MASTER THESIS
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Redesign of the inbound exception process

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THE REDESIGN OF THE INBOUND EXCEPTION PROCESS

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Preface

This report presents my graduation research for the master study Industrial Engineering and Management at the University of Twente. I am looking back to a wonderful time during my study and time in Enschede. A place where I felt at home, made friends, learned a lot in my field of interest, and enjoyed studying at a university where doors stood always open.

I experienced the time during my internship at bol.com as very interesting and I am thankful for the great opportunity. It was very valuable to work on one hand on the operational side, in the warehouse and on the other hand working on the larger perspective. It was rewarding to see that my project played a substantial role in the improvement of the exception process. And that some of my findings and recommendations are already being implemented. Besides, I want to thank my colleagues at the logistical department for the interest, motivation and seeing me as a bol.com colleague. In special, I would like to thank Petra for being a continuous supervisor, both on content as well as on a personal level. I greatly appreciated the time Petra spend with me.

Furthermore, I would like to thank Peter and Martijn for the supervision, guidance and advice on my report and methodology. They supported me to bring the theoretical and scientific aspect to a higher level.

Last but not least, I want to thank my friends and family, for their support, advice, for being a listening ear, and for the nice distractions. Thank you Tom, I really appreciate your time, effort, and your positive vibe to motivate me.
I hope you enjoy your reading!

Utrecht, March 19th, 2020

Irene van Dam

Executive Summary

This version is the public version. All confidential information regarding detailed processes and performance is removed.

This thesis represents the research to the inbound exception process, performed at bol.com. As online retail platform, bol.com offers retailers the service Logistics via bol.com (Lvb). For those Lvb Partners, bol.com takes care of the logistics from stock to delivery. The Partner remains owner of the product and pays a fee for the service. During the inbound process, exceptions occur. These exceptions are resolved via the Exception Process. This process was not functioning well and together with the expected growth in Lvb products, there is ample motivation to start this research. Bol.com has no clear insight in the procedures, responsibilities and performance of the exception process. This results in longer lead times, high costs, and partner dissatisfaction. The following research question is formulated:

> *"How can bol.com design the exception process to improve the performance on throughput time, costs, and partner dissatisfaction?"*

In order to answer this question, first the current process is analysed. Using available data and time measurements from 2019, we conclude the following.

- Each day in 2019, **x** exception cases are registered, containing 281 exception items.
- The current forecast is that this will grow to 17.3 cases, with a total of **x** exception items at Dec' 2020.
- The total throughput time per exception case is **x** days.
- Every exception case costs on average **€x** (**€x** per exception item), which result in the total costs of **€x** in 2019 and forecast costs of **€x** in 2020.
- Partner dissatisfaction is measured by bol.com questionnaires and shows **x**.

Using literature, we selected Lean as the most suitable improvement methodology by our defined selection criteria. We used the Lean tools to identify the current inefficiencies. The inefficiencies are clustered and solutions are identified. These are sorted by potential impact. The solutions with the highest impact are: (1) A new stacking rack, which replaces the tote storage and separate the storage of identical exception items. (2) Relocation of all related materials to the exception corner, to reduce handling time. (3) A new Standard Operating Procedure for the Coordinator of bol.com, for faster throughput time.

A simulation model is created to test and optimise the improved exception process. In four scenarios, multiple priority interventions are tested to see the impact on the throughput time per exception case and the idle time of the Exception Specialist and Coordinator of bol.com. At first, the improved exception process with initial settings (**x**exception cases per day, standard working hours: Exception Specialist at the work floor works in two shifts from 7:00 to 23:00 and the Coordinator of bol.com works during office hours, from 9:00 to 17:00) has a total throughput time of **x**days. Performing tests to multiple priority interventions, we conclude that in all scenarios the following priority rule is best to apply.
Sort on:

1. Case that is the longest in the solving process
2. Small exception items
3. Next processing steps CB : Mail 2 - Call 1 - Registration 2

The impact of the priority rule in this scenario is not large, 0.5%. However, in a second scenario, we tested the impact of an increased arrival of exception cases per day. When the number of cases increases, the performance of the process remains strong, compared to no priority ruling. Applying the priority rule and using standard working hours, an average rate of 26 exception cases per day can be handled while keeping performance sufficient. In the third and fourth scenario, we tested the minimum required working hours at an arrival rate of **x** and **x**respectively (arrival rate now and end 2020). Currently, the working can be decreased for the Coordinator of bol.com to four hours, without a loss in throughput time. End 2020, the coordinator needs seven hours to complete his exception tasks. The working hours for Exception Specialist can be decreased from 2 to 1 shift, due to idle time. However, due to the higher workload of the Coordinator of bol.com, we strongly advise not to change the working hours. Instead, use the idle time to let the Exception Specialist do other activities.

When all solutions are implemented, the expected process performance is vastly improved.

- The new throughput time is estimated to be **x** days, a reduction of 74%.
- The costs of a single case is reduced from **€x** to **€x** per case, a 44% decrease. In 2020 the expected savings amount to **€x**
- By estimation, the partner dissatisfaction will be decreased, since 80% of the Partners are contacted within 36 hours. Because of the faster contacting of Partners and the faster processing of exception cases, we prevent Partners to contact bol.com about delayed stock.

To realise the improved process, fifteen improvement projects are identified, of which three are already implemented during the research. The remaining are clustered by evaluating the impact versus effort. First, a new way of working for the coordinator is to be implemented. Second, the layout changes needs to be implemented and the used computer is upgraded. Third, the ways of working on the work floor need to be optimised. Fourthly, all employees need to be trained inline with new manuals and finally the working hours of the coordinator and additional tasks for the Exception Specialist is to be checked.

The two responsible teams within bol.com for the successful implementation of the projects are the 'inbound operations team' and 'product team inbound' at the logistical department. It is important that the project leaders include and convince all layers of the organisation and staff that are involved in the exception process, consisting of the warehouse operations manager, the inbound process coordinators, the team leads, and the exception employees. The proposed implementation planning is provided in Figure 1. In nineteen weeks, the improved exception process can be completely implemented. The projects are described in Table 1.

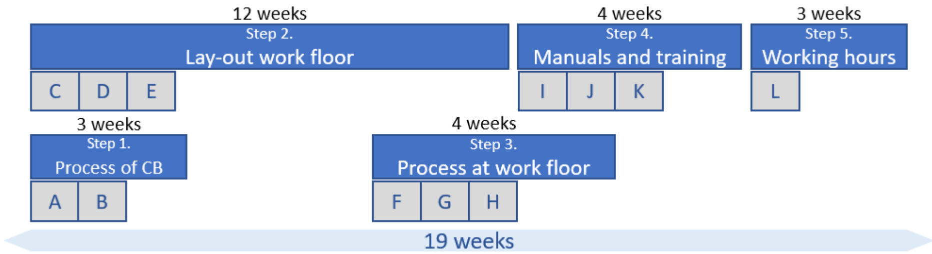

Figure 1: Overview implementation planning for the improved exception process

Table 1: Implementation project overview

Step	Number	Project	Responsible team
1	A	Introduce and manage the standard operating procedure for Coordinator of bol.com	Operations team
	B	Implement the use of a priority rule for the tasks of the Coordinator of bol.com	Operations team
2	C	Implement a stacking rack	Product team
	D	Place all materials close to desk of Exception Specialist	Operations team
	E	Replace one computer by a screen	Product team
3	F	Change the process such that the Trouble Shoorter always walks to the operator at the Working Station	Operations team
	G	Introcude that the Trouble Shooter registers information in shared Excel	Operations team
	H	Introduce that the Exception Specialist always hand over the items to the closest operator at the Working Station	Operations team
4	I	Provide a standard operating procedure for the Exception Specialist	Operations team
	J	Provide a manual for the shared Excel for the ES	Operations team
	K	Train the Trouble Shooter and the Exception Specialist	Operations team
5	L	Align the workload of the Exception Specialist & the Coordinator of bol.com	Operations team
Projects are executed		The lay-out of the shared Excel is improved	Operations team
		The printer is installed at the desk of the Exception Specialist to print the supplier's information	Operations team
		The lay-out of the shared Excel is maintained by the Coordinator of bol.com	Operations team

We identified four implementation risks: (1) The unavailability of the project leads and (2) delayed implementation of the stacking rack, can both lead to a delay at all subsequent projects. Furthermore, (3) the insufficient involvement of stakeholders & employees and (4) the lack of monitoring the execution of the new process, can result in a less improved performance.

The exception process can be improved significantly on throughput time, costs, and partner dissatisfaction if all proposed improvement projects are implemented with full attention.

Contents

List of acronyms

		Introduced on page
BFC	Bol.com Fulfilment Centre	2
BPR	Business Process Re-engineering	38
bSKU	bol.com Stock Keeping Unit	19
CI	Continuous Improvement	39
CB	Coordinator of bol.com	14
DOA	Dead on Arrival (defect item)	13
DMAIC	Define, Measure, Analyse, Improve, Control	36
ES	Exception Specialist	12
EAN	European Article Number	19
I/E ratio	impact / effort ratio	99
FO	Frequent Offender	78
HD	Handling Device	11
i.i.d.	independent & identically distributed	82
KPI	Key Performance Indicator	21
Lvb	Logistiek via bol.com	1
MSER	Marginal standard error rule	82
OWS	Operator at Working Station	14
PDCA	Plan, Do, Check, Act	39
PFD	Process Flow Diagram	42
SCP	Supply Chain Portal	11
SKU	Stock Keeping Unit	16
SOP	Standard Operating Procedure	44
TIMWOODS	Transport, Inventory, Motion, Waiting, Over-production, Over-processing, Defects, Skills unused	35
TS	Trouble Shooter	14
T&T	Track & Trace	15
TQM	Total Quality Management	37
VAS	Value Added Service	11
VSM	Value Stream Map	36
WIP	Work in Progress	43
WMS	Warehouse Management System	14
WS	Working Station	11

Chapter 1

Introduction

This thesis is written to finalise my Master's Industrial Engineering & Management with the specialisation 'Production and Logistics Management'. The last step of the Master is performing research and writing a thesis about an existing and relevant problem within a company. I executed this research at bol.com at the logistics department. This chapter starts with an introduction of bol.com, continues with the explanation of the logistical process and the problem identification & research goal and ends with the research questions & research design. The following chapters subsequently answer each research question. Finally, this thesis ends with conclusions and recommendations for further research.

1.1 Introduction bol.com

In 1999, bol.com (Bertelsmann On-line) started as one of the first online bookstores in the Netherlands [1]. Since 2012, Ahold Delhaize is owner of bol.com and is a growing internet retail company that sells products in all categories. From 2015 onwards, partners started selling their products by logistics via bol.com. Henceforth, the strategy of bol.com is switching from an online retailer to an online retail platform. Bol.com strives to be the undisputed number one shopping platform for anyone who aims to buy or sell something in the Netherlands and Belgium and make its customers daily lives easier and more fun [2].
Bol.com offers over twenty million products in their webshop and sends around **200,000** products from their warehouses to customers every day. Bol.com offers three different product sources on their platform:

- Own products
  Bol.com buys these products from suppliers, stores the products in the warehouses and sends the products to the customers on order.
- Plaza products
  Plaza partners make use of bol.com's webshop to sell their products, but do not use other facilities of bol.com. When a customer orders a plaza product, the plaza partner sends the ordered products directly to the customer.
- Logistics via bol.com (Lvb) products
  Lvb partners make use of the webshop and the logistical services of bol.com. The

partner sends all his products to bol.com's warehouse, where the product ownership remains at the partner. When a customer orders a Lvb product, the product is picked and packed in the warehouse and sent to the customer. This process is identical as bol.com's own products, except that a Lvb partner keeps the ownership of the products and decides by itself how many items are sent to the warehouse. Therefore, a customer can receive bol.com's own products and Lvb products in one package at home.
In this research the Lvb process is set as scope, because of the involvement of Partners (and their ownership over the products) in the process. This is more explained at the inbound process.

1.2 Logistical process

This paragraph provides an overview of the logistical process. First, an overview of bol.com processes is given. Second, the inbound process is described. Third, a deep dive in the exception process is provided. At last, the focus of the research is explained.

1.2.1 Bol.com processes

At the moment, bol.com has five different warehouses in the Netherlands. Currently, a second building Bol.com Fulfillment Centre 2 (BFC2) is built next to BFC1.

- Bol.com Fulfillment Centre 1 (BFC). This warehouse is the most automated warehouse and stores small to medium items. Also, most Lvb (Logistics via bol.com) products are stored here. Bol.com is owner of this warehouse and the operation has been outsourced to Ingram Micro.
  This research is focused on the BFC. This scope is chosen because most of the Lvb products are stored in this warehouse.
- Centraal Boekhuis. This warehouse is not only used by bol.com, but also by other parties. Most books, CDs, and DVDs are shipped from this warehouse.
- Veerweg. This warehouse is the first warehouse that bol.com opened after the extension of other products than sold by Centraal Boekhuis. This warehouse stores small to large products. Bol.com is in the lead over the warehouse, but leases the building and outsources the operation to Ingram Micro.
- BFC XL. This warehouse stores the extra large products of bol.com such as washing machines.
- Amsterdam Hub. This small distribution centre is located in Amsterdam to facilitate same-day delivery.

When ordered, products are shipped to the customers. The logistical process of own and Lvb products consists of five steps:

1. Inbound - Products arrive at the warehouses and are processed before stored;
2. Stock - Products are stored in the warehouse;

3. Outbound - Ordered products are picked, packed, and loaded on pallets;
4. Distribution - The shipment of products to customers is distributed by multiple transport companies. PostNL is their main distribution partner.
5. Returns - Products returned by customers arrive at the warehouse again.

The logistical process is visualised in Figure 1.1. Retailers (Lvb partners) and suppliers (for bol.com's own products) deliver products to the warehouses. From there the products flow through inbound, stock, outbound, and distribution and are delivered to the customers. A customer has the option to return the product to bol.com, it will be returned to the warehouse. One of the five warehouses receives and processes the returned goods (Veerweg). This return flow is therefore not part of each warehouse.

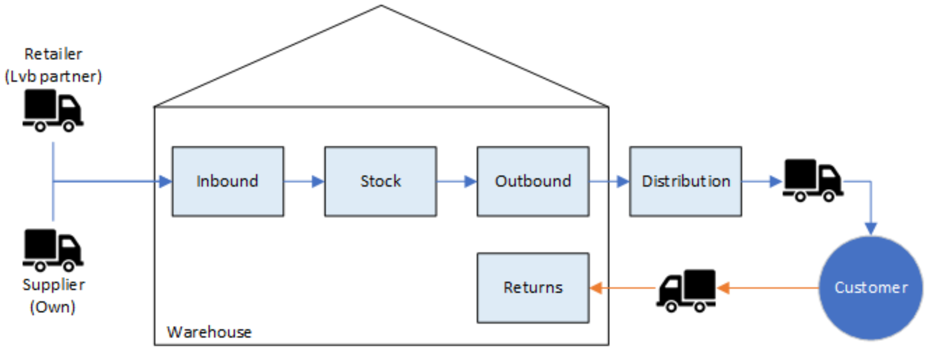

Figure 1.1: Overview logistical process

1.2.2 Inbound process

From now on, all warehouse processes described in this report are based on BFC. The inbound process is visualised in Figure 1.2. When a truck enters the docking station, the driver starts unloading the boxes from the truck. All the items are stored in the unloading bay. The products are sorted on shipment and registered accordingly. Based on the priority of the items within the shipment and the shipment date, boxes are moved to the buffer zone. From the buffer zone, boxes are moved to receiving and divided over the working stations. At the working stations an operator scans the items and places them in an open crate; tote. When a tote is full, it is sent to the warehouse. In most cases the product can be processed directly. However, it may occur that the registration fails. In this case, the products follow a different procedure: the exception process. For bol.com's own products, all exception items are handed over to a second hand buyer. This is because it is easier and mostly cheaper to resell those items, than solving and processing the items. However, for the Lvb exception items, this option is not applicable, since the Lvb Partner is the owner of the item. It is not legal to resell the items to a second hand buyer, besides the Partner pays for the service to store and distribute their items and expects bol.com to do so. Therefore, the Lvb exception process is designed to solve the exception items and process them to stock. On average, BFC receives 281 Lvb exception items each day at inbound. *From now on, if we speak of the exception process, we intend the Lvb exception process.*

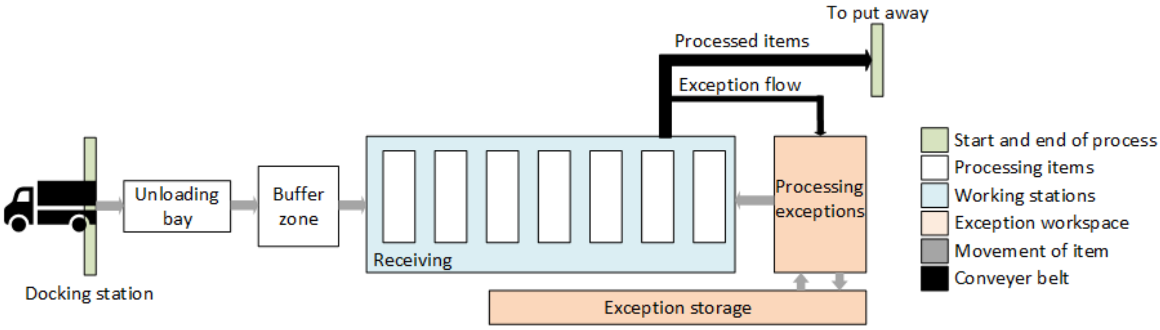

Figure 1.2: Inbound process

1.2.3 The exception process

The exception process consists of multiple steps. The high level steps are explained below. Chapter 2 provides more details about the exception process.

