discussed separately, namely Do (3.1), Determine(3.2) and Decide(3.3). Lastly, key to any proper systematic approach for scientific problems is a sound understanding of "good" research, in the last part of this chapter a definition of good research is provided(3.4).

3.1 Do

The MPSM defines this section of the problem-solving approach as a list and description of all activities one must perform for the research. The activities below are numbered to roughly indicate in which order execution of the tasks should take place, this is however not a strict policy and may vary in actual execution. Some of the activities require knowledge problem solutions, behind each activity the relevant (if any) questions (Q) are stated, see sub-chapter 3.2.

Interview key process individuals

Interviews are unarguably the best method of inquiring what all stakeholders want out of a potential solution, as well as indicate present issues in an early stage, so that no problem is left behind. The conclusion of these interviews is a list that stated the problems and proposed solutions/improvements from the stakeholders. With this information relevant research can be conducted. Another question that will have to be answered is how VDL would like to see purchasing cycle packaging processes in the future. (Q 1,2,3,4,7,8)

Create a process overview

After receiving information from the stakeholders, the next logical step is to take this information, consider the goals of this assignment, consider the decision and finally make a general overview using business process mapping (BPM). First to construct the exact current process, then what programs/methodologies have to change to reach the realistically set norm situation. Finally arriving at an overview of to do tasks to reach the norm situation. (Q 3,4,6,10)

Automation & software research

In the previous task more specific information about obstructions and trivial tasks associated with the purchasing cycle packaging process were exposed. Now knowing what goals to strive for, the various programs at my disposal will have to be researched to see what changes can bring the present software and work instruction to the desired goals. (Q 5,9,11,12)

Sketch, convene and reiterate

After the research the stage is set; solutions are thought through what is possible and what is not becomes apparent. What solutions would look like and how they would tackle the various problems found in previous stage must now be sketched using Lean and six sigma as to give stakeholders a good idea of what each potential solution will involve. Through this process the solution must be aligned with what the stakeholders want. In this step, "futureproofing" is already taken into consideration.

Develop methodological and software changes

Once the decisions have been made in coordination with Mr. Machiels and stakeholders these changes will have to be programmed / created / written, this part may constitute the bulk of the work, as

developing and mapping these solutions may take considerable time, taking into account what can be done realistically must of course have been decided upon.

Create implementation plan and essential work instructions

Once the new software, the new work instruction and the solution in general has formed, a plan must be made to assure seamless implementation and adoption of the new procedure. (Q 14). VDL has a standard methodology of assuring effective documentation of any new work process, namely the creation of work instructions. All essential work instructions will have to be written to assure smooth running of the process.

Futureproofing

During the creation of the implementation plan but if necessary, afterwards too, steps must be undertaken to assure that changes such as employees leaving or software changing (update to windows 10 for instance) does not interfere with the usability of the program (Q 13)

Scale recommendation and implementation

Due to the scale of this bachelor assignment the extent to which this task can be performed is uncertain, but as stated in the deliverables, VDL has multiple branches that operate this ERP system, and encounter similar issues in their cycle packaging. An overview of how cycle packaging is handled in other VDL ETG branches should allow for a meaningful recommendation on whether the solution created for VDL ETG Almelo can used across the ETG branch. (Q 15) Recommendations regarding deployment of the results of this thesis can found in 7.3 Recommendations

3.2 Determine

Determining is all about obtaining knowledge, it is about answering questions rather than undertaking action. If necessary, some context is given to the question to help define it. An important distinction to make is that the following problems are not the deep knowledge questions asked in chapter four of this assignment.

The questions below are factual questions or calls for speculation, if it is the prior it is usually easily answerable by the right person, it does therefor not require an extensive amount of research. Some questions posed for speculative reasons, to invoke mind mapping and thinking about the matters brought forth by the questions. A distinction is made below between factual questions (F) and speculative questions (S). The answers to these questions can be found in chapter 4.

1. *How do purchasers of products presently handle the ordering process?(F)*
2. *How does the factory retrieve information about what to do when for cycle packaging?(F)*
3. *How does(F) and will(S) cycle packaging storage work?*
4. *How does(F) and will(S) cycle packaging ordering work?*
5. *What can be automated?(S) (i.e. what manual labor is waste)*
6. *Where does the current package handling process go wrong?(F)*
7. *What are the specifics of the product obtainment and package sending process?(F)*
8. *Who can I ask difficult questions regarding VDL's ERP system (BaaN)?(F)*
9. *What are the options within BaaN?(S)*
10. *How is the purchasing cycle packaging process different from in-house cycle packaging in BaaN?(F)*
11. *What functionalities can I add to purchased products within BaaN?(S)*
12. *What add-in functionalities does BaaN support?(F)*

13. *What is the best futureproofing methodology for such a process?(S)*
14. *How can I safely test my solutions?(F)*

A test environment exists within BaaN for the sake of experiment with upgrades and or changes to its core software, this option can be utilized if the right people are asked for access and introduction

15. *How similar are VDL ETG branches regarding this issue?(F)*
16. *Is cycle packaging also frequently used for returning faulty products?(F)*

3.3 Decide

Deciding is a topic preserved for the choice of alternatives, namely who to involve in which process, what actions to undertake given certain circumstances. Briefly, the goal of this category is to list all choices that must be made to arrive at a solution.

Decision 1: What is a realistic norm?

As stated in 2.4 the true establishment of a norm situation is yet unclear as ERP system upgradeability and other factors remain unpredictable. A decision will have to be made however as to what norm is realistically reachable, whether it be full automation of all communications after order placement, or merely a set framework on how communication should be conducted, is yet to be decided. This decision will decide on what software should be used for the norm situation and what extend of implementation instructions are expected for this assignment.

Decision 2: Who to include in deciding software/work instruction solutions

When clarity arises regarding what software choices are available a decision must be made on who to include in the decision-making process, i.e. should the order makers have a say? Who is representative of the purchasers/factory employees?

Decision 3: Advice

Considering the time frame a decision must be made to see if the other branches of VDL ETG can be helped within the confines of this bachelor assignment, if time permits then implementation of this project into other branches may prove to be a relatively simple task as the ERP system is the same. Implementing a project of this scale however cannot be expected to take merely one or two days, and if that is all the time available for such an intervention, then it may be a wiser decision to opt for quality rather than quantity.

Decision 4: What type of overview

Lastly this self-explanatory decision is that a method of overview creation must be selected. The goal of this overview is to supply a helicopter-view of the process and its flaws and aid in finding the problem by adding clarity and understanding of relationships between players. Whichever overview is selected must be excellently suited at providing this clarity and understanding.

3.4 Scientific approach

Here the scientific accuracy of this research is discussed by means of addressing validity and reliability, as well as a discussion if this research qualifies as "good research" by the definition provided by Cooper & Schindler[i].

3.4.1 Validity

Validity knows two mayor varieties; internal and external validity, both will be discussed with the context of this bachelor assignment in the hopes of reaching an understanding to the potential vulnerabilities of this research and furthermore how to best assure no breach of validity occurs.

Internal validity

Internal validity is a measurement to which extend a study proves a problem is caused by a specific source. Two potential threats that may come to light in the interview stage is the repeated testing/testing effects threat in addition to the functional bias threat I will discuss below

Testing effects

Due to this cycle packaging problem existing for some time, most involved parties have been asked what the cause is, to define the problems they face or to change their behavior, this may make some employees less motivated to share all information to this research, as previous attempts lead to little improvement.

This problem will be overcome by illustrating to individuals this is a project set in place exclusively for overcoming this problem, upon explaining that my assignment is to improve the purchasing cycle packaging process, that I have exclusively this task and there will be no end to this task until the problem is solved adequately. A measure of convincing may be required, which is why in the interview stage all interviews were conducted in a professional manner in a private room, giving each individual the scheduled time to properly describe the problems they encounter in this process.

Functional bias

Due to being a multi-departmental problem, some may feel inclined to prioritize their own department over others, thus for instance stating that a problem can be solved by giving a control task to forklift staff, this is an example of attempting to cast the problem away from one's own department, to prevent having to make significant changes in one's own process. This is prevented by means of not using the data gathered for direct consequences, but rather initially just gather information, then create an overview, then objectively judge what the pareto-optimal solution is for VDL ETG Almelo as a whole.

The human factor is the main risk in internal validity. This means is that interaction with employees for the sake of this assignment must be done deliberately, and with realistic effort put in assuring that what it stated is not due to circumstances or variables outside this research.

External validity

External validity may be at risk because this assignment is done within VDL ETG Almelo exclusively, while the eventual scope of implementation may include ETG Eindhoven, Singapore and Switzerland. This issue cannot be addressed by means of broadening one's perspective as information from sections such as Singapore and Switzerland will be impossible for this study to observe given the budget and timeframe.

In order to optimize external validity information will be requested about the comparability of the branches, and where the branches state significant differences what their influence would be on the proposed solution. Furthermore an effort shall be made to allow to specific application to VDL ETG Almelo, but to uphold development of a "standard" solution that need only be applied to facility specifics to allow for sufficient external validity to make at this standardized solution applicable to all branches of VDL ETG.

3.4.2 Reliability

A reliable result implies consistent results. The research to be conducted requires quite some human input, which is subject to variation as employees, times and other factors outside of this research differ. To ensure reliability this research must therefore be conducted using methodology that minimizes ambiguity and attempts to remove the human factor from obtained information.

One method to employ in order to decrease the human factor is making the interviews in the first stage of this assignment as fact based as possible to reduce potential interpretation flaws from either side of the interview. Furthermore, clear and identical explanation shall be given to each interviewee in order to standardize the input information to each employee as much as possible.

Re-testing is a method frequently used to test whether the outcome of a step is reliable. For the sake of reliability it may prove resourceful as proof of reliability to spread the conducting of interview over a timespan of multiple days and to interview at least two employees per relevant department, as to assure no personal temporary factors may be influencing the input from employees and thus the reliability. Steps after the initial interview process will follow a strict as possible methodology leaving for minimal reliability concerns.

Reliability concerns may return upon the decision making process, making this decision largely fact-based and requiring a motivation to be written of the chosen solution based on facts will minimize the impact of this decision making process on the reliability of the research.

4. Problem analysis

This section concerns the third phase of the MPSM. This section is a documentation of the execution of the problem-solving approach mentioned in the previous chapter. In this chapter, details, causes of disorder and previous solutions are vital. In the first section (4.1) the interviews will be summarized, and conclusions from said interviews elaborated, when possible, with data. Then, using information from the interviews and then further investigating the current state of affairs, the overview (4.2) will be created, including:

1. A present process overview
2. The main problems with the process "as is"

After painting a clear as possible picture, the research begins. In the following segment (4.3) research questions will be stated, researched and solved. Some of these research questions require literature research, which will be discussed in 4.4.

4.1. Interviews

4.1.1 Interview approach

In the initial stages of this bachelor assignment I conducted a series of interviews with various VDL employees, for privacy reasons merely function descriptions will be utilized, with an exception for the assignment coordinator Mr. N. Machiels:

- Purchaser Systems
- Purchaser Parts Manufacturing
- Contracts Purchaser Parts Manufacturing
- Supply Chain Manager
- Head of logistics N. Machiels
- ERP system expert

These interviews usually were conducted one on one in private meeting rooms, this with the hope of assuring a place where any criticism of the purchasing cycle packaging process is welcome and exclusively their view of the process becomes clear to me. In the annex you will find a summary of findings from the interviews. The conclusions of said interviews will be discussed here.

4.1.2 Interview takeaways

The goal for these interviews was to gather a list of problems and proposed solutions the stakeholders perceived. The goals is to use information as the basis for creating an overview of the problem, and what has been done in the past to attempt resolving it. This section provides the answer to some of the questions in 3.2 (Q 1,2,3,4,7,8)

How do purchasers of products presently handle the ordering process?

Purchasers in parts manufacturing currently get a purchasing advice from the ERP system, in addition to requests from the chief of logistics, or other people requesting purchases through email after looking at these sources, the purchaser proceeds to order the desired products in accordance with the Materials Requirement Planning(MRP).

In the entirety of this process the packaging in entirely absent in theory, in practice however, it occurs very frequently (~25% of cycle packaging related orders) that purchasers are emailed regarding missing packaging, both internally and externally. Internally being a request from production to move a

produced/assembled part but lacking the required packaging. Externally implies a supplier requesting the packaging for their finished product to be brought to VDL.

Failure to comply with packaging demand leads to mayor delays in the process, and can disturb reserved production slots in suppliers further in the manufacturing process, as well as cause the final product to not be finished on time for customer delivery.

Some hard data to supplement this handling. Over 2 months the average amount of packaging related emails on a day came down to 1,7 emails. The average resolve time can be calculated using the two main events that occur:

- a phone call / email to materials handling, or if necessary, to the factory to locate packaging easily and then send request said packaging to be sent to supplier, average may be assumed at 5 minutes, as stated by the stakeholder most frequently in contact with this problem, this occurs roughly 80% of the time.
- A genuine problem, namely a shortage of a certain packaging, which can take well over an hour according to the stakeholder, stated as 2 hours to arrive at an average. This occurs the other 20% of times

Adding these values and their weights mean the average resolution time for an email is 28 minutes, meaning 47.6 minutes per workday is being spent in purchasing alone resolving recurring cycle packaging problems. Assuming 22 working days a month, that means **17 hours of work per month in tracking missing / lost packaging in the purchasing department alone.** A number only set to increase as future demand is on the rise.

How does the factory retrieve information about what to do when for cycle packaging?

For internal production the cycle packaging is very much a result of insufficient information. The logistical department is in charge of assuring the arrival and departure of packaging, meaning when a product needs to be produced a purchasing advice is created in Baan ERP for the raw materials, and said raw material can only be delivered in the cycle packaging, rendering the problem entirely a purchasing issue. What is however frequently overlooked is that some packaging is left at factory floors.

The consequences of a lack of packaging frequently becomes apparent at the production lines however, production can't begin as there is no packaging for the product to arrive in, meaning there is nothing to work on for the production floor. Another possibility is that there is no packaging to ship the assembled final product to the customer. Packaging sometimes lays at the assembly part of the production plant, as visualized below

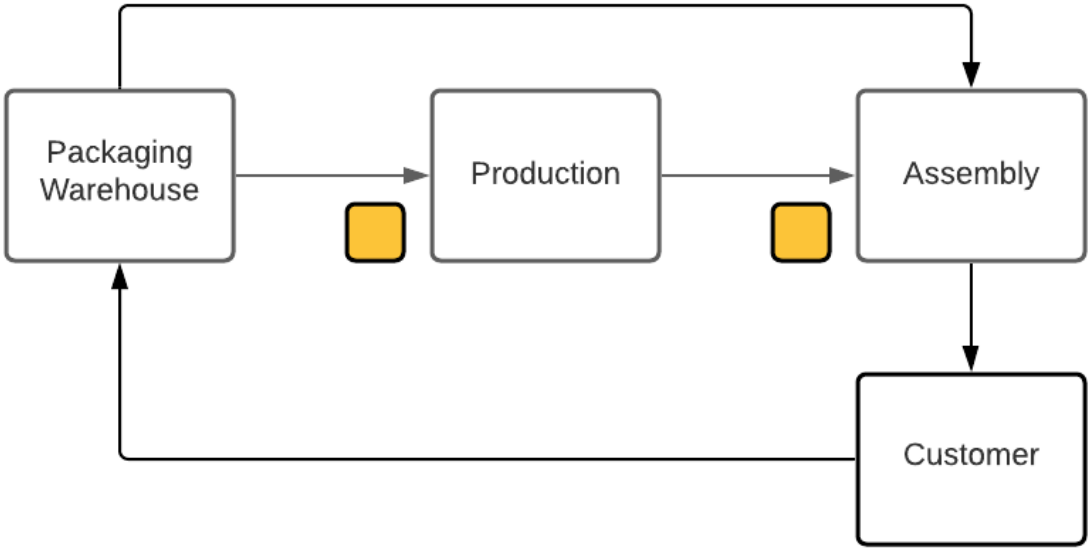


Figure 7 Visualization of where packaging goes missing

Some packaging is swapped out at either production or assembly due to a change of the shape of the product being created, for this reason the product is taken out of the packaging and put into the packaging required for the following step. The previous packaging should then in theory return to the packaging warehouse. This however is not always done, leading to packaging going missing in plain sight. This requires a purchaser to look at typical locations for this abandoned packaging.

How does cycle packaging storage work?

Currently there is a separate, yet adjacent location called "hall 4" where all large and cycle packaging is stored, hall 4 has staff that is emailed or called whenever cycle packaging needs to be sent or will be arriving soon. Next to this the hall 4 staff has the scheduled task of sending and receiving the large packaging according to the MRP.

How does cycle packaging ordering work?

To clarify, this question answers how new cycle packaging is ordered, not ordering existing packaging to be placed somewhere. Currently, based on what is known as the "move rate", which is a multiplication of how many packaging are in production on average (given max meetable demand) multiplied by how long a product takes to make (throughput time), the following formula:

$$I = ((\frac{A_i}{M}) * T) * \sim 1.3$$

Where I = desired packaging inventory, A_i = average number of products in production, M = Multiplicity, i.e. how many products fit in a packaging and T = throughput time

cycle packaging gets purchased once and never rebought until the move rate increases. In practice however, whenever cycle packaging is insufficiently present for long enough, or has caused sufficient delay for serious consequences to ensue, new cycle packaging is bought "ad hoc" usually taking a percentage of the packaging required by the move rate, say 30%, and ordering that amount of new cycle packaging.

What are the specifics of the product obtainment and package sending process?

The entire story of how packaging comes into and leaves VDL is far too complex for this bachelor assignment to cover, as VDL Project and VDL Systems all have sporadic and different orders and packaging, and inexpensive non-cycle packaging making up the bulk of manufacturing packaging being sent and received, the main logistical terminal of VDL ETG Almelo, called "materials handling" is significantly more complex than will be portrayed in the remainder of this report. The important aspects for the sake of cycle packaging can be accurately simplified as "in exceptions, identified cycle packaging will be sent back to hall 4".

4.1.3 Table of problems and proposed solutions

Here is a brief overview of the problems and proposed solutions found through interviewing:

Problem	**Proposed solutions (if any)**
Packaging goes missing Broken packaging is not reported Communicating about cycle packaging takes too much time for purchasers Currently active packaging is untraceable	- Track every entry and departure from Hall 4 - Clarify to Materials Handling who they need to inform about broken packaging - Within Baan ERP, a tool called contract forms has "emballage" software meant for basic cycle packaging solutions. Nothing is currently modeled in a manner to let this properly function however
"Project owners" the officially responsible party for sufficient packaging, are not aware of the trouble in packaging / do not feel they are responsible for solving it	Shift responsibilities to purchasers
Purchasers are not procedurally connected to the packaging they need	
Product serial number is frequently not associated to packaging serial number	Packaging information can usually be found by digging through the "werkvoorbereiding" manual of each product
Current ERP is not being developed, "end of life" stage	
Lacking communication means all parties feel like the packaging process is uncontrolled	Have collective discussions about who bears responsibility for what action

Table 2: Problem and solution overview from interviews

The above table serves to indicate the most important conclusions drawn from the interviews, not all problems described in these interviews are shown here, this because some problems where too far from this assignment for me to consider them relevant. See the annex for a more elaborate summary of interviews.

The problems in the above table have been discussed in 4.1.2. or are self-explanatory, the proposed solutions however have not been discussed, these solutions will be discussed at the end of the next sub-chapter, where the overview will be used to determine the effect on the process should any and each of these proposed solutions be implemented.

4.2. Problem overview

In this section of the Problem analysis, the goal is to reach a complete view of the process and its flaws. This chapter will therefore be divided with observations that lead to this overview (4.2.1) to begin with, followed by the actual overview of the current process (4.2.2). Finally, the flaws of the current process (4.2.3), so that the most urgent of problems in the path of solving the core problem come to light. This then also sets the stage for these urgent to be researched further in 4.3.

4.2.1 Preliminary observations

To clarify, these preliminary observations serve to fill the gap between the information obtained through interview and all information used in the creation of the overview.

When analyzing the process what became glaringly apparent is that purchasing and sending of packaging has no connection, meaning that a shortage of packaging only becomes apparently when in the field either suppliers cannot deliver or damaged packaging cannot be replaced. This leads to the absence of any "pull" or "push" mechanic, which in turn prevents many forms of preventive action from being taken.

The ERP systems sees packaging simply as an inventory integer, this means there is currently no software in use that manages packaging location, destination, or state. Whenever a packaging is returned to VDL, and the product therein is unloaded, it is simply standard procedure to return this packaging to Hall 4, where the packaging number is registered and therefor this type of packaging now has one more in storage. The limitations of such a system are mainly that traceability becomes a considerably larger challenge.

4.2.2 The overview

As discussed in 4.2.1, the process as it stands is actually two entirely separate processes, which will first be presented in this independent form, after which one flow will be presented, showing how the purchasing process and the materials handling process come together in their current form. In 4.2.3 this unified process map will then be used for analysis of the flaws.

The first process map we will look at is the Purchasing process, as this process precedes the materials handling process. Below one can find a small table to help understand the variables at play followed by the purchasing process illustrated, lastly under this illustration, a description of every step throughout the process.

Variable	**meaning**
X	Product that goes into cycle packaging Y
Y	Cycle packaging, the reusable packaging used by VDL
Z	Location, usually the supplier. A place a product X with packaging Y can be sent.
n	Number representing the number of products "X" purchased

Table 3: explanation of variables used in Figure 8

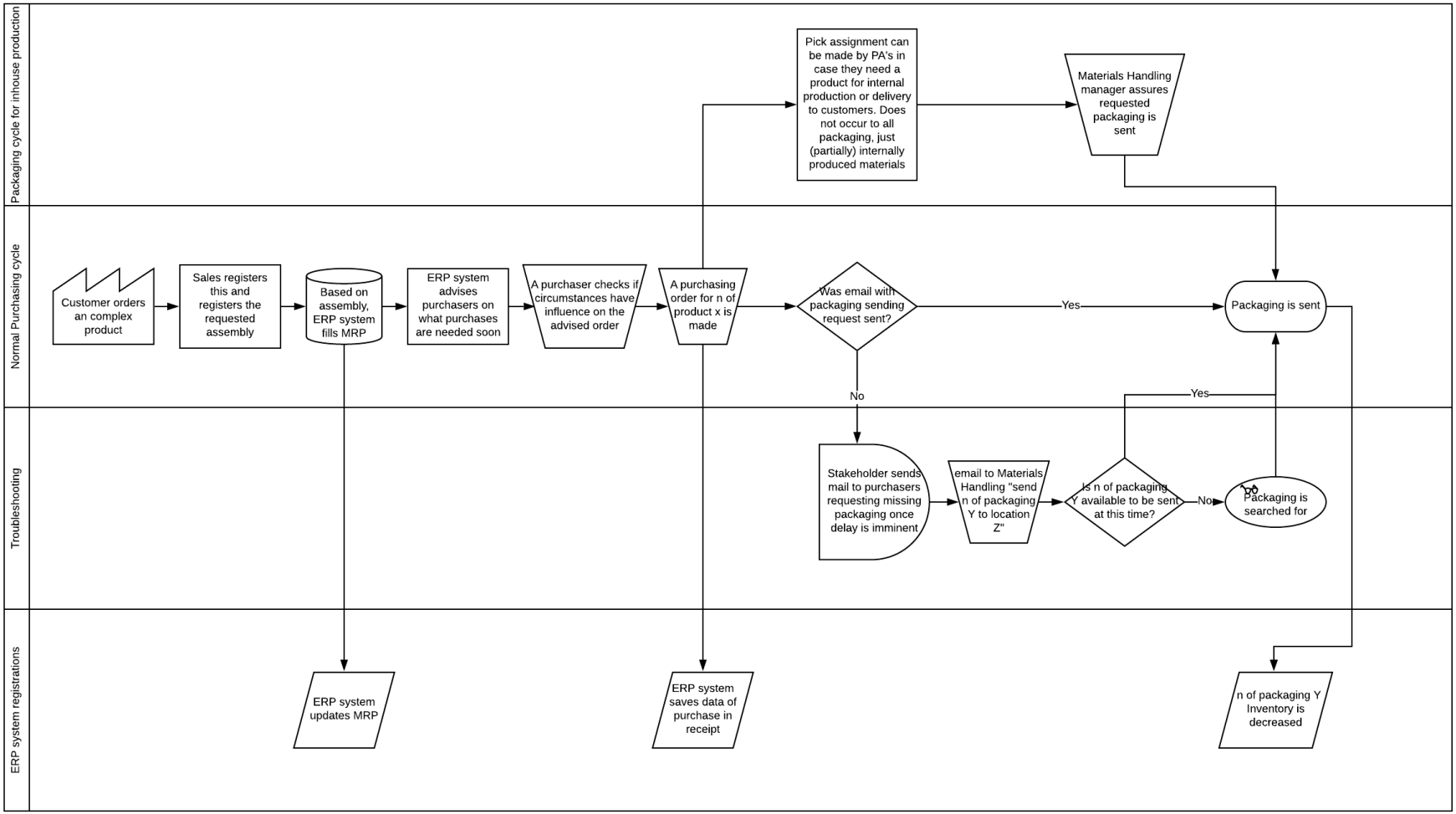


Figure 8 Current purchasing process

The purchasing process starts when a salesman within VDL enters the order for a new a new product to be made by VDL. After this entry into the ERP system, the ERP systems then offers some recommendations of when it can be delivered at the earliest (this is a simplification, on larger contracts certain levels of capacity are held free for the dynamic low-lead time of ordering parts). Once a product has been registered in the ERP system, it can give recommendations to purchasers for purchasing the necessary parts needed for production.

Once the recommendations end up in the dashboard of the purchasers, a critical step begins for the cycle packaging process; exact dates and quantities are selected for ordering. As VDL attempts to minimize products in storage, it rather frequently orders "layered", meaning that rather than ordering 36 pieces of something, they would rather order 12 every week for 3 weeks. Using this method across purchasing means fewer storage space is required. It also means however, that getting the right packaging at the right place exactly is crucial.

After the setup of the purchasing order, the purchaser may release the order, after which formally the process ends for the purchaser, a receipt of the purchase is saved in the ERP system, and the job appears done. This assumption of completion however does not hold up in a fair amount of cases, particularly for Parts manufacturing, where there is an expectation from Materials Handling to receive an email whenever packaging needs to be sent.

As specified in Chapter 2, the objective of this research is to solve the packaging problems surrounding the purchase of products within VDL ETG Almelo Parts Manufacturing. This is however not the complete picture for all of VDL ETG Almelo, as many outsourced production steps also require a cycle packaging.

The job of allocating and sending cycle packaging for intermittent outsourced production steps is left to Production Assistants(PA). This is not as urgent of a problem as in the majority of cases the packaging associated with the to be outsourced part has already been delivered, as the start of said product was delivered in said box, see Figure 6.

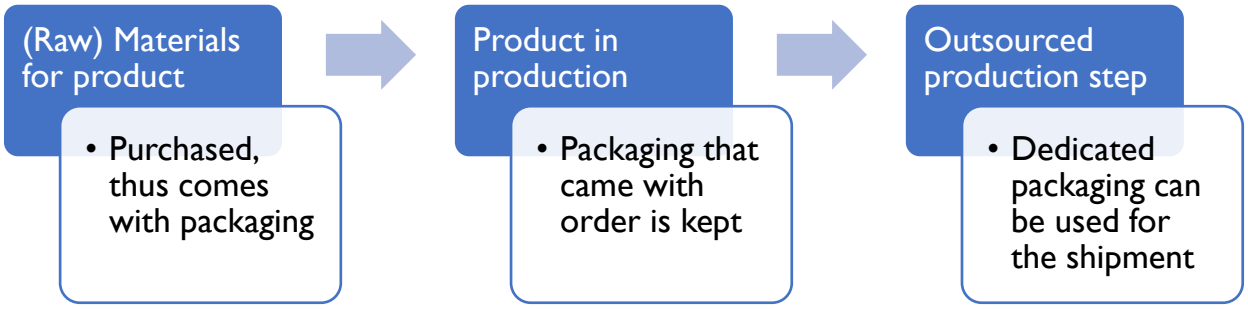


Figure 9 How partially outsourced parts obtain packaging

Naturally, this is not the case in 100% of products, as some products undergo fundamental changes is product size and features that require a different packaging, this however is mostly the case in the assembly section of VDL ETG Almelo, which is not the main focus of this research, as discussed in 2.2. This description was an elaboration of the top lane, titled "Packaging cycle for inhouse production".

In an attempt to recreate which activities purchasers physically end up doing, the following split is included in this process: "Was email with packaging sending request sent?" This to set the problematic cases from the untroubled cases.

In the untroubled cases, expedition, a department of Materials Handling, is told to always immediately return packaging to the supplier ("automatic") This is the case if the cycle packaging is not ours, or if the warehousing of said cycle packaging has been outsourced to the supplier. Some cycle packaging however is ours and the supplier does not offer a storage location for cycle packaging, leading to the other path.

A fair amount (60 ~ 75%) of cycle packaging orders (80 ~ 100% of Parts Manufacturing) ends up being in the problematic path, 50% due to an email from the supplier requesting packaging, and in a more severe small percentage of cases, the following production step inquiries about the arrival of their outsourced product, which is then still located at the supplier, usually meaning severe delays.

Once this alternate process has started, the purchaser will contact materials handling and request the required number of packaging be sent to the supplier as soon as possible, when there is sufficient packaging that solves the problem.

In less fortunate situations however there is not sufficient packaging for the order to be deliverable, therefor the purchaser must begin looking for packaging in the aforementioned places (See figure 3). Which can take alarming amount of time, one purchases placing the average of receiving the call for packaging to resolving a shortage issue at an hour. When this problem occurs to frequently, it may occur that purchasers decide to purchase more of the frequently missing packaging, this is however not standard practice, and is therefore not part of this process map.

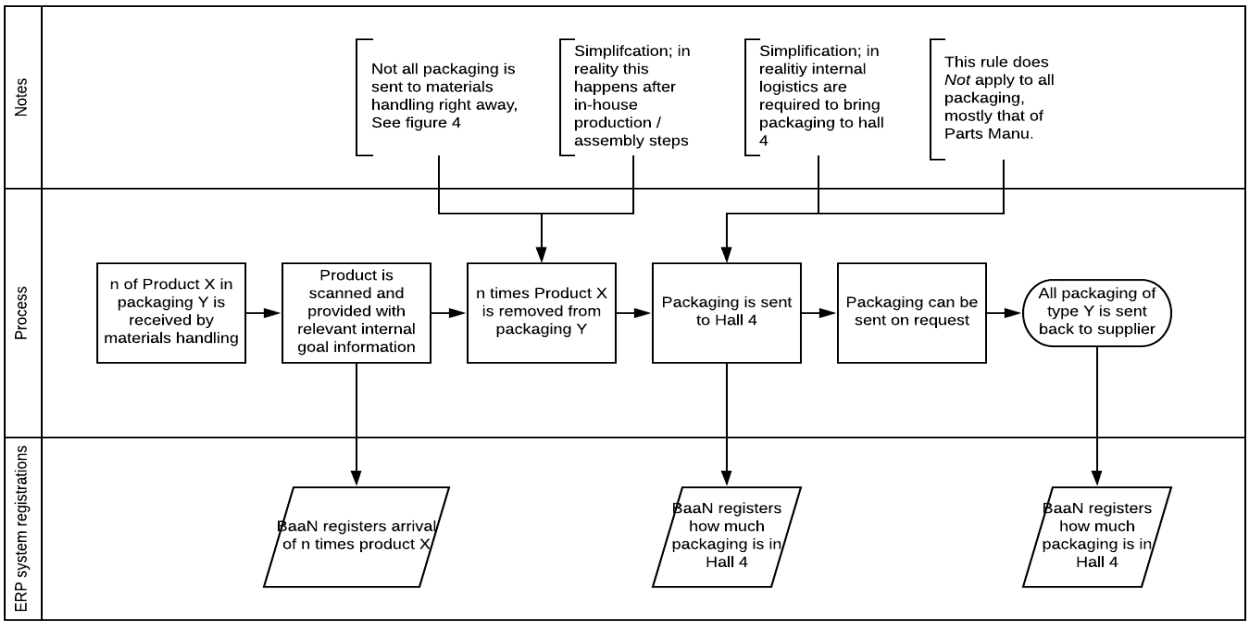


Figure 10 Current materials handling process

These processes are purposely separated in this report; they have no connection. The urge to connect these processes stems from the desire to solve the core problem:

*The present cycle packaging process for purchasing is **insufficiently organized** to be traceable or reliable*

The beginning of the packaging cycle for materials handling starts with the packaging being received with the purchased product inside. After this, the product and the packaging it arrived in go through the internal production process. This end when the product is modified to such an extent that different packaging is required (most frequently when going into assembly).

At this point the packaging is left in front of assembly, to then get periodically picked up by internal transport professionals that bring said cycle packaging to Materials Handling. The department of Materials Handling that first obtains the packaging is called "expedition", they determine this is a cycle packaging for Parts Manufacturing and send the packaging to Hall 4.

Upon arrival a Materials Handling professional places the packaging into the Hall 4 warehouse and registers its arrival in BaaN. This is how packaging enters Hall 4. The way out for this Packaging comes in the form of an email. Hall 4 Materials Handling professionals will receive an email from logistics, purchasing or elsewhere that packaging needs to be sent. This email will include the type of packaging, the number of packaging needed, and its destination. The Materials Handling professional will then:

- print a label with the destination and type of packaging required for each packaging to be sent
- place this label
- place the packaging at the pickup location and assist loading it into the truck
- register in BaaN that "n" number of Packaging has now been removed from storage

This process can be measured by the indicators time savings and traceability, in sub-chapter 5.1 these indicators are elaborated, after which an improved process is shown in sub-chapter 6.1.3.

4.2.3 The improvement opportunities of the current process

Having discussed both processes most relevant to achieving order within the cycle packaging process, something of an overview has already been achieved. Combining the two processes gives a complete overview of the path undergone by cycle packaging, the only part missing in obtaining an overview that is useful in research, is zooming in on its flaws. For clarification, parts of the two processes will be illustrated here again, possibly with addition, to allow zooming into these flawed parts of the process.

Input

Part of the insufficient organization is the source of input for Materials Handling. As the only method of being informed of packaging to be sent is email from employees throughout VDL ETG Almelo, the Materials Handling professionals do not obtain any idea of what orders have actually been placed or what might be coming up in the future. This makes preventive action impossible, because receiving information that a packaging needs to be sent some time prior to it needing to be send, allows for vital breathing space to the Materials Handler te resolve any issues.

Bringing reliable input information into the Materials Handling cycle packaging process is therefore key in establishing a more organized process overall, if integrated into the right solution it may lead to the awareness of missing packaging before any email arrives, be it internal or worse, external. This change would allow materials handling personnel to deal with the lack of packaging before it can lead to delays. See Appendix i for the meaning of each shape presented in Figure 11 & 12.

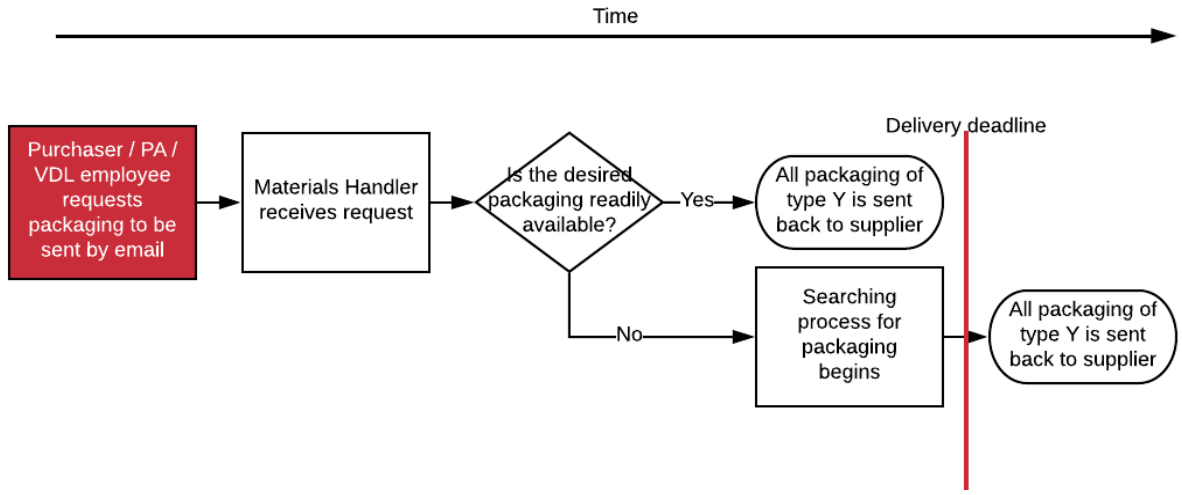


Figure 11 The cause and consequence of emailing

Missing packaging

Upon further inspection there is actually a separate flawed process occurring in the internal packaging transport, illustrated below.

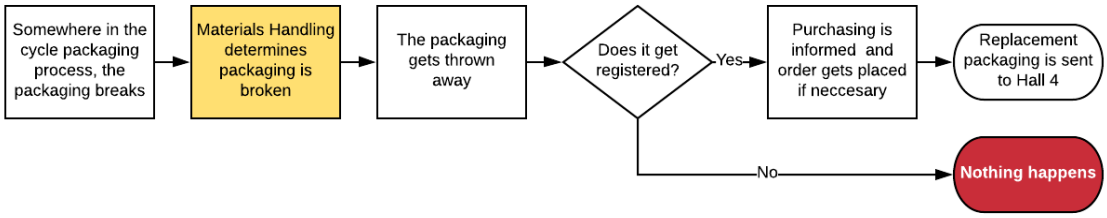


Figure 12 How packaging goes missing

Upon asking purchasing whether they get informed about packaging being broken or going missing, the response comes down to "sometimes". An exact percentage of how often packaging is broken without registration is impossible to obtain, as, naturally, the not registered packaging is unregistered. Estimations from purchasers based on how frequently packaging has to be reordered, despite no passed on information about broken or lost packaging, are 75%. Though estimations varied significantly between stakeholders, multiple pieces of packaging on a monthly basis is a certainty.

From this a rather evident flaw from the current process comes forward, the complete lack of traceability of packaging leads to a lack of information about fleet size, and where and how deterioration takes place.

Information

The last flaw to be discussed in this subchapter is the absence of many forms of information. In the process, though not intuitively illustratable, the clear database combination of packaging and product is missing, leading to purchase orders which could easily be immediately alarming considering the amount of packaging required, not being alarming, as neither the purchaser nor the Materials Handler is aware that it will be type Y of packaging that will need to be sent in quantities greater than currently in storage. This information, as said in the interviews summary in more detail, can usually be found in the work instruction of the product being produced.

Another information shortage problem ties into the previous Missing packaging problem, considering packaging does not have a unique identification, it is impossible to know whether your packaging is missing, broken or still somewhere.

A last information problem is the numbering of standardized packaging, packaging numbers meant to illustrate a unique, or updated packaging design are at times used interchangeably, meaning that despite the ERP system indicating that product X can only go in Y_{1101}, it can also go into Y_{1102}, leading to perceived lack of packaging, when in reality, packaging that could be used is available, yet assigned to an outdated packaging number it is as if this packaging no longer exists.

The conclusion that can be drawn from this overview is the importance of a direct connection between the purchasing department buying products and the rest of the process. As presently all stakeholders within this process seemingly operate with little knowledge of the other.

4.3. Research questions

In the previous subchapter, the overview was completed, finishing the second step in the execution of this assignment "create an overview". Completing this overview provides us with clear examples of the most urgent problems faced every day in the cycle packaging process.

Now the following step is to research two venues; firstly VDL, and its opportunities for change to resolve the issues within their process. This part will discussed in this subchapter, by looking at the research questions, and seeing to what extent we can answer them looking internally at VDL and its process, and wishes. Secondly, in the next subchapter focused on the academic world, methods that exist within the realm of VDL's capabilities to resolve the core problem are reviewed.

With the creation of the process overview, redesigning the process for added accountability and traceability is a possibility, research how this is best achieved is centerpiece in the academic literature to be reviewed.

4.3.1 What are the possibilities for ERP system changes?

One of the primary challenges in this assignment is irrefutably the changes that need to be made to the software currently in use by ETG Almelo, mainly to realize a substantial increase in traceability and efficiency. Thus, the knowledge problem at hand is figuring out how to change aspects of the ERP systems method of handling cycle packaging, getting to the bottom of this knowledge problem will require asking the following questions:

- How do I add functionality to a product receipt?
- How do increase traceability of the purchasing cycle packaging?
- How do I make the ERP system reliably order packaging movement to correct locations?

Answer:

The present ERP system used by VDL ETG Almelo is at its end-of-life stage, updates or changes to the system no longer occur and VDL largely does not invest in improvements to the ERP system at this stage. Research into a future ERP system is underway, this is however said to be years from implementation. Investing heavily in the ERP system in order to resolve the cycle packaging process presently in place is thus not a strategy deemed realistic or desirable by VDL.

4.3.2 What is the most effective method of process modelling for this transition?

Mapping the problems as done in the previous subchapter obtained an adequate helicopter view of the problems at hand. In order to assure a good transition from the present to the desired future, research into overviews will be necessary. Key questions that come forward:

- What overview for similar supply chain issues are available?
- What specific needs should this overview be able to fulfill?
- How advanced of an overview is still an efficient use of time?

Answer:

In order to ensure the method of process modelling suits the deliverables for VDL, their desired outcomes have to translated into desired information on the process map, what can be deduced of the deliverables as stated in 2.9:

- Information exchange in ERP should be part of the map, as this is an important aspect of the "fit" requirement
- Role (i.e. purchaser) assignment should be definite and findable in the process map, assigning roles to tasks assures employee changes do not upset the smooth operation of the process
- A dedicated "future change" swim lane should be added on top of a new process map to indicate the new process is to handle change

In the literature research(4.4.1), an in-depth explanation is given which method of mapping is chosen, and what adaptations where made to tailor to the needs of VDL stated above. The used method is based on Value Stream Mapping (VSM), why this decision was made is motivated in chapter 5.

4.3.3 What innovations are necessary to achieve an organized process?

The creation of the improved process will require new methodologies, systems and/or products. The assessment of these depends on to what extent they assist the current process transition into a desirable one. However, tracing or automating everything may prove an inefficiently arduous task, thus time must be spent efficiently. This section therefore begs the question; what criteria are best for my selection process in chapter 5?

Answer

What innovation should and should not be implemented in this process can be best assessed by combining criteria derived directly from the variables we defined to measure the quality of our solution:

- Lifetime cost of realization

Lifetime cost of realization provides the necessary reality check, costs always matter. As difficulty increases, so does the probably of failure or more work as more specialized solutions will have to be supported for the various varieties in cycle packaging. Briefly put, making any solution overly complex will make it incompatible with a process that inherently has variety, as suppliers, lead times, packaging methods and much more that can vary.

As an example of this criterium, integration of any software into the ERP system is an expensive process, as many of the functionalities within BaaN ERP are not variable, and changes to the ERP system in any way are therefore heavily discouraged by the ERP specialist in VDL ETG Almelo, it would require dedicated external ERP consultants. Working with the database software tied into Baan ERP called iQBS

also brings its fair set of challenges when used. This criterium weighs costs and robustness, allowing for a measure of *feasibility*

- Amount of time saved

How much does the solution decrease unnecessary workload on employees? As is discussed in the overview, purchasers, Materials Handlers and many others put time into resolving the issues that come forth from the disorganized state of affairs regarding cycle packaging. An important measure to increase our second defined variable in 2.7, namely "process performance", is to minimize the amount of time the various stakeholders of this process will have to spent searching, doing data entry, or any other time spent on the cycle packaging process.

In this variable the type of stakeholder being asked to perform tasks in the process and the time said stakeholder invests is measured. This to prevent moving significant workload from different groups of stakeholders, and to prevent any solution from putting disproportionate workloads on any stakeholder. This variable adds a direct pulse of process performance, as decreasing time lost due to hiccups in this process, equates a more streamlined process to begin with.

- Provision of traceability

As an organized process requires some measure of quality assurance, the creation of channels for data acquisitions are invaluable to assuring the key parameters of the process are always observable, when possible even controllable.

These three criteria indicate in broad terms how a potential improvement can be graded for being worthwhile or not. In the section "*proposed solutions*" many opportunities for improvement are discussed in more detail, providing more specific indicators to measure traceability and time savings.

To accurately gauge the effectiveness based on these criteria we must reflect on the desired outcome of this assignment, to what extent should the ideal situation be traceable, and to what extent is the current process in need of reducing unnecessary tasks.

Realizing that this type of process improvement should only be done if the required investment is appropriate, a bargain must be struck. What level of time saving and/or added traceability is adequate for a given amount of time invested? Table 5 shows an example of how defining the three criteria above give aid in determining whether or not a solution is currently worth implementing. This example is motivated and used in chapter 5:

Task description	Measurement scale	Value Stream mapping	Update ERP system	Make packaging production paths	Etc.
Realization cost & difficulty	1-5 (5 is easiest)	4	1	2	
Time Savings	1-5 (5 is most time savings)	5	-	1	
Added traceability	1-5(5 is most traceable)	2	-	4	
Combined value	2-10 (10 is best)	**11**	**-**	**7**	

Table 4: template solution value scoring

The values obtained from research are then to simply comply to a check: the cost of realization should be no worse than a 2, as a 1 indicates this task cannot be overseen within the confines of a modest process improvement but would rather lead to disproportional costs. Besides this, the highest scoring solutions are the first candidates for testing and realization. This process could theoretically be repeated until a point is reached where no conceivable improvement is worth the effort of implementation.

The abstractness of Time Savings and Added traceability are solved in the MPSM by allowing for indicators to take their place. In subchapter 5.1 these indicators are defined and used in stead of time savings and added traceability in order to arrive at a final table, determining the added value of each tool or method discussed in subchapter 5.2.

4.4. Literature Research

In the following section scientific literature in four fields Is discussed, this research provides a foundation in science for the conclusions brought forward further down this thesis. This chapter has four main research aims, all a consequence of the research questions stated in the previous sub-chapters, for example, Process analysis literature aims to help solve research question 4.3.2.

4.1.1. presents a process analysis, 4.1.2 presents innovative solutions, 4.1.3 presents Preliminary Research into Modernizing Purchasing, and lastly 4.1.4 presents Supply Chain Management. Literature research is executed using Scopus exclusively, filtering out any study older than 25 years old.

4.4.1 Process analysis: information logistics & proactive process mapping

Literature heavily implies the importance of a mapping process to bring to light evident issues that may not have been observed had a helicopter view not been created (Cicmil & White, 2016). In industry 4.0 flexibilization is as crucial as autonomation to being ready for the future of demand. (Bueno, Filho, & Frank, 2020) This flexibility can best be approached with a higher level of understanding and documentation of all processes involved in one's supply chain, as any change in the process will have clear consequences visible in the process map.

Considering the chaotic present state of the cycle packaging process, order must be created. In order to facilitate said order, research into process mapping tools lead to the conclusion that applying such a method is a proven way to benefit many aspects of the production industry (Singh, Garg, Sharma, & Grewal, 2010). Therefore, this section of the research aims to find the proper tools for designing an improved process, aimed at removing waste, and creating order.

First order of business is to determine what production method is being used, a quick analysis of Parts Manufacturing shows that the purchasing and manufacturing process only commences once an order has been placed, this production approach is called Make To Order (MTO), which is widely considered the highest variety production approach to still be a viable candidate for Process Mapping (Koch & Lödding, 2014). Literature even suggests the MTO industry may be just outside of the edge, but states a clear exception for logistically oriented VSM efforts.

A template already exists for process *flows* within VDL, yet it is sporadically used and exclusively illustrates the decision points of a process, rather than mentioning in detail what each process path can entail. An example of such a process *flow* can be found in Appendix xii.

Existing methods

One of the most widely accepted practices in improving processes is applying the value stream mapping (VSM) method (Kanbanize, 2020). VSM allows one to easily identify the process steps with greater

significance on the entirety of the process. In addition, this method intends to look at processes critically, to determine where customer value is created and what steps might be unnecessary in the creation of this customer value (a form of waste; "muda"). The advised methodology (Hines & Rich, 1997) is to use value stream mapping to:

- observe the current state as accurately as possible
- discuss said current state with stakeholders to define Necessary but Non-Value Adding (NNVA) actions and Non-Value Adding (NVA) actions
- create a future state and a plan to transition into this new future state

A historic limitation of value stream mapping is its inability to handle a dynamic or frequently changing process (Dal Forno, Pereira, Forcellini, & Kipper, 2014), to some extent this problem occurs within this process as well. The process is dynamic as some packaging material is to be used for more than just this process, some packaging is to be used for more than one product and some packaging is to contain multiple products. Furthermore, as customers request new products, new packaging and potentially new methods of packaging are constantly in development.

A solution to this is however to use the VSM 4.0 method as a basis, this method allows for significantly more flexibility, in addition to better information flow (mentioned in more detail at the end of this subchapter) and a better overview of complex situations like the packaging described above. (Hartmann, Meudt, Seifermann, & Metternich, 2018)

Considering the good fit between the desired outcomes of this assignment and what VSM 4.0 offers, this method was selected for creating the process map for cycle packaging, putting a clear mark on the horizon for the desired orderly process of the future.

Having chosen VSM, one abstraction must be resolved, as in the context of this assignment customer value is slightly more abstract, as there is no clear customer we are providing with a product of value. There is however a recipient of the cycle packaging that is dependent on this process to continue the production of parts: Parts Manufacturing.

For the purposes of this research, Parts Manufacturing (the section of VDL ETG Almelo where the non-sheet metal production takes place) is the customer of this process, the value this customer desires is a timely and reliable delivery of the right packaging. As the value stream in question concerns a Transportation centered process, it makes sense to take inspiration from Transportation value stream mapping (TVSM), where emphasis is placed on that a value-adding activity is considered to be any activity that contributes a benefit appreciated by the customer. (Villarreal, 2012) As an example, the customer desires instant awareness if deviations from the norm situation are about to occur. Essentially, the customer desires the resolution of the core problem.

For the purpose of this research, we will assume all products come in predetermined standard packaging, this implies different products may go into different packages, including combinations of packaging and products, but one product always fits in only one type of packaging. this assumption holds for the majority of packaging within Parts Manufacturing. For 3 different products the problem described at the end of 4.2.3 occurs, considering the 40 types of cycle packaging registered in the solution database, that would mean this problem occurs in ~8% of cycle packaging cases. There are no products that fit into multiple packaging types in Parts Manufacturing.

A framework

Considering the vast variety of Value Steam Mapping (VSM) methods (Slack, Brandon-Jones, & Jonhston, 2016), for example:

- variety in scope, taking an entire production facility versus details of a process
- static or dynamic
- depth in terms of variables measured in each step
- complexity in terms of looking exactly how information transfers versus aggregation of information transfer

It is important to converge from the broad term of VSM to an exact overview usable and profitable for VDL to make, as discussed in 4.3.2. a process mapping solution should meet conditions derived from the desired deliverables of VDL, remain sufficiently precise to add value, but workable enough to prevent excessive unnecessary complexity and work.

By accepting the industry 4.0 equivalent of VSM, the desire for digital information exchange to become an insightful part of the process map is fulfilled, as VSM 4.0 recognized digital information transfers as cornerstone information (Hartmann, Meudt, Seifermann, & Metternich, 2018).

In Business Process Models, one of which being VSM, it is an empirically proven fact that size directly negatively impacts the understandability of a model. This because interrelations become near impossible to track in large models, and errors such as deadlocks become more common. (Reijers & Mendling, 2011) This ties in to VDL and their desire for clear definitions of role assignment (role assignment in this context meaning that each task within the process is executed by an employee fulfilling a role). Because of interrelation understandability dropping as complexity increases, a conscious choice must be made to simplify where possible, as to keep the interrelation responsibilities between roles clear.

Study of Operations management (Slack, Brandon-Jones, & Jonhston, 2016) shows that the best approach to adjusting a process is to create not only the aforementioned current and future state, but to create a 'micro' set of process activities that allow for an enhanced view of the tasks and interaction that will come forth due to the introduction of new software. Such micro-managing assures the prevention of overlooked steps in the operation and maintenance of new innovations. (Sharda, Delen, & Turban, 2014)

In addition to these micro sets of activities, in Operations it is a ubiquitous fact that changes are a daily reality, other datasets, employees leaving and joining, management changing. When possible, effort should be put into "futureproofing" these inevitable changes, in order to preemptively succeed at the final task in this assignment

A popular tool for process analysis is Process Mining(PM), this has been shown in the past to give VSM a valuable boost in laying out the dynamics of the process being mapped, as well as the transfers of information within the ERP system. (Knoll, Reinhart, & Prüglmeier, 2019) PM seems an invaluable asset to determine event logs and identify waste. Process mining is however dependent on information systems (Knoll, Reinhart, & Prüglmeier, 2019) that can reliably produce relevant data regarding the process, due to the inability of Baan ERP to present any transaction overviews as it does not save them, it is unfortunately impossible to use this valuable tool for process mapping.