- The exception item is registered.
- The item is stored temporarily in the exception corner.
- Information is gathered and registered to identify the missing data that is necessary to process the exception item. In case of a Lvb exception, often, the partner needs to be contacted to collect missing information.
- An employee in the exception corner collects the exception item and provides the item with correct labels.
- The exception item can be processed in three different ways; processed to stock, returned to the Lvb partner or destroyed (in consultation with partner).

1.2.4 Lvb products

This research is focused on the exception process of Lvb products, because this Lvb process requires attention. The three most important reasons are:

1. the Lvb inbound flow has a relatively high percentage of Lvb exceptions (**x**%) compared to the percentage of bol.coms own exception flow **x**%).
2. The partner remains owner of the Lvb products during storage. During the exception process, the partner's product is not on stock and cannot be sold. It is important to keep the partner satisfied and guarantee that lost sales are minimised.
3. The number of products of the Lvb inbound flow is planned to grow, which results in a growing number of Lvb exceptions. This planned growth has two causes: First, due to bol.com's strategy, the current share of Lvb products within bol.com's warehouse is currently **x**% and is planned to increase. Secondly, as a result of the expected and realised Lvb growth, bol.com reallocated most Lvb products to BFC. This increases the Lvb inbound flow in this warehouse even more.

1.2.5 Bol.com's motivation of research

Bol.com has difficulties controlling the exception process. The process misses clear insight in the procedures and responsibilities. This results in a lot of products that are stored for a long time in the exception storage and therefore cannot be sold to customers. The expected growth of the Lvb products, together with the inefficiency of the process, the misuse of valuable warehouse space and dissatisfied partners motivated bol.com, and specifically the Lvb & inbound team, to gain control over the Lvb exception process in BFC and to start this research. An example of the status of the exception corner is given in Figure 1.3.

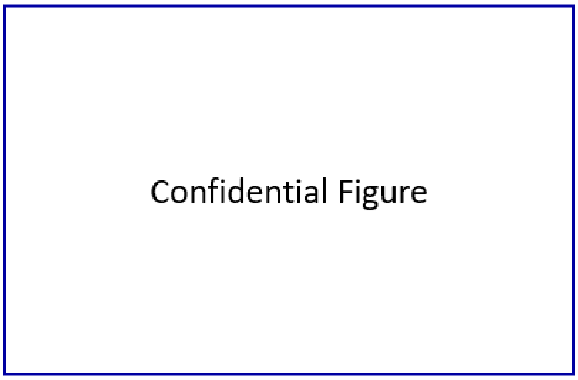

Figure 1.3: Example of products stored in totes in the exception corner

1.3 Problem identification and research goal

In cooperation with bol.com a problem bundle is created to identify all the problems related to the exception process. This problem bundle is visualised in Figure 1.4. All arrows indicate a cause-consequence relationship. The bundle should be read as follows. Start at the left side of the bundle and follow a path of sequencing (with arrows connected) problems to the right. At the right side of the problem bundle the orange marked problems are the impacted performance indicators: throughput time, costs, and partner dissatisfaction. As bol.com already indicated, these indicators are underperforming. To improve the performance, the underlying problems (more at the left side) need to be solved. Together with bol.com, we selected one key problem, which is the main focus of this research. This problem is marked green in the problem bundle. The key problem is defined as: 'There is no standard exception procedure available'. Solving this problem results in a clarification of the process and is assumed to have the highest impact on improving the performance. Solving this problem will impact 22 out of 34 problems and is expected to influence all three performance indicators positively. The impact is visualised in Figure A.1 in Appendix A.1.

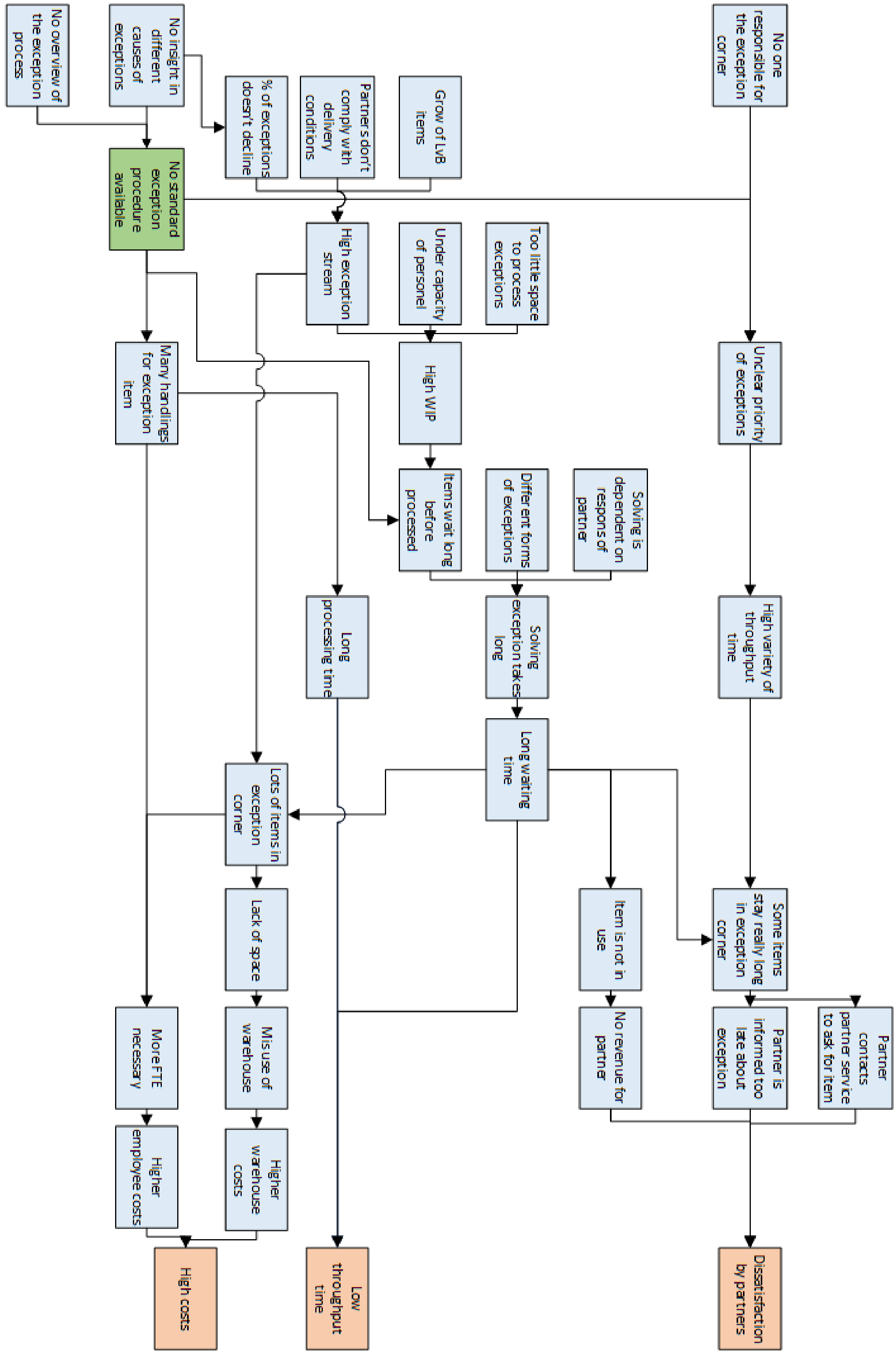

Figure 1.4: Problem bundle

This problem identification leads to the following **problem statement**:

➢ There is no standard procedure of the Lvb exception process, leading to low performance resulting in:

  - long throughput time;
  - high costs;
  - partner dissatisfaction.

Based on the problem statement, the **research goal** is formed:

➢ The research goal is to design an efficient and well performing Lvb exception process.

The performance is defined in Section 2.2.1.

1.4 Research questions & research design

In order to achieve the research goal, the main research question is formulated.

> *"How can bol.com design their Lvb exception process to improve their performance on throughput time, costs, and partner dissatisfaction?"*

To answer the main question, several research questions are formulated. Each research question is answered in a chapter. An overview of the chapters and their interrelations is provided in Figure 1.5. The outline of the thesis together with the research questions is described below.

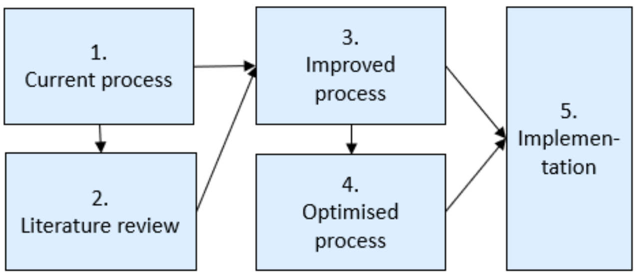

Figure 1.5: Research approach

- **Chapter 2. The exception process**
  To improve the performance of the exception process, first a clear understanding of the current exception process and the current performance is required. This chapter explains the current exception process and provides the performance of the throughput time, costs, and partner dissatisfaction.

  RQ1 What does bol.com's current exception process look like and how does bol.com perform?

  RQ1.1 What does bol.com's current exception process look like?

  RQ1.2 What KPIs are currently in place and what is the current performance of the exception process?

- **Chapter 3. Literature review**
  This chapter provides information for Chapter 4. First, a review is executed to multiple process improvement methodologies and corresponding tools. Next, the best applicable process improvement methodology is selected, and finally we explain which tools can be used to apply the selected methodology on the exception process.

  RQ2 Which knowledge provides input for an improved exception process?

  RQ2.1 To which requirements need the process improvement methodology meet?
  RQ2.2 Which process improvement methodologies are commonly used?
  RQ2.3 How does these process improvement methodologies work and which characteristics do they have?
  RQ2.4 Which process improvement methodology is best to apply?
  RQ2.5 Which tools can be used to apply the process improvement methodology?

- **Chapter 4. The improved exception process**
  In this chapter the exception process is improved based on the current exception process that is analysed in Chapter 2 and the selected process improvement methodology from Chapter 3.

  RQ4 What does the improved exception process look like?

  RQ4.1 Which inefficiencies are present in the current exception process?
  RQ4.2 Which improvements contribute to mitigate the inefficiencies in the exception process?
  RQ4.3 How does a new process design look like when the improvements are integrated?
  RQ4.4 What is the expected performance of the improved exception process?

- **Chapter 5. The optimised exception process**
  In this chapter the improved exception process is simulated to test the impact on the performance of prioritising tasks and decreasing the working hours of employees. Furthermore, we tested the impact of an increase in exception items to estimate the performance in the future. From the results, we translated the improvement opportunities into implementation projects.

  RQ5 What does the optimised exception process look like?

  RQ5.1 What is the goal and scope of the simulation model?
  RQ5.2 Which input data is used to simulate the improved exception process?
  RQ5.3 How to simulate the improved exception process, how to calculate the performance in the simulation model, and what does the experimental design look like?
  RQ5.4 Is the simulation model sufficient accurate to achieve the determined goal?
  RQ5.5 What are the results of the simulation model?
  RQ5.6 How can the results of the optimised exception process be translated into implementation projects?

- **Chapter 6. The implementation of the redesigned exception process**
  This chapter provides an approach on the implementation. We explain how the improved and optimised exception process can be integrated in the current exception process. In short term and long term projects the exception process needs to shift from the current process to the optimised process in order to improve the performance.

  RQ6 How can bol.com implement the new optimised exception process?

  - RQ6.1 Which projects support bol.com to change from the current exception process to the improved and optimised exception process?
  - RQ6.2 How can the projects be scheduled best taking into account the impact and effort?

The research ends with conclusions and recommendations.

1.5 Writing remarks

Two remarks are made on the writing style of this thesis.

1. All analyses are performed by the author of this research, unless states otherwise.
2. People involved in the exception process can be a male or female, in the report no distinction is made and a human is always referred to as ‘he’.

Chapter 2

The exception process

The exception process is part of the inbound process. This chapter explains the current inbound process in more detail as opposed to the high level overview provided in Chapter 1. First, in Section 2.1 the process overview is given. Second, Section 2.2 provides insight in the performance of the process. Finally, a conclusion is given in Section 2.3.

2.1 Process overview

This section starts with providing information about the inbound process and where the exception process fits in. It continues with providing an exception process overview. The section ends with an analysis of the different types of exception items and how often they occur.

2.1.1 Inbound process overview

As explained in Section 1.2, the exception process is part of the inbound process. The inbound process is summarised in the flowchart given in Figure 2.1 and is explained below. The inbound process starts when an Lvb Partner preregisters his shipment online and sends the shipment to the warehouse. A truck with multiple shipments is assigned to a dock and the truck is unloaded. Next, the received shipments are sorted and registered in the Supply Chain Portal (SCP). For every shipment a packing list, named the Handling Device form (hereafter named HD form), is printed and attached to the belonging boxes. The boxes are moved to the buffer zone until the items are planned to be processed. Once planned, the items of one shipment are moved from the buffer zone to a Working Station (WS) and scanned by an operator. If an item cannot be scanned correctly, the item is further processed as an exception. If the item has correct delivery conditions, the article is placed in a tote. It may be possible that bol.com has to perform a value added service (VAS), for example an expiration date need to be added. This consists of placing an additional label over the item code before placing the item in the tote. The items are sent to put away and placed at the right location in the warehouse. Subsequently, the product becomes available on the website to sell.

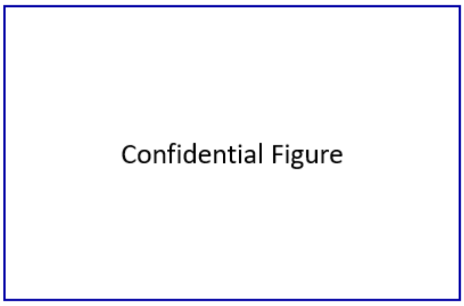

Figure 2.1: Flowchart of the inbound process

2.1.2 Exception process overview

This section starts with providing a high level overview of the exception process to indicate the scope of the exception process. Next, the process that is part of the scope, is explained in more detail. The involved employees and steps are introduced.

High level exception overview

The exception process starts at the WSs and is visualised in a flowchart in Figure 2.2. A floor plan is provided in Figure 2.4. An operator at a WS is equipped with a scanner and screen. On this screen, the system information is provided. Every WS has seven locations for totes. In the totes, the scanned items are placed. The totes on location one to six are reserved for normal items and tote on location seven is used for exception items. When a shipment is processed at a WS, an operator starts with scanning the HD form and scans an item. When the system accepts the item and no abnormality is detected by the operator, the item is placed in one of the first six totes. These items are known as the 'Happy Flow'. However, in four cases the process requires additional actions due to a rejection from either the system or the operator. These four different cases are explained.

1. Expiration date
   If an item is scanned and the expiration date exceeds or almost exceeds due date, the item is declined by the system. The Exception Specialist (ES) places the (nearly) expired items into a large 'Expired' box. Astonishingly, all the items are are destroyed in accordance to the procedure.
2. New item
   When a shipment contains new items, the dimensions and weight of the item need to be determined. This information is used to stock the item on the right location. The first new item that is scanned is assigned to the tote at location seven. The tote is moved by the system to the exception corner. From there, the ES places the new item on a scanner that measures dimensions and weight. The data is saved and the item is placed in an outgoing tote. The new item is processed and fully registered in the relevant systems.
3. Dead on arrival (DOA) item
   If an operator detects a damaged or incomplete item it is assigned manually to tote

seven. When the tote arrives at the exception corner, the ES registers the DOA item in a specific excel sheet. Subsequently, the operator places the item in the specific DOA box. These items are sent return to the Partner.

4. Dummy item

   A dummy item is an item that is refused by the scanning system or detected by an operator, because there is a mismatch with the preregistration of the shipment and the item in the actual shipment. A temporary dummy code is labeled on the item to process the item.