To conclude, VSM 4.0 is an applicable and effective method to resolve logistical issues in manufacturing (Koch & Lödding, 2014), making Parts Manufacturing the customer of this process, making basic assumptions and customizing VSM to allow for an emphasis on

- information exchange
- stakeholder roles
- micro processes

within the process. This leads to a unique VSM method that answers all process information needs, creating a far more ordered process overall.

4.4.2 Innovative Solutions

This section of research is focused on finding related literature regarding cycle packaging, as to directly assist in the obtainment of answers to research question 3: "What innovations are necessary to achieve an organized process?". This subchapter is to lay the academic basis for innovative solutions, however, solutions thought of internally shall also be discussed below in Chapter 5.

Research into when one should use cycle packaging or not seemed a logical starting point, if only to ensure that the reorganization of the cycle packaging process would not be fundamentally flawed due to the very existence of cycle packaging. Luckily, various sources indicate cycle packaging is a commercially viable and frequently implanted method of packaging in organized supply chains with somewhat predictable demand, a description that fits Parts Manufacturing. (Mollenkopf, Closs, Twede, Lee, & Burgess, 2011) (Twede & Clarke, 2008)

Having established the usefulness of cycle packaging, innovations in the packaging field relevant to this research would have to imply either modifying existing packaging cost-efficiently or using said packaging according to a new methodology, as any step greater than this would not be containable within the bounds of this research and therefor be irrelevant.

The main issues to tackle are described earlier in this chapter, they include:

1 a lack of registration when packaging is broken
2 a lack of traceability
3 a lack of a clear departure time for packaging.

1 Packaging failure registration

An important note to start on with the lack of registration when packaging is broken is that there is a manual regarding how to act when encountering broken packaging. This manual is however not commonly found, updated or in active use in general. Naturally, a first important step is to train personnel on where to find manuals, and not to act without consulting procedures. Literature regarding the lack of compliance to manuals credits the lack of adherence to two factors:

- Manual that are not explanatory, are not followed as strictly (Cao, Chan, & Elkamel, 2019)
- Workflows that are not logic based, are not followed as strictly (Ferilli, 2014)

Considering the concise nature of the manual currently in existence, writing a logical and explanatory manual is vital information for the implementation stage, as this will allow for greater adherence to the guidelines laid down in the manual.

2 Traceability

Moving on to traceability innovations. The consensus in the logistical industry has been to use the Internet of Thing (IoT) technological developments to help improve traceability, in addition to making them a known individual entity in a company's database. (Slack, Brandon-Jones, & Jonhston, 2016)

Comparing this method of thinking about packaging to the present situation at VDL ETG Almelo, there is clear potential in changing the current methods, however a previously mentioned limitation occurs; the ERP system. The ERP system currently does not allow incorporation of IoT tech, as it is software last updated in early 2003 (Baan Timeline, 2008) (excluding limited custom made changes). Understanding this situation means the necessity to increase cycle packaging traceability without using a conventional ERP package.

Certain technologies have taken center stage in the addition of traceability in packaging. Barcodes have taken a particular lead due to their inexpensive cost per packaging. Barcodes achieve the most important objective of an addition to any packaging; an identity. (Ghaani, Cozzolino, Castelli, & Farris, 2016)

By providing packaging with a unique number it now exists within a database, allowing for the supply chain to develop processes where old packaging can be written of and the corresponding ID number discarded, allowing for an overview of total packaging of each sort. Furthermore, having packaging type be expressly defined (as is already partially the case at VDL ETG Almelo) allows for insights into which packaging holds which part, possibly allowing for the reuse of otherwise discarded packaging.

Further technological developments in the field of packaging traceability aim to add an indicator to values relevant to the product being shipped(for instance, indicators for the freshness of food). As this research is aimed purely at creating more organization around the existing packaging, traceability additions that add information regarding the contents of the packaging are not useful, as the contents of the packaging already have unique ID's and clear destinations.

3 Departure time for packaging

Lastly there is a lack of a clear departure time. This problem directly causes a fair amount of late deliveries. Looking at the root cause, purchasers are responsible for their purchases, thus they in principle are also responsible for the timely delivery of packaging for the requested product. There is however no methodology for the purchasers to send packaging to the supplier at a pre-set date. This begs the question what inventory policy would best suit this section of VDL.

Whereas most inventory models are managed on the basis of demand rates, the majority of demand for VDL ETG Almelo is insufficiently cyclical, in the annex is data presenting example data suitable for automation. This will be shown in the next subchapter 4.4.3. What the literature (Winston, 2004) suggests provided insufficiently stable demand but a predictable forecast for the DOS window field is utilize a "Days of Supply" method, that operates based on this forecast.

Due to the nature of this assignment, priority lies in creating a solution that is variable to any changes or extremes that may be caused by emergency demand by a VDL customer, therefor the decision to stay away from highly uncertain and constantly changing demand rates in favor of deterministic forecast based on placed orders is the most logical approach.

4.4.3 Preliminary Research into Modernizing Purchasing

This section of research aims to investigate to what extent VDL may be helped by increasing autonomy within the purchasing segment of Parts Manufacturing. If this proves resourceful it may be worth noting in further recommendations that increased stability in the cycle packaging process could arise from

autonomy, allowing for instance a monthly shipment to certain suppliers giving the packaging required for the upcoming month.

In the Annex, A file called database orders is a modified version of an orders database from VDL for confidentiality reasons. Based on said database some clear patterns become apparent. Many of VDL ETG Parts manufacturing purchases fall within reasonable measure of cyclicality. This implies opportunities for automation.

Considering that much of the workload currently being done by the purchasing department is reactional (Parts Manufacturing purchasers turn pre-made purchasing advice into actual orders) and the step before purchasing (purchasing) does little more than set up simple cyclical demand based on an MRP.

Studies into intelligent Purchasing, show intelligent purchasing shows much growth potential (Alla-Chérif, Simón-Moya, & Ballester, 2021) (Martinez & Gitlow, 2011), numbers including notable savings, increased conformity leading to a more stable cycle packaging process, an accelerated purchasing process and more, proving there is plentiful opportunity for notable savings.

However, ineffective implementation of intelligent purchasing solutions, meaning an inability to change decision-making activities and roles performed by involved actors can lead to negligible if not negative effect (Caridi, Cavalieri, Pirovano, & Diazzi, 2004).

Concluding, modernizing purchasing holds great value for VDL in the future, but this potential can only be brought to fruition through meticulous planning, and an ERP system capable of embedding advanced functionality. This section of research therefor contributes to the solution only that this method of order creation is a sound, yet extensive option, left out of the consideration due to IT and scope constraints.

4.4.4 Supply Chain Management

This final section of research aims to answer parts of research questions one and three, specifically innovations and changes in regards to Supply Chain Management. This topic is taken separately from Innovative Solutions as this research subchapter is meant to conduct research with the intent of resolving the three key issues mentioned there. In this subchapter however, changes in the industry are observed to comprehend where the logistical arm of manufacturing industry is trending towards, as to ensure some research effort is made to "futureproof" any solution brought to VDL ETG Almelo.

For quite a few years now, supply chain research has shown that increased cooperation between supplier and customer leads to a better Supply Chain performance (Tjahjono, Ares, & Pelaez, 2017) (Li & Lin, 2006). Currently at VDL though communication lines are short and most purchasers can reach a relevant employee at a supplier within a day, there is no communication between systems. Though pilots and experiments have been run, strategic supplier relationships have not lead to IT investments to allow for decreasing manual steps, or information sharing.

Information sharing between customer and supplier has been proven to yield benefits such as increased financial performance, better performing production plants, a higher order fulfillment rate and shorter-order cycle time. (Li, Ragu-Nathan, Ragu-Nathan, & Subba Rao, 2006) A sound conclusion to make is to incorporate as much integration with suppliers as possible in the creation of order in the cycle packaging process. Furthermore, it is a worthwhile recommendation to invest further in supplier relationships.

Moving on to supply chain innovations; some of the most notable innovations to bring about significant reductions in the "ripple" effect (an effect that causes companies further down the supply chain to be

affected greatly to a Supply Chain disruption that could not be localized) as well as improvements to overall supply chain reliability are:

- Business intelligence
- The Internet of Things
- Automatic identification and data collection (AIDC)
- Radio-frequency identification (RFID)

These technologies are all known to have a notably positive impact on the supply chains they are successfully implemented in (Tjahjono, Ares, & Pelaez, 2017). The key now lies in finding methods to tie the newest Supply Chain Management innovations to the situation at hand at VDL ETG Almelo.

A notable limitation to the literature is that nigh all literature suggests implementation into the larger ERP system (Davenport & Brooks, 2004). Baan ERP is however currently at end of life, meaning no further investments are to be made coupling software to the program. This means a tool will have to be used or created that either:

- seamlessly integrates into the current ERP system
- operates separately from the ERP system in its entirety.

Literature suggests however that any communication between ERP and separate software that is not automated, is extremely error-sensitive. (Davenport & Brooks, 2004) This last piece information implies that a robust solution regarding cycle packaging must be one of two options:

- A solution that integrates into the ERP so seamlessly that it requires no programming.
- A solution that operates autonomously, either complementing or operating next to the operating system without requiring manual entries between the "solution" system, and the ERP system.

Combining the two main lessons learned in this sub-chapter, it is essential that cooperation with suppliers is encouraged, as insight into their supply chain can lead to tremendously better understanding of what leads to stock-outs. Their increased knowledge of VDL operations can allow them to better anticipate for potentially irregular demand from VDL and vice versa.

In addition, supply chain improvements (by means of software and/or hardware innovations) are best either autonomous in function and thus do not interfere with the ERP process, or seamlessly integrated in the ERP system and thus allow for a change in methodology of the stakeholders. This decreases workloads and increases supply reliability in the process.

5. Innovations

This chapter is meant to embody the majority of the fourth step in the Problem Solving Approach: "Sketch, convene and reiterate". As the previous chapter brought about numerous ideas and innovations to solve the core problem and/or it subproblems, this chapter is meant to converge from the knowledge gained back to a single manageable solution. This is done by looking back at the business, and using the knowledge gained to turn variables defined in the second chapter into measurable Key Performance Indicators (5.1).

After the stage is set, comes the time to bring together all potential solutions into a comprehensive list of tools and methods (5.2). Then, to rank and decide upon these tools and methods based on Decision Analysis provided in the MPSM (5.3). After this convergence into a single solution, the curtain is up, meaning the solution can be discussed in chapter 6.

5.1. Indicators

Finding indicators to measure the variables mentioned in chapter 2.7 that prove improvements over the present scenario are crucial in being able to present confidently why one's solution should be implemented. Below, 4 indicators are defined that together should represent the troubles found by VDL at present time, meaning improvement in all these 4 indicators is to accurately indicate the resolving of the core problem, and the subproblems caused as a consequence.

1 Amount of emails received

The main form in which VDL notices troubles regarding their purchasing cycle packaging process is through emails sent from their suppliers, therefor an effective solution to this problem should include the reduction and ultimately the end of this email traffic regarding missing packaging. An important note here is that only emails specifically regarding the purchasing cycle packaging process are taken into account.

2 Emergency shipment demand

Secondly, emergency shipments are the consequence of failing to do proactive sending of packaging, in addition to neither side reacting to the problem at hand before the situation is rendered an emergency. An organized procedure should have methods and systems in place to make the segment of demand supplied by emergency shipment lower, if not zero. Therefor looking direct at how frequently emergency shipments are necessary, shows for frequently the system in place failed to a notable degree, and therefor showing a lack of robustness. This indicator will have to be meticulously observed, as various emergency shipments are requested at VDL, without a causational log.

3 Time savings

Another indication of an improved process is a decrease in the amount of time spent on matters surrounding the cycle packaging process. Orderly process steps should erase the need to constantly communicate regarding obvious matters, such as when cycle packaging needs to be sent. Furthermore, clarity on what information is required for a seamless process (when should packaging be sent, address, etc.) should lead to new cycle packaging setups to be done at a notably faster pace.

4 Traceability of packaging

This last variable is meant to portray the increase in traceability due to the resolving of the core problem. This implies that whatever solution is to bring a more organized structure to the purchasing

cycle packaging process, should include as much traceability for "purchasing cycle packaging" as is economically feasible. (Implying not at greatly increased costs) This variable will be measured merely as a state value, the worst state being "no traceability" at all for purchasing cycle packaging, and any improved result will be considered a separate state, the more precise the location of the packaging, the better the score.

5.2 List of tools and methods

In the following subchapter all tools, methods and other matters relevant to a solution to the core problem are listed. A brief definition, and advantages and disadvantages are stated at once, to be referenced in the decision-making process in the following subchapter.

Automate cyclical purchasing orders

Presently, cyclical ordering is not a recorded part of the purchasing process. BaaN ERP makes advise based on BOM (bill of materials) requirements of each planned part, and thus makes ordering advice accordingly. This advice is always hand-controlled by the purchasers, assuring the right quantity, delivery time, etc.

The gap in this ERP purchasing process is however that only the "products" get ordered, and not the packaging that is required to ship said product, in case of single use packaging this problem is solved by having the ERP system treat the single use packages as separate products to be ordered simultaneously (listen in the BOM), ordering cycle packaging again every time though is not an option, meaning they are not on the BOM.

Researching the more stable and cyclical demand for products should identify parts that are frequently ordered without error (80/20 rule may apply) and set these processes up for full automation, perhaps with sporadic control.

The specific changes this solution brings are as follows:

- Purchasers will no longer setup each purchase, as the ERP system will now automatically order proven cyclical demand
- Purchasers will obtain the new task of analyzing their purchases for consistency, and as a result automatability

One could argue the amount of effort placed into these orders is relatively little (avg 50 a week for the Parts Manufacturing logistical team, Head of purchasing estimates an order placement to take 15 minutes, meaning (15*50)/60 = 12.5 hours weekly) and that the effort required for setting up and monitoring may be too grand for this effort to be worth it. It however a noteworthy change, as other departments within ETG Almelo have considerably more purchasing orders, totaling over 500 purchasing orders. Automating even a quarter of these orders would already lead to a significant decrease in man hours necessary to facilitate the purchasing process.

Value Stream Mapping (VSM)

This method, as extensively discussed in the Literature research, is a method meant to review a process in order to find the steps where customer value is created, and to eliminate or reduce waste. Considering the various different types of waste(Waiting, Transport, unnecessary inventory, unnecessary motion & Defects, for more details see chapter 6) relevant to this cycle packaging process, there appears to be sufficient reason to motivate VSM.

A limitation of VSM is however, that there is a moderate constant process that occurs repetitively. As was investigated in the literature research however VDL ETG Almelo's process appears to use production methods and a customer order type that allows for VSM to add value.

As described in *the current overview* a loophole in the current cycle packaging system is that broken packaging is rarely registered and processed. It is noteworthy to say one of the keystone issues that could be resolved by Value stream mapping is to sketch and realize a future state in which any broken packaging is registered in an orderly manner, removing the uncertainty of cycle packaging quantities.

Incorporate QR-codes into packaging process

The lack of traceability in the cycle packaging process can be in part accredited to the lack of (automated) documentation on packaging itself. The norm in the present form of transport is that each *product* has a barcode that can be scanned to obtain information and to register departure of this part. There is however no such infrastructure for the packaging. This idea stems from both interviewing and the literature research.

Incorporating QR-codes by pasting QR-codes on all cycle packaging would lead to an instantaneous trivial awareness of the location of the packaging, namely, where it was last scanned. This can be incorporated into the ERP system to arrive at an accurate warehouse capacity, allowing not only traceability but also better capacity indication.

This solution would lead to notable man hours being dedicated to placing the QR-codes on all cycle packaging In addition to the man hours spent on placing the QR-codes, organizing the underlying software infrastructure will also take some time, however this is not very complex.

This solution is considered a continuation of a proposed solution in the interview stage, namely *"Track every entry and departure from Hall 4"*

Automate picklist for packaging

As currently no adept software is in place to handle purchasing cycle packaging, this solution means the introduction of a program that looks at ordered materials and cross-references this information with how much packaging has been sent. By referencing this information, and combining it with packaging data such as delivery time and products per packaging an accurate list can be compiled of packaging that needs to be sent, varying degrees of urgency can then be presented to the materials handling professionals so they know what packaging is most behind.

The difference between this innovation and the first discussed innovation is that the first innovation specifically automates work for the purchasing department, whereas this innovation merely removes the manual task of communicating the daily orders to be sent from purchasing to Materials handling.

Determine responsibilities, and make stakeholders responsible for their part

This method embodies the numerous requests from various stakeholders to solidify responsibilities and create clarity as to whose responsibility it is to resolve issues in what segment of the cycle packaging process. In addition to an manager responsible for the process as a whole.

This method results from various solutions mentioned in the interview segment of this bachelor assignment.

Automate response to missing packaging

This proposed solution is to act on the basis of received emails, meaning that whenever a complaint is received an email is automatically sent to Materials Handling, extracting key information about what supplier has which shortage from the email, and then requesting materials handling to solve the problem.

Make packaging its own product with production paths

Considering the notable amount of physical labour required to manage the incoming and outgoing materials, the possibility of (partial) automation of the packaging process arises. Automation in this context implying that the majority of packaging no longer pass the materials handlers, but rather becomes a product of its own with final destination return to supplier. This would add considerable complexity however, as two process flows would then form for each purchased product.

Update ERP system with specialized packaging-software

Another proposed solution is the development of BaaN software upgrade to encompass cycle packaging, investing considerable amounts in the current ERP system could see warehousing software and BaaN purchasing capability upgrades lead to an integrated solution to the chaotic cycle packaging problem. This would require training purchasers to allocate packaging to each material when ordered,

Create a database of packaging – product combinations

This last solution is a solution specifically to the problem brought up at the end of subchapter 4.2. There it is mentioned that product X can not only go in packaging Y_{1101}, but also Y_{1102}, the warehouse storage database however only stores the amount of packaging for each type, thus not which packaging fits how much of which product.

5.3 Decision Analysis

In this section we hope to arrive at a selection of tools and methods that will lead to the most optimal solution to the core problem. This goal is achieved by using all information gathered so far. The variables mentioned in 2.7 are abstract, they therefor are not very suitable as a measurement of individual tools or methods. In 4.3 we narrow down the three core aspects of any innovation within the context of this research:

- What does it cost
- What does it save
- What information is gained

These criteria are now applied to arrive at a final selection of tools and methods that should be pursued, scores are given here, with a more detailed description of the scoring in Appendix xiii.

Task description	Measurement scale	Value Stream Mapping	Incorporate QR-codes into packaging process	Create a database of packaging – product combinations	Determine responsibilities, and make stakeholders responsible for their part	Automate response to missing packaging	Make packaging its own product with production paths	Update ERP system with specialized packaging-software	Automate cyclical purchasing orders
Realization cost & difficulty	1-5 (5 is easiest)	4	4	3	4	2	2	**1**	2
Time Savings	1-5 (5 is most time savings)	5	2	3	4	4	1	-	4
Added traceability	1-5(5 is most traceable)	2	4	4	1	1	4	-	1
Combined value	2-10 (10 is best)	**11**	**10**	**10**	**9**	**7**	**7**	**-**	**7**

Table 5: the definite scores for each innovation

Using the above methodology, the four leftmost tools and methods were selected as most resourceful improvements for VDL ETG Almelo.

6. Solution

In this chapter the solution to core problem is discussed, this will be subdivided into the following components:

1. Value Stream Mapping (VSM)
2. The software solution
3. Implementation
4. Maintenance

Each of these components is a vital part of redesigning this process into a more streamlined, data-driven and traceable process.

6.1 Value Stream Mapping

In order to solve the disorganization amid the cycle packaging process, a clear flow would have to come forth. The VSM methodology advises creating two maps:

- A current state map
- A future state map

6.1.1 Current Value Stream Map

Considering the use of VSM 4.0, an additional step has to be added to the traditional creation of a VSM (Meudt, Metternich, & Abele, 2017), leading to the following step process:

1. Determine the product family
2. Determine the material flow
3. Determine the information flow
4. Storage media are listed
5. Data points have to be connected
6. Data usage is checked
7. Analysis

Because most of the topics in the value stream map have been discussed before in this thesis, step 1 till 4 will only be briefly summarized below. These four steps lead to figure 10

The Product Family

Basically all packaging not considered relevant to this value stream map have already been taken out of consideration in chapter 4. Put simply, only cycle packaging is taken into consideration, particularly, only cycle packaging that takes part in the purchasing process.

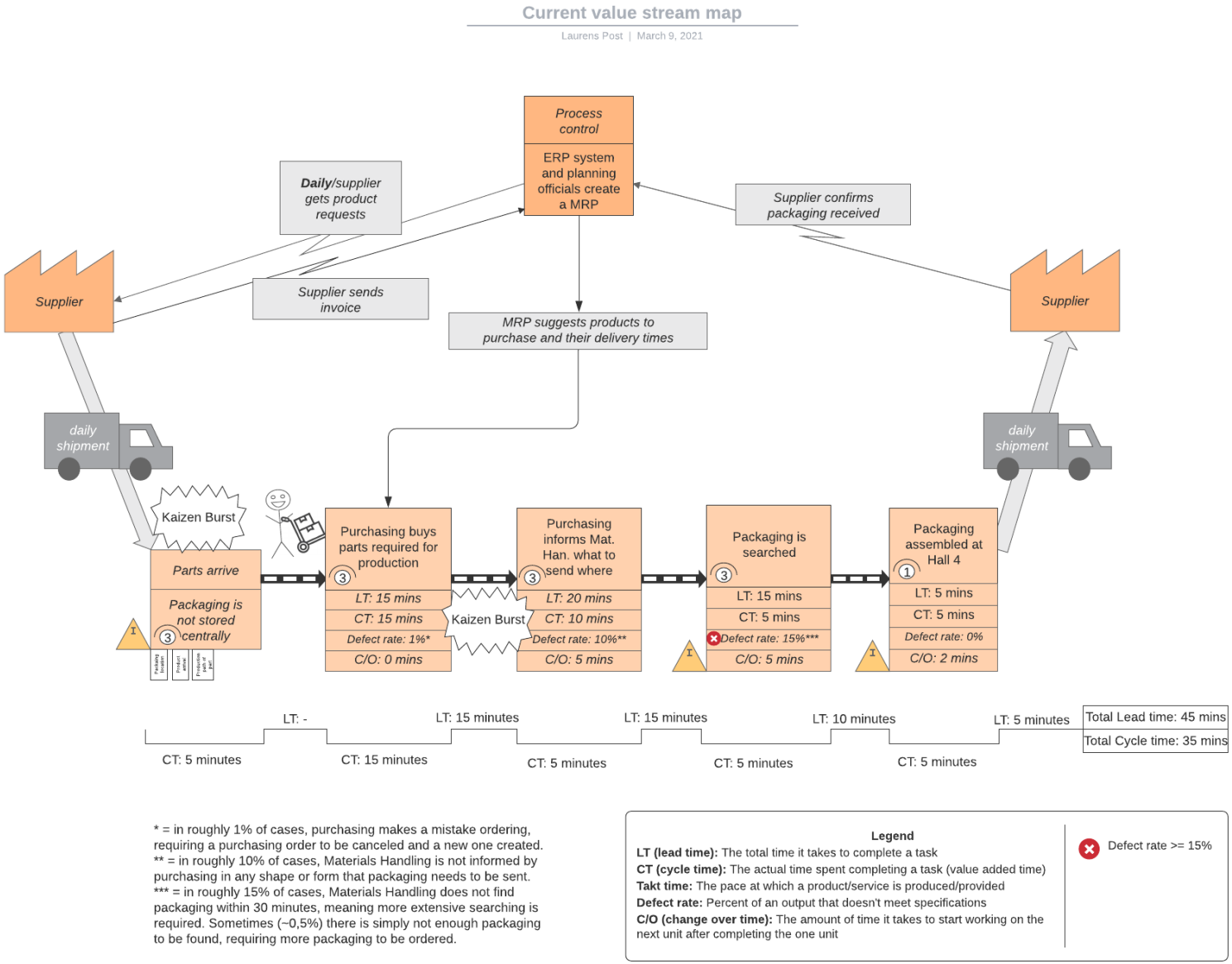


Figure 13 The current value stream map

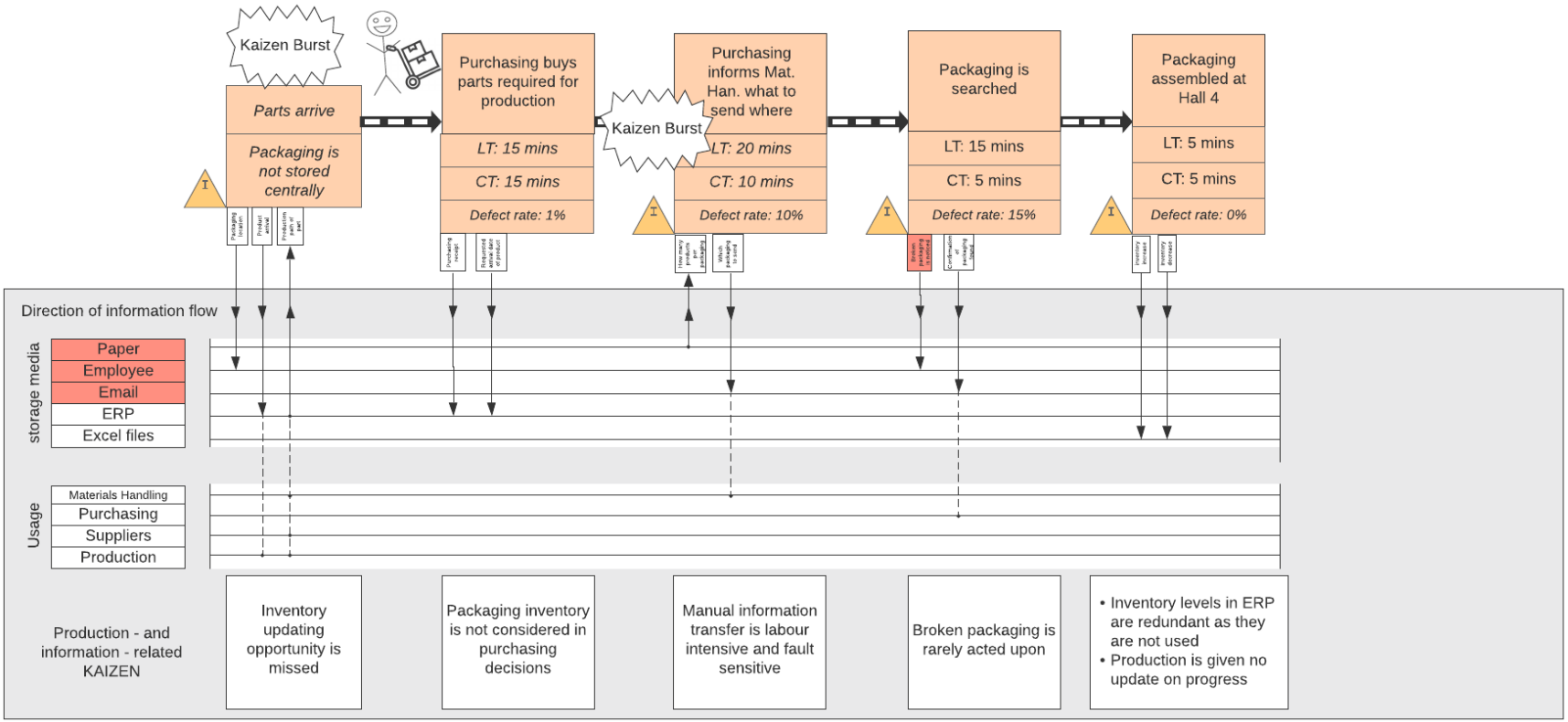


Figure 14 The current value stream map 4.0

The material flow

Here the VSM first starts to take shape. See figure 10 for the current cycle packaging process and its main steps. The three notes at the defect rates, elaborate the abstract "defect rates" provided in a typical VSM.

Information flow

The upper half of Figure 10 represents the information flow. Essentially four information flows exist:

- The supplier informs VDL that packaging has been received
- The supplier sends an invoice to VDL after sending finished products
- The suppliers receives new orders
- The ERP system translates the Master Resource Planning into upcoming Purchase requests and sends these to purchasers

The storage media

Figure 11 shows the storage media, with "Paper", "Employee" and "Email" marked in red, as these modes of storage most frequently lead to information not being universally and permanently accessible.

The connection between data points

Figure 11 shows the connections between the process and the data storage directly under each process description block. Each connection is stated in the Annex. The most important connection is called "Broken packaging is noticed". This connection, marked in red, is in the majority of cases (75%) not communicated, instead just being noticed, then destroyed. This recorded lack of communication verifies problems found earlier in the process regarding broken packaging.

Data usage

Data usage implies interaction of individuals with the data, in Figure 11, you can see the interactions as arrows going from the connectors such as the "Broken packaging is noticed" to the swim lanes representing the storage media. Furthermore, dotted lines going further than the arrows into the "Usage" section of the swim lanes represent information stakeholders. The groups marked by a dot in Figure 11 use the data point in order to information themselves or interested parties on the progression of the cycle packaging process.

Analysis

Lastly for the current situation, we arrive at the analysis. This analysis consists of two sections; KPI analysis on the basis of recommendations by authors of VSM 4.0, followed by a free section where the problems visible in Figure 10 & 11 are explained.

The literature suggests using three KPI's to measure the performance of the current process:

- Data Availability (DA)
- Data Utilization (DU)
- Digitization Rate (DR)

These variables require the organization to have "planned data points" which in the current state will be the same at the data points available, as no additional data points where envisioned for the current process. Due to the email requiring a "employee media break", it is considered a non-digitized process step

	Current cycle packaging process

Data points	11
Used data points	4
Planned data points	11
Data availability	100%
Data usage	36%
Digitization rate	45%

Table 6: Literature suggested Key Performance Indicators of the current process

The low Data usage and Digitization show that this process is not using the data at its disposal, in addition to using inefficient methods of data communication. These are both notable problems to combat in the future state.

Now we arrive at the free form section of the analysis, which elaborates on the current value stream.

Arguably the most urgent of problems was the absence of a trigger for the people in Materials Handling to know what packaging had to be sent. The core of this problem is that the purchasing department has no communication with Materials Handling besides communicating when problems in the supply chain occur (for instance, a supplier wanting to deliver a product but being unable to do so due to a lack of packaging)

Predictive communication ("the supplier will need this packaging at this date") towards Materials Handling is absent, meaning they are largely left using unguided sending methods. In some cases these methods meant "send packaging as soon as 5 of them have accumulated in the warehouse", this method, though effective given plentiful surplus of parts, is not desirable for the supplier for it is not self-regulating, the supplier now has the responsibility to check whether packaging has been obtained, and inquire about additional shipments of packaging.

The situation described above warrants a Kaizen Burst. A Kaizen Burst is a 3 to 5 day event that aims to shed light on the problems at hand in this subprocess. (USA, 2018) This method is applied in a concise form, meaning for Kaizen Burst "1" (marked in Figure 10), all purchasing and materials handling stakeholders are observed, then opportunities for improvement are discussed, the likeliness of success is brainstormed, and the improvements are implemented.

Kaizen Burst "2" in the front of the process is the next point of attention. Inventory management takes place insufficiently at part arrival. As mentioned in the problem analysis, improper handling of packaging upon receiving products in cycle packaging leads to packaging going missing for long durations of time, in addition to an unorganized workplace. In this Kaizen burst packaging and supply chain professionals spoke of the motivations behind behaviorisms, and similar to the previous Kaizen Brust, identified, selected and implemented improvements into the future state.

Lastly, there is the notably high failure rate in the second to last process step "Packaging is searched". This process, a near inevitable step in the process due to the frequency of packaging being insufficiently available, can have process defects, as the process of a timely delivery of packaging is hindered or halted altogether by the lack of this packaging. In the stated 15% of times, sufficient packaging to fulfill the packaging request by a supplier can not be located within 30 minutes. After these 30 minutes we speak of a notable disruption of the process, as multiple stakeholders start interrupting their daily activities to track down and locate packaging, or create alternate solutions.

Altogether the current cycle packaging process should take only 30 minutes of actual cycle time (actual time spent working on "producing" one timely packaging delivery). Searching however increases this total cycle time by 50%, up to 45 minutes.

6.1.2 Changes to the process

Three mayor shortcomings arose from the current Value Stream Map and prior process analysis:

1. No streamlined method for materials handling to process packaging
2. High frequency of searching for packaging, leading to shipping delays in the process as a whole
3. No clear information transfer about when packaging should go

Streamlining materials handling

The first shortcoming was debated with materials handling professionals to obtain more information regarding the obstructions they observed, and what solutions they had attempted. After this a brainstorming session concluded the following sub-process would help prevent packaging loss:

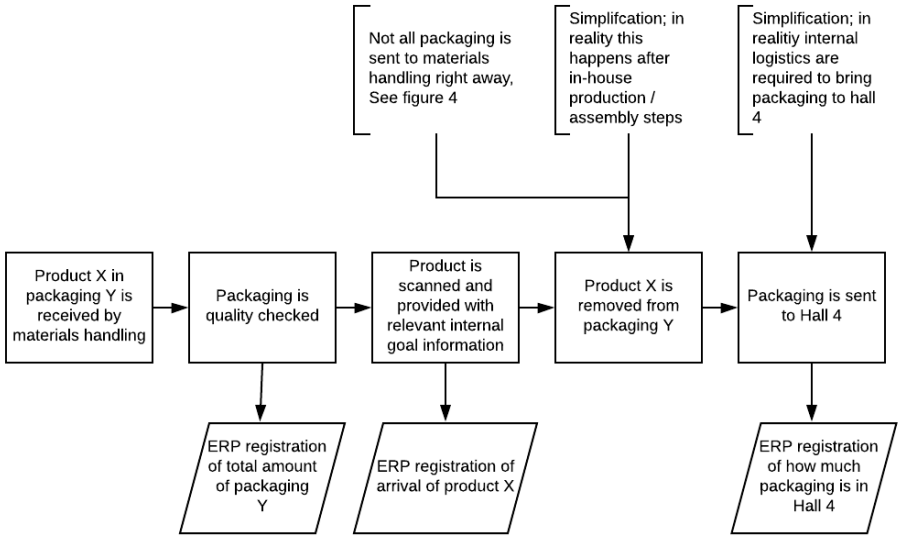


Figure 15 Revised product processing sub-process

Whereas the old process implied checking the packaging quality after product removal (if any quality control took place in the first place), the new process placed this task at the front of the process. The main result is the removal of unnecessary complexity.

In the old process doing packaging quality control was difficult, the process recommended quality controlling the packaging after product removal. This is complex however, as the majority of cycle packaging went into production along with the part, being returned to inventory at various points across the factory. The new process checks the packaging quality right at arrival (something that is possible, as packaging quality control is possible with the product still inside).

This solved half of the matter of lost packaging, as damaged packaging can now be identified and the total tally of packaging Y updated. The other half lies in production. As shown in Figure 4, production steps usually require taking the product out of packaging, and temporarily placing said packaging elsewhere. Though there is place for packaging adjacent to the production location, it is frequently insufficient to

place all packaging. This leads to further displacing of packaging loss. In addition, at various production steps products may receive different packaging, as the shape of the product has changed significantly. In both cases, packaging is regularly displaced. The solution to this side of the packaging problem falls outside of the scope of this research, as production takes place in various methods across the factory, varying notably. Uniform recommendations for this solution are however straightforward:

- Write in every relevant product process map explicitly, that packaging must be sent to inventory at the point is ceases to be of use.
- Materials Handling should track which process steps require the most additional packaging due to packaging going missing

This does not interfere with successfully improving process performance as it will become possible for VDL to measure the amount of packing at the supplier, in storage, and in total. Reducing the total from the supplier and storage count will give VDL the number of packaging currently in the internal process, a number that should match the amount of packaging required to move the products currently being manufactured in-house.

Packaging departure planning

The other notable change necessary involves linking the daily operations of materials handling to purchasing. This change involves creating implementing new communications between two departments that previous only communicated on a reactive basis (i.e. a shipping problem from purchasing getting reported to materials handling). Rather than this reactive basis, a proactive communication system can prevent emergency shipments and delays. More on the system itself in chapter 6.2.

The purchasing and the shipping processes are now tied together in a new process flow:

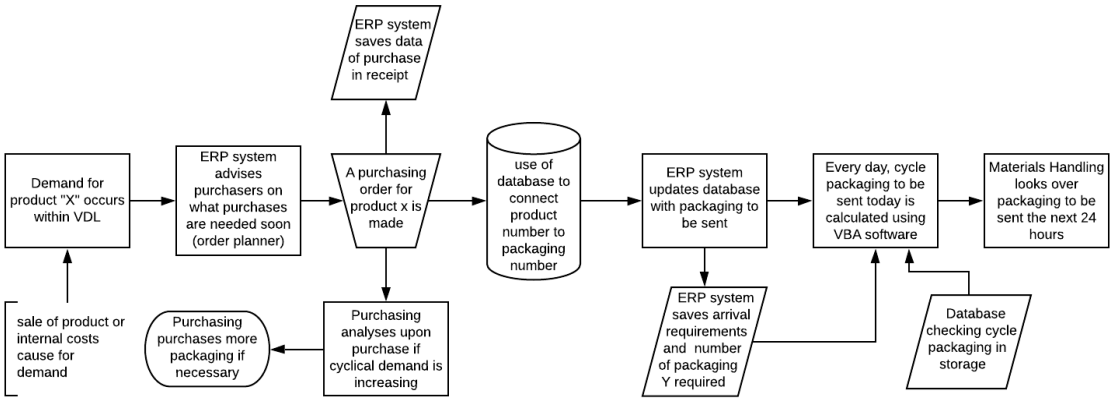


Figure 16 A connected process

In this process map it already becomes clear that the vital predictive communication between purchasing and shipping will be handled by using VDL's orders database in connection with the created cycle packaging program. After this initial setup, the process can now run based on a lean pull system, where only a customer order causes actions to be taken.

Having the core process in mind, many possible problems come to light in the further defining of the process. In many cases, the product requested by the purchaser requires packaging that is no longer in stock. In the present situation this would lead to communication requesting one such packaging, and in

many cases, mostly if the demand is urgent, a manual search through the VDL ETG Almelo facility in order to find said packaging.

To resolve this labour intensive issue, significant change is a necessity. Analyzing this chaotic process reveals the following additional causes of problems in the cycle packaging process:

No registration of:
- packaging location
- packaging in storage
- packaging in total
- changes in demand (regarding cycle packaging)

The conclusion is that data about cycle packaging presently is entirely absent. To solve this, a two-step approach is required. Initially a transition will have to take place, meaning the stakeholders must keep in mind that the program is not yet functioning, yet are providing the Cycle Packaging Software (CPS) with correct information. See subchapter 6.3 Implementation for more details regarding the transition process.

See the annex for the complete transition process, below the most important part:

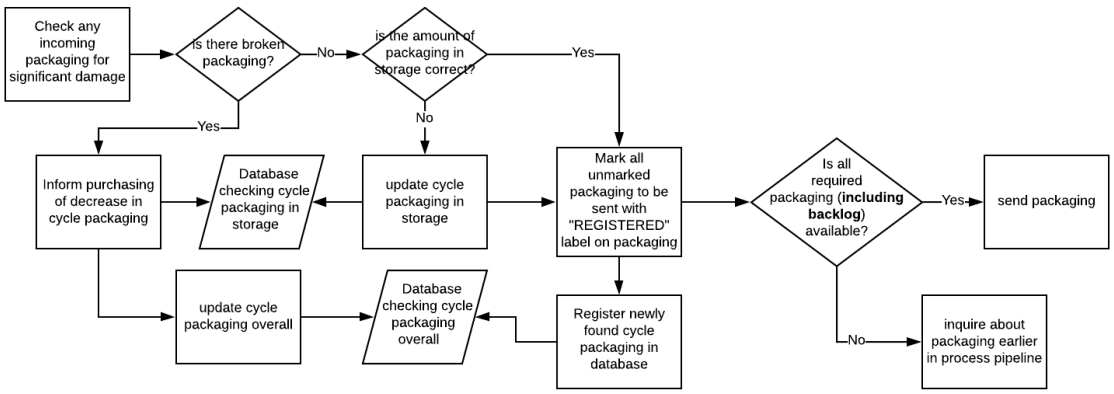


Figure 17 A section of the transition process

As is visible in the above process, the main distinct differences you will see between the final process in the annex and the transition process is the assumption that the software system is wrong (materials handling must still ask the question "is the number correct?"). This means some additional work in checking will be required:

- labels saying "Registered" or "Geregistreerd" will need to be placed on packaging in order to ensure the total amount of packaging can become clear.
- The above method of constant control over possible packaging breaking will be necessary in order to map the change in total packaging due to breakage.
- A regular check of all cycle packaging (selective daily check in transition phase) will be necessary to assure the "packaging in storage" database becomes reliable.
- Purchasing will need to start tracking changes in demand for cycle packaged products

The second step is the goal process. In this process the stakeholders can rely on the program and the program is fed reliable data by stakeholders, leading to an elimination of unplanned packaging shortages and searching altogether. This second step is described in the sub-chapter maintenance

6.1.3 Future Value Stream Map

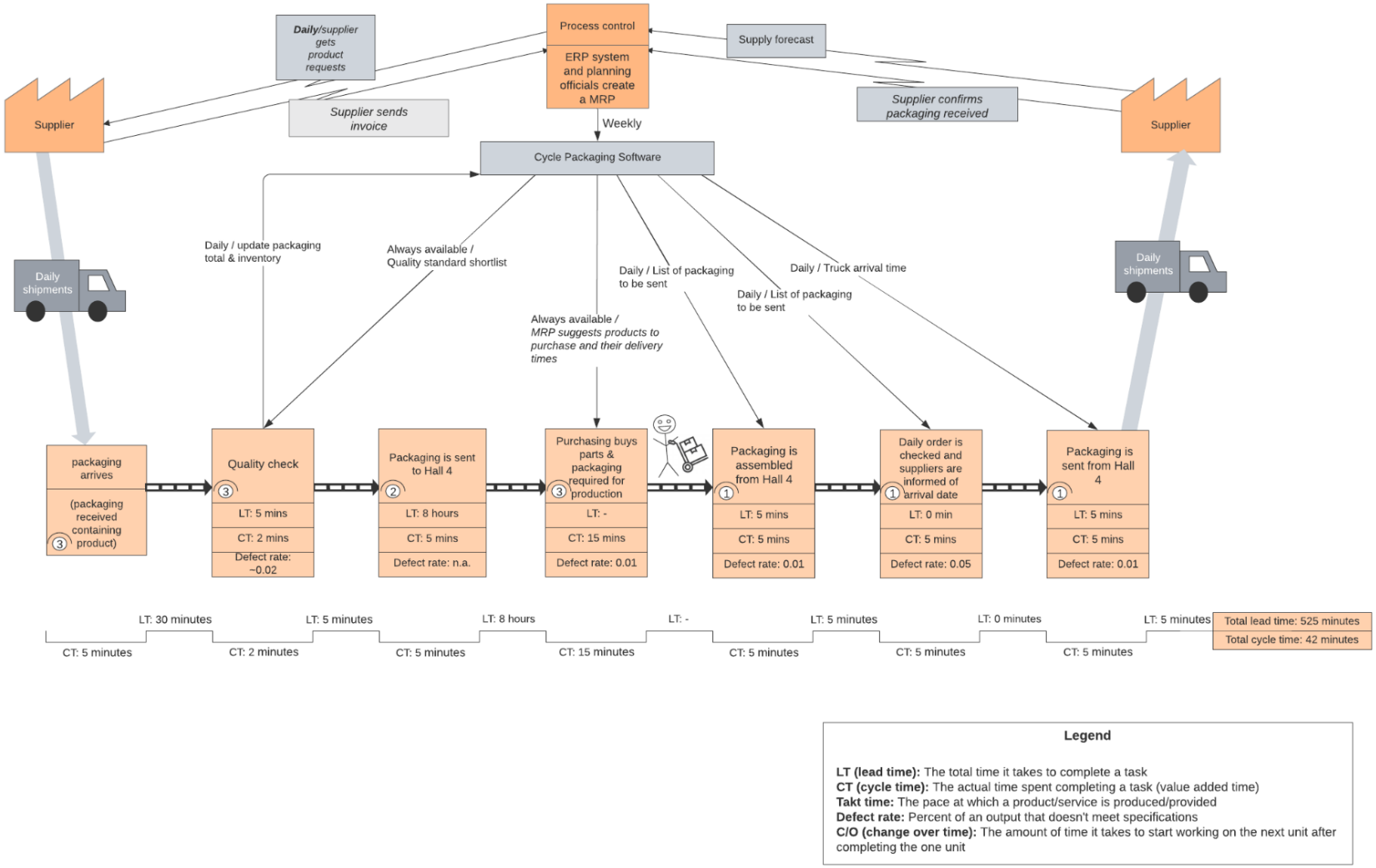
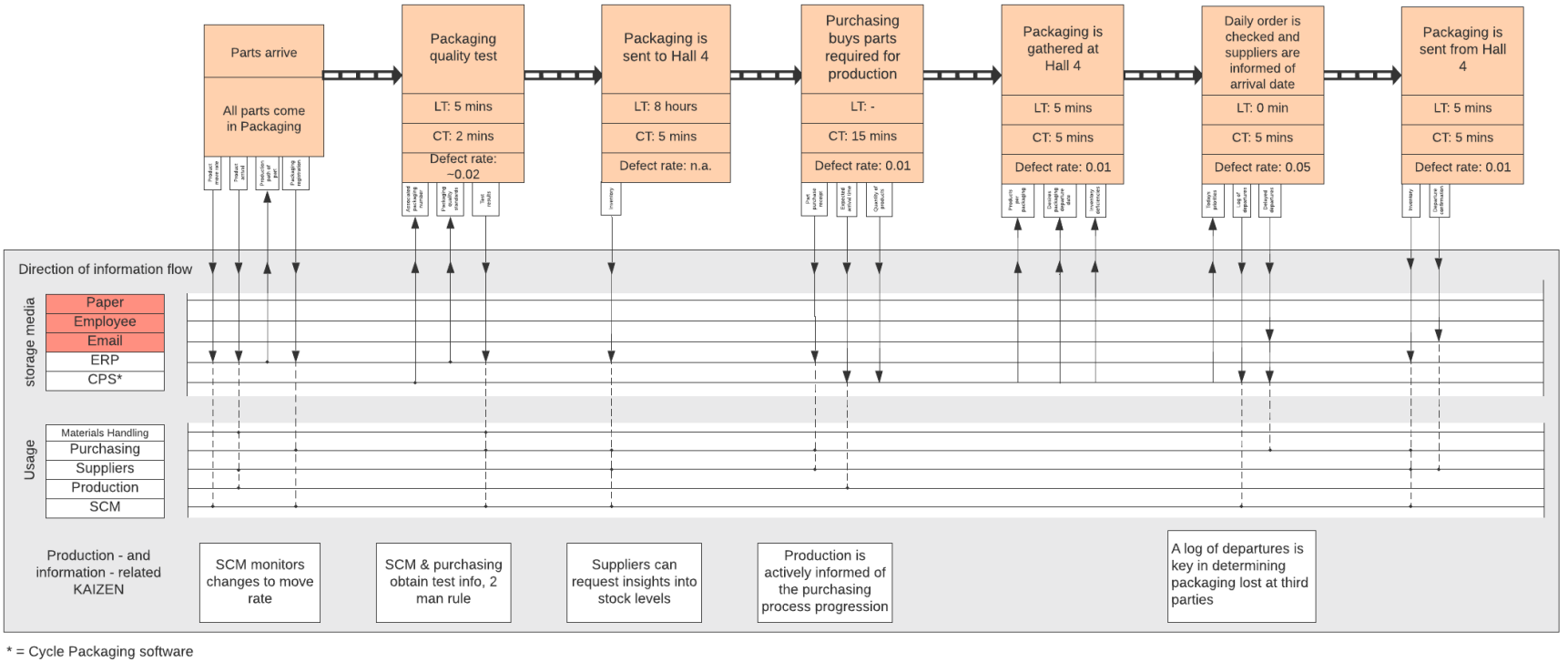


Figure 18 The future value stream map



* = Cycle Packaging software

Figure 19 The future value stream map 4.0

Due to the similar nature of the current and future value stream map, the material flow and product family remain identical, therefor not warranting these matters to be addressed here.

Information flow

The upper half of Figure 15 represents the information flow. The information flow in the new process is notably more complex, but comes down to two key changes.

Firstly, communication to the process is now more active, meaning each part of the cycle packaging process is sent information that can assist in their tasks, be it a Quality standard shortlist, or a packaging list to be sent.

Secondly, information the supplier needs out of the cycle packaging process is largely removed, as increased certainty and standard arrival dates remove the need for packaging updates. On the other side however, VDL can now request supply forecasting. With supply forecasting live updates on expected completion dates of products are meant. What successful implementation of supply forecasting means, is that VDL will have more time to adapt to changes in supply, in addition to cutting out many loopholes that arise when products are done early or late, the main advantages:

- VDL has more time to adapt to supply variation (dual sourcing opportunities)
- Packaging can be sent according to live data, enabling early delivery
- Removal of many unnecessary intermediaries in communicating supply updates
- Closer connectivity between VDL and its suppliers

The storage media

Figure 15 shows the storage media, much in the same way as in the current state, apart from the Cycle Packaging Software (CPS) and Supply Chain Management (SCM). CPS is the new software to be used by VDL to streamline information gathering and sending.

Supply Chain Management is also taken into the equation in the future value stream, as to include them in the increase of information obtained from the cycle packaging process. SCM can then more informed decisions about supplier delivery reliability, in addition to making more informed strategic decision regarding cycle packaging capacity and storage.

The connection between data points

Figure 15 shows the connections between the process and the data storage directly under each process description block. A key difference is the removal of the prior connection “broken packaging is noticed”, for it to be replaced with a comprehensive method preventing finding out about broken cycle packaging late in the process. In addition, the CPS takes a large role in the connection between data points, as it organizes data flows and outputs usable information for materials handling and other parties.

Data usage

Comparing the current to the future value stream map, one can arguably see the largest difference, it is evident in the increase from 6 data interactions to 20 that more stakeholders are informed of the information available, and more stakeholder are actively partaking in the upkeep of a reliable stream of information. This allows for the packaging to be held up to agreed upon standards, for materials handling to know when packaging can ideally be sent, and more.

Analysis

For the final part of the Value Stream Mapping section of the solution, the same approach is taken as was taken for the current value stream, KPI analysis on the basis of author recommendations, followed by free section.

The ideal analysis would require full implementation of the future value stream map, to compare which of the planned data points actual came into being and are consequentially in use in every day operations. Due to this information not being available, and the lack of comparison material as the current VSM lacked the same information, Planned data points will be considered equal to data points.

	Future cycle packaging process
Data points	19
Used data points	17
Planned data points	19
Data availability	100%
Data usage	89%
Digitization rate	95%

Table 7: Literature suggested Key Performance Indicators of the future process

To elaborate on the numbers. Data usage is 89%, due to it being 17/19. The two data points not in use are the following:

- Part purchase receipt
- Departure confirmation

The first data point remains an active part of this process as purchasing chooses to continue using purchasing receipts as a method of logging purchases besides their existent database. This means the data point is actively created and saved in the appropriate location every time, but cannot be considered a "used" data point. Next to this there is the "Departure confirmation", a data point created for the prevention of manual communication regarding the status of potentially urgent shipping. Due to the large variance of suppliers and extent of communication however, more work may be required to tailor these message to their recipients.

Next to these points, all data points have an evident and place in the cycle packaging process, a brief description of the contribution of each data point is given in the annex.

Digitization rate also does not consider "Departure confirmation" as digitized, as it not an integrated ERP solution, nor does it allow for information transfer without manual work. Besides the confirmation however, all communications regarding the cycle packaging process are now digital. Communications are archived and processed for later data analysis, this is paramount in long term process improvements, and in the short term optimal process performance measurement.

Now we arrive at the free form section of the analysis, which elaborates on the future value stream.

The first and foremost problem mentioned in the current value stream and numerous times before in this assignment; the absence of a trigger for materials handling, is resolved by proper implementation of the future value stream. Enabling these two parties to be informed fully of the matters at hand will come a long way in organizing the process.