Scope of exception items

This research focuses on the dummy items, because these are the most time consuming, multiple employees need to get involved and they use extra warehouse space when they are stored temporarily at the work floor. Furthermore, no clear procedure is in place. We speak of an exception case when multiple identical items in a shipment are exception items. *From now on, exception items refer to dummy items.*

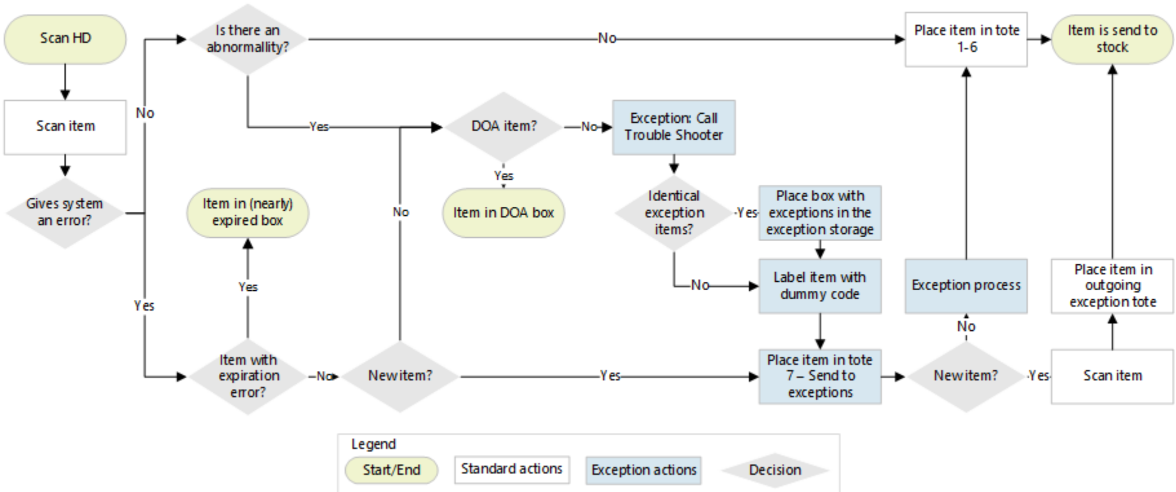

Figure 2.2: Flowchart of high level exception process

Detailed exception overview

We created a detailed process flow of the exception items (dummy items). This is visualised in Figure 2.3. A floor plan is provided in Figure 2.4. The process starts when a shipment arrives at the receiving station and ends when an item is processed; processed to stock, returned to the supplier, or if the item is placed in the destroy box. The explanation of the Swimlane Diagram starts with providing the roles and corresponding responsibilities. Next, the path of an exception case is described.

Roles and responsibilities

Six actors are involved in processing an exception item, they have the following responsibility.

- Operator Working Station (OWS)
  The OWS's main task is scanning items and place them in the correct tote that is provided by the system. When the system or the operator detects an error, the operator informs the Trouble Shooter. Finally, the exception item is placed in the tote at location seven.
- Trouble Shooter (TS)
  The TS is responsible for labeling a dummy code on one exception item of the exception case. On the dummy code label, the supplier ID, shipment date and quantity are noted. Also, the TS is responsible that the dummy item is placed in tote seven by the OWS. Furthermore, the remaining items are stored in the exception corner on the pallets if a case consists of multiple identical exceptions.
- Exception Specialist (ES)
  The ES receives the exception items, he registers the exception items and stores them in the exception corner. When the exception can be processed, the ES collects the exception items from storage and processes them.
- Team lead
  The Team lead is responsible for the return of exception items to the Partner.
- Coordinator of bol.com (CB)
  Bol.com is the link between the ES and Partners. The CB is responsible for preparing the information of the dummy items such that they can be processed. The CB informs the Partner about his exceptions, collects missing information, and discusses how to prevent more exceptions in the future.
- Partner
  The Partner is informed about his exceptions, he provides missing information and needs to improve his process to avoid more exceptions.

Path of exception item

An exception case follows three consecutive stages. The first stage is the registration phase. Here, the exception item is detected, registered and stored in the exception corner (see red blocks in Figure 2.3). The second stage consists of solving the exception case by informing the partner and collecting missing information (see blue blocks in Figure 2.3). In the third phase the exception case can be processed in three possible ways (see orange blocks in Figure 2.3). The steps per stage are explained below.

1. Registration of the exception case
   The OWS or the Warehouse Management System (WMS) detects a mismatch between the preregistered shipment and the scanned item. The OWS informs the TS. The TS labels the exception item with a dummy sticker, and places the item in tote seven. In case of multiple identical exceptions, the remaining items are stored at the exception corner on pallets. The storage area is depicted in Figure 2.5. The system moves

tote seven to the exception corner, where the exception item is received by the ES. The specialist assigns the exception item to an exception tote in the WMS and notes available information of the supplier, product information, and quantity of identical exceptions in a shared Excel file. When the tote is full, the specialist places the exception tote in the exception corner at the exception totes storage, see Figure 2.6.

2. Solving exception case
   The CB receives information from the registered exceptions and copies this information to its own registration files (Excel, and Blue - a client information portal). The coordinator calls the Partner to collect information about the cause of the exception and the missing information. In addition, the coordinator reminds the Partner about proper preregistration and labeling to reduce exceptions in the future. The CB corrects the mistakes of the Partner, updates the information in the registration files and complements the necessary information to process the exception item in the shared Excel file. He also updates how the ES can process the exception case.
3. Processing the exception case
   The ES searches in the shared Excel file for exception cases that are highlighted as 'can be processed'. He collects the dummy item from the tote and he searches, if present, for the identical exceptions at the pallet storage. The specialist removes the dummy item from the tote in the WMS. Subsequently, the ES processes the exception as indicated in the shared Excel file. This is possible in three ways:
   - Process to stock
     To process the exception items to stock, the exceptions need to be provided with correct labels. The specialist generates and prints the labels with the information from the shared Excel file. Besides, the HD form is printed, which is necessary to start scanning the items. All the exception items are collected together with the labels and HD form and is given to an OWS. The exceptions need to be stickered with the labels and can be processed as 'Happy flow'.
   - Return to Lvb Partner
     The ES ensures that the exceptions are packed in a sturdy box and notes the address. The exceptions are handed over to the Team lead. He returns the ES with a Track & Trace (T&T) code which is e-mailed to the CB and forwarded to the Lvb Partner.
   - Destroy
     When an exception remains unidentified or when the Partner gives permission to destroy the items, the ES places the exceptions in the 'Destroy' box.

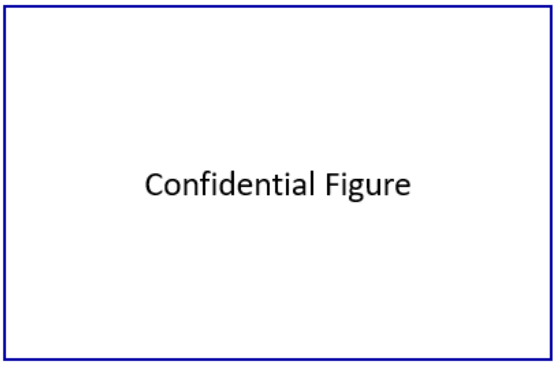

Figure 2.5: Exception storage boxes

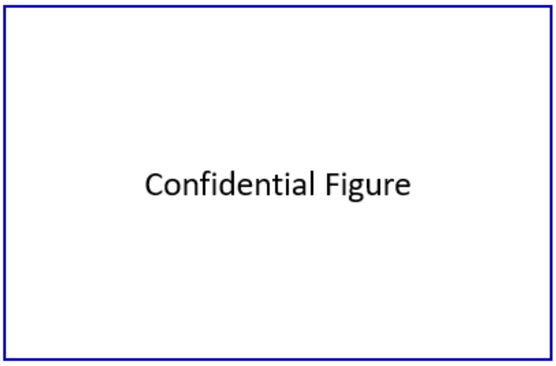

Figure 2.6: Exception storage totes

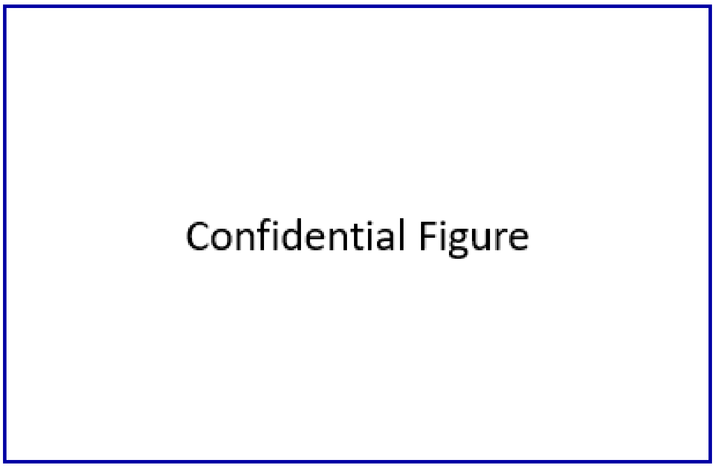

Figure 2.3: Detailed exception flowchart

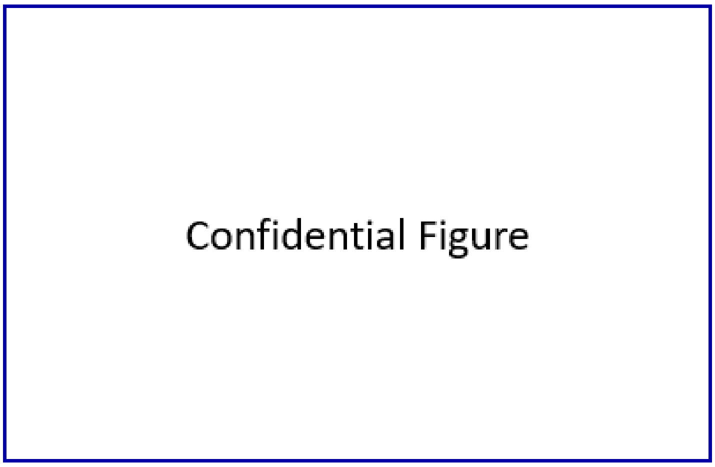

Figure 2.4: Floor plan

2.1.3 Analysis of the exception items

In the analysis, insight is provided in the flow of exceptions, the causes and types of exceptions, and the shares of these types of exceptions.

Flow of inbound and exception items

In the past year (Sep 2018 - Aug 2019), **x** items enter BFC on average each day. From these items **x** % (**x**) are Lvb items. In September 2019, the Lvb inbound flow is already increased with 34% due to the reallocation of almost Lvb items to BFC. Forecasting numbers show that in 2020 the expected Lvb inbound stream will increase by **x** % , leading to **x** Lvb items each day. Of this inbound flow, **x** % are exception items (dummy items). This results in on average **x** Lvb exceptions each day (week 40 2018 - week 39 2019) and will lead to **x** Lvb exceptions each day in 2020. The analysis of the inbound flow is provided in Appendix B.1.

Bol.com has varying sales over the year and sells the most items during the peak in November and December (Singles Day, Black Friday, Santa Claus, and Christmas). The inbound peak starts already in October to fill the warehouse for these sales. In October, November, and December, the inbound streams rise to over **x** items a day and in specific **x** Lvb items a day in 2018. This results in relatively high number of exception cases in those months.

Causes and types of exception items

As already mentioned, items are exceptions because the system or the OWS detects a mismatch with the preregistration and the actual items. The two mistakes that mainly cause this mismatch are: (1) *an incorrect or missing item label* or (2) *incorrect or missing preregistration.* The two main causes, together with other exception causes are explained.

Incorrect or missing item label

All stored Stock Keeping Units (SKUs) are provided with a specific code that is coupled to the item information. This code is the EAN (European Article Number). Because bol.com has own items and items sold by Partners a distinction in the code needs to be made to pick the correct item from the warehouse if the product is sold (the product from bol.com or a Partner). A specific code is created for Partners. This code consists of a combination of the EAN and the supplier ID, called the bSKU (bol.com Stock Keeping Unit). All Lvb items require a bSKU number that is labeled over the EAN. Multiple mistakes are made by the Partner:

- The item has no label to scan.
- The item has only an EAN label and no bSKU. This reason is often noted incorrect by the ES, and is mostly registered as that the preregistration is missing.
- The label cannot be scanned. For example the label is printed too small, the label is printed on low quality paper, or the ink of the code is smudged.
- The item has both, EAN and bSKU. Only the bSKU is allowed to be visible and the EAN has to be taped, otherwise the OWS might scan the incorrect code.

Because the bSKU is an additional action for the Partner, bol.com offers to label the items with a bSKU. If partners use this service, the Partners have to provide the items with the correct EAN code. However, the Partner is not always aware of the required EAN code and sends the items without any label.

Incorrect or missing preregistration

An item can only be scanned if preregistered correctly by the Lvb Partner. The preregistration consists of reporting the shipment that the Partner is going to sent. Per item type the Lvb Partner needs to fill in: The number of items, the EAN, the bSKU (created by the system), the expected shipping date, and whether the labeling of the bSKU will be executed by the Partner or by bol.com.

The main mistakes made by the preregistration are:

- Incorrect EANs/bSKUs in the shipment. The items that arrived with the shipment do not match with the expected items. For example, the item is the same but the color is different, or extra items added that are not registered at all.
- There is no shipment preregistered. It is possible that the Partner sends a shipment before the completion of the preregistration.

Other exception types

Other occurring types of exceptions that are not caused by preregistration or labels are given below.

- An item is being sold as set, but it arrives as two single parts. One part is labeled with the bSKU, this part is scanned and sent to stock. The other part is scanned as exception item. It is difficult to track down the mistake. Eventually, the part that is processed to stock has to be picked and removed.
- The packaging is incorrect.
- It is unclear from which Partner the product originates.
- A Partner exceeded the stock limit. Every Partner has a stock limit and items are declined if the Partner sends more items than preregistered.

Analysis of different exception types

Multiple analyses are performed to provide insight into the exceptions. First the share of exceptions from the total Lvb inbound flow is calculated. Second, the percentage per occurring exception form is calculated.

Share of exception items

Bol.com analysed from the Teams Excel used by the ES and data from the WMS in the second quarter of 2019 the share of 'Unhappy flow' and dummy items from exception items in the BFC. From an analysis of the Teams Excel (April - July 2019) the division of exception reasons is calculated. This is visualised in Figure 2.7. From the inbound flow, **x**% cannot be processed directly. From the 'Unhappy flow',**x**% of the items require a dummy code. This is **x**% of the total Lvb received items.

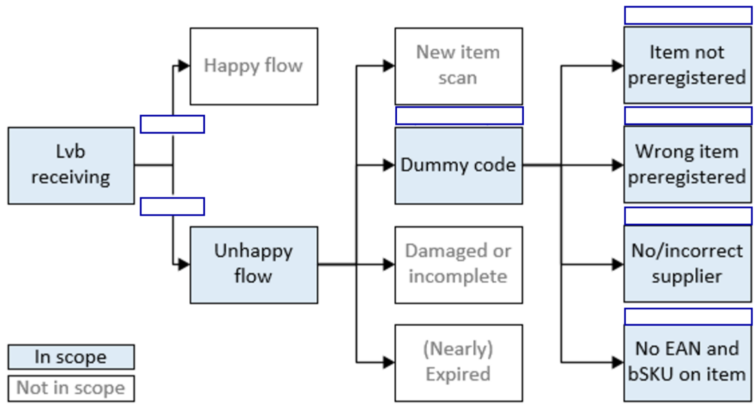

Figure 2.7: Division of exception types

Share of exception types

The shared Excel file used by the ES and CB in the exception corner is analysed to calculate the share of each exception form. The occurrence of each exception reason is counted. All exceptions types that have a share of more than 1% are included in the analysis. The results are provided in Figure 2.7. The share is calculated based on the occurrence of the exception case, and not on the occurrence of the total exception items. This is because exceptions are solved and processed per case. A definition of an exception item and case is given below.

- Exception item: This is a single item that is detected as an exception.
- Exception case: Multiple identical exception items (same product, supplier, shipment, and exception form). For example, if a box with fifty equal items is detected as exceptions, we speak of one exception case.

2.2 Performance

This section discusses the performance of the current process. First, three key performance indicators (KPIs) are specified. Second, an overview is given of how the process performance is measured to clarify the calculations. Lastly, all the steps provided in the overview are executed to analyse the performance of each KPI.

2.2.1 Definition of the performance

The performance of the exception process is measured based on three KPIs: throughput time, costs, and Partner satisfaction. These KPIs are set based on the importance of those indicators in the exception process, at bol.com, and in literature.