Predictive communication is the vast majority of communication required in the future value stream, as any information needed regarding packaging to be sent or quality checks parameters automatically makes its way to materials handling. Any error in said information would be the reason for manual communication, meaning every manual communication is potential feedback that can help improve the process, or at the very least remove bugs.

Then there is the reduction in failure rate. As the largest contributor to the failure rate in the current process was searching for packaging. Removing this step altogether has made the (untested) process theoretically capable of achieving a no defects probability[1] of over 90% compared to under 75% in the current process.

The specific results of implementing the future value stream map are discussed in the chapter Conclusion, they involve:

- The ability to predict when stockouts of packaging will occur, and act preventively
- Insight into packaging surplus or deficit
- Insight into warehouse capacity
- Clarity regarding what packaging needs to be sent when
- Clarity regarding who is responsible for what part of the cycle packaging process
- Insight into average packaging lifetime, potentially usable to predictively reorder packaging
- A notable increase in productivity for purchasing and Materials Handling professionals
- A notable decrease in clutter
- Cost reduction due to a decrease in emergency shipments

[1] all probabilities of no defect multiplied, defect probabilities based on employee estimates or available data

6.2 The software solution

In this section of the solution, the software solution is presented. The software solution contributes largely to the filling of the gap between the value stream maps of the current and future state. The software solution implements a large number of selects tools into the final selection, see 5.3 for the selection process, the following tools are implemented into the CPS:

- Automate picklist for packaging
- Incorporate QR-codes into packaging process
- Create a database of packaging – product combinations (albeit not incorporated into ERP)

6.2.1 Front page

The front page is created primary as an overview tool for purchasing and supply chain management. It allows both parties to:

- Make changes to preferred delivery times
- Make changes to products per packaging
- Make changes to product-packaging combinations
- Manually add a priority packaging to be added to today's priority list
- Manually register a new purchaser

It allows all this in a safe environment where none of the usual data entry errors can occur, as nonexistent packaging numbers for example are not accepted. (New packaging should gets filed into the ERP system during the design phase, meaning no packaging should be missing from the database)

Should the facility need an extra copy of a prior priority list or wish to recalculate priorities due to an anomaly or change in the data, this can be done simply by pressing the "calculate priorities" button.

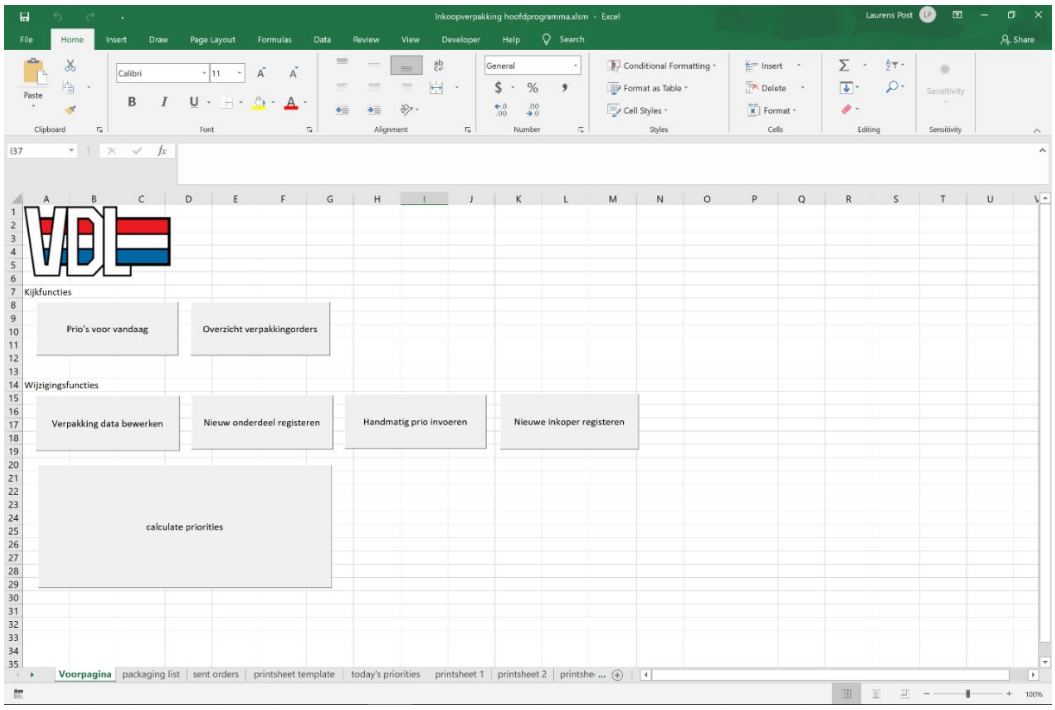
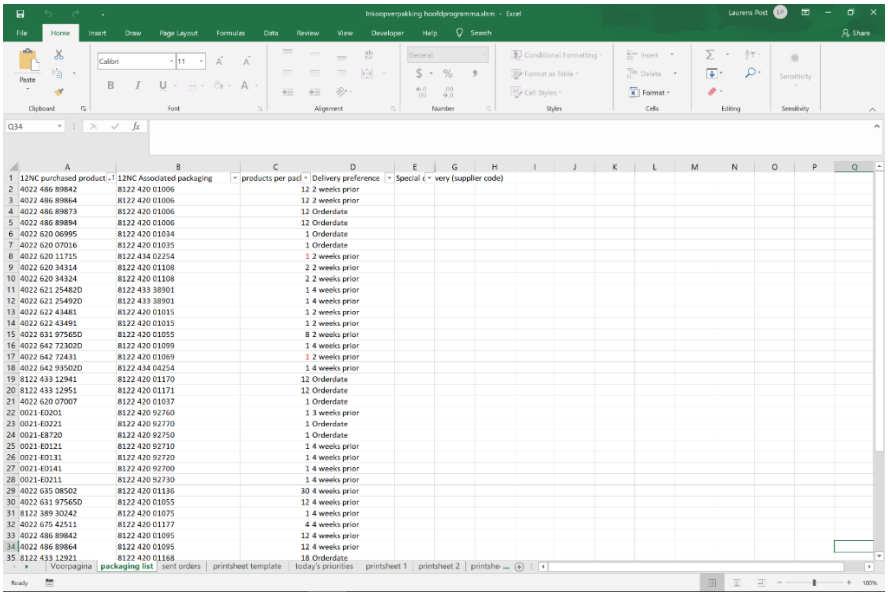


Figure 20 The front screen of the CPS

6.2.2 Packaging list

The packaging list is an overview of all data necessary to connect products to their associated packaging, as the ERP system does not offer this functionality. The CPS harbors all relevant product data required to inform materials handling on how much packaging to send when.

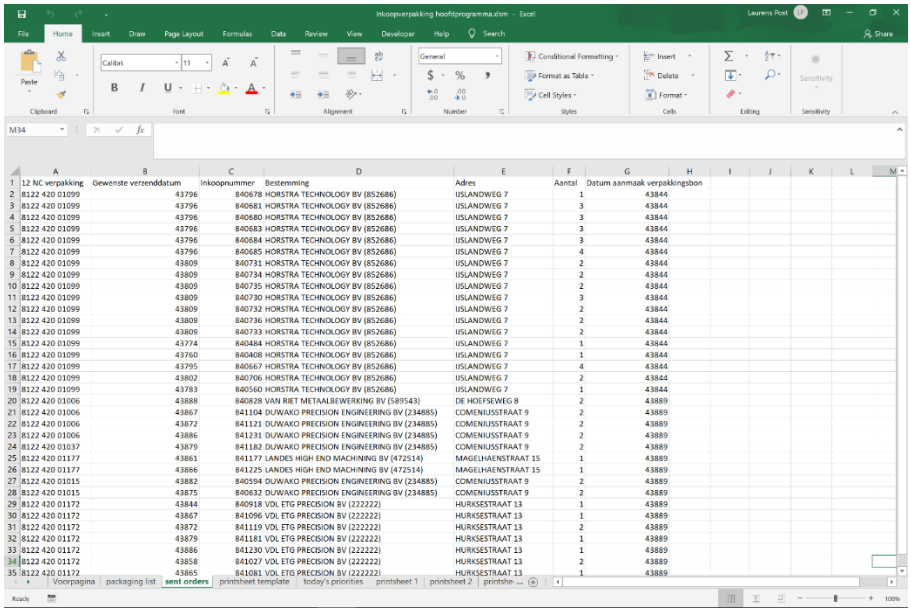


12NC purchased product	12NC Associated packaging	products per pacl	Delivery preference	Special (	very (supplier code)
4022 486 89842	8122 420 01006	12	2 weeks prior		
4022 486 89864	8122 420 01006	12	2 weeks prior		
4022 486 89873	8122 420 01006	12	Orderdate		
4022 486 89894	8122 420 01006	12	Orderdate		
4022 620 06995	8122 420 01034	1	Orderdate		
4022 620 07016	8122 420 01035	1	Orderdate		
4022 620 11715	8122 434 02254	1	2 weeks prior		
4022 620 34314	8122 420 01108	2	2 weeks prior		
4022 620 34324	8122 420 01108	2	2 weeks prior		
4022 621 25482D	8122 433 38901	1	4 weeks prior		
4022 621 25492D	8122 433 38901	1	4 weeks prior		
4022 622 43481	8122 420 01035	1	2 weeks prior		
4022 622 43491	8122 420 01035	1	2 weeks prior		
4022 631 97565D	8122 420 01055	8	2 weeks prior		
4022 642 72302D	8122 420 01099	1	4 weeks prior		
4022 642 72431	8122 420 01069	1	2 weeks prior		
4022 642 93502D	8122 434 04254	1	4 weeks prior		
8122 433 12941	8122 420 01170	12	Orderdate		
8122 433 12951	8122 420 01171	12	Orderdate		
4022 620 07007	8122 420 01037	1	Orderdate		
0021-E0201	8122 420 92760	1	3 weeks prior		
0021-E0221	8122 420 92770	1	Orderdate		
0021-E8720	8122 420 92750	1	Orderdate		
0021-E0121	8122 420 92710	1	4 weeks prior		
0021-E0131	8122 420 92720	1	4 weeks prior		
0021-E0141	8122 420 92700	1	4 weeks prior		
0021-E0211	8122 420 92730	1	4 weeks prior		
4022 635 08502	8122 420 01136	30	4 weeks prior		
4022 631 97565D	8122 420 01055	12	4 weeks prior		
8122 389 30242	8122 420 01075	1	4 weeks prior		
4022 675 42511	8122 420 01177	4	4 weeks prior		
4022 486 89842	8122 420 01095	12	4 weeks prior		
4022 486 89864	8122 420 01095	12	4 weeks prior		
8122 433 12921	8122 420 01168	18	Orderdate		

Figure 21 The packaging list

6.2.3 Sent orders

The sent orders tab servers as a log of all packaging sent at some point using the CPS. The information can be used to ensure the balance of arrivals and departures of packaging, in addition to serve as auxiliary proof that packaging was sent.



12 NC verpakking	Gewenste verzenddatum	Inkoopnummer	Bestemming	Adres	Aantal	Datum aanmaak verpakkingsbon
8122 420 01099	43796	840678	HORSTRA TECHNOLOGY BV (852686)	IJSLANDWEG 7	1	43844
8122 420 01099	43796	840681	HORSTRA TECHNOLOGY BV (852686)	IJSLANDWEG 7	3	43844
8122 420 01099	43796	840680	HORSTRA TECHNOLOGY BV (852686)	IJSLANDWEG 7	3	43844
8122 420 01099	43796	840683	HORSTRA TECHNOLOGY BV (852686)	IJSLANDWEG 7	3	43844
8122 420 01099	43796	840684	HORSTRA TECHNOLOGY BV (852686)	IJSLANDWEG 7	3	43844
8122 420 01099	43796	840685	HORSTRA TECHNOLOGY BV (852686)	IJSLANDWEG 7	4	43844
8122 420 01099	43809	840731	HORSTRA TECHNOLOGY BV (852686)	IJSLANDWEG 7	2	43844
8122 420 01099	43809	840734	HORSTRA TECHNOLOGY BV (852686)	IJSLANDWEG 7	2	43844
8122 420 01099	43809	840735	HORSTRA TECHNOLOGY BV (852686)	IJSLANDWEG 7	2	43844
8122 420 01099	43809	840730	HORSTRA TECHNOLOGY BV (852686)	IJSLANDWEG 7	3	43844
8122 420 01099	43809	840732	HORSTRA TECHNOLOGY BV (852686)	IJSLANDWEG 7	2	43844
8122 420 01099	43809	840736	HORSTRA TECHNOLOGY BV (852686)	IJSLANDWEG 7	2	43844
8122 420 01099	43809	840733	HORSTRA TECHNOLOGY BV (852686)	IJSLANDWEG 7	2	43844
8122 420 01099	43774	840484	HORSTRA TECHNOLOGY BV (852686)	IJSLANDWEG 7	1	43844
8122 420 01099	43760	840408	HORSTRA TECHNOLOGY BV (852686)	IJSLANDWEG 7	1	43844
8122 420 01099	43795	840667	HORSTRA TECHNOLOGY BV (852686)	IJSLANDWEG 7	4	43844
8122 420 01099	43802	840706	HORSTRA TECHNOLOGY BV (852686)	IJSLANDWEG 7	2	43844
8122 420 01099	43783	840560	HORSTRA TECHNOLOGY BV (852686)	IJSLANDWEG 7	1	43844
8122 420 01006	43888	840828	VAN RIET METAALBEWERKING BV (589543)	DE HOEFSEWEG 8	2	43889
8122 420 01006	43867	841104	DUWAKO PRECISION ENGINEERING BV (234885)	COMENIUSSTRAAT 9	2	43889
8122 420 01006	43872	841121	DUWAKO PRECISION ENGINEERING BV (234885)	COMENIUSSTRAAT 9	2	43889
8122 420 01006	43886	841231	DUWAKO PRECISION ENGINEERING BV (234885)	COMENIUSSTRAAT 9	2	43889
8122 420 01037	43879	841182	DUWAKO PRECISION ENGINEERING BV (234885)	COMENIUSSTRAAT 9	2	43889
8122 420 01177	43861	841177	LANDES HIGH END MACHINING BV (472514)	MAGELHAENSTRAAT 15	1	43889
8122 420 01177	43866	841225	LANDES HIGH END MACHINING BV (472514)	MAGELHAENSTRAAT 15	1	43889
8122 420 01015	43882	840594	DUWAKO PRECISION ENGINEERING BV (234885)	COMENIUSSTRAAT 9	2	43889
8122 420 01015	43875	840632	DUWAKO PRECISION ENGINEERING BV (234885)	COMENIUSSTRAAT 9	2	43889
8122 420 01172	43844	840918	VDL ETG PRECISION BV (222222)	HURKSESTRAAT 13	1	43889
8122 420 01172	43867	841096	VDL ETG PRECISION BV (222222)	HURKSESTRAAT 13	1	43889
8122 420 01172	43872	841119	VDL ETG PRECISION BV (222222)	HURKSESTRAAT 13	2	43889
8122 420 01172	43879	841181	VDL ETG PRECISION BV (222222)	HURKSESTRAAT 13	1	43889
8122 420 01172	43886	841230	VDL ETG PRECISION BV (222222)	HURKSESTRAAT 13	1	43889
8122 420 01172	43858	841027	VDL ETG PRECISION BV (222222)	HURKSESTRAAT 13	2	43889
8122 420 01172	43865	841081	VDL ETG PRECISION BV (222222)	HURKSESTRAAT 13	1	43889

Figure 22 The sent orders log

6.3.4 Printsheet template

Below are the templates used to present information to the materials handling professionals. The left showing an unfilled individual template for an individual packaging, this printsheet gets printed once for every packaging to be sent to a supplier, so the left template can serve as a address sticker, a packaging number verification, and a barcode at the bottom of the template for ease of increasing or lowering the amount in inventory. The right template is the overview template printed every workday for Materials Handlings professionals, meant to give a complete overview of what needs to be sent for Parts Manufacturing today, it provides a comprehensive list of how much of which packaging needs to be sent where today, as well as marking potentially troublesome packaging (shortage) and the purchaser responsible.

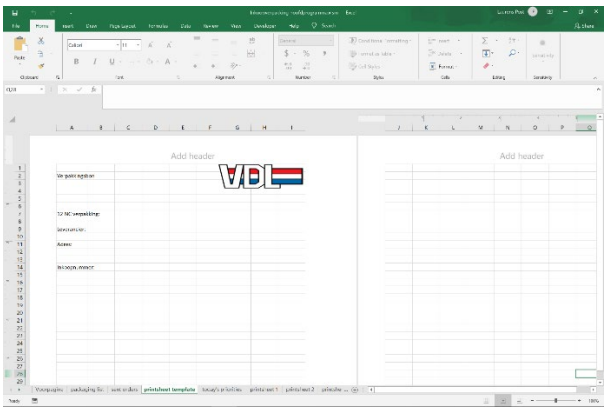


Figure 23 The individual printsheet template

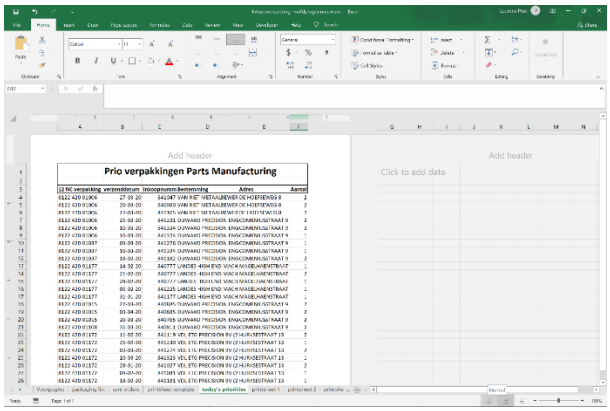


Figure 24 The overview template

6.3.5 Back office

Finally, there is the back office, in the annex is the full code used in the CPS, below is a brief summary of what the code does:

The code starts by opening and refreshing all relevant ERP database files that can be extracted using iQBS, once the information is available the code searches through all purchasing orders made in the last year. Every order with a delivery date in the past is immediately ignored, any order with a delivery date in the future or present starts a new process.

In the new process the relevant packaging and the relevant preferred packaging send date is found. Is the preferred packaging send date today or in the past? Then the "sent orders" tab is searched to see if this order was already shipped, if this is not the case, the CPS creates a print sheet for each packaging to be sent (so 4 print sheets when 4 packaging Y's must be sent in one order) in addition to adding a new row to the overview page describing the order and its destination.

Once all purchasing orders of the past year have been checked, the program proceeds to check all current inventory levels with the amount of packaging required of each type of packaging today. Each packaging that is not sufficiently in storage to send the sum of that packaging type needed today is marked red, after which the CPS automatically sends an email to the responsible purchaser.

After completing this cycle, the documents are printed, and the new delivery orders are archived in the "sent orders" tab.

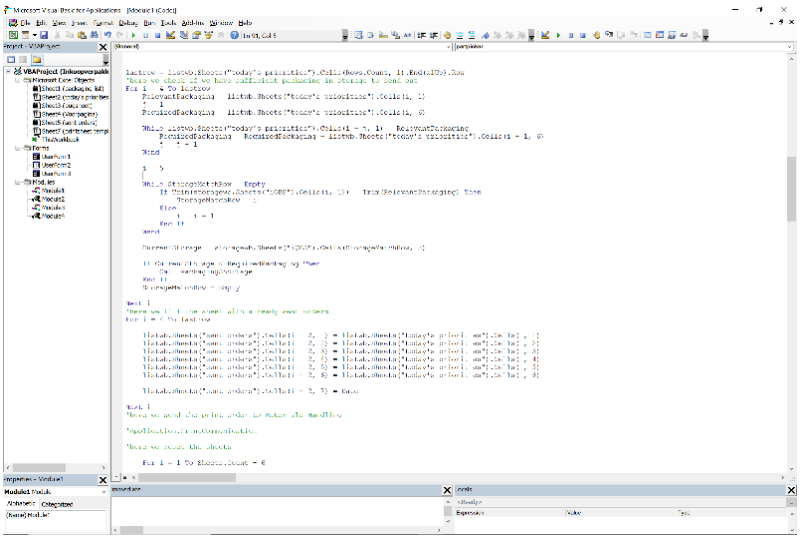


Figure 25 The VBA code behind the CPS

6.3 Implementation

In this subchapter the implementation of the solution described above is discussed. The main courses of action paramount to successful implementation are, these are important because, cost? None:

- Training staff
- Software implementation
- External parties

6.3.1 Training Staff

Changing the way various stakeholders operate on a daily basis requires a well thought out process that is a presentably superior alternative. The solution provided in the previous sub-chapters of chapter 6 show potential for notable improvement over the present situation. This cannot occur overnight however, notably because a reliable set of data can not appear overnight. VDL's ERP system luckily already provides accurate data regarding what product should arrive at VDL when. Data regarding packaging quantity, quality and location however is entirely absent at the offset of implementation. The transition process is meant to bridge this gap.

The primary goal of the transition progress is to accumulate information regarding cycle packaging, while not yet relying on the data available regarding cycle packaging. That data will however be an increasingly valuable asset as it becomes more reliable.

See the annex for the complete transition process, below the most important parts of the first step, the transition process:

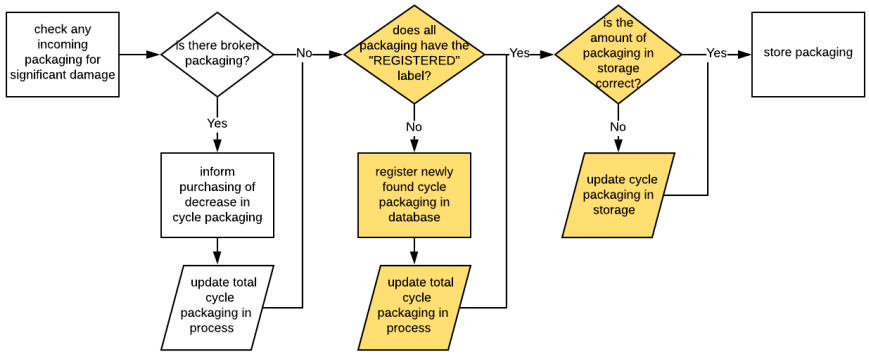


Figure 26 The transition process for receiving packaging.

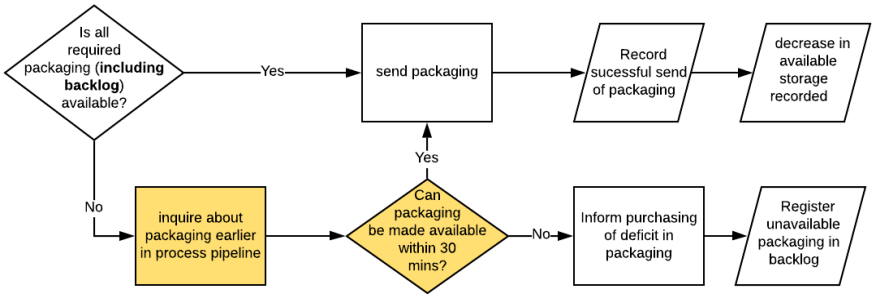


Figure 27 The transition process for sending equipment.

The main distinct differences between the final process in the annex and the transition process shown in figure 24 & 25 is the assumption that the system is wrong (i.e., materials handling must still ask the question "is the number correct?"). This means some additional work in checking will be required:

- labels saying "Registered" or "Geregistreerd" will need to be placed on packaging in order to ensure the total amount of packaging can become clear.
- The above method of constant control over possible packaging breaking will be necessary in order to map the change in total packaging due to breakage.
- A regular check of all cycle packaging (selective daily check in transition phase) will be necessary to assure the "packaging in storage" database becomes reliable.
- Purchasing will need to start tracking changes in demand for cycle packaged products

To assure this all occurs in a seamless manner, presentations at two key moments are needed:

- At implementation

At implementation, though most stakeholders have been involved in the creation of this improved process, it is vital to remind all involved of the importance of this change and the potential for improvement. Informing everyone on the goal and their part in realizing said goal is a final method to maximize stakeholder compliance.

- As soon as results are visible

Once results are visible, be it a decrease in problematic cases, or a realization of packaging deficiency, this should be an important moment for the implementing team to assemble those involved in this process. By informing all involved that the process is factually improving the quality of work at the location, stakeholder can remain motivated in this pursuit, solidifying the new process and setting the groundwork for other improvements to come.

6.3.2 Software Implementation

Software implementation consists mostly of a concrete to-do list of tasks to be achieved, after which guaranteeing successful operation through software and hardware updates is discussed in 6.4 Maintenance.

Software Implementation requirements are straightforward, a computer must have a recent version of windows (2010 or later) installed in addition to Microsoft Office. Furthermore, this computer needs to be tied into the VDL ETG Almelo network, to give it access to printers and internal emailing servers, in addition to the iQBS database containing vital information for the Cycle Packaging Software(CPS). The most recent version of the CPS should be available and openable on the computer.

For minimum manual interaction the CPS can be activated on an "always-on" computer, this allows the program to automatically provide all required services on every workday, provided it is maintained.

6.3.3 External parties

The primary change regarding external parties is that VDL must require its suppliers to provide information on when they wish to receive cycle packaging. Whereas in the past packaging was sent at will, the supplier must now inform when VDL can send packaging to them at the latest, this ensures that

- sufficient packaging is in supply at VDL
- the suppliers have sufficient space to store the packaging
- the suppliers have sufficient time to execute the process steps involving moving products

Once implementation is successfully executed, stakeholders can rely on the program and the program is fed reliable data by stakeholders, leading to an elimination of unplanned packaging shortages and searching altogether. Assuring the prevention of fallbacks is discussed in the following sub-chapter maintenance.

6.4 Maintenance

This last segment of the solution concerns the structure to be put in place to assure the solution continues to operate indefinitely. There are two section to this part of the solution, the software maintenance, and the process maintenance.

Software maintenance

The primary objective of software maintenance is assure the software can continue to execute the task it was created to do. In the context of this assignment two relevant factors come forward:

- Input variables must remain relevant

A key part of the success of the software's ability to improve the cycle packaging process, is its ability to contact the responsible purchaser in case of a shortage, so he has ample time to correct the shortage, and investigate the cause of the shortage. This is an example of a data point that in the end, needs to be filled manually. Though the software has built-in error messages to alarm the user of incomplete information, the head of purchasing will remain responsible for periodically updating the software to reflect reality.