First, the problem identification, provided in Section 1.3, points out that these three KPIs are underperforming. Second, the indicators are used within the bol.com environment as KPIs. As mentioned before, bol.com planned to scale up the Lvb share and Partner satisfaction is of high importance. To reach customer satisfaction, fast delivery, and therefore a high throughput time, is required. Furthermore, in the contract with a Lvb Partner, bol.com states to process the Partners items within 72 hours after receiving the shipment. Also, bol.com is a profit-seeking company. Lowering costs helps to realise higher profits. To conclude, literature states that throughput time, costs, and Partner satisfaction are often used KPIs in operations [3]–[10].

The definitions of the KPIs in the exception process are given as follows.

- Throughput time
  The length of time between the detection of an exception item and the processing of an exception item (processing to stock, return to Lvb Partner, or destroy).
- Costs
  The total costs generated by spending time, space, and materials to exceptions.
- Partner dissatisfaction
  The percentage of Partners that have negative experiences with the Lvb partnership indicated from a quarterly sent questionnaire and the contact of Lvb Partners with Partner Service about delayed stored items.

2.2.2 Process performance methodology

To determine the performance, a structured analysis is performed. The methodology of the analysis is clarified in this section to provide better understanding of the steps taken to calculate the performance. First of all, we define for each KPI what is calculated and which corresponding information is required. Subsequently, we formulate steps to perform the calculation of the performance.

Calculation definition and required information of KPIs

- Throughput time
  The throughput time is calculated by the summation of all independent processing steps. This requires:
  - All independent processing steps.
  - All throughput times of each processing step.
- Costs
  The total costs consists of all costs of the cost items. The costs of each cost item are calculated by multiplying the costs per time frame with the total time that a cost item is in use (occurrence) and with the percentage that the cost item is in use. Information required to calculate this:
  - All cost items.
  - Price per time frame for every cost item.
  - The probability that the cost item is active per case (occurrence).
  - The total time that a cost item is in use.
- Partner dissatisfaction
  The Partner dissatisfaction is expressed by two indicators.

- Percentage of Lvb Partners that have had exception items (hereafter named exception Lvb Partners) and mark the Lvb Partnership with a six or lower (out of ten).

  An assumption is made that a Partner is not satisfied with the process if it scores a six or lower. In the future, it is desirable that this percentage of detractors reduces. Required information is:

  * The scores of all exception Lvb Partners that filled in the questionnaire.

- Percentage of exception Lvb Partners that contact the Partner Service of bol.com with the reason that (a part of) their sent items are not on stock.

  Partners contact bol.com if they notice in the Partner portal that some items of their shipment are not within 72 hours on stock. We conclude that these Partners are faster with contacting bol.com than that the coordinator of bol.com contacts the Partner. We assume that Partners prefer a proactive approach instead of a reactive response. Also, ideally a Partner is contacted before 72h and it should not occur that a Lvb Partner has to contact Partner Service. Required information is:

  * List of exception Lvb Partners that contacted Partner Service because of delayed items on stock (in 2019).
  * List of all exception Lvb Partners (in 2019).

The two indicators are used because the first indicator is the result of a voluntary questionnaire. To wider the measurement of dissatisfaction, also an indicator is used that measures negative experiences based on actions (contacting Partner Service).

Steps to calculate the KPIs

The calculation of the total throughput time and costs is a complicated calculation and involves multiple analyses. To structure the explanation, five steps are formed in which these two KPIs are calculated. An additional step is used to explain the calculation of the Partner dissatisfaction. This is step six. A matrix is designed to collect the necessary information to calculate the total throughput time (PT) and total costs (TC) in five steps. This matrix is visualised in Figure 2.8. The 'P' refers to 'Processing step' and 'C' to 'Cost item'. In the figure the different collar marks are used to indicate which fields are filled in first. The light marked cells are filled in first, until eventually the darkest blue fields (total throughput time and costs) are filled in.

The six steps that calculate the three KPIs are explained below to provide a better understanding of the performed calculations in Section 2.2.3. The information that is gathered as input for the matrix corresponds with the letters given in Figure 2.8.

I. The independent processing steps (P1) and cost items (C1) are determined.

II. For each processing step it is determined which cost items are involved. When a cost item is active at a processing step, a 'x' is noted. In the matrix, this is visualised by filling the centre of the matrix (P1·C1).

III. The throughput time of each processing step is measured and analysed (P2). Summing these steps result in the performance of the total throughput time (PT).

IV. All costs per cost item per time frame are identified by gathering the employee costs, storage costs and material costs (C2). Also the probability that a cost item is used per exception case (occurrence) of each cost item is measured (C3).

V. To determine the total costs, first the measured throughput time per time step is used to calculate the total time a cost item is in use (C4). Next, the total costs per cost item (C5) is calculated by multiplying the costs per time frame (C2) with the occurrence (C3) and with the time that a cost item is in use (C4). Summing all costs per cost item result in the total costs performance (CT).

VI. The Partner satisfaction is calculated based on two measurements. For the first indicator the percentage of all exception Lvb Partners that score below a seven is calculated. For the second measurement the percentage of all exception Lvb Partners that contacted Partner Service is calculated.

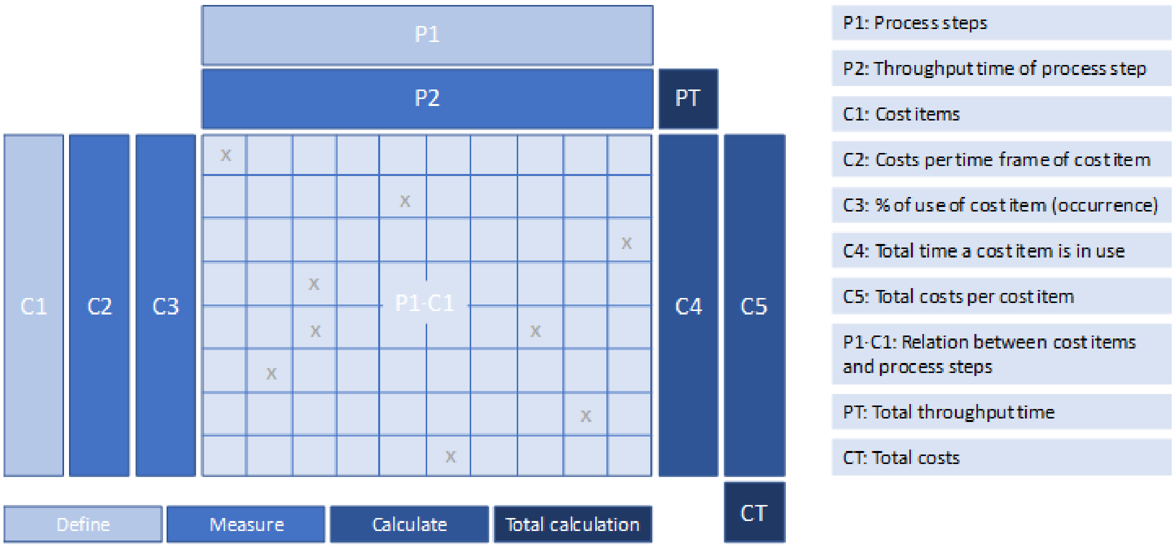

Figure 2.8: Methodology matrix of throughput time and costs

The next section continues with the execution of all six steps.

2.2.3 Analysis of KPIs

This section follows the steps explained in Section 2.2.2 in order to calculate the performance of the throughput time, costs and Partner satisfaction.

I. Processing steps and cost items

The processing steps (P1) and cost items (C1) are clarified. These form the base of the matrix given in Figure 2.9. The processing steps are determined such that the throughput time of each processing step can be determined. The cost items are determined in order to define which costs are made in the exception process.

Processing steps

From Figure 2.3 the following independent processing steps are determined (P1). The processing steps are necessary to understand the matrix and are explained below. For some processing steps, the probability that a step occurs is explained as well and cursively written.

- Detect exception by OWS
  When the system shows an error when an item is scanned or when the OWS detects an exception item itself, he walks to the TS and shows the exception item(s). When the exception item has a dummy item, he scans this dummy item to tote 7.
- Detect exception by TS
  When the OWS shows the exception case, the Trouble Shooter checks the shipment, labels one item of the exception case, and writes the shipment information on the label.
- Store identical exception items in exception corner
  When an exception case consists of more than four identical exceptions, one item is placed in tote seven and the remaining items are stored on a pallet in the exception corner by the TS.
  In 69% of the cases, an exception case consists of more than four identical exceptions.
- Move tote seven
  When the exception item is placed in tote seven, the item waits until the tote is full. When it is full, it is sent to the exception station. This can be seen as a temporary storage location.
  This step plays a role in the total throughput time, however there are no costs associated to this step.
- Register dummy item
  On arrival of tote seven at the exception corner, the items with a dummy label are registered by the ES.
- Store dummy item in exception tote
  The exception item is stored in an exception tote in the exception corner.
- Storage before solving exception
  This is the storage time where the exceptions are registered by the ES, but not registered by the CB.
- Storage during solving exception
  This processing step consists of the time that the CB has registered the exception case, but did not solved the exception.
- Solve exceptions
  This processing step indicates the average time spend by the CB to solve the exception case.
- Exception items wait before processed
  This is the storage time of exception items between the exception item is solved by the CB, but is not processed by the ES.
- Search for dummy item
  When an exception case is solved by the CB, the ES search for the dummy item in an

exception tote in the exception corner.

- Search for identical exception items
  When the exception case consists of multiple identical items (69% of the cases), the ES collects (next to the dummy item) the remaining identical exception items on the pallets at the exception corner.
- Process exceptions
  The ES executes multiple tasks to process the exceptions of a case.
- Label
  In 86% of the cases, an exception item can be processed and stored by bol.com. All exception items require a correct label. One exception case consists on average of 37 exception items that need to be labeled.
- Create T&T and send items return
  In 12% of the cases, the exception items need to be returned to the Lvb Partner. The Team lead takes care of this return shipment.
- Forward T&T
  When the exception case needs to be returned (12% of exception cases), a T&T code is created and send to the Partner.

Cost items
Three different cost segments are identified. Within the cost segments, different cost items are indicated (C1).

1. Employee costs
   The five involved employees are: the OWS, the TS, the ES, the CB and the Team lead.
2. Warehouse storage costs
   The warehouse storage costs consists of the storage of the exception totes and the storage of the identical exceptions on pallets in the exception corner. When an exception is placed in tote seven, this is also seen as temporary storage and visualised as cost item.
3. Material costs
   When exceptions can be processed to stock, the items require a new label. A fixed price is determined by bol.com for the label and the handling fee.
   The label costs are not time dependent and are calculated per exception item.

II. Processing steps and cost items matrix
A matrix is designed to indicate which cost items are involved in which processing step (P1·C1 in the matrix). This is used to calculate the total active time of the cost items. The relation between the processing steps and cost items is visualised in Figure 2.9. The cells are marked green with a 'x' if a cost item is active in a processing step. For example, the coordinator of bol.com is involved in solving the exception and forward the T&T code.

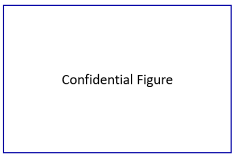

Figure 2.9: Processing step and cost item matrix

III. Throughput time

This section provides insight in the performance of the throughput time. It starts with the calculation of the total throughput time (PT in the matrix). This is based on the throughput time per processing step (P2 in the matrix). Second, more detail is given about the performed analysis. Third, a conclusion of the throughput time is given. Lastly, an additional analysis is performed about the exception items on storage and the relation with the throughput time.

Throughput time per processing step

For each processing step the throughput time is measured. Table **x** provides for each processing step the measurement method, the average duration of the time step, the lower- and upper bound of the duration, the probability that the step is executed per exception case, the adjusted time calculated by multiplying the occurrence with the measured time, and an analysis number. This analysis number refers to the explanation of the performed analysis in the next paragraph. Here, each listed explanation corresponds with the number in the table. The processing steps are measured in two ways: tasks are timed and data is analysed. The used data originates from the WMS, the Shared Excel file used by the ES, and the Excel file used by the coordinator of bol.com. The adjusted time is the average time over all cases and is used to calculate the total throughput. The analysis number is added to provide more insight in the performed analysis in the next paragraph.

Confidential Table

Information of measured frequencies and additional data analysis

We executed multiple analyses to determine the frequency that a processing step occurs. The numbers in Table **x** in column info frequencies refer to the numbers in the explanation below.

1. If an exception case consists of four or less items, all items are stored in tote seven. The TS does not have to walk to store the identical exception items. The exception cases consist in 31% of four or less items.
2. When a cases consists of more than four items, all other items than the dummy item (the identical items) are stored in the exception corner. This is in 69% the case.
3. A query is written to provide data from the WMS about the average time that it takes before the tote moves from the working stations to the exception corner. The frequency is set to 50% because we assume that on average, the exception item has to wait half of the time before it is sent to the exception corner.
4. An exception item that is registered by the ES is placed in a tote that is standing at

the ES's desk. This tote is stored in the exception corner when it is full. On average 2.17 exception items are stored in one tote, this result in that on average the tote is stored in 46% of the time.

5. To solve the exception case, the Lvb Partner is called and informed about his exception case. The goal of the call is to prevent exception cases in the future and to obtain missing information. The duration of the call is dependent on the cause of the exception and how well the Partner understands the Lvb shipment process. Sixteen different causes are identified, together with the call duration and the frequency of the cause. The causes are categorised based on the expected call duration. The average time spend on solving the exception is calculated by the weighted average of the duration of the different causes. The analysis is provided in Appendix B.2.

6-7-8. The exceptions can be processed on three different ways; processed to stock (6), returned to the Lvb Partner (7), and destroyed (8). From the Excel sheets is calculated in which ratio the three processing solutions occur.

Furthermore, an extensive analysis is performed to indicate the processing times of the storage time. The Excel data was not directly ready to use and is cleaned to generate reliable dates. The lay-out of the shared Excel is not optimal. For example, dates are noted in different styles (American style MM-DD-YY / European style DD-MM-YY), some dates are written in comments or left blank.

Lastly, we analysed the average number of exception items and cases that are stored on average, since the throughput time is dependent on the total exception cases. The the stored exceptions have to wait on their turn to be solved and again to be processed. On average x exception items are stored constantly in the exception corner. This is equal to x exception cases, which is very high and occupies a lot of space.

Conclusion of throughput time

The total throughput time is on average days. Table **x** provides an overview of the storage time, the handling time and the total throughput time. The storage time has by far the most impact on the total throughput time. In the agreements between the Partner and bol.com, bol.com guarantees that all items of the shipment are on stock within 72 hours after delivery of the shipment. The exception process is not in line with this agreement. A more detailed analysis is performed about the variation of the total throughput time in Appendix B.3.

Confidential Table

IV. Costs per time frame and occurrence of each cost item

This section provides the costs per time frame (C2) and the occurrence (C3) of each cost item. This is used to calculate eventually the total costs per cost item. For each cost item the costs and occurrence are provided in Table **x**. Per cost segment, the costs are determined.

- Employee costs - We assume that all employees have equal cost rates.

- Storage costs exception corner - The storage costs in the exception corner are based on the storage costs per month per item in the warehouse. A dummy item always consists of a single item. The identical exception items consists on average of **x** items per case (this occurs in 69% of the cases). There are no costs associated with the operation of the line.
- Material costs - The material costs consist of the label costs. The label costs per case are not dependent on time and are calculated based on the labeling costs of **€x** per item, an occurrence of 86%, and on average **x** items per case that needs to be processed.

Confidential Table

V. Total costs

In this step the total costs are calculated, this is visualised in Figure 2.10. Additionally, a conclusion is given. The total costs of processing an exception case is **€x**. This results in **€x**per exception item, based on an average of **x** items in a case.

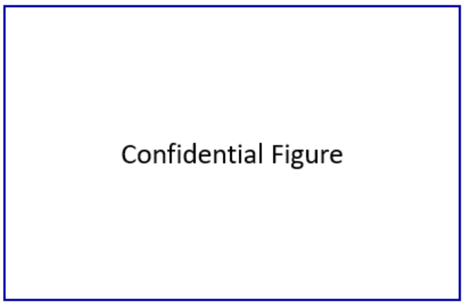

Figure 2.10: Calculation of total costs per exception

The calculation of the total costs is divided in three parts.

1. The total active minutes of a cost item are calculated (C4). The total active minutes are derived by summing the throughput time of the processing steps (P2) where the cost item is involved (indicated by a ‘x’ in the P1·C1 field in the matrix).
2. The total costs per cost item (C5) are calculated by multiplying the costs per minute (C2) by the occurrence (C3) time the total time spend per cost item (C4).
3. All costs per cost items (C5) are summed to provide the total costs (CT).

Conclusion total costs

The total costs per cost segment are provided in Table **x**. The costs consists mostly of the operator costs.

Confidential Table

The yearly costs of processing all the exception items result in **€x**in 2019 (**x** exceptions each day, five days a week) and will be **€x** in 2020 (**x** exception items each day).

VI. Partner dissatisfaction

In this step, the Partner dissatisfaction is determined. Two indicators are specified to determine the current Partner dissatisfaction. In the future, these indicators can be calculated again and compared with the current situation to evaluate if the situation is improved.
The two indicators are:

- Percentage of Lvb Partners that have had exception items (hereafter named exception Lvb Partners) and mark the Lvb Partnership a six of lower (out of ten).
  Sixty exception Lvb Partners filled in the questionnaire. From these participants, seven marked the Lvb Partnership with a six or lower. This is equal to **x**%. In the future, this percentage has to reduce.
- Percentage of exception Lvb Partners that contact the Partner Service of bol.com with the reason that (a part of) their sent items are not on stock.
  The number of exception Lvb Partners in 2019 is **x**. From these Partners, **x** contacted Partner Service at least once. This result in **x**%. Furthermore, **x** % of all exception Lvb Partners had at least two times contact with Partner Service. It is desirable that in the future the delayed shipments decrease and therefore the percentage of exception Lvb Partners that contact Partner Service decrease.

2.3 Conclusion

The current exception process consists of three stages. In the first stage the exception case is detected, registered, and stored in the exception corner. In the second stage, the exception case is solved. Here, the partner is contacted, the missing information is collected and there is discussed with the Partner how to process the exception items (to stock, return to Lvb Partner, destroyed). In the last stage, the items of the exception case are picked from the exception storage and processed.
In 2019, each weekday on average **x** exception items arrived. This is equal to **x** different exception cases. This will grow approximately to **x** exception items (**x** cases) in 2020. The performance of the current exception process is analysed by three KPIs. The total throughput time is **x** days. The total costs per exception case is €**x** and €**x** per exception item. The total costs for 2019 result in €**x** in 2019 and will be €**x** in 2020. The Partner satisfaction is defined by two indicators: from a survey and from the contact with Partner Service. The results of multiple questionnaires show that **x** % of the exception Lvb Partners are dissatisfied. In **x**% of the exception Lvb Partners, they have had contact with Partner Service about delayed items on stock.

Chapter 3

Literature review

The literature review is written to provide information necessary for the improvement and redesign of the exception process. In section 3.1 a research is performed to identify the most applicable process improvement methodology for the exception process together with corresponding tools. This information is used in Chapter 4. Subsequently, a conclusion is written in Section 3.2.

3.1 Analysis of process improvement methodologies and corresponding tools

To ensure long-term successes, operational organisations need to possess a functional and holistic understanding of the operating system, suitable process improvement methods, approaches and tools in order to apply successfully sustainable improvements in a changing business environment [11]. First, requirements for the methodologies are listed. Next, research on multiple process improvement methodologies is performed. By comparison, the most applicable methodology is chosen. Lastly, a literature review is performed to useful tools of the chosen methodology to gain insight in how to apply the improvement methodology in Chapter 4.

3.1.1 Requirements process improvement methodologies for the exception process

To determine which methodology can be applied best, four requirements are listed. The requirements are based on the KPIs that need to be improved, defined in Section 1.3 and based on characteristics of the exception process.

1. Focused on throughput time, costs, and partner satisfaction
   The methodology needs to focus on and needs to have potential to improve the three KPIs: throughput time, costs, and partner satisfaction. The focus on throughput time is expressed by to focus on speed, flow, and effectivity in the process. Besides, it requires to have a goal of saving costs. Also, the methodology needs to have the partner (customer in the methodologies) as starting point of the process.

2. Product quality is not the main focus
   Product quality is not of high importance within the scope of this research. The process is focused on processing exceptions instead of creating products. The improvement methodology has to be mainly focused on improving the process rather than on improving product characteristics. Improving product quality is mostly realised by reducing variation. The variation in the exception process is already caused before the exceptions enter the exception process and this will not be changed within the scope of this research. Important to remark is that process quality and service quality are important for the exception process.
3. The methodology needs to allow decisions and differentiation in the process
   The methodology needs to be able to handle different flows in the process based on decisions. An exception will follow a different process based on the cause of the exception and related decisions.
4. Clear methodology tools
   The methodology needs to be clear on how to apply the method and which tools contribute to improve the exception process.

3.1.2 Process improvement methodologies overview

This section describes the most well known process improvement methodologies. These methodologies are explained and an overview is generated to make a comparison. Finally, we selected one methodology to apply to improve the exception process, based on the set requirements and the focus areas of the methodologies. Lastly, the chosen methodology is validated by use of the framework provided by M.J. Hicks & J. Matthews [11]. This framework describes which process improvement methodologies can be applied for which process focus.
Multiple search terms are used to find articles that describe multiple process improvement methodologies. This analysis is described in Appendix C.1. Five methodologies occur in fifty or more percent of the articles, therefore these methodologies are chosen to compare. All methodologies are often applied and well suited in the manufacturing and operation industry [12, 13]. Since the exception process is characterised as an operational process, all methodologies can be applied.

The five well known methodologies are explained below.

I. Lean
The concept of Lean was first introduced by Womack, Jones and Roos (1990) in order to describe the working philosophy and practices of the Japanese vehicle manufacturers and in particular the Toyota Production System. The philosophy involves eliminating waste and unnecessary actions and connects all value creating steps [5]. Lean is a very structured methodology to improve processes and can lead to improvements on customer satisfaction, costs, throughput time, and quality [6]. The five key principles of Lean are [11, 12]:

1. Specify value
   Define value precisely from the perspective of the end customer in terms of the specific product with specific capabilities offered at a specific time.
2. Identify value streams
   Identify the entire value stream for each product or product family and eliminate waste.
3. Create a flow
   Reorganise processes in order to smoothly move products through the value-creating steps.
4. Let the customer pull value
   Design and provide what the customer wants only when the customer wants it.
5. Pursue perfection
   Strive for perfection by continually removing successive layers of waste as they are uncovered.

Lean distinguishes three forms of waste. These are expressed by the Japanese terms muda, muri, and mura and are explained below [14].

- Muda - Uselessness
  Muda aims to reduce uselessness in every processing step. It focuses on the eight types of process waste:
  - Transport - Transporting materials or products
  - Inventory - Unnecessary supplies or stock
  - Motion - Searching and unnecessary movement
  - Waiting - Goods or documents not being processed or waiting employees
  - Over-production - producing more than asked by the market
  - Over-processing - Taking unneeded steps to process parts
  - Defects - Faults, scrap or bad quality
  - Skills unused - Not using existing expertise or knowledge

  These eight waste types are denoted by TIMWOODS, where every letter stands for one type of waste [12, 15].
- Muri - Overburden
  Muri is associated with waste of overloading of equipment, facility or people resources beyond its capacity. It can also be the under utilisation of capacity resulting in idle time in the process. Two causes of overburden are poorly organized workstations, where more effort than necessary is put in ordinary activities and a lack of standardised work, where unclear work instructions and poor communication play a role [15].
- Mura - Unevenness
  Mura refers to unevenness in the production volume. It occurs in two different ways: it is originated from variation in the production scheduling, or in an uneven production workload and pace of work. It focuses on the elimination of fluctuations in scheduling or preparation level [12, 15].

Lean uses multiple qualitative and quantitative tools to analyse and improve a process. The tools can be structured following DMAIC (Define, Measure, Analyse, Improve, and Control) [12]. This approach is originated from Six sigma and is explained in more detail in the next paragraph. First, tools to define the process are the Swimlane Diagram, Process Flow Diagram and the Spaghetti diagram. In the measure phase, multiple indicators need to be calculated to provide insight in the performance of the process. In order to analyse, the following Lean tools can be used: current state Value Stream Map (VSM), identifying TIMWOODS, analysis of levelling the processing times, analyse if the process can become more standardised, and look into the possibilities of levelling the workload. The Improve phase consists of using all gathered information to improve the process by designing a new process and creating a future state VSM. The control phase has no specific tools [12, 13].

II. Six sigma

In 1979 Motorola was the first company that completely changed their company after it discovered their cause of market loss; poor quality. The company gained big successes by improving the processes by being “Critical to Quality”. Motorola sets its quality standard to a process variability that has a maximum standard deviation of 6 sigma [12].

If a defect is defined by specification limits, separating good from bad outcomes of a process, then a six sigma process has a process mean (average) that is six standard deviations from the nearest specification limit. This result in that a maximum of 3.4 out of one million can be a defect.

Next, Six sigma is further disseminated by the CEO of General Electric, Jack Welsch. Welsch started in 1996 a campaign called “The GE-Way”, where the company switched their strategy and production processes totally. The strategy changed to quality, aiming to produce nearly defect-free products [7, 16].

Six sigma is a long-term, forward-thinking initiative designed to fundamentally change the way corporations do business. It provides methods to recreate the process so that defects are significantly reduced or even completely prevented. The methods can be used to continuously improve the standardisation and stabilisation of the process. The base of Six sigma is reducing variability. Less variability leads to a more stable process, higher quality reliability, less defects, resulting in less costs [7]. Next to improved quality and cost savings, Six sigma can lead to partner satisfaction [13].

The method used for applying Six sigma is DMAIC, a continuous improvement method standing for Define, Measure, Analyse, Improve, and Control.

1. Define
   Practitioners start with identifying who the customers are and what their problems are.
2. Measure
   The key characteristics are categorised, data is collected and measurement systems are verified.
3. Analyse

The data is processed to statistical outcomes. Important causes of defects or problems are identified supported by root cause analysis tools.

4. Improve
   Solutions of the problem are designed and implemented. The results of implementation need to be measured by evaluating whether process improvement is successful at solving the problem.
5. Control
   The sustainability of the solution is measured, where it is performing at a desired and predictable level. The process is monitored over a longer period, to assure that no unexpected changes occur [17].

Six sigma uses statistical tools to identify and remove causes of variation for which measures are needed. [7, 11]. Implementation of Six sigma requires trained employees (so called green and black belt specialists) specialised in the improvement methodology [12]. Besides, a Six sigma project works best if variation of the process is the cause of the problem [18].

III. Total Quality Management (TQM)
Total Quality Management (TQM) has become the major business strategy in the nineties [19, 20] and it is the precursor to Six sigma [6]. TQM is a process improvement philosophy aimed at continuously improving the performance of products, processes and services to achieve and exceed customer expectations [21, 22]. TQM aims for an error free business performance [6]. The focus of TQM is on the employees, quality and customers. There are no clear tools available to apply TQM. [22, 23]. Complete implementation of TQM in an organisation can lead to the following advantages: improved employee involvement, improved communication, increased productivity, improved quality and less rework, improved customer satisfaction, reduced costs due to poor quality, and eventually improved competitive advantage [22].
These areas are expressed in six elements [23]:

1. Leadership
   Strong leadership will facilitate high organisational performance, individual development, and organisational learning.
2. People Management
   All employees should be aligned with the organisation's strategic directions. The voice of the employees is important together with a pleasant work ambiance.
3. Customer focus
   The organisation needs to focus on current and emerging customer requirements and expectations. Besides, customer relationship management demands attention.
4. Strategic planning
   The organisation's planning and deployment of plans are important, along with the organisation's attention to customer and operational performance requirements.
5. Information and analysis
   The use of data and information is of high value to maintain a customer focus and

drive to quality excellence. TQM uses various types of statistical process control tools under which Control charts, Pareto charts, Cost-of-quality analyses, Cause and effect diagrams, The Check sheet, Histograms, and The Scatter diagram [24, 25].

6. Process management
   Process management focuses on the interrelation between multiple processes such as the design of products, production, delivery, supplier management and how they are integrated.

TQM is a process improvement methodology applicable when the organisation's focus is on quality and the customer. It needs to be implemented at the whole organisation. It requires a strong management and trained managers. TQM uses an improvement cycle to improve the business consisting of four stages: Plan, Do, Study, Act (PDSA cycle) [26].

IV. Business Process Re-engineering (BPR)

In 1990, Business Process Re-engineering (BPR) was first introduced by Hammer and by Davenport and Short [27, 28]. BPR is originated when the market changed from costs and quality to flexibility. Three driving forces of BPR are: focus on diverse customers, focus on the customer needs in all niches, and a change to be flexible and fast changing organisation [29]. BPR is the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in performance such as cost, quality, service and speed [30]. It focuses on the restructuring around the client base and is therefore customer driven. The complete process is restructured, which gives potential to large improvements in throughput times, costs, and customer satisfaction [6, 31].

Re-engineering a company is associated with a large improvement process. The choice of applying BPR needs to depend on the magnitude of the needed change, the corresponding feasibility of the implementation, and the required resources. An advantage of BPR is that it searches for a long term solution in comparison to improve a not working process over and over. Appropriate candidates for applying BPR are complete companies or the management of the company that is not well functioning. Or in contrast companies that outperform and see opportunities to develop a lead over their competitors [29].

Five principles help to manage change and to reinvent the company's competitive advantage [29, 32]:

1. Strategy has a wider meaning than only providing a company's vision. It needs to be related to questions as what is being done? Why it is being done? And how can it be done differently?
2. Top management needs to be committed to vision, strategy and objectives both at the organisational and functional levels.
3. Where change is necessary, clear goals are required, together with projects broken down into manageable parts.
4. The cross-functional activities need to be promoted with shared objectives and by externally oriented thinking.

5. Decision making in terms of production needs to be decentralised, to a point as close as possible to the customer.

Tools used in BPR are in the field of Process visualisation, Process mapping, The operational method study, Change management (human side), Benchmarking, and tools focused on quality (see other tools in the quality methodology fields) [29].

V. Kaizen

The Kaizen methodology has been introduced and applied in 1986 by Imai at Toyota. Thereafter, Kaizen has become part of the Japanese manufacturing system [33, 34]. Kaizen is a Japanese word used to describe a process improvement methodology. The word refers to a process of continuous improvement of the standard way of work [35]. It is a compound word involving two concepts: Kai, meaning 'change' and Zen, meaning 'for the better' [36]. The term comes from Gemba Kaizen meaning Continuous Improvement (CI). CI is one of the core strategies for excellence in production, and is considered vital in the competitive market [37]. Kaizen calls for endless effort for improvement involving everyone in the organization [38] and is explained as 'To disassemble and put together again in a better way' [12]. Kaizen can lead to improved efficiency, productivity, reduction of costs, increase of quality, improved customer satisfaction, decrease of security incidents and eventually to competitiveness [33,39]. It focuses on small improvement projects in which the performance is not optimal [12]. Kaizen has five foundations [39]:

1. Teamwork - Create commitment for all.
2. Personal discipline - Follow the standards.
3. Better moral - Assure good work moral.
4. The quality circle - Follow the Plan, Do, Check, Act (PDCA) improvement cycle.
5. Suggestions for improvement - Be open for ideas and suggestions.

Kaizen improvements can be distinguished in two categories. The first is Small Kaizen for simple ideas, which can be solved during daily team meetings within five minutes. Second, there is Big Kaizen or Kaizen Blitz for complex problems, which requires a project team that solves a problem in three to five days. For a Big Kaizen project, VSM is used to make a current state VSM and a future VSM together with an implementation plan to change the process from current to future state. Other tools used for Kaizen are: creating a visual workplace (using for example 5S to control this), use root cause analysis (to detect the actual cause of a problem), and use TIMWOODS to detect the types of waste. Solving issues always start at the customer side [12].

Process methodology overview

A summary of the methodologies is provided in Table 3.1. Here, the advantages, focus areas, tools and requirements are given.

Table 3.1: Summary of process improvement methodologies

Vision	**Lean**	**Six sigma**	**TQM**	**BPR**	**Kaizen**
Start	1990	1996	1980	1990	1986
Vision	Waste, value creation, flow, customer	Variation, quality	Leadership, quality	Radical change, flexibility, cross functionality	CI, instant approach, performance
Performance improvements	Costs, throughput customer satisfaction, quality	Quality, standardization, costs, customer satisfaction	Quality, employee satisfaction, communication, productivity, costs, customer satisfaction,	Costs, quality, service, speed	Efficiency, productivity, costs, quality, customer satisfaction
Focus areas	Waste, value in each process step, flow, customer, CI, process analysis	Variation, quality, customer, standardized and stable processes, CI	Quality, leadership, employees, management, customer, strategic planning, information analysis, process management, CI	Radical improvement, flexibility, customer, strategy, management, project goals, cross functional processes, customer, process visualisation	CI, teamwork, personal discipline, better moral, quality circle open for improvement
Tools	Process flow and spaghetti diagram, VSM, TIMWOODS, Heijunka, process standardisation	Statistical tools, root cause analysis tools	Statistical tools: control charts, pareto charts, cost-of-quality analysis, cause and effect diagrams, check sheet, histograms, scatter diagram. Cycle: PDSA	Process visualisation, process mapping, the operational method study, change management, benchmarking, quality tools	VSM, visual workplace (5S), root cause analysis, TIMWOODS,
Requirements	Applicable for all processes	Green/black belt trained people, variation reason for improvement, suitable for standardised processes	Strategy aligned, quality focus	Large investment and the possibility to change a process completely	Applicable for all processes

Appropriated methodology for the exception process

The match between the methodologies and the requirements given in Section 3.1.1 are discussed below per requirement. One item is added, ‘satisfaction of requirements’. This item provides information about the requirements specific for each methodology and checks if the exception process satisfies these requirements.