In order to maximize the probability of this task not being forgotten, there must be a knowledgeable and in-depth oversight of what needs to be maintained. (Edberg, Ivanova, & Kuechler, 2014) This oversight was created and handed over to IT professionals in VDL ETG Almelo, visible in Appendix viii.

- Possible operating system / ERP changes must not break the software

This section of maintaining the solution lies primarily in the hands of the IT services of VDL ETG Almelo. This task is purposefully kept as simple as possible by requiring only two things to operate:

- The computer running the CPS must have Microsoft Excel version 2010 or later.
- The computer running the CPS must have access to the iQBS' database continually updated by the current ERP system.

Process maintenance

Process maintenance ties relies on the same tools to uphold effective use of changes, a comprehensive and in-depth oversight must be created and maintained, Figure 14 & 15 already provide an notable oversight into the process, but considering the iterative nature of value stream mapping, repetition and continuous improvement is key to prevent stagnation and eventually, falling back into disorder.

Due to this, the recommended path for the future of the cycle packaging process is to recreate this value stream map periodically. At this point the process can be reassess and possibly improved upon further, should there be new demands, challenges or upcoming changes.

7. Conclusion

The final chapter of this assignment answers the question; where the intended results achieved? To perfectly assess any result, the solution needs to be implemented fully for some time. At the time of writing this conclusion, the full process was not yet implemented. However, a large section of the solution involving the automating priority software (CPS) has been implemented, every step described in sub-chapter 6.2 is functional and in operation as of June 2020. This conclusion discusses the following topics:

- The performance of the solution for VDL.
- Recommendations for VDL based on this research.
- The academic value of this research.

7.1 Solution Performance

When looking at the solution performance, the variables in sub-chapter 2.7 come into place, the main variables to measure the process improvement are:

- Robustness
- Process performance
- Traceability

7.1.1 Robustness

Robustness, as stated before is a measure of to what extent the solution prevents process deviation, and if process deviation does occur, a robust process will overcome this. As the original process was far from robust it is difficult to measure prior performance to be compared to the solution. An indication of robustness will therefore be given by how long the process can operate without fail, and when a fail occurs, how long the process needs to recover.

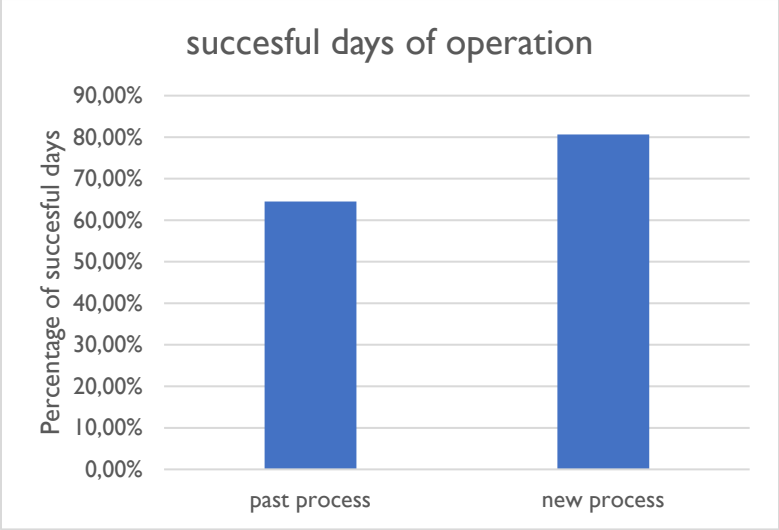


Figure 28 percentage of days without errors

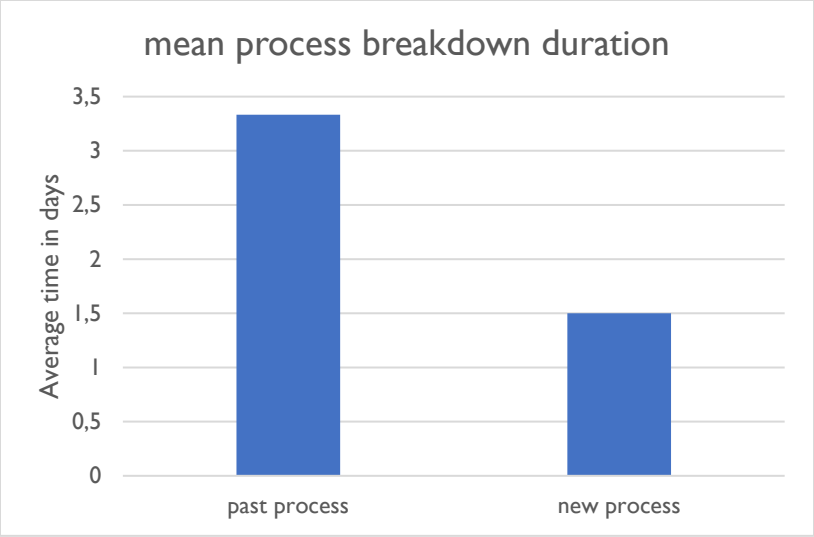


Figure 29 average duration of process errors

In Figure 28 "successful days of operation" is mentioned, a day is considered a successful day of operation if and only if:

- No requests were received for emergency packaging delivery.
- Materials Handling was able to send any packaging not out of stock according to the ERP.
- Any out-of-stock packaging was sent within 5 working days.

To help visualize the last demand, see figure 29:

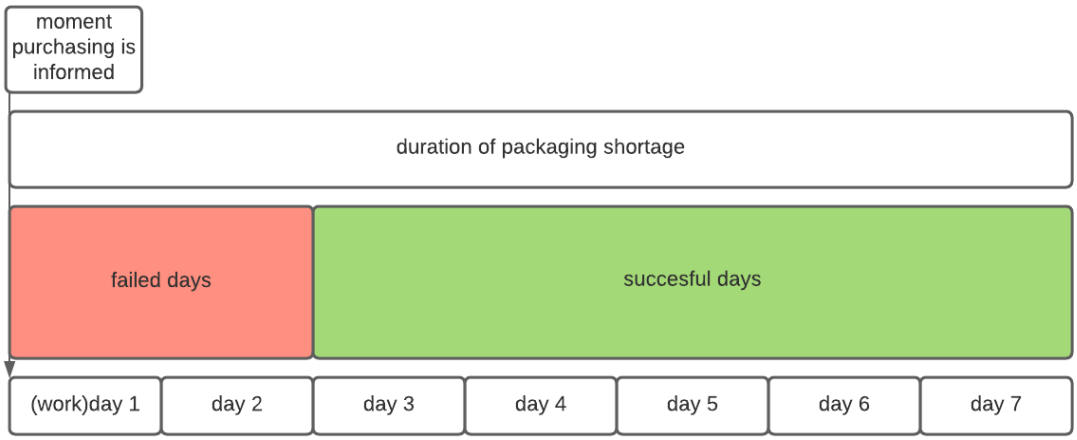


Figure 30 explanation of successful days

Figure 30 shows that when purchasing is informed of a packaging shortage, they are given one work week to find the correct packaging and allow the order to be sent. Starting 5 workdays after the request reached purchasing, every day starting from the first day a packaging shortage occurred, is considered a failed day until the packaging is sent.

In figure 25 and 26, two empirically measured data points come forward. 6 weeks of data (30 working days) from prior to solution implementation, and 6 weeks of data afterwards. These data were gathered over an identical timespan, however in different parts of the year. Mr. N. Machiels stated though fluctuations in demand for VDL exist, this did not affect the frequency of errors in the cycle packaging process.

Due to the recent increase in order portfolio (~50% 2018 -> 2021) for VDL the rate of failure was however expected to grow, providing further evidence the solution increased robustness notably. Concluding, despite increase in demand and a solution that was still in implementation phases, the robustness of the process has increased.

7.1.2 Process performance

With regards to process performance, the aim lies in proving the process performs better than it did before. In order to prove this, three metrics are used as discussed in indicators:

- Requests received

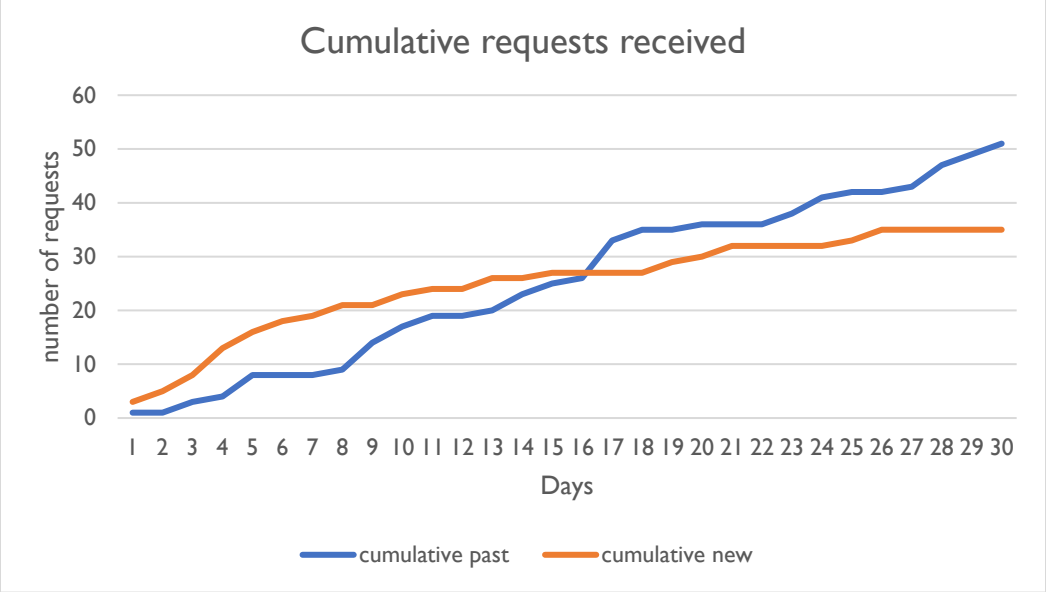


Figure 31 emails/calls received about cycle packaging.

In Figure 31, one can see the number of emails or calls received about packaging that needs to be sent, requested by suppliers. The "cumulative new" line shows data starting day one of implementation, a clear pattern can be deduced in which the amount of emails received sharply declined after activation of the Cycle Packaging Software and implementation of the new process.

An explanation for the initially higher request rate of the new process is that firstly demand was higher at the time of measuring the new process, and secondly due to increased packaging departures (in line with the proactive nature of the new process). Initially more packaging was required to meet both the immediate reactive demand, and to initiate the new process. This combination could, at times lead to packaging being sent preemptively, leading to reactive demand not being met. The problem was however solved soon by packaging searches and the improved registration of packaging.

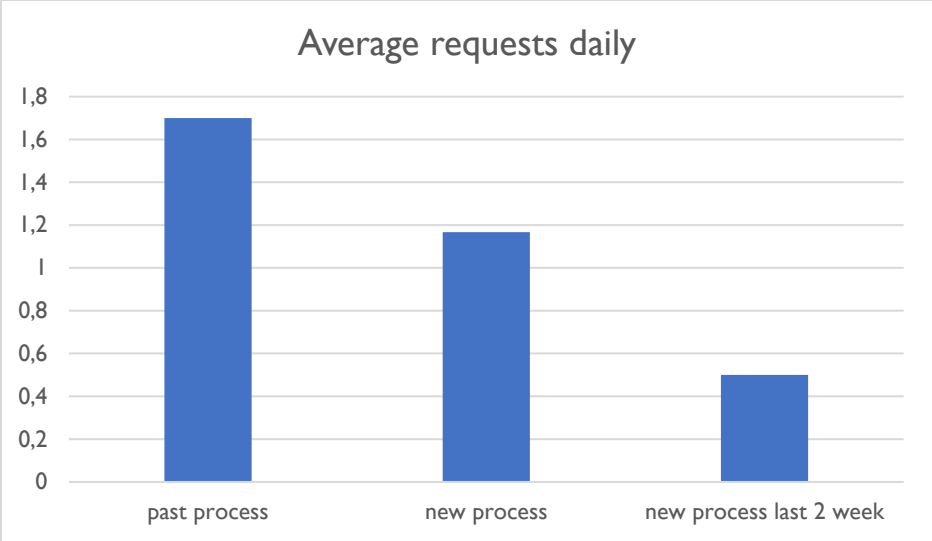


Figure 32 average emails/calls daily

Figure 32 regarding the email/call frequency clearly shows the steepness of the downward trend, although this data set does not prove elimination of the erroneous process that involved having to pursue packaging, it shows a notable decrease in the frequency searching had to take place and shows potential for a complete elimination of reactive packaging requests in the future.

- Emergency shipment demand

The emergency shipment demand is the most financially relevant indicator, as here VDL feels the direct financial consequence of having to send packaging last minute. It was not possible to gather data regarding this indicator as other sections of VDL ETG Almelo made use of emergency shipments and separating which emergency shipment served which purpose cannot be done with certainty.

Therefor the best level of information in the past can be gathered by estimation of relevant stakeholders. Stakeholders at purchasing (the only people that exclusively perceived emergency shipment demand from the purchasing cycle package process) estimated 2 monthly emergency shipments occurred, but that these emergency shipments would usually come in quick succession, for instance 4 in a week every 2 months.

The new process required 0 emergency shipments in the 6 weeks of measuring. Although the unstable nature of emergency shipments means the data may not be of sufficient length to guarantee the elimination of emergency shipment demand, it, alongside other evidence presented in this assignment suggest the demand in emergency shipping is heavily reduced, if not eliminated.

- Time savings

This aspect of process performance involves relieving the various stakeholders in the purchasing cycle packaging process of tedious manual tasks associated with the process. The information regarding this topic is a combination of information from purchasers regarding the amount of time they spent on the purchasing cycle packaging process starting two weeks after introduction and a calculation based on the emails/calls information in the "robustness" section of this chapter.

The first half, stakeholder feedback focusses on three stakeholders, purchaser R. van den Berg, purchasing assistant H. Peddemors, and materials handler A. Csigi. These people where asked some

months after initial implementation regarding their experiences. Below are the scores given to the past process on the left, and the new process to the right:

	Past process			New process		
	% of workload	Hours spent searching (month)	Hours spent communicating	% of workload	Hours spent searching	Hours spent communicating
Purchaser	2	4	4	2	0	3
Purchasing assistant	15	12	4	5	0	1
Materials handler	20	8	2	10	1	0

Table 8: workload reductions due to future cycle packaging process

Table 9 shows that the various stakeholders have all perceived a decrease in their required effort to keep the purchasing cycle packaging process (PCPP) running. Though these are not hard facts, stakeholders experience a decrease in workload which is positive in terms of time savings nonetheless.

As can be noted, the hours spent communicating by the purchaser has only decreased minimally, which can be in part accredited to purchasing's new responsibility to arrange missing cycle packaging, but also relates to the factory continuing to struggle to properly move packaging to storage after use in the factory. This however falls outside of the scope of this research.

Secondly there is the logical time saving calculation that can be done based on the perceived emergency emails and multiplied as done in 4.1, assuming the average amount of requests from the last 2 weeks:

17 hours monthly spent on the PCPP in the past.

5 hours monthly spent on the PCPP in the new process.

This amounts to a roughly 70% reduction of working hours in the new PCPP, with stakeholders stating the majority of tedious tasks being eliminated. Concluding, a notable amount of time was saved using the new process.

7.1.3 Traceability

Now on to the last variable defined in 2.7. Due to the intangibility of traceability, the traceability of the PCPP will be address through two metrics, the state method described in 2.7 and the digitization and usage rate described in 6.1.

The digitization rates of the past and new process are straightforward and stated below:

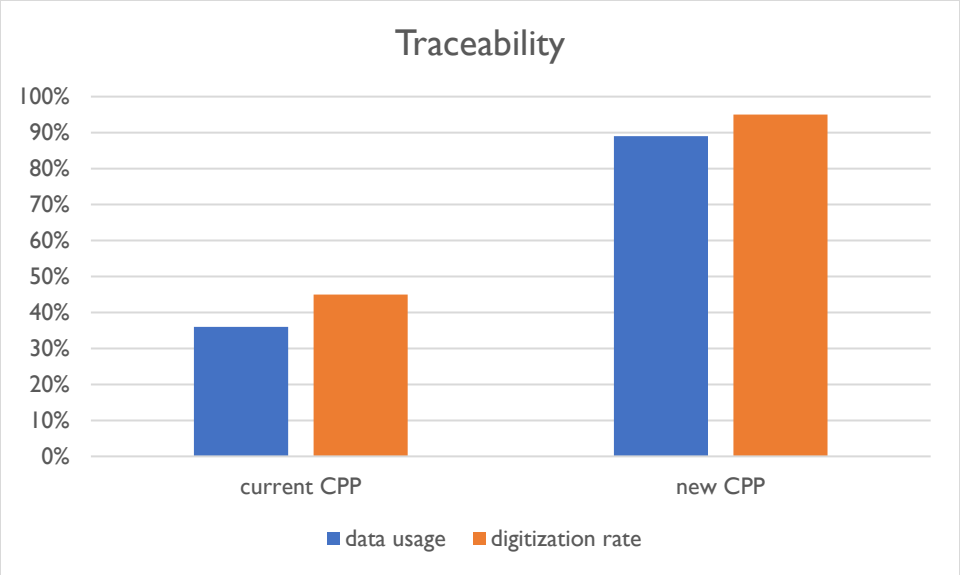


Figure 33 data usage and digitization rate

Though the figure does not provide direct concrete information on how much more traceable the average packaging is, it does provide an apt overview of the increases of information digitization and data usage in the new process. This insight means far more measurability, allowing to much easier deduce the source of any problems occurring to a single process step, this is indirectly visible in the decrease in mean process breakdown duration.

This leaves the state method. In appendix ix the exact state descriptions are given, the value ranks from 1 (no traceability whatsoever) to 5 (constant knowledge of packaging location). In this regard the past PCPP scores a 2, where the new process scores a 3.5. The reason for the 3.5 rather than 4 rating is that at the time of writing, there were still packages that were not registered. Meaning there is not 100% coverage in packaging. This problem is however expected to resolve over time, as the duration of a cycle packaging routine (VDL -> supplier -> VDL) rarely exceeds a year.

In summary, this solution has provided VDL ETG Almelo with:

- The ability to predict when stockouts of packaging will occur, and act preventively
- Insight into packaging surplus or deficit
- Insight into warehouse capacity
- Clarity regarding what packaging needs to be sent when
- Clarity regarding who is responsible for what part of the cycle packaging process
- Insight into average packaging lifetime, potentially usable to predictively reorder packaging
- A notable increase in productivity for purchasing and Materials Handling professionals
- A notable decrease in waste
- Cost reduction due to a decrease in emergency shipments

Accumulating all the individual indicators and variables into a single overview, in Figure 34. The scoring of this overview is explained in appendix x, in addition to a brief motivation of the values admitted in the 0 to 10 scoring.

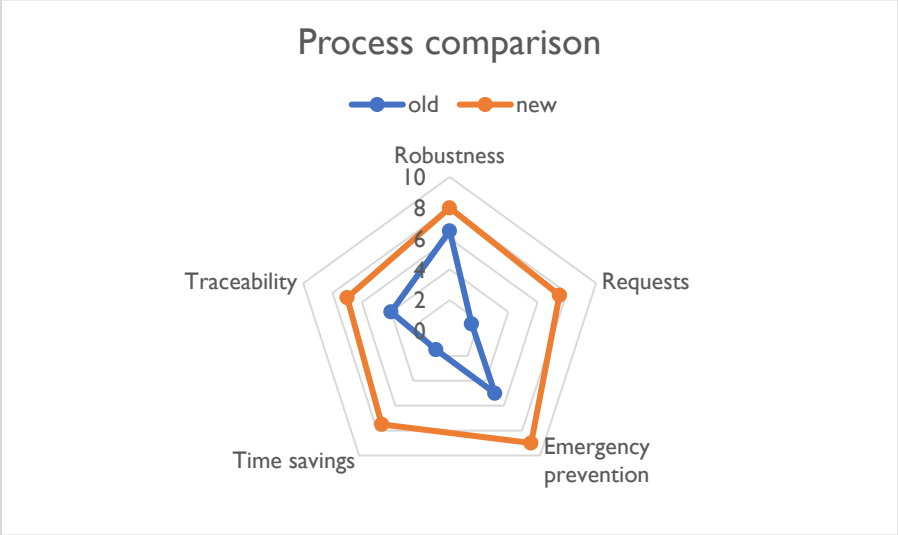


Figure 34 old and new process comparison

This chart provides the overview of performances changes brought about by implementation of the solution discussed in this assignment. Concrete results show clearly the increase in robustness, traceability and process performance solving the core problem.

7.2 Limitations

This solution was implemented for a small section of VDL ETG Almelo, namely the purchasing department of Parts Manufacturing, whether this solution will provide similar results throughout VDL ETG Almelo is up for speculation, and is largely dependent on process similarity, technical knowhow, and the communications struggle of implementing an improved process if some stakeholders do not feel the advantage of said improvement.

7.3 Recommendations

Even when the core problem is resolved, there are some suggestions to VDL ETG Almelo in order to facilitate further progression, and increase process performance to a further extent. These recommendations are as follows:

- Analyze what segment of VDL demand for products is cyclical, if this number is significant, consider automatization.

Though the ERP system already employs cyclicality for the basis of purchasing advice, some products show an extent of cyclicality that make full automation of the order seems logical. Though this research is not aimed at reducing the workload of purchasing, the purchasing database gives clear indication of products that are candidates for higher levels of autonomy.

- Directly tie the packaging ID number to the product ID, allowing for a sturdier bond of product and its shipping material

This point primarily ties into an unused section of VDL ETG Almelo's ERP system. A limited amount of products have the relevant packaging alongside the product written in the bill of materials within the BAAN ERP system. This is however sporadically the case, to the limited extent that extracting this information into an iQBS database is currently not feasible for implementation into the (CPS)Cycle Packaging Software. Should factory engineers choose to pursue this registration effort more seriously, it could eliminate the need for purchasing to manually fill in which packaging belongs to which products. The end result would be a further reduction in the work required to keep the CPS functional as new products enter production at VDL.

- Consider applications in other VDL (ETG) facilities

Due to the independent operating methods of VDL ETG branches, their processes are not very similar, and different ERP systems are used in the international offices of VDL ETG Switzerland, China and Singapore. The conclusion to draw from the level of independence each international ETG branch has, is that this process cannot be direct copied for other international branches. It can be used to trigger an international conversation about logistical improvement, and start similar VSM studies to trigger logistical efficiency. For this reason, the communications office at VDL ETG Almelo intends to mention this innovation among others at the next ETG wide progression meeting, a yearly event.

For the other national branch VDL ETG Eindhoven this research may have more direct results, therefor this report in addition to the created program (CPS) was communicated to the head of logistics in Eindhoven.

- Let suppliers fill in far ahead when they want packaging.

In the literature research, specifically 4.4.4. It became apparent that closer collaboration between VDL and its partners is scientifically proven to benefit both parties in revenue and efficiency. One concrete example of collaborating with suppliers if for suppliers to gain access to a portal or method of data communication, that would let the suppliers fill in how long beforehand they would like to receive cycle packaging. This again removes the need for purchasing to manually fill in and inquire about these values, but instead allows suppliers themselves to do this, in addition to giving them the possibility to change these values, should both parties agree.

- Upgrade the CPS to automatically give a notification on when to reorder packaging.

The CPS currently does not recommend when to purchase more packaging, though it does use information originating from the inventory database to determine whether sufficient packaging is in store. This in combination with full packaging inventory registration (knowing how much packaging you have, and where it is) would allow the move rate calculation to run on a daily basis within the CPS. This would require no extra effort but give the purchasing department autonomous updates on when their own formulas indicate that an inventory (including WIP) level is reached based on updated move rates and inventory.

- Link the CPS to the new ERP system

Though this point is highly speculative as the new ERP systems capabilities are unknown and years out, there is legitimate potential within the CPS software to write and read directly from ERP databases, allowing for seamless integration into a potential new ERP system, reducing the severity of change upon first implementation of the new ERP system.

- Move to industry 4.0? (Meudt, Metternich, & Abele, 2017)

The internal factory lacks vital data points to aid in tracking cycle packaging and products themselves in the factory. Allowing IoT solutions to be implemented in not only packaging, but products, storage locations, manufacturing machines and workstations would allow vastly more insight into what causes most delays, and what key products lead to a storage overfilling.

- Create a causational log for emergency shipments

Though outside the scope of this research, the occurrence of emergency shipments is a fair indicators of challenges in other logistical processes, registering the cause of every emergency shipment sent out could be a valuable source of information to Supply Chain Management in determining their primary optimization priorities.

7.4 Academic value

This research is a successful case study of the VSM 4.0 process improvement method applied to the logistical arm of an MTO manufacturing operation. This study can be used as reference for any manufacturing companies without the ability to fully integrate their cyclical logistics into their ERP system. This study uses a novel implementation of the VSM 4.0 method, which can be used to reflect on the strengths and weaknesses of this VSM variant in future iterations.

Furthermore, this research shows the validity of the MPSM method for solving organizational problems within manufacturing companies. This study can therefore be used as a reference leading to the decision to use this methodology.

References

Alla-Chérif, O., Simón-Moya, V., & Ballester, A. C. (2021). Intelligent purchasing: How artificial intelligence can redefine the purchasing function. *Journal of Business Research, 124*, 69-76. doi:https://doi.org/10.1016/j.jbusres.2020.11.050.

Baan Timeline. (2008, 04 06). Retrieved 06 10, 2021, from baanboard: http://www.baanboard.com/node/1707

Bueno, A. F., Filho, M. G., & Frank, A. G. (2020). Smart production planning and control in the Industry 4.0 context: A systematic literature review. *Computers & Industrial Engineering, 149*. doi:https://doi.org/10.1016/j.cie.2020.106774

Cao, S., Chan, K., & Elkamel, A. (2019). A Controlled Experiment Investigating the Effects of Explanatory Manual on Adherence to Operating Procedures. *Safety*. doi:https://doi.org/10.3390/safety5020019

Caridi, M., Cavalieri, S., Pirovano, C., & Diazzi, G. (2004). Assessing the impact of e-Purchasing strategies through the use of business process modelling and simulation techniques. *Production Planning & Control, 15*(7), 647-661. Retrieved from https://www-tandfonline-com.ezproxy2.utwente.nl/doi/full/10.1080/09537280412331298175

Cicmil, S., & White, G. R. (2016). Knowledge Acquisition Through Process Mapping: factors affecting the performance of work-based activity. *International Journal of Productivity and Performance Management, 6*, 303-323. doi:10.1108/IJPPM-01-2014-0007

Dal Forno, A. J., Pereira, F. A., Forcellini, F., & Kipper, L. M. (2014). Value Stream Mapping: a study about the problems and challenges found in the literature from the past 15 years about application of Lean tools. *International Journal of Operations & Production Management, 17*, 46-64. doi:10.1108/01443579710157989

Davenport, T. H., & Brooks, J. D. (2004). Enterprise systems and the supply chain. *Journal of Enterprise Information Management*, 8-19. doi:10.1108/09576050410510917

Edberg, D., Ivanova, P., & Kuechler, W. (2014). Methodology Mashups: An Exploration of Processes Used to Maintain Software. *Journal of Management Information Systems*, 271-304.