1. KPIs
   The performance benefits are compared with the required benefits: throughput time (or efficiency, speed), costs, and partner satisfaction. From Table 3.1, the methodologies Lean, BPR, and Kaizen satisfy these conditions. Six sigma and TQM miss the focus on throughput time.
2. Product quality is not the main focus
   Six sigma and TQM focus both completely on quality. The other methodologies have not their main focus on quality.
3. Decisions and differentiation in the process is permitted
   Six sigma and TQM are focused on quality and corresponding to variation. This makes it difficult to deal with differentiation and decisions in a process. Lean, BPR, and Kaizen have no constraints relative to decisions and differentiation.
4. Clear methodology tools
   All methodologies provide tools to improve the process. The clearness of the approach and categories of tools variate. Lean and Kaizen focus mostly on visualisation tools and ways to identify waste. Lean has clear steps and in each step tools are available. BPR uses visualisation tools as well. Additionally it focus on change management of employees. It uses mainly qualitative tools. A clear approach is missing. Six sigma and TQM uses both statistical tools and problem identification tools. The statistical tools are less applicable on the exception process, because these tools require a standardised process, which is the exception process not. However, the process approach is clear.
5. Methodology specific requirements
   From Table 3.1 we conclude that BPR is not a desirable methodology to use. Applying BPR is only profitable when the process is completely failing. It would be unwise if the complete inbound process will be changed due to the under performing exception process. Besides, a complete change is not preferable, due to the large investment and the complexity of changing drastically the way of working of employees. Also, Six sigma and TQM function only if the strategy is focused on quality. In addition, applying Six sigma requires trained employees and a standardised process.

In summary, Lean and Kaizen are methodologies suitable to use for the exception process. These methodologies focus on the main three KPIs and not in particular on product quality, have no differentiation or methodology specific restrictions and they use clear tools. TQM and Six sigma have a different focus and do not satisfy the requirements. BPR is too radical and the scale is to large for the scope of the research. This makes this methodology unsuitable to implement. Lean and Kaizen show similarities, the methodologies are interrelated [26,40]. Kaizen is one of the underlying principles of Lean manufacturing [5,41,42]. As Kaizen is part of Lean and Lean offers a suitable set of improvement tools, Lean is the preferred methodology to apply.

Validation of the chosen process improvement methodology
To validate the choice for Lean as process improvement methodology, the framework 'Manufacturing improvements paradigms and their corresponding tools and methods' from B.J. Hicks & J. Matthews, 2010 is used. In this framework, six principles are named together with paradigms that can be used when the principle is the main focus of the organisation. Next to the six principles, two additional overarching manufacturing paradigms are listed; Lean and BPR. These overarching paradigms are best to apply when there is not a specific focus point on one principle. This is consistent with the exception process, where no specific focus on a principle is desirable. In accordance with Hicks' framework, Lean is an appropriate process improvement methodology [11].

3.1.3 Tools to apply the process improvement methodology

This section provides detailed information about the tools of the chosen process improvement methodology: Lean. These lean tools are explained in order to be used in Chapter 4 for the improvement of the exception process. In Section 3.1.2 already an overview is provided of the Lean tools. These are explained in more detail below. The tools are structured by the DMAIC approach. As mentioned earlier, there are no tools specified for the Control phase.

- Define
  - Process Flow Diagram
    A Process Flow Diagram (PFD) is a diagram that indicates the general flow of activities carried out on the product and includes decisions to be made. It is the graphical representation of the routing of the product. The diagram has a clear start and end, activities, and decisions.
  - Swimlane Diagram
    A Swimlane Diagram visualises the process with the purpose to distinguish responsibilities for sub-processes. The diagram has multiple vertical or horizontal lanes (swimlanes) that represent the responsible parties. The sub-processes are drawn in the lane of the responsible party. The Swimlane Diagram is an extension of the PFD. It makes it easier to detect improvement opportunities, such as double work or unnecessary switching between responsible parties. This diagram is already created and given in Figure 2.3 in Section 1.2.3.
  - Spaghetti Diagram
    A Spaghetti Diagram visualises (unnecessary) movements on the work floor. Creating a Spaghetti Diagram consists of tracking all the movements of a product or employee and visualise this in a map. Analysing the movements indicates where time and energy is wasted and where improvements are desirable [12].

- Measure

  The following performance indicators are important to measure:

  - Takt time

    The rhythm at which products are requested by the customer. This can be calculated by dividing the available work time by the customer demand.
  - Cycle time

    The speed of the process. This is the (average) time between the completion of two successive products or the time it takes an employee to go through all of the work elements before repeating them.
  - Lead time

    The time for a product or service to travel the entire process from start to finish. The average lead time can be calculated by dividing the Work In Progress (WIP) by the Completion Rate.
  - Processing time

    The Lead Time of an individual processing step.
  - Queue time

    The waiting time between to processing steps.
  - Work In Progress (WIP)

    The total number of products or amount of work that is in progress or that is waiting.
  - Completion rate

    The amount of work that is completed within a certain time period.

  The Measure step provides quantitative input for the tools in the Analysis step. In particular for designing the Value Stream Map [12].

- Analyse

  - Current state Value Stream Map (VSM)

    A Value Stream Map is a qualitative tool that describes all processing steps and how much capacity is required to create a flow. After the analysis of the current state VSM, an improved future state VSM can be designed together with an implementation plan (see the Improve phase). For the design of a current state VSM, a lot of measurements need to be mapped. First, each processing step has to be drawn. The following information needs to be gathered for each processing step, starting with the step that is closest to the customer: the cycle time, change-over time, up-time, availability in shifts, the working time per operator, the number of operators, numbers of products, and the inventory of products between steps. The next step is to calculate the value adding time and the lead time. Lastly, note the product flows and information flows.
  - TIMWOODS (Muda)

    TIMWOODS (Transport, Inventory, Motion, Waiting, Over-production, Over-processing, Defects, and unused Skills) helps to identify the eight types of waste.

Analyse for each type of waste if they occur in the process and how this can be improved.

- Levelling process time (Muri)
  One of the Lean principles is 'Flow'. Analysing the flow consists of analysing the differences between the duration of each processing steps. Eventually, the process flows as fast as the slowest mover. It will not help to optimise only the first processing step, because this generates a queue for the second processing step. In an optimal process, the duration of each processing step equals the takt time (rhythm at which products are requested).
- Standardised process (Mura)
  Mura stands for unevenness and can be improved by reducing variation in the process. This can be realised by critically analysing each processing step and create for each step a Standard Operating Procedure (SOP).
- Type levelling (Mura)
  Another tool to create a standardised process is by levelling the type of products. Type levelling can be realised by creating a process where the production is not in batches, but where the different types alternate each other. For example, if ten products of A and five products of B need to be produced. One solution can be, produce A completely, than B. Another solution is to produce two of A and one of B and repeat that five times. In this case, you are guaranteed that if the production fails, you have some parts of A and some parts of B [12].

- Improve
  In three steps the improvements of the current process can be realised.

  - Design new process
    With all the information gathered, determine how the process needs to be organised and which improvements can be made. Look for all problems into improvement opportunities. Visualises the desired process in process flows.
  - Future state VSM
    In the future state VSM the changes that are made in the new designed process are translated to a VSM. The VSM provides a clear overview with new processing times, capacity. It provides insight in how the process will perform.
  - Implementation plan
    To realise the desired new process, it is important to create a plan that changes the current process to the new one. Tasks, responsible parties, deadlines, and required resources need to be clear [12].

3.2 Conclusion

By literature research, the five most occurring process improvement methodologies are selected. These are further researched in order to find the best method to apply on the current exception process. These five methods are Lean, Six sigma, TQM, BPR, and Kaizen. We defined five criteria to which the Process Improvement Methodology has to meet. In short, these criteria are: The methodology needs to have potential to improve the KPIs, does not mainly focus on product quality, differentiation in the process cannot be an issue for improving the process, and the methodology needs to recommend clear tools to improve the process. Based on the vision of the process improvement methodology, potential improved performances, focus areas, recommended tools to use, and methodology dependent requirements, the methodologies are compared and the multiple criteria are tested. From this analyses, we conclude that Lean and Kaizen are methodologies suitable to use for the exception process. These methodologies focus on the main three KPIs and not in particular on product quality, have no differentiation or methodology specific restrictions and they use clear tools. TQM and Six sigma have a different focus and do not satisfy the requirements. BPR is too radical and has a too large scale for the scope of the research. This makes BPR not applicable to use. As Kaizen is part of Lean and Lean offers a suitable set of improvement tools, Lean is the preferred methodology to apply. Lean tools that can be applied are a Process Flow Diagram, Swimlane Diagram, Spaghetti Diagram, Measurement performance indicators, Value Stream Map and TIMWOODS.

Chapter 4

The improved exception process

Section 4.1 consists of applying the Lean tools on the exception process to identify and group inefficiencies. Second, Section 4.2 provides solutions to mitigate the inefficiencies. Third, the solutions are integrated in the current exception process. The design of the 'improved exception process' is further explained in Section 4.3. In the fourth part, Section 4.4, the expected performance for the improved exception process is calculated. Lastly, a conclusion is provided in Section 4.5.

4.1 Application of Lean Tools and identification of inefficiencies

In this section, multiple Lean tools are applied to identify the inefficiencies in the process. The applied Lean tools were explained earlier in Section 3.1.3. We created Figure 4.1 to provide an overview of the approach of how the waste is identified. First, the lean tools from the phase Define, Measure, and Analyse are applied on the exception process. For each tool inefficiencies are identified. In addition, also inefficiencies from observations are listed. Secondly, an overview of all identified inefficiencies is created by grouping Lean's eight types of waste; Transport, Inventory, Motion, Waiting Over-production, Over-processing, Defects, and Skills unused (TIMWOODS).

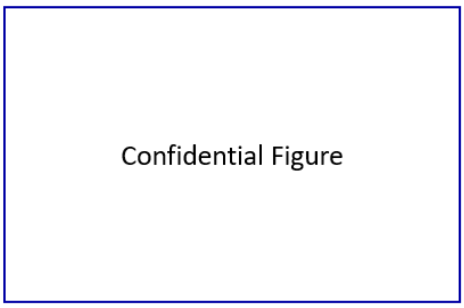

Figure 4.1: Approach to identify Lean's eight types of waste

4.1.1 Inefficiencies identified by the Define tools

The Swimlane Diagram and the Spaghetti Diagram are mapped and inefficiencies are identified. Additionally, inefficiencies from observations is discussed.

Swimlane Diagram

The Swimlane Diagram introduced in Section 2.1.1 in Figure 2.3, is used to evaluate the contribution of each specific handling. In this Swimlane Diagram, actions that include inefficiencies are marked with a red cross and a number. This is visualised in Figure 4.2. The explanation of the identified inefficiencies is provided in Appendix D.1.1. Here, the inefficiency numbering corresponds with the numbering in Figure 4.2.

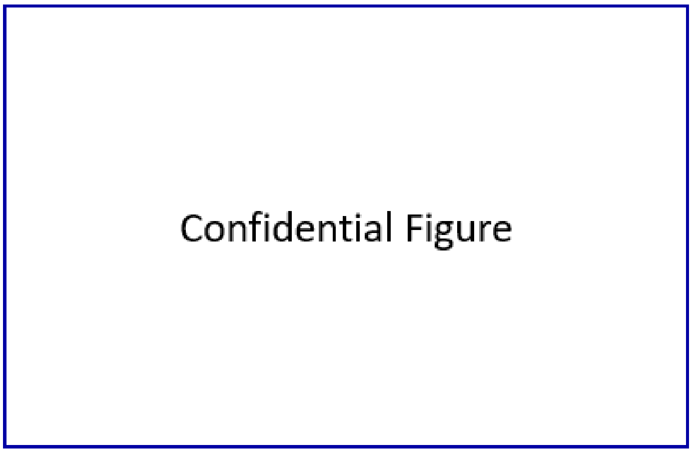

Figure 4.2: Inefficiencies identified from the Swimlane Diagram

Spaghetti Diagram

The Spaghetti Diagram is created by tracking the movements on the work floor. This floor plan is introduced in Figure 2.4 in Section 2.1.2. Three Spaghetti Diagrams are created: the movements of the ES (Exception Specialist), the movements of the exception item and the movements of the TS (Trouble Shooter) together with the OWS (Operator at the Working Station). The visible inefficiencies are identified. Most inefficiencies are detected by the Spaghetti Diagram of the ES. Therefore, this Spaghetti Diagram is visualised in this section in Figure 4.3. The Spaghetti Diagrams of the exception item and of the TS and OWS are provided in Appendix D.1.2, in Figure **x** and Figure **x** respectively. All identified inefficiencies are explained in Appendix D.1.2. Each number in the Spaghetti Diagrams refers to a detected inefficiency.

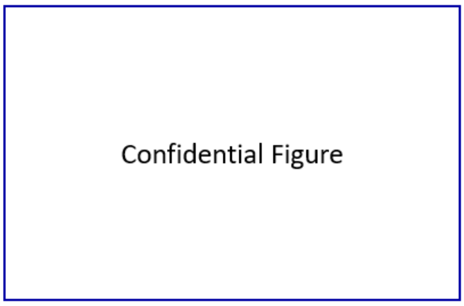

Figure 4.3: Spaghetti Diagram: Movements of the Exception Specialist

Observations

Additional inefficiencies are identified by own observations. This is provided in Appendix D.1.3.

4.1.2 Inefficiencies identified by the Measure tools

The second lean phase is the measurement phase, where multiple indicators are calculated. All these indicators are measured for the current exception process. There is no inefficiency identified directly, however the measurements contribute as input for the VSM (Value Stream Map) in the Analysis phase. The measurements are provided in Appendix D.2.

4.1.3 Inefficiencies identified by the Analysis tools

The current state VSM is created and inefficiencies are identified. Furthermore, three analyses are performed to evaluate the presence and improvement possibilities of: levelling processing time, process standardisation, and type levelling.

Current state VSM

The current state VSM is created. In Figure 4.4 the VSM is provided, together with the identified inefficiencies. In Appendix D.3.1, the identified inefficiencies are explained.

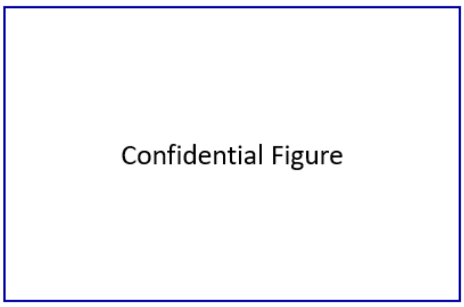

Figure 4.4: Identified inefficiencies at the current state Value Stream Map

In the following eight steps, the aspects and numbers in the VSM are explained.

1. Processing steps
   As mentioned in the measurement phase in Appendix D.2, there are four main processing steps: dummy registration, case registration, solve case, and prepare to process

case. The detection of the exception is used as input step, because this is not the only task of the Trouble Shooter and Operator at the Working Station. The output is that the exception case is processed (either to stock, as a return to the partner, or destroyed). Between the fourth processing step and the output is a step placed where the processing of the case is finalised. No definition is used, because these tasks are executed by different employees as a side task.

2. Input of processing steps

   The dummy registration and the prepare to process case are executed by the Exception Specialist (ES), the Case registration and Solve case are executed by the Coordinator of bol.com (CB).

   - C/T: The cycle time is equal to the cycle time calculated in the measurement phase.
   - C/O: There is no changeover time in the processing steps.
   - Step one and four share one employee (ES). The employee share is calculated based on the processing time of the steps. Step four takes two times longer than step one. Step two and three share one employee as well.
   - The ES has two breaks during the shift and works two shifts. The up time is set to 70% because the ES does not work totally productive. During work there is time for chatting and working slower than necessary.
     The CB works one shift without breaks (this is outside working hours). The productivity is set to 80% because some other meetings or tasks require some time.

3. Inventory

   The average amount of cases stored in the exception corner is **x**. This is the total inventory between steps one and four. The cases are divided based on the throughput time between the steps. On average two cases are placed in tote 7 before it arrives by processing step one. Also, two cases are waiting before the processing of the case is finalised.

4. Output

   As mentioned in the measuring phase, the output is equal to the input. All the exception cases need to be processed as fast as possible. Therefore each day ten cases are processed with on average 37 exception items. This is equal to **x** cases per month. The items can be received during two shifts, five days a week. The flow is continuously, because the parts can be handed over to output directly and it is done by an employee.

5. Input and flow

   On average, each day ten cases arrive. This is equal to **x** cases a month. The cases are detected at the Working Station and they are handed over by the Trouble Shooter continuously.

6. Exception control & flows

   The Exception items are controlled by the Logistics Inbound Group. The main file used is the Shared MS Teams Excel file. Here, all cases are stored. In step one, the information is stored in the file. This is used by the CB in step two. Next, the CB enters additional information in step three in the file, which the ES uses in step four. Between each processing step, the cases are pushed to the next step.

7. Timeline
   In the timeline the storage time is placed at the upper line, the processing time (value adding time) of the processing steps is placed at the lower line. The times are provided from the measurements phase.
8. Production lead time & value added time
   The total production lead time is **x** day and the value adding time is only **x** seconds. The value added time is equal to 0.24% of the total time. This is really small.

Levelling processing times, process standardisation, and type levelling

After an analysis about the levelling of processing times, process standardisation, and type levelling, we can conclude that no clear inefficiencies are detected by this analysis. The analyses are further explained in Appendix D.3.

4.1.4 TIMWOODS analysis

Figure 4.5 provides an overview of the inefficiencies. These are grouped by the types of waste.

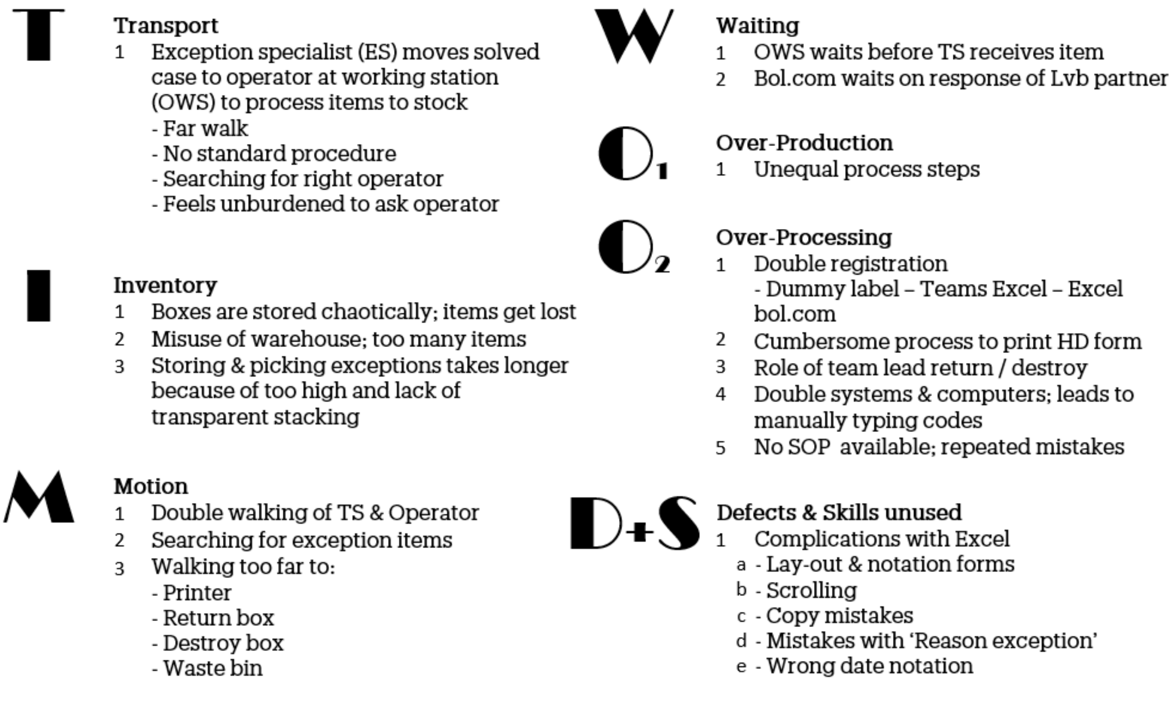

Figure 4.5: Inefficiencies grouped by TIMWOODS

In Figure 4.5, SOP stands for Standard Operating Procedure. In Appendix D all the inefficiencies are explained in more detail per tool. In the next section, the inefficiencies are substantiated as well, together with the solutions for the inefficiencies.

4.2 Solutions to mitigate the inefficiencies

In order to mitigate the found inefficiencies, solutions are introduced. These solutions are designed based on analytical thinking, observations from the process, and discussions with operators on the work floor and bol.com. An overview is provided in Figure 4.6. Per waste type, the solutions are explained using the following structure: the problem is introduced, the solution options are explained together with the implementation conditions, by argumentation the best suitable solution is selected, and the impact is assessed. In case of one suitable solution, only this solution is introduced. In agreement with bol.com five criteria are set to which the solution needs to satisfy:

1. The solution solely impacts the exception process.
2. During the implementation, the employees at receiving are able to execute their tasks.
3. The exception process is not disturbed longer than one day. The solution has to be implemented outside of working hours.
4. The break even point of the investment needs to be reached within three years.
5. The solution can be implemented within six months after finalising this report.

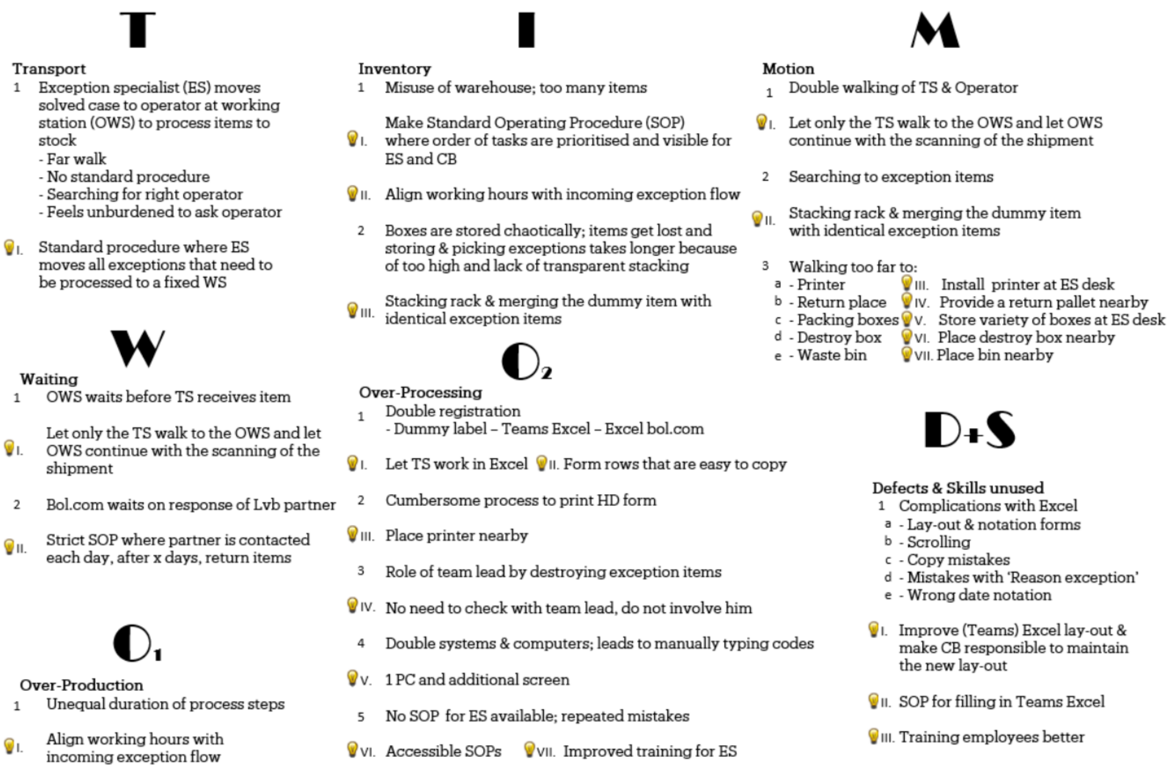

Figure 4.6: Solutions for inefficiencies

All numbered solutions correspond with the roman numbers in Figure 4.6.

Transport solutions

I. Cooperation ES and OWS

When an exception item can be processed to stock, the ES (Exception Specialist) is responsible for printing the labels and the HD form. However, it is not officially specified who is responsible for labeling and scanning the items to stock (the ES or the OWS (Operator at the Working Station)). When the ES would be responsible for that task, it would lead to additional work and less time available for the registration and processing of exceptions. Although, the ES will not have to search for a qualified OWS that can process the exception items to stock. If an OWS would process the exception items to stock, his work load would not change, since for the OWS the targets are dependent on how many items they process, exception items included. A qualified OWS is necessary, because it is important that all items are labeled correctly and that no items get lost. We propose a solution where the ES has no additional work and where no searching for a qualified OWS is necessary. In the new SOP, the ES hands over the items, labels and HD form to the closest WS (Working Station). The team lead can allocate a suitable OWS at the closest WS. The solution requires only an explanation of the new way of working. It is not dependent on the implementation of other solutions.

This solution results in faster movements, no searching for an adequate employee, and a SOP is followed.

Inventory solutions

The solutions are focused on reducing the throughput time, because this leads to less work in progress items and subsequently to less inventory.

I. SOP for ES and CB

There is currently no specified Standard Operating Procedure (SOP) for the ES and CB. To speed up the process it is desirable to develop an SOP, with a fixed order of tasks and a visible priority of these tasks for the ES and CB. When an overview of tasks is available, the best order can be determined such that the total throughput time is as low as possible, there is less inventory, and the CB and ES need to have always work to do.

In the SOP for the ES it is defined how to use the shared Excel file properly and it provides which tasks require attention. There are no large changes in the ES's way of working, it is only better specified. In the SOP for the CB, the contact between the CB and Lvb Partner is specified. Here, the way of working is changed such that if the Lvb Partner does not respond within a specified number of days, the exception items will always be returned. The new SOP for the CB is elaborated in Section E.2. The SOPs of the ES and CB can be used when a clear overview of the tasks is provided. This can be realised by adding a status column in the Shared Excel and in the Excel used by the CB. The implementation of the SOPs requires training and an overview of the procedure steps need to be available.

Before the priority of tasks for the ES and CB can be visualised, the priority rules need to be determined. In the next chapter, a simulation model is built to research which

priority rules can be applied best.
This solution results in a standardised process, provides a clear overview of tasks, faster throughput time, better flow of the process, and less inventory.

II. Align the workload of the ES and CB
Working hours of ES and CB need to be aligned with the workload and the processing time of the exception items. In Chapter 5, we determine the working hours with the use of a simulation model.
This leads to more value adding activities, higher efficiency.

III. Improvement of the storage location
Currently, the items are stored on two locations that are difficult to find: the dummy items are stored too high and in heavy totes. The identical exception items are randomly stored on pallets. The identical exception items are packed in their original box, which makes it impossible to recognise which items are stored in each box. We compared four solutions for the storage of the exception items.

- Number the pallets beneath the totes and the pallets beneath the identical exception items.
  The exception totes and the identical exception items are stored on pallets. When these pallets are numbered, the location is easier to find and less items get lost. In Figure 4.7, an example is provided. To realise this solution, two columns have to be added to the shared Excel. Next to the tote number, the number of the pallet where the tote is located needs to be filled in manually. The pallets that store the identical exception items can be numbered with the days of the week. In the second new column, a formula needs to be added that automatically fills in the day of the week that the exception item is registered. This is equal to the location of the pallet where the identical exception items are stored. In this case, no additional registration for the identical exception items is necessary.
  The benefits of this solution are that it is really easy to implement. Only two columns need to be added to the shared Excel, the pallets need to be numbered, and the ES has to fill in one additional number in the shared Excel. Furthermore, the items can be found more easily. However, the ES still has to search on a pallet for the right tote and box with identical exception items. It might be error sensitive since the TS (Trouble Shooter) can place a box with identical exceptions on a wrong pallet. Also, the ES still has to pick the items at two locations.

Confidential Figure

Figure 4.7: Example of numbering pallets of the exception storage

- Store all items in totes
  When all items from an exception case are stored in a tote, all locations of the items are registered and stored together. At the WS the TS places the dummy item together with as many items as possible in tote 7 and send this to the Exception corner. The other items are stored as well in totes and these tote numbers are written down in the shared Excel. The totes with identical exceptions are stored close to each other.
  Implementing this solution leads to a situation where all items are stored to a registered location and close to each other. However, it requires to replace all items to totes. All totes that are in use, need to be documented in the shared Excel and this easily lead to mistakes. The problem with heavy and high stored totes remain.
- Store the items in a stacking rack
  In the racks the stacking places are numbered. First, the TS places the identical exception items in the rack and registers this location. The dummy item is send with tote 7 to the Exception corner. The ES registers the exception case, scans the dummy item to the location in the WMS. It brings the dummy item to the registered location and places it at the other identical exception items. In this situation, the location is checked directly. If the identical exception items fit all in tote 7, the step of the TS to place the identical exception items in the stacking rack can be passed, which saves time.

  For this solution stacking racks need to be procured and locations need to be marked clearly. Besides, all locations need to be provided with a code, such that the location can be scanned. Besides, the TS has one additional task; the registration of the location of the identical exception items. The benefits of the solution are that the dummy item and identical items are stored together, the location is specified and can be find directly and the items can be picked immediately, no totes have to be lifted of moved.
- Using a Paternoster Storage Machine
  The Paternoster Vertical Storage Machine is an automated high stacking rack that works through vertical rotation of the storage and therefore delivers on command the requested boxes or totes. It increases the picking speed of the exception items and ensures storing the items on fixed locations, where items cannot be lost. Furthermore, the Paternoster makes optimal use of the available warehouse space.
  At this moment, the Paternoster is not a suitable solution to store the exception process, since it requires a large investment and building the storage system takes time and space which is not available. Making a large investment takes longer than six months and need to be prepared carefully. However, in the future it might be desirable to look into the opportunities of implementing an automated storage system.

The best solution is the solution that simplifies the process for the TS and ES, is not mistake sensitive, and can be implemented within a short period. We can conclude that the stacking rack contributes most to a simple and save process. Besides, the implementation can be realised within a short period. The solution is more beneficial if the TS uses the shared Excel (see Over-Processing I.) for the registration, but also without other implementation of solutions will this solution improve the process significantly. *This leads to less searching, less space, less items lost, faster and less movements.*

Motion solutions

All solutions will lead to less movements, time savings, and it will avoid the batching of exceptions.

I. Cooperation OWS and TS
Currently, the cooperation between the OWS that detects an exception case and the TS, results in the action of double walking and waiting. This happens because the TS stands on a fixed location and the OWS walks to the TS when he detects an exception case. In the proposed solution, the TS receives a message over his transceiver when the OWS detects an exception case. In this situation, only the TS has to walk to the Working Station, which is also happening in the current situation. The OWS can continue with scanning while the TS arrives and labels the dummy item. In this situation, the TS has to bring the desk with laptop to the working station, which takes only a few seconds longer. However, it saves time for the OWS and the OWS is less dependent on the TS. Therefore, we choose the new situation as solution.
This procedure avoids double work (walking) and results in a faster handling time for the OWS and less waiting.

II. See solution Inventory II. Align the workload of the ES and CB.

III. Install printer at desk of ES
Installing a printer for HD forms at the exception desk prevents the ES from walking completely to the end of the hall and back. He also does not have to note the supplier ID anymore, because the HD form can be printed directly. No investment costs have to be made, because there is already a printer available, it only has to be installed.
Less movements, saves time, no over-processing.

IV. Improve lay-out for returns
Place a pallet or car specifically for items that need to be returned close to the exception corner. This prevents unnecessary walking. Also, the team lead is nearby, to hand over the Track & Trace codes. Besides, store multiple box dimensions for returns at the desk of the ES, in order to avoid walking to another floor to pick the correct box size.