Ferilli, S. (2014). WoMan: Logic-Based Workflow Learning. *IEEE Transactions on Systems, Man, and Cybernetics: Systems, 44*(6), 744-756.

Ghaani, M., Cozzolino, C. A., Castelli, G., & Farris, S. (2016). An overview of the intelligent packaging technologies in the food sector. *Trends in Food Science & Technology, 51*, 1-11. doi:https://doi.org/10.1016/j.tifs.2016.02.008

Hartmann, L., Meudt, T., Seifermann, S., & Metternich, J. (2018). Value stream method 4.0: holistic method to analyse and design value streams in the digital age. *Procedia CIRP*, 249-254. doi:https://doi.org/10.1016/j.procir.2018.08.309.

Heerkens, H., & van Winden, A. (2017). *Solving Managerial Problems Systematically*. Enschede: Noordhoff Uitgevers bv.

Hines, P., & Rich, N. (1997). The seven value stream mapping tools. *International Journal of Operations & Production Management*, 46-64. doi:10.1108/01443579710157989

Kanbanize. (2020, 06 10). *What Is Value Stream Mapping? Definition and Details*. Retrieved 06 10, 2021, from Kanbanize: https://kanbanize.com/lean-management/value-waste/value-stream-mapping

Knoll, D., Reinhart, G., & Prüglmeier, M. (2019). Enabling value stream mapping for internal logistics using multidimensional process mining. *Expert Systems with Applications, 124*, 130-142. doi:https://doi.org/10.1016/j.eswa.2019.01.026

Koch, C., & Lödding, H. (2014). Requirements for a Value Stream Mapping in Make-To-Order Environments. *IFIP International Conference on Advances in Production Management Systems* (pp. 391-398). Hamburg: Springer. doi:https://doi.org/10.1007/978-3-662-44733-8_49

Li, S., & Lin, B. (2006). Accessing information sharing and information quality in supply chain management. *Decision Support Systems, 42*(3), 1641-1656. Retrieved from https://www-sciencedirect-com.ezproxy2.utwente.nl/science/article/pii/S0167923606000327?via%3Dihub

Li, S., Ragu-Nathan, B., Ragu-Nathan, T. S., & Subba Rao, S. (2006). The impact of supply chain management practices on competitive advantage and organizational performance. *Omega*, 107-124.

Martinez, D., & Gitlow, H. S. (2011). Optimizing employee time in a purchasing department: a Six Sigma case study. *International Journal of Lean Six Sigma, 2*(2), 180-190. doi:10.1108/20401461111135046

Meudt, T., Metternich, J., & Abele, E. (2017). Value stream mapping 4.0: Holistic examination of value stream and information logistics in production. *CIRP Annals - Manufacturing Technology*, 413-416.

Mollenkopf, D., Closs, D. D., Twede, D., Lee, S., & Burgess, G. (2011). ASSESSING THE VIABILITY OF REUSABLE PACKAGING: A RELATIVE COST APPROACH. *Journal of Business Logistics, 26*(1), 169-197. doi:https://doi-org.ezproxy2.utwente.nl/10.1002/j.2158-1592.2005.tb00198.x

Reijers, H. A., & Mendling, J. (2011). A Study Into the Factors That Influence the Understandability of Business Process Models. *IEEE Transactions on Systems, Man, and Cybernetics - Part A: Systems and Humans*, 449-462. doi:10.1109/TSMCA.2010.2087017

Schindler, C. &. (2014). *Business Research Methods 12th edition.* New York: McGraw-Hill/Irwin.

Sharda, R., Delen, D., & Turban, E. (2014). Business Intelligence. In R. Sharda, D. Delen, & E. Turban, *Business Intelligence* (Vol. 3, pp. 124-129). Stillwater: Pearson.

Singh, B., Garg, S. K., Sharma, S. K., & Grewal, C. (2010). Lean implementation and its benefits to production industry. *International Journal of Lean Six Sigma*, 157-168. doi:10.1108/20401461011049520

Slack, N., Brandon-Jones, A., & Jonhston, R. (2016). Operations Management. In N. Slack, A. Brandon-Jones, & R. Jonhston, *Operations Management* (Vol. 8, pp. 197-200). Harlow: Pearson.

Slack, N., Brandon-Jones, A., & Jonhston, R. (2016). Operations Management. In N. Slack, A. Brandon-Jones, & R. Jonhston, *Operations Management* (pp. 254-255). Harlow: Pearson.

Tjahjono, B., Ares, J. E., & Pelaez, G. (2017). What does Industry 4.0 mean to Supply Chain? *Procedia Manufacturing*, 1175-1182.

Twede, D., & Clarke, R. (2008). Supply Chain Issues in Reusable Packaging. *Journal of Marketing Channels, 12*(1), 7-26. Retrieved from https://www.tandfonline.com/doi/abs/10.1300/J049v12n01_02

USA, G. S. (2018, 11 27). *What is a Kaizen Burst Event?* Retrieved from 6sigma: https://www.6sigma.us/kaizen/what-is-a-kaizen-burst-event/

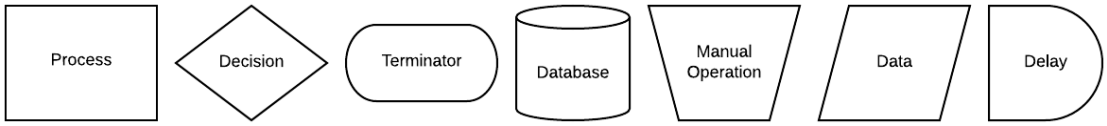
VDL. (2019, 08). *VDL Weborganigram*. Retrieved 06 10, 2021, from vdlgroep: https://www.vdlgroep.com/_asset/_public/Brochure/VDL_Weborganigram_UK_2019-08_DEF.pdf

Villarreal, B. (2012). The transportation value stream map (TVSM). *European Journal of Industrial Engineering*, 216-233. doi:10.1504/EJIE.2012.045606

Winston, W. L. (2004). Operations Research. In W. L. Winston, *Operations Research.* Cengage.

Annex

Appendix i: process map shape meanings



Appendix ii: Problems found in the problem identification phase

the process for "purchasing cycle packaging" is chaotic

This perceived problem has ample causes, as various aspects of the cycle packaging process show unclarity. Upon inquiring about handling purchasing orders a problem that quickly became apparent is that there is no clarity regarding whether or not the purchasing process is cyclical, which is a sub problem of its own.

the process for purchasing cycle packaging is time consuming.

When cyclical demand is not met with a degree of automation, a repetitive task are required to allow this stream to continue such as check-ups, frequent ordering from scratch rather than a standard reorder option, etc.

the process for purchasing cycle packaging is expensive.

Because of lack of organization, a lot of opportunities for cost minimizing are left unhandled, cost reduction could come from better grouping of deliveries, to fewer emergency deliveries, to fewer man hours invested in controlling this process.

there is no analysis regarding whether or not the purchasing demand is cyclical.

Upon asking why there are no software systems in place to record and simplify this process limitations of the ERP system came to light, illustrating that in its present form BaaN is incapable of "tying" anything to a purchasing order other than a receipt. This means the following:

ERP system presently does not support any cycle packaging options.

This problem points at a lack of methodology and software for this cycle packaging process, however when inquiring about how VDL ETG Almelo handles its purchases new problems come to light.

The first of these issues is that ownership and responsibility of the cycle packages with suppliers is varyingly established, meaning that though usually VDL or the relevant supplier own the purchasing cycle packaging, who has to send it where when is usually a blur. Meaning this in itself is a problem that needs to be addressed:

Some suppliers lack a clear delivery methodology

Suppliers do not always have coherent consistent policy on their product deliveries, and thus their expectations regarding packaging returns. Furthermore every department (Parts, Projects, Systems & Assembly) all order entirely separately from one another, even when ordering from the same supplier.

No uniform clarity towards suppliers what VDL wants

VDL does not have a uniform voice towards their suppliers indicating how packaging should be handled, requested or reported in case of damage. This leads to rampant variety in how suppliers communicate and handle packaging.

Different departments all arrange transport differently

This lack of organization leads to everyone sending their outbound material to Materials Handling, who sets materials on a truck to central transportation hub without regard that the next day more product may have to go to the exact same delivery location, meaning VDL pays twice for delivering a truckload that could have fit in one delivery.

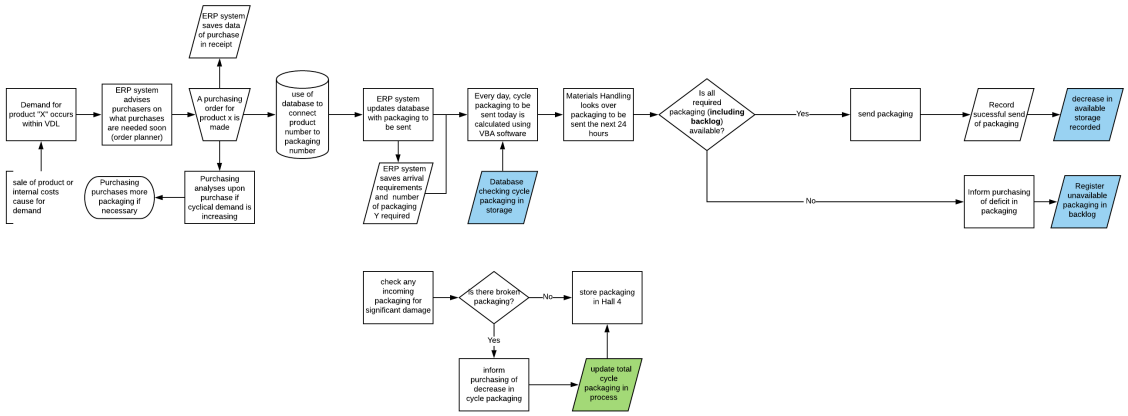
A new order starts a new process of uncoordinated requests to arrange packaging

When inquiring who is chiefly responsible for assuring these purchasing cycle packages are delivered on a timely basis and communication is kept to the necessary minimum, a clear answer of who was in charge when was absent, this lead to the discovery of another final problem:

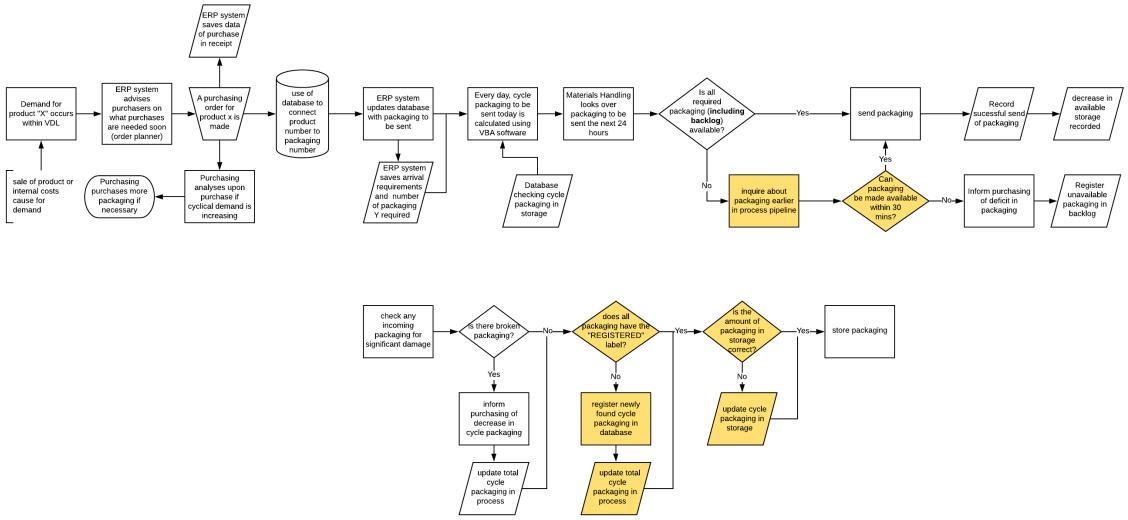
There is no clarity of who does what or is in charge of what in the purchasing cycle packaging process

Responsibility and ownership are difficult to purse in the current process because very few parties feel responsible for the errors happening. Materials Handling misplaces packaging because it has no instructions on where to place them. Purchasing doesn't feel responsible for missing packaging as purchasing did not physically lose the packaging. Until definite responsibilities are defined all parties have shared, but not individual responsibility.

Appendix iii: the new cycle packaging process (simplified)



Appendix iv: the transition cycle packaging process (simplified)



Appendix v: current Value Stream information transferred.

From left to right:

- Packaging location
- Product arrival
- Production path of part
- Purchasing receipt
- Requested arrival date of product
- How many products per packaging
- Which packaging to send
- Broken packaging is noticed
- Confirmation of packaging found
- inventory increase

- inventory decrease

Appendix vi: Future Value Stream information transferred

From left to right, with a brief description

- Product move rate

Useful for SCM to see whether the factual product move rate resembles theory.

- Product arrival

Useful for both suppliers as well as production.

Suppliers because they can measure the shipment time of their sent products, and for production as they are preventively informed of products arriving and thus entering the production process in the near future. This allows production to be more of the situation in earlier steps, knowing immediately that if they have not heard of product arrival, it is not yet present at VDL.

- Production path of part

Standard VDL process map given to any product, including those that come in packaging. Product map is registered as "printed" upon printing, but can be reprinted using the ERP system at any time.

- Packaging registration

This step is key in the transition process, as this is where the packaging is checked for an existing packaging number, and if not, the packaging can be registered and the total tally of packaging type Y can be updated, giving a better indication of total packaging in the cycle for SCM.

- Associated packaging number

The combination that the Cycle Packaging Software saves in order to understand what packaging must quality checked based on the product that arrived.

- Packaging quality standards

Standard issue quality standards with any cycle packaging that determine what constitutes an operational cycle packaging, examples of standards are that the packaging must seal, that the internal surfaces must still adequately be able to dampen vibrations that may occur during shipping, etc. This standards file also contains the destination of any broken packaging, meaning cluttering of the workplace is prevented.

- Test results

Quality check test results, useful for SCM to determine how the life cycle of cycle packaging.

- Inventory

Updates the total cycle packaging in inventory of packaging Y.

- Part purchase receipt

Unique ERP document that saves the details of the purchase sent to a supplier, binding contract between purchasing and supplier.

- Expected arrival time

As soon as purchasing orders are finalized, production is informed of the expected arrival date of the ordered products. The CPS uses this information alongside preferred departure times (i.e. 3 weeks prior to intended product delivery) to determine cycle packaging departure times.

- Quantity of products

Information the CPS uses to determine how many packaging must be sent at what date, used alongside the Products per packaging data point.

- Products per packaging

Information the CPS uses to determine how many packaging must be sent at what date, used alongside the Quantity of products data point.

- Desired packaging departure date

Ideal moment of packaging departure calculated based on the preferred departure times registered by purchasing, for example 2 boxes of product X are due in 4 weeks, the preferred departures time is 4 weeks in advance, so 2 boxes will be picked today.

- Inventory deficiencies

When calculating today's priorities, the CPS compares currently required cycle packaging Y with currently available cycle packaging Y, if there is insufficient packaging Y available, this new integer value implicating the size of the shortage is sent to the relevant purchasing official, to they may preventively resolve the matter.

- Todays priorities

Specific list of how many of which packaging has to be sent to which address

- Log of departures

Log of all outgoing cycle packages saved in the CPS. This information is relevant for SCM, as it can be used alongside to ensure the balance of arrivals and departures of packaging, in addition to checking travel times to the supplier.

- Delayed departures

Whenever a product could not be sent on the ideal delivery date, this information is sent by email to the responsible purchaser and saved, allowing for a registry of times there was insufficient packaging to complete an order to build up. Very useful for detecting insufficient packaging in the process

- Inventory

Updates the total cycle packaging in inventory of packaging Y.

- Departure confirmation

Sends and email to the relevant supplier, containing information about the shipment that was sent to their location.

Appendix vii: Summary of interviews

Packaging from all sources is presently being registered more than ever before. In a special hall called hall 4 packaging is registered upon entry and departure, giving Supply Chain Management some idea of the number of packaging in stock at all times, the average level of stock can be considered safety stock if adjusted for the amount of time there is a shortage of packaging (packaging numerical shortage x time shortage lasted). This could potentially be used for estimations for packaging numbers of key packaging.

The possibility of estimating total amount of packaging from level of stock was discussed yet too many outside variables influence the level of stock to arrive at an accurate assumption based just on in-house stock level.

PA's routinely search the workplace for packaging they need for a delivery, this happens mostly for outsourcing steps, but also occurs for purchasing products.

The number of packaging that is ordered for a new product is dependent only on its move rate and thus quantity simultaneously produced times WIP in addition to a safety factor <- chosen arbitrarily. Should there be a buffer time for expected delay?

Broken or written off packaging is not always recorded as broken, implying a non-closed system. The broken packaging process requires the "project owner" which is not always still employed at VDL Almelo, causing no one willing to take responsibility, and thus desertion of a proper handling method.

Packaging method is not water-tight, meaning packaging availability may vary due to:

1. Unregistered broken packaging
2. Missing packaging somewhere in the factory
3. Delay somewhere in the process meaning packaging buildup

This also implies that looking up how much packaging was purchased at some point in time is not useful as packaging routinely goes missing without documentation.

There is no direct or easy connection to the 12NC (identification number) of packaging and the product that belongs inside.

Consider an "Emballage" ERP software part, dedicated software meant for this type of cycle packaging, will probably come at considerable cost.

Complaints from suppliers about lack of packaging come in exclusively through purchasing, through a communications portal. The issue is usually handled down to a Production Assistant(PA), who can send a pick-order to Materials Handling, a list of pick orders is visible to the manager of materials handling, who assures that all mentioned packaging is sent.

Within the observation function of Baan it is possible to obtain a bill of material (stuklijst) of purchasing products, these bills contain the ID number of the packaging connected to each product. Using this bill of materials may prove difficult as querying these bills is not authorized currently due to the amount of work that is required, in addition to BaaN not supporting such queries.

If packaging has not been adequately sent, purchasing will at some point receive a communication through portal or mail with the warning "we haven't received packaging yet!"

New packaging is only bought if the move rate increases or if a defect packaging is registered, which happens rarely.

Discussed idea about putting barcodes on all the outbound packaging, meaning you have the departure registered within BaaN, and will know its location from henceforth. This means a significant time investment for materials handling. Purchaser expressed interest, though insists that getting this operational may take months.

One possibility is to put barcodes on all the packaging going out, this means you have it registered within BaaN's ecosystem. Does mean a considerable time investment for materials handling.

In the "werkvoorbereiding" of the relevant product, the 12NC of the packaging is routinely mentioned.

Contract forms seemed like interesting opportunities for packaging management within the ERP system, the functionality of Contract forms is however limited within Baan ERP in addition to this solution requiring every purchasing order be removed from Baan as it is and reregistered as a contract. No transition software in place.

The packaging process is far from a watertight process.

Appendix viii: information that needs to be updated on a quarterly basis

- Information regarding every relevant purchaser (name, email address)
- Information regarding new cycle packaging (parts per packaging, 12NC packaging, 12NC product, preferred departure time)

Appendix ix: State descriptions for traceability analysis

1 no traceability whatsoever

2 some level of traceability achieved for packaging, but not all. No unique numbering

3 either some level of traceability achieved for all packaging, or unique numbering for registered packaging

4 some level of tracebility for all packaging, with unique numbering for all packaging

5 constant knowledge of packaging location, unique ID

Appendix x: Spider diagram scoring

Process	Robustness	Requests	Emergency prevention	Time savings	Traceability
old	6,5	1,5	5	1,5	4
new	8	7,5	9	7,5	7

Appendix xi: CPS code

(VBA code used in Excel 2016):

```
Public Filemade As Boolean
Public RelevantPurchasersArray(1 To 200) As String
Public Z As Integer

Sub partpicker()

Dim DataPoints(1 To 5) As String
Dim k As Long

ReDim duplicatechecker(1 To 20) As Single
```

```
Workbooks.Open ("S:\Parts Manufacturing\3. Logistiek\Inkoop verpakkingen geautomatiseerd\database orders.xlsx")
Workbooks.Open ("S:\Parts Manufacturing\3. Logistiek\Inkoop verpakkingen geautomatiseerd\supplier address.xlsx")
Workbooks.Open ("S:\Parts Manufacturing\3. Logistiek\Inkoop verpakkingen geautomatiseerd\voorraad hoeveelheid.xlsx")

Set Sourcewb = Workbooks("database orders.xlsx")
Set listwb = Workbooks("inkoopverpakking hoofdprogramma.xlsm")
Set addresswb = Workbooks("supplier address.xlsx")
Set storagewb = Workbooks("voorraad hoeveelheid.xlsx")

Application.DisplayAlerts = False
   Sourcewb.RefreshAll
   addresswb.RefreshAll
   storagewb.RefreshAll
Application.DisplayAlerts = True

   Sourcewb.Sheets("iQBS").PivotTables("PivotTable1").PivotFields("Orderdatum").ClearAllFilters
   Sourcewb.Sheets("iQBS").PivotTables("PivotTable1").PivotFields("Orderdatum").ClearAllFilters
   Sourcewb.Sheets("iQBS").PivotTables("PivotTable1").PivotFields("Orderdatum").PivotFilters. _
   Add Type:=xlAfterOrEqualTo, Value1:=Format(Date - 180, "dd/mm/yyyy")          'IMPORTANT, sample provided had an average of 45 days and a std dev of 45 days, _
                                                                                 assuming normal distribution 99,85% of values lie under 180 days, meaning one outlier every 667 orders

'"Hr.J.W. van den Berg (60112)"
'"Hr. P. Meyer (60116)"
'"Hr. I. Holtkuile (60114)"

lastrownewarticle = listwb.Sheets("packaging list").Cells(Rows.Count, 10).End(xlUp).Row
lastrow = Sourcewb.Sheets("iQBS").Cells(Rows.Count, 2).End(xlUp).Row

Z = 1

For i = 3 To lastrow          'Here starts the loop of going through all orders made this month to _
                              sort the priorities for Materials Handling
   Call checkprio(i)

Next i

'here we add identical lines together

lastrow = listwb.Sheets("today's priorities").Cells(Rows.Count, 1).End(xlUp).Row

For i = 4 To lastrow
'the program uses datapoints such as delivery address to check whether rows are identical, allowing for two rows to be combined
   DataPoints(1) = listwb.Sheets("today's priorities").Cells(i, 1)
   DataPoints(2) = listwb.Sheets("today's priorities").Cells(i, 2)
   DataPoints(3) = listwb.Sheets("today's priorities").Cells(i, 3)
   DataPoints(4) = listwb.Sheets("today's priorities").Cells(i, 4)
   DataPoints(5) = listwb.Sheets("today's priorities").Cells(i, 5)

   If DataPoints(1) = Empty Then
      i = lastrow
   End If

   j = i + 1

   For j = i + 1 To lastrow
   'Here it checks if any rows are identical to the datapoints above
      If listwb.Sheets("today's priorities").Cells(j, 1) = DataPoints(1) And _
      listwb.Sheets("today's priorities").Cells(j, 2) = DataPoints(2) And _
      listwb.Sheets("today's priorities").Cells(j, 3) = DataPoints(3) And _
      listwb.Sheets("today's priorities").Cells(j, 4) = DataPoints(4) And _
      listwb.Sheets("today's priorities").Cells(j, 5) = DataPoints(5) Then

         'Adds the number of packages on row j to row i
         listwb.Sheets("today's priorities").Unprotect
         listwb.Sheets("today's priorities").Cells(i, 6) = listwb.Sheets("today's priorities").Cells(i, 6) + _
                                                listwb.Sheets("today's priorities").Cells(j, 6)
         listwb.Sheets("today's priorities").Protect

         'Here we adjust the purchaser database to the deleted row
         RelevantPurchasersArray(j - 3) = RelevantPurchasersArray(i - 3)
         For k = i + 1 To 100
            RelevantPurchasersArray(k - 3) = RelevantPurchasersArray(k - 2)
         Next k

         'Deletes the now already tranfered row j
         Application.DisplayAlerts = False
         listwb.Sheets("today's priorities").Unprotect
         listwb.Sheets("today's priorities").Rows(j).Delete
         listwb.Sheets("today's priorities").Protect
         Application.DisplayAlerts = True

      End If

   Next j
DoEvents
Next i
```

```
NumOfNewOrders = listwb.Sheets("today's priorities").Cells(Rows.Count, 1).End(xlUp).Row - 3

If NumOfNewOrders = 0 Then
    Exit Sub            'no matches found, nothing needs to be printed
End If

'here we check if we have sufficient packaging in storage to send out
For i = 4 To lastrow

    RelevantPackaging = listwb.Sheets("today's priorities").Cells(i, 1)
    RelevantProduct = listwb.Sheets("today's priorities").Cells(i, 7)

    j = 1
    RequiredPackaging = listwb.Sheets("today's priorities").Cells(i, 6)

    While listwb.Sheets("today's priorities").Cells(i + j, 1) = RelevantPackaging       'checks if the next row also requests the same packaging, if so, adds the extra amount to RequiredPackaging
        RequiredPackaging = RequiredPackaging + listwb.Sheets("today's priorities").Cells(j + i, 6)
        j = j + 1
        If RelevantPackaging = Empty Then
            RelevantPackaging = 1
        End If
    Wend

    k = 5
    StorageMatchRow = -1
    While StorageMatchRow = -1

    If Trim(storagewb.Sheets("iQBS").Cells(k, 1)) = Trim(RelevantPackaging) Then
        StorageMatchRow = k
        CurrentStorage = storagewb.Sheets("iQBS").Cells(StorageMatchRow, 3)
    ElseIf k > 10000 Then
        CurrentStorage = 0
        StorageMatchRow = 0
    Else
        k = k + 1
    End If

    Wend

    If CurrentStorage < RequiredPackaging Then
        Call PackagingShortage(RelevantPackaging, RequiredPackaging, CurrentStorage, RelevantPurchasersArray(i - 3), RelevantProduct)
    End If
    StorageMatchRow = Empty

Next i
'here we fill the sheet with already sent orders

lastrow = listwb.Sheets("sent orders").Cells(Rows.Count, 1).End(xlUp).Row
j = 4
For i = lastrow To lastrow + NumOfNewOrders - 1

    posdup = listwb.Sheets("today's priorities").Cells(j, 3)
    l = 1
    listwb.Sheets("sent orders").Unprotect

    For k = 1 To lastrow

        If listwb.Sheets("sent orders").Cells(k, 3) = posdup Then
            duplicatechecker(l) = k
            l = l + 1
        End If
    Next k

    posduptwo = listwb.Sheets("today's priorities").Cells(j, 2)

    Sheets("sent orders").Protect

    If duplicatechecker(1) > 0 Then

        For m = 1 To l - 1
            If listwb.Sheets("sent orders").Cells(duplicatechecker(m), 1) = listwb.Sheets("today's priorities").Cells(j, 1) And listwb.Sheets("sent orders").Cells(duplicatechecker(m), 2) =
listwb.Sheets("today's priorities").Cells(j, 2) And listwb.Sheets("sent orders").Cells(duplicatechecker(m), 3) = listwb.Sheets("today's priorities").Cells(j, 3) Then
                'this value is already present in the "sent orders" sheet, therefor no new row will be created
                Exactmatch = True
            End If
        Next m

    Else

    End If

    If Exactmatch = False Then

        Sheets("sent orders").Unprotect
        listwb.Sheets("sent orders").Cells(i + 1, 1) = listwb.Sheets("today's priorities").Cells(j, 1)
```

```
        listwb.Sheets("sent orders").Cells(i + 1, 2) = listwb.Sheets("today's priorities").Cells(j, 2)
        listwb.Sheets("sent orders").Cells(i + 1, 3) = listwb.Sheets("today's priorities").Cells(j, 3)
        listwb.Sheets("sent orders").Cells(i + 1, 4) = listwb.Sheets("today's priorities").Cells(j, 4)
        listwb.Sheets("sent orders").Cells(i + 1, 5) = listwb.Sheets("today's priorities").Cells(j, 5)
        listwb.Sheets("sent orders").Cells(i + 1, 6) = listwb.Sheets("today's priorities").Cells(j, 6)
        listwb.Sheets("sent orders").Cells(i + 1, 7) = Date


        If listwb.Sheets("sent orders").Cells(i, 1) = Empty Then
            listwb.Sheets("sent orders").Rows(i).Delete
        End If
        Sheets("sent orders").Protect

    End If

    j = j + 1
    ReDim duplicatechecker(1 To 20)
    Exactmatch = False
Next i

'we remove the product number here, because Materials Handling does not need this number
Sheets("today's priorities").Unprotect
listwb.Sheets("today's priorities").Columns(7).EntireColumn.Delete
Sheets("today's priorities").Protect
'here we send the print order to Materials Handling


Dim MyOriginalPrinter As String
Const MyPrinter As String = "\\ETGAPS001.VDLGROEP.LOCAL\PRTALM022 on Ne04:"
Const MyPrinterTwo As String = "PRTALM022"

sCurrentPrinter = Application.ActivePrinter
Set mynetwork = CreateObject("WScript.network")

With mynetwork.EnumPrinterConnections
    For j = 0 To .Count - 1 Step 2
        If InStr(1, .Item(j + 1), MyPrinterTwo, vbTextCompare) > 0 Then
        c4 = IIf(c4 = "", "", c4 & vbCr) & .Item(j + 1) & " on " & .Item(j)
        CreateObject("Wscript.network").SetDefaultPrinter (.Item(j + 1))
        End If
    Next
End With


On Error Resume Next
Application.ActivePrinter = MyPrinter   'this checks if the printer is actually set to the right printer, will give error code if this is not the case
If Not Application.ActivePrinter = MyPrinter Then
                                'IF IT DOES NOT FIND A PRINTER, SEND A MAIL TO SOMEONE HERE TO FIX THE PROBLEM
End If
Worksheets("today's priorities").PrintOut
'From:=5, to:=Sheets.Count, Copies:=1, Preview:=False

For i = 6 To Sheets.Count
    Worksheets(i).PrintOut
    'From:=5, to:=Sheets.Count, Copies:=1, Preview:=False
Next i

Application.ActivePrinter = sCurrentPrinter

'here it creates a MsgBox notifying user of all new articles the program encountered
lastrow = listwb.Sheets("packaging list").Cells(Rows.Count, 10).End(xlUp).Row
j = 1
ReDim newval(1 To lastrow - lastrownewarticle + 2) As String

If lastrownewarticle < lastrow Then
    For i = lastrownewarticle + 1 To lastrow
        newval(j) = listwb.Sheets("packaging list").Cells(i, 10)
        j = j + 1
    Next i
    MsgBox "er zijn nieuwe artikelnummers gedetecteerd in het inkoopbestand, de volgende artikelen zijn toegevoegd aan de ""non-retourverpakking"" database:" & vbNewLine & newval(1) &
vbNewLine & newval(2) & vbNewLine & newval(3) & vbNewLine & newval(4) & vbNewLine & newval(5) & vbNewLine & newval(6) & vbNewLine & newval(7) & vbNewLine & newval(8) &
vbNewLine & newval(9) & vbNewLine & newval(10)
End If


Call cleanfile

Application.DisplayAlerts = False
Sourcewb.Close
addresswb.Close
storagewb.Close
listwb.Sheets("Voorpagina").Activate
End Sub

Sub cleanfile()
'here we reset the sheets and the report
```

```
Set listwb = Workbooks("inkoopverpakking hoofdprogramma.xlsm")

    For i = 1 To listwb.Sheets.Count - 6
        Application.DisplayAlerts = False
        Sheets(Sheets.Count).Delete
        Application.DisplayAlerts = True
    Next i

lastrow = listwb.Sheets("today's priorities").Cells(Rows.Count, 1).End(xlUp).Row

    Sheets("today's priorities").Unprotect
    For i = 1 To lastrow - 3
        Sheets("today's priorities").Rows(4).Delete
    Next i
    Sheets("today's priorities").Protect
    listwb.Save

End Sub


Sub checkprio(rownum)

Dim artlength As Integer
Dim NumOrdered, ProdsPerPack As Double
Dim shipdate As Date

Set Sourcewb = Workbooks("database orders.xlsx")
Set listwb = Workbooks("inkoopverpakking hoofdprogramma.xlsm")
Set addresswb = Workbooks("supplier address.xlsx")

ReDim duplicateloc(1 To 50) As Single

' priofilename = Date & " Materials Handling prio list"
' Workbooks.Add
' ActiveWorkbook.SaveAs (PrioFileName & ".xls")
' Set reportwb = Workbooks(PrioFileName & ".xls")

articlenum = Sourcewb.Sheets("iQBS").Cells(rownum, 5)   'All required information is pulled from the orders database

If articlenum = Empty Then
    Else
    artlength = Len(articlenum)
    articlenum = Left(articlenum, artlength - 2)

End If

PlannedDate = Sourcewb.Sheets("iQBS").Cells(rownum, 3)

i = 1
While PlannedDate = Empty
    PlannedDate = Sourcewb.Sheets("iQBS").Cells(rownum - i, 3)
    i = i + 1
Wend

i = 1
While Orderdate = Empty
    Orderdate = Sourcewb.Sheets("iQBS").Cells(rownum - i, 2)
    i = i + 1
Wend
Supplier = Sourcewb.Sheets("iQBS").Cells(rownum, 6)
PurOrdNum = Sourcewb.Sheets("iQBS").Cells(rownum, 8)
NumOrdered = Sourcewb.Sheets("iQBS").Cells(rownum, 11)

On Error Resume Next
matchloc = WorksheetFunction.Match(articlenum, listwb.Sheets("packaging list").Range("A:A"), 0) 'finds the article number in the list file

If matchloc = Empty Then
    articlenum = Sourcewb.Sheets("iQBS").Cells(rownum, 5)   'All required information is pulled from the orders database

    If articlenum = Empty Then
    Else
        artlength = Len(articlenum)
        articlenum = Left(articlenum, artlength - 1)
    End If
    matchloc = WorksheetFunction.Match(articlenum, listwb.Sheets("packaging list").Range("A:A"), 0) 'finds the article number in the list file
End If


If matchloc > 0 Then

preference = listwb.Sheets("packaging list").Cells(matchloc, 4)

Select Case preference

    Case "Orderdate"
```

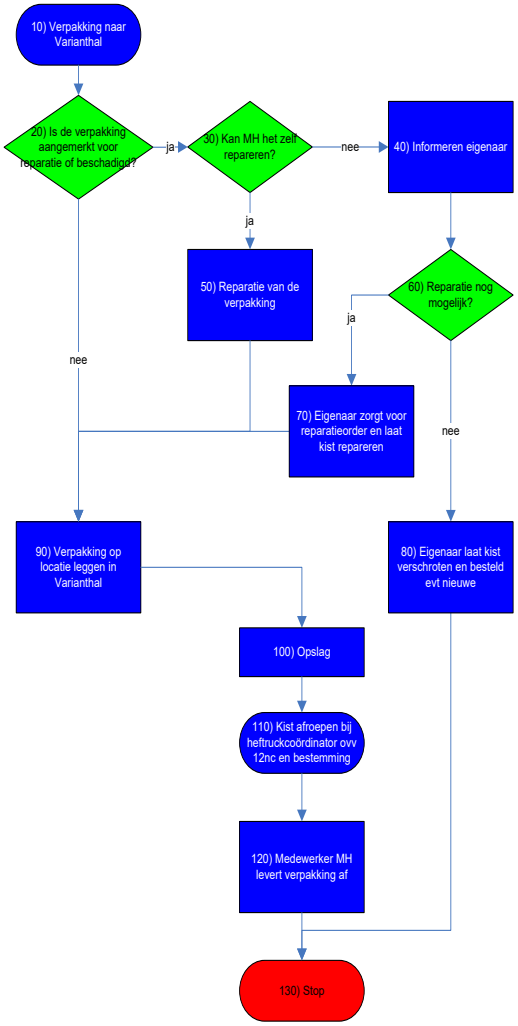
```
        If Orderdate < Date Then
            prio = True
            shipdate = Orderdate
        End If

    Case "1 week prior"
        If PlannedDate < Date + 7 Then
            prio = True
            shipdate = PlannedDate - 7
        End If
    Case "2 weeks prior"
        If PlannedDate < Date + 14 Then
            prio = True
            shipdate = PlannedDate - 14
        End If
    Case "3 weeks prior"
        If PlannedDate < Date + 21 Then
            prio = True
            shipdate = PlannedDate - 21
        End If
    Case "4 weeks prior"
        If PlannedDate < Date + 28 Then
            prio = True
            shipdate = PlannedDate - 28
        End If

    Case Else
    MsgBox "verpakkingnummer " And articlenum And "heeft nog geen versturingsstrategie, vul die s.v.p. in d.m.v. de knop op de voorpagina"
End Select



Else
' if there is no match then the product in question is either not registered or is not transported _
using cycle packaging, therefor it does not need to show up on the priority list
    lastrow = listwb.Sheets("packaging list").Cells(Rows.Count, 10).End(xlUp).Row

    For i = 2 To lastrow
        If listwb.Sheets("packaging list").Cells(i, 10) = articlenum Then
            Exit Sub
        End If
    Next i
    Sheets("packaging list").Unprotect
    listwb.Sheets("packaging list").Cells(lastrow + 1, 10) = articlenum
    Sheets("packaging list").Protect
    Exit Sub
End If


'if the program concluded packaging must be sent now, it will create another line in the report
If prio = True Then

    packagingnum = listwb.Sheets("packaging list").Cells(matchloc, 2)
    'HERE WOULD BE WHERE YOU DISTINGUISH BETWEEN ARTICLENUMS THAT USE THE SAME PACKAGING
    ProdsPerPack = listwb.Sheets("packaging list").Cells(matchloc, 3)

    'checks if the template is correct and if not corrects it
    If listwb.Sheets("today's priorities").Cells(1, 2) = "Prio verpakkingen Parts Manufacturing" And listwb.Sheets("today's priorities").Cells(3, 6) = "Aantal" Then
    'this means the template is correct, thus skip correcting the template

    Else
        listwb.Sheets("today's priorities").Range("B1").Select
        With Selection.Font
            .Name = "Calibri"
            .Size = 20
            .Underline = xlUnderlineStyleNone
            .ThemeColor = xlThemeColorLight1
            .TintAndShade = 0
            .ThemeFont = xlThemeFontMinor
        End With
        ActiveCell.FormulaR1C1 = "Prio verpakkingen Parts Manufacturing"

    listwb.Sheets("today's priorities").Range("A3").Select
    ActiveCell.FormulaR1C1 = "12 NC verpakking"
    listwb.Sheets("today's priorities").Range("B3").Select
    ActiveCell.FormulaR1C1 = "Gewenste leverdatum"
    listwb.Sheets("today's priorities").Range("C3").Select
    ActiveCell.FormulaR1C1 = "Inkoopnummer"
    listwb.Sheets("today's priorities").Range("D3").Select
    ActiveCell.FormulaR1C1 = "Bestemming"
    listwb.Sheets("today's priorities").Range("E3").Select
    ActiveCell.FormulaR1C1 = "Adres"
    listwb.Sheets("today's priorities").Range("F3").Select
    ActiveCell.FormulaR1C1 = "Aantal"

    listwb.Sheets("today's priorities").Range("D:D,E:E").Select
```

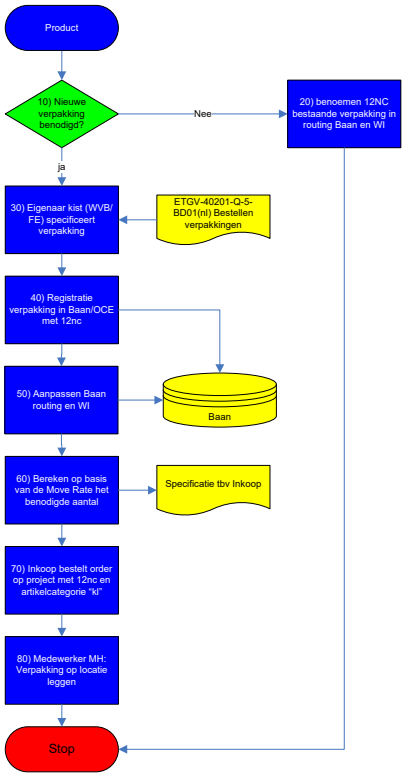
```
    With Selection
        .HorizontalAlignment = xlGeneral
        .VerticalAlignment = xlBottom
        .WrapText = True
    End With

    listwb.Sheets("today's priorities").Columns("A:A").EntireColumn.AutoFit
    listwb.Sheets("today's priorities").Columns("C:C").EntireColumn.AutoFit
    listwb.Sheets("today's priorities").Columns("D:D").ColumnWidth = 13
    listwb.Sheets("today's priorities").Columns("E:E").ColumnWidth = 13
    listwb.Sheets("today's priorities").Columns("F:F").EntireColumn.AutoFit
    listwb.Sheets("today's priorities").Columns("B:B").ColumnWidth = 20

    End If

    'Here we check if the specified row has already been ordered
    duplicateloc(1) = WorksheetFunction.Match(PurOrdNum, listwb.Sheets("sent orders").Range("C:C"), 0)
    i = 2
    While allfound = False
            duplicateloc(i) = WorksheetFunction.Match(PurOrdNum, listwb.Sheets("sent orders").Range(Cells(duplicateloc(i - 1) + 1, 3), Cells(10000, 3)), 0)

            If duplicateloc(i) = Empty Then
                allfound = True
            End If

            i = i + 1

    Wend
    allfound = False
    i = 1

    While duplicateloc(i) <> 0
        If duplicateloc(i) <> 0 Then
            If shipdate = listwb.Sheets("sent orders").Cells(duplicateloc, 2) And listwb.Sheets("sent orders").Cells(duplicateloc, 1) = packagingnum And listwb.Sheets("sent
orders").Cells(duplicateloc, 3) = PurOrdNum Then
                Alreadyordered = True
                i = 40
            Else
                Areadyordered = False
            End If
        Else
            Alreadyordered = False
        End If

        i = i + 1
    Wend

    If Alreadyordered = False Then

        'here we save information about the relevant purchaser, for mailing purposes should there be a packaging shortage
        RelevantPurchasersArray(Z) = Sourcewb.Sheets("iQBS").Cells(rownum, 4).Value
        Z = Z + 1
        'Here we use the gathered information to create a new packaging delivery row
        lastrow = listwb.Sheets("today's priorities").Cells(Rows.Count, 1).End(xlUp).Row
        listwb.Sheets("today's priorities").Unprotect
        listwb.Sheets("today's priorities").Cells(lastrow + 1, 1) = packagingnum
        listwb.Sheets("today's priorities").Cells(lastrow + 1, 2) = shipdate
        listwb.Sheets("today's priorities").Cells(lastrow + 1, 3) = PurOrdNum
        listwb.Sheets("today's priorities").Cells(lastrow + 1, 4) = Supplier
        listwb.Sheets("today's priorities").Cells(lastrow + 1, 7) = articlenum

        suppliercodeloc = InStr(1, listwb.Sheets("today's priorities").Cells(lastrow + 1, 4), "(", vbTextCompare)
        suppliercodeLocEnd = InStr(1, listwb.Sheets("today's priorities").Cells(lastrow + 1, 4), ")", vbTextCompare)
        suppliercode = Mid(listwb.Sheets("today's priorities").Cells(lastrow + 1, 4), suppliercodeloc + 1, suppliercodeLocEnd - suppliercodeloc - 1)
        AddressLoc = WorksheetFunction.Match(suppliercode, addresswb.Sheets("iQBS").Range("A:A"), 0)
        Address = addresswb.Sheets("iQBS").Cells(AddressLoc, 2)
        AddressPostal = addresswb.Sheets("iQBS").Cells(AddressLoc, 3)
        listwb.Sheets("today's priorities").Cells(lastrow + 1, 5) = Address

        listwb.Sheets("today's priorities").Cells(lastrow + 1, 6) = WorksheetFunction.RoundUp(NumOrdered / ProdsPerPack, 0)

        listwb.Sheets("today's priorities").Protect

        'Here we create a print sheet for the Materials Handler
        For i = 1 To WorksheetFunction.RoundUp(NumOrdered / ProdsPerPack, 0)
            lastrow = listwb.Sheets("today's priorities").Cells(Rows.Count, 1).End(xlUp).Row
            NewSheetName = "printsheet " & listwb.Sheets.Count - 5
            listwb.Sheets("printsheet template").Activate
            listwb.Sheets("printsheet template").Copy After:=Sheets(Sheets.Count)
            listwb.Sheets(Sheets.Count).Select
            listwb.Sheets(Sheets.Count).Name = NewSheetName


            listwb.Sheets(NewSheetName).Unprotect
            listwb.Sheets(NewSheetName).Cells(8, 1) = packagingnum
            listwb.Sheets(NewSheetName).Cells(10, 1) = Supplier
```

```
            listwb.Sheets(NewSheetName).Cells(12, 1) = Address
            listwb.Sheets(NewSheetName).Cells(13, 1) = AddressPostal
            listwb.Sheets(NewSheetName).Cells(15, 1) = PurOrdNum
            listwb.Sheets(NewSheetName).Cells(32, 1) = Replace(packagingnum, " ", "")
            listwb.Sheets(NewSheetName).Protect
        Next i
    End If

End If
'Replace( , " ", "")
End Sub

Sub PackagingShortage(RelevantPackaging, RequiredPackaging, CurrentStorage, Purchaser, RelevantProduct)

Set Sourcewb = Workbooks("database orders.xlsx")
Set listwb = Workbooks("inkoopverpakking hoofdprogramma.xlsm")
Set addresswb = Workbooks("supplier address.xlsx")
Set storagewb = Workbooks("voorraad hoeveelheid.xlsx")



    ' SET Outlook APPLICATION OBJECT.
    Dim objOutlook As Object
    Set objOutlook = CreateObject("Outlook.Application")

    ' CREATE EMAIL OBJECT.
    Dim objEmail As Object
    Set objEmail = objOutlook.CreateItem(olMailItem)

PurchaserPersonelNumber = Right(Purchaser, 6)
PurchaserPersonelNumber = Left(PurchaserPersonelNumber, 5)

lastrow = Sheets("users database").Cells(Rows.Count, 1).End(xlUp).Row
For i = 1 To lastrow
    If Sheets("users database").Cells(i, 1).Text = PurchaserPersonelNumber Then
        GoalEmailAddress = Sheets("users database").Cells(i, 2)
    End If
Next i

If GoalEmailAddress = Empty Then
    AddOnToEmail = "PS: personeelsnummer " & PurchaserPersonelNumber & " is niet bekend in de gebruikers database, indien u deze mails naar een andere medewerker wil laten versturen,
vul dan de gegevens van de nieuwe inkoper in, in het Inkoopverpakking hoofdpgramma"
    GoalEmailAddress = Sheets("users database").Cells(2, 6)
End If

With Sourcewb.Sheets("iQBS").PivotTables("PivotTable1").PivotFields("Verwerver")
    .PivotItems("Dhr. B. Alferink (25112)").Visible = False
End With

lastrow = listwb.Sheets("today's priorities").Cells(Rows.Count, 1).End(xlUp).Row

rowmatch = WorksheetFunction.Match(RelevantPackaging, listwb.Sheets("packaging list").Range("B:B"), 0)
k = 1

While nextvalisdifferent = False

    If listwb.Sheets("packaging list").Cells(rowmatch, 2) = listwb.Sheets("today's priorities").Cells(3 + k, 1) Then

        targetarticlenum = RelevantProduct
        i = 3

            While valfound = False
                If Sourcewb.Sheets("iQBS").Cells(i, 1) > 0 Then

                    startval = InStr(1, Sourcewb.Sheets("iQBS").Cells(i, 1), "(", vbTextCompare) + 1
                    endval = InStr(1, Sourcewb.Sheets("iQBS").Cells(i, 1), ")", vbTextCompare) - startval
                    currentrowval = Sourcewb.Sheets("iQBS").Cells(i, 1)

                    If endval > -1 Then
                        artnumfoundinsource = Mid(currentrowval, startval, endval)
                    End If
                    If artnumfoundinsource = targetarticlenum Then
                        valfound = True
                        rowmatchtwo = WorksheetFunction.Match(RelevantPackaging, listwb.Sheets("today's priorities").Range("A:A"), 0)
                        allvalsmarked = False
                        While allvalsmarked = False

                        listwb.Sheets("today's priorities").Unprotect
                        listwb.Sheets("today's priorities").Activate
                        listwb.Sheets("today's priorities").Range(Cells(rowmatchtwo, 1), Cells(rowmatchtwo, 1000)).Font.Color = vbRed
                        listwb.Sheets("today's priorities").Protect

                        rowmatchtwo = rowmatchtwo + 1
                        If Cells(rowmatchtwo, 1) = Cells(rowmatchtwo - 1, 1) Then
                        'do nothing
                        Else
```

```
                    allvalsmarked = True
                End If

                Wend
                Sheets("Voorpagina").Activate

                Shell ("OUTLOOK")
                With objEmail
                    .To = GoalEmailAddress
                    .Subject = "Verpakkingstekort van verpakking " & RelevantPackaging & ", Product " & RelevantProduct
                    .Body = "Beste collega," & vbNewLine & vbNewLine & "Van verpakkingtype " & RelevantPackaging & " zijn er " & CurrentStorage & " beschikbaar maar zijn er " &
RequiredPackaging & " nodig voor de leveringen van vandaag." & vbNewLine & "Het bijbehorende 12NC is " & RelevantProduct & "." & vbNewLine & "de verantwoordelijke inkoper is " &
Purchaser & vbNewLine & vbNewLine & "met vriendelijke groet" & vbNewLine & "VDL automation" & vbNewLine & vbNewLine & AddOnToEmail
                    .Send       ' SEND MESSAGE.
                End With

                objOutlook.Quit

                j = 1
                While nextPackage = False

                    If Sourcewb.Sheets("iQBS").Cells(i + j, 1) > 0 Then
                        nextPackage = True
                    End If

                j = j + 1
                Wend

            End If
        End If
        i = i + 1

    Wend
  nextvalisdifferent = True
  End If

  k = k + 1
Wend
'here we make the row with insufficient storage red and inform the purchaser

'objOutlook.ActiveExplorer.Quit
Set objEmail = Nothing:    Set objOutlook = Nothing
valfound = False
nextPackage = False
nextvalisdifferent = False

End Sub
```

Appendix xii: Process flows from VDL





Appendix xiii: Innovation scoring motivations

Task description	Measurement scale	Value Stream Mapping	Incorporate QR-codes into packaging process	Create a database of packaging – product combinations	Determine responsibilities, and make stakeholders responsible for their part	Automate response to missing packaging	Make packaging its own product with production paths	Update ERP system with specialized packaging-software	Automate cyclical purchasing orders
Realization cost & difficulty	1-5 (5 is easiest)	Very cost effective, nothing but minimal time investment to implement this solution	Very cost effective	Moderately cost effective	Very cost effective	Significant time and financial investment required	Significant time and financial investment required	**Too expensive for thesis scope**	Significant time and financial investment required
Time Savings	1-5 (5 is most time savings)	Systematically extremely time saving, over 10+ hours monthly	Sporadically time saving	Systematically time saving, at least 1 hour monthly	Systematically time saving, multiple hours monthly	Systematically time saving, multiple hours monthly	Hardly or not time saving	-	Systematically time saving, multiple hours monthly
Added traceability	1-5(5 is most traceable)	Traceability added modestly by motivating stakeholders to use other traceability improvements	Notable traceability added, set to have a notable effect on time spent searching for cycle packaging	Notable traceability added, set to have a notable effect on time spent searching for cycle packaging	Hardly or not provisional for tracability	Hardly or not provisional for tracability	Notable traceability added, set to have a notable effect on time spent searching for cycle packaging	-	Hardly or not provisional for tracability
Combined value	2-10 (10 is best)	**11**	**10**	**10**	**9**	**7**	**7**	**-**	**7**