V. Destroy box in exception corner
Place destroy box especially for Lvb exception items in the exception corner.

VI. Waste bin at desk of ES
Place waste bin close to the exception desk.

Waiting solutions

I. See solution Motion I. Cooperation OWS and TS.
II. See solution Inventory I. SOP for ES and CB.

Over-production solutions

I. See solution Inventory II. Align the workload of the ES and CB.

Over-processing solutions

I. TS registers information in shared Excel
   In the current situation, the TS writes information about the exception case on a very small dummy label. Later, the ES has to translate the small letters and register this in the Shared Excel. A solution for this double and mistake sensitive method is to let the TS register the exception information directly in the Shared Excel. In solution *Motion I.* it is determined that the TS walks to the OWS with a mobile desk, with a laptop. The TS has to check the supplier ID and it would not take much more time to register the information in the shared Excel instead of on the dummy label. On the HD form all information is provided and can be filled in immediately in the Excel. This solution can be implemented only on condition that the TS learns how the Shared Excel works. Often, TSs are trained to work as ES, which makes it easy to implement the new task. As the Stacking Rack is implemented as suggested in solution *Inventory III.*, it makes it easier to note the location of the identical exception items as well.
   This solution results in less mistakes and avoids double registration
II. See solution Defects and unused Skills I. Change and maintain excel lay-out.
III. See solution Motion III. Install a printer at the desk of the ES.
IV. No permission from team lead to destroy items
   Forego the step where the ES asks for permission to destroy items to the Team lead. The Team Lead agrees on this solution. The CB can be trusted to provide correct information in the Excel.
   Saves time due to the removal of requesting and awaiting approval.
V. Replace computer by screen
   Currently, two computers are used which results in manual registration, because information cannot be copied between the two computers and the scanner is only connected to one computer. Replace two computers with one computer with a second screen. One screen has to be procured. This is a minor investment since many computer screens are used at the office. *Less mistakes, less double work, saving time.*
VI. Manual for the ES
   A manual needs to be accessible where the SOP for the ES is described. Here is stated how the Excel needs to be filled in correctly.
   Saves mistakes, no time wasted on solving mistakes, faster working because of skills.
VII. Train the ES
   The ESs are not trained by an official training program, they learn from other ESs.

There is no control that all information is explained correctly. Also the ESs are not informed well when updates are made. A starters training needs to be developed. This should be part of the mandatory starts introduction. *Less mistakes, no time wasted on solving mistakes, faster working because of skills.*

Defects and unused Skills solutions

I. Improve shared Excel lay-out
The shared Excel file is not used optimally. The information in the sheet is not easy to find and to use. The lay-out has to be improved such that only necessary information is saved. Furthermore, the columns that need to be copied to another excel needs to be placed next to each other. Also a better overview about the status and priority of cases need to be provided. Lastly, the correctness of the information notation and lay-out has to be monitored. Many mistakes are made with copying the finalised cases to another sheet. Also, one employee needs to be responsible for executing this task correctly as well. The CB is the most suitable candidate, because he is a full-time employee and benefits the most from a good working Excel.
This solution results in a faster and better registration. It makes it easier to analyse the progress of cases, it saves time, less mistakes are made, and it result in less double work, data analysis is possible.

II. See solution Over-processing VI. Manual for the ES.

III. See solution Over-processing VII. Train the ES.

4.3 Improved process design

The solutions introduced in the previous section are applied to the current exception process. This results in a new design: the improved exception process. The improved process is explained by a changed Swimlane Diagram and an adapted floor plan.

4.3.1 Improved Swimlane Diagram

In Figure 4.9, the Swimlane Diagram is visualised. Only the changed steps are given to provide a clear overview. The green outlined boxes are completely changed steps. The yellow outlined boxes are steps where the actions do not change but are executed differently. For each employee the changes are explained.

OWS The OWS (Operator at the Working Station) calls the TS (Trouble Shooter) instead of walking to the TS. He continues with scanning the remaining items of the shipment.

TS The TS walks with a desk on wheels (including computer) to the OWS, sticks the dummy label and registers the shipment information in the Shared Excel. When all identical exception items fit in the tote, he places these items in tote 7. When there are too large or to much items, the dummy item is placed in tote 7 and the remaining identical exception items are stored in the stacking rack. The TS notes the location of the exception items in the shared Excel.

ES *Registration*

The ES (Exception Specialist) assigns in the WMS (Warehouse Management System) the dummy item a place in the stacking rack, instead of an exception tote. The shared excel is filled in; less information has to be added. The dummy item is stored at the noted location in the stacking rack at the identical exception items. The ES directly checks if the noted location is correct. In case that all identical exception items are sent by tote 7, the ES chooses a free spot in the stacking rack, stores all items there and notes this location in the Excel sheet.

Processing items

The processing is easier and faster because the ES easily sees which task and corresponding case he has to process. Also, he walks to the specified place at the stacking rack and collects all identical exception items and the dummy item at once. When a case can be processed to stock, the HD form and labels are printed at the the exception desk. The ES moves all exception items to the closest working station, resulting in less walking and less time spend searching for an adequate OWS. In case that the exception items have to be returned, multiple box dimensions are stored at the ES desk, such that the items can be packed easily. The box can be placed in the exception corner on a specified 'return pallet'. When a case needs to be destroyed, the items are placed directly at the 'destroy box' in the exception corner.

Team lead There is not much changed for the Team lead except from the location where the return cases are stored.

CB All steps of the CB (Coordinator of bol.com) remain the same, however he follows a SOP where each Lvb Partner is daily contacted by mail or phone. The CB has a clear overview of tasks (and their priority) he has to execute. If the Partner does not respond within four days, the items are returned.

Partner The Partner has to respond quicker and provide missing information.

4.3.2 Floor plan of improved exception process

Figure 4.8 provides an overview of the improved exception process floor plan. The implemented solutions are also visible on the floor plan. A stacking rack is placed, all movements of the ES are to places close by, and one working station is depicted to receive all exception cases that need to be processed to stock.

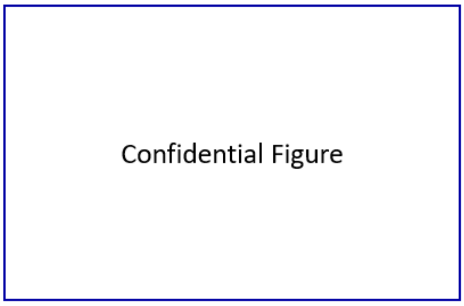

Figure 4.8: Floor plan: Improved exception process

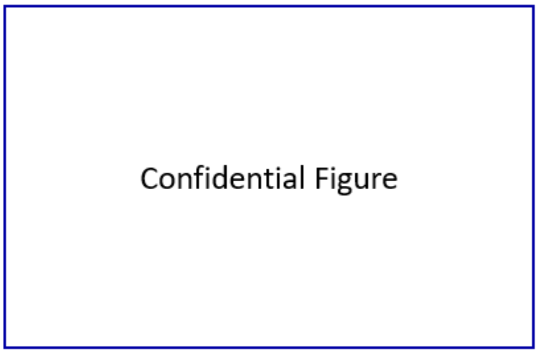

Figure 4.9: Swimlane improved exception process

4.4 Expected performance of the improved exception process

In this section, first, the expected performance of the improved exception process is calculated. To calculate the new performance, we assume that all solutions to improve the exception process are implemented. Second, the improved performance is compared with the current performance to see if and how much the performance is improved.

4.4.1 Performance calculation of the improved exception process

The calculation of the expected improved performance is explained by the same methodology used to explain the performance of the current situation. In six steps, the total throughput time, the total costs, and the partner dissatisfaction are explained. The six steps are provided below, see Section 2.2.2 for the complete explanation.

I. The independent processing steps and cost items are determined.
II. The relation between the processing steps and the involved costs items are determined.
III. The throughput time of each processing step is measured and analysed. This result in the performance of the total throughput time.
IV. All costs per cost item are identified, together with the frequency that this cost item is used.
V. The total costs are calculated by multiplying the costs of the cost item per time frame by the frequency that it is in use, and with the time that a cost item is involved.
VI. The Partner satisfaction is calculated based on two measurements. For the first indicator the percentage of all exception Lvb Partners that score below a seven is calculated. For the second measurement the percentage of all exception Lvb Partners that contacted Partner Service is calculated.

I. Processing steps and cost items
There are three changes in the processing steps and the frequency that a processing step occur. There are no changes in relation to the cost items that are involved in the process. The changes are explained below.

1. The identical exceptions are still stored by the TS, however the probability that this is necessary has decreased. If all exception items fit in tote 7, they are all sent by tote 7. *We analysed that the average number of items that is sent in tote 7 is eight items. This result in **x**% of the exception cases that can be sent all by tote 7.*
2. The ES can pick all exception items together at the stacking rack. He does not have to search, because the exact location is noted.
3. The exception items are processed in three different ways: to stock, return to the Partner, and destroyed. This remains identical, however there is assumed that the ratio processed to stock and return to Partner changes. This is due to the introduced protocol that if a Partner does not respond within time, all exception items are sent return. *The percentage processed to stock, return to Partner, and destroy is set by expert judgement to 78%, 20%, and 2% respectively.*

II. Processing steps and cost items matrix

There are no changes in the relationship between the processing steps and the cost items.

III. Throughput time

The throughput time for each processing step is calculated. The mean processing times are provided in Table **x**, together with the lower- and upper bound of the processing steps. The column 'Freq.' refers to the frequency that the sub step is executed per exception case. For example at step B3. in 38% of the cases, the TS walks back without storing the identical exception items (because the are sent with tote 7). In the remaining cases, the TS has to store the identical exception cases. The total throughput time resulting from the summation of all throughput times, is equal to 5928 minutes. This is equal to 4.1 days. For each sub processing step is explained how we determined these processing times in the column 'Measurement Method'. The term n.c. stands for not changed in the table. The processing times are identical to the processing times from the current situation, see Table **x** in Section 2.2.3. The term new refers to a new estimation. We timed the tasks by executing the sub steps on the improved way. For example, the ES walked multiple times to the new place where items are returned. Some processing times are determined in another way. These are numbered in the table and explained below.

1. The measurement combined the steps "walking" and "labelling" from the current situation.
2. The measurement combined the steps "Check supplier" and "fill in excel".
3. The maximum capacity of the tote is reached earlier, because on average more exception items are placed in tote 7 (due to the change that if all identical exception items fit in a tote, they are all sent to the exception corner).
4. We estimated that the new processing time is reduced with 30%, due to better overview excel and less writing.
5. In the improved situation, the CB focus more on contacting the partner as soon as possible. We estimate that 80% of the Lvb Partners is contacted within **x** days. This leads to an estimated average of **x** days and a maximum of **x** days.

6. The CB follows a strict procedure in which Partners are contacted a couple of times based on their response. When there is no reaction, the partner receives his items return after five days. In Appendix E.2, the calculation is provided of which percentage of partners respond, to which tasks this lead and how long the tasks take. From this analysis, we see that the average throughput time (storage time during solving) is **x** day.
7. In the improved situation, more attention is payed to directly processing the exception cases when they are solved. We expect that 95% o the exception cases is processed within 1 day, which lead to an estimated average of 0.7 day.
8. The upper- en lower bound remain identical to the current process, however, the mean is reduced due to less walking to outbound for picking packaging boxes.

Confidential Table

IV. Costs per time frame and occurrence of each cost item

The costs per time frame are not changed. Only the frequency of labelling the exception items is changed to 78%. This is
related to the shift in share of processing items to stock.

V. Total costs

In three steps the total costs are calculated. An overview of all the throughput times and costs is provided in Figure 4.10.

1. The total time that a cost item is active is calculated. This is executed by summing all processing times (P2) of the active processing steps (P1· C2) for each cost item. The results are visualised in C4.
2. The total costs per cost items (C5) are calculated by multiplying the costs per minute (C2) by the occurrence (C3) and by the time that the cost item is active (C4).
3. The total costs are calculated by summing the total costs per cost item. The result is visible under TC. Per exception case, the total costs for one exception case is **€x** Since one exception case consists of on average **x** items, one exception item costs **€x**.

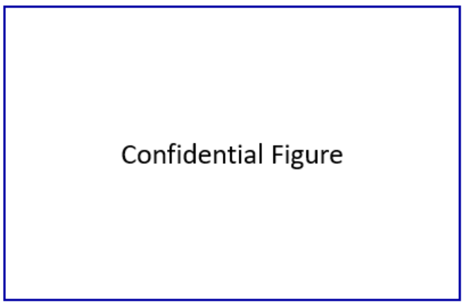

Figure 4.10: Improved matrix: Total throughput times and costs

VI. Partner dissatisfaction

As mentioned in Section 2.2.2, the dissatisfaction is indicated based on two analyses. These are the percentage of Partners that mark the Lvb Partnership lower or equal than a six and the percentage of Partners that contacted Partner Service with the reason that sent shipments are not processed to stock in time. Both indicators are discussed below.

Percentage of Partners that is dissatisfied identified by a questionnaire

No estimation can be made about the Partner dissatisfaction analysed from a quarterly questionnaire. When all solutions are implemented, results can be compared to the results of the current exception process. A decline of dissatisfied Partners is plausible.

Percentage of Partners that contacts the Partner Service concerning delayed items on stock

The percentage of Partners that contacts the Partner Service is expected to reduce significantly. Partners can only contact Partner Service about delayed items on stock after 72 hours have passed after their shipment arrived at the warehouse. In the improved situation, all exception Lvb Partners should be contacted contacted within 72 hour. However, there will always remain some Partners that contact Partner Service before the 72 hours are passed. The exact percentage of Partners that will contact Partner Service is hard to estimate. When all solutions are applied, new measurements are necessary to draw reliable conclusions about the dissatisfaction of Partners using this indicator.

4.4.2 Comparison of the performance between the current and improved exception process

The results of the calculated performance of the throughput time and costs of the current and improved exception process are compared. The Partner dissatisfaction cannot be estimated for the improved exception process and is disregarded in this comparison.

Total throughput time

The storage times and the total throughput time of the current and improved exception process are visualised in Table **x**. The total throughput time is reduced with **x** days and is in the improved process **x** days. This is a reduction of 66% of the total throughput time.

Confidential Table

Total costs

The total costs are visualised in Table **x**. In 2020 a reduction of €**x** can be realised. This equals a saving of 44.6%.

Confidential Table

4.5 Conclusion

The inefficiencies in the current exception process are identified by applying different lean tools. For each inefficiency, solutions are identified. The solutions with a potentially high impact are: (1) The replacement of the tote storage and separate storage of identical exception items with a stacking rack that stores all exception items of a case together. (2) All movements of the ES are within the exception corner, which reduces the handling time of the ES. (3) The SOP for the CB ensures a fast throughput time of exception cases. In the improved exception process, all solutions are implemented and this results in changed processing steps and subsequently in a changed performance. The expected performance of the throughput time and the costs are calculated. No reliable estimations of the Partner dissatisfaction could be made. For the improved exception process, the total throughput time of an exception case is estimated to be **x** days, corresponding with a reduction of 71% compared to the current situation. The total costs will decrease to 45%. The costs in the improved exception process reduce from **€x** to **€x** per exception case. In 2020, the exception process has a savings potential of **€x**.

Chapter 5

Optimised Exception Process

The previous chapter introduced an improved design for the exception process, where all introduced solutions are incorporated in the improved exception design. However, two solutions where not elaborated completely. These two solutions are: the priority of tasks and the aligned working hours of the Exception Specialist and the Coordinator of bol.com. To optimise the improved exception process, these solutions are further developed and tested with the use of a simulation model. In Section 5.1, we provide the problem statement, the goal, the scope, the assumptions, and simplifications of the simulation model. In Section 5.2, the input of the simulation model is described. Section 5.3 provides the logic of the simulation model, together with an explanation about how the performance is calculated and the experimental design. Section 5.4 provides the validation of the simulation model. The results of the simulation model are explained in Section 5.5. In Section 5.6, the results of the simulation model are translated to projects, such that the results can be implemented in the exception process. Lastly, Section 5.7 provides the conclusion of this chapter.

5.1 Problem statement, goal & scope of simulation model

This section provides at first the problem statement and goal, to explain the added value of the simulation model. Next, the scope, assumptions and simplifications of the simulation model are provided.

5.1.1 Problem statement & Goal

As described in Section 4.2, two solutions require further specification before these can be implemented. This specification can be tested, using a simulation model. Furthermore, the impact of the estimated increase of exception cases per day is tested.
The problems that arise in the current exception process are:

1. No insight into the (priority of) tasks that need to be executed.
2. The working hours of the ES and the CB are not aligned with the work load.

The combination of the two problems results in exception cases that are stored too long, the average throughput time is too long and there are too many exception items on storage.

The goal of the simulation model is:

- ➢ Provide insight in the tasks of the ES and the CB, prioritise these tasks and determine the ES and CB working hours such that the average throughput time is reduced, for the current situation and for the situation where the exception cases per day increase.

In consultation with bol.com, we identified a set of criteria to which the results of the simulation needs to meet:

- The Partner is contacted about his exception case within 48 hours.
- The maximum throughput time from detecting to processing an exception case is seven days (including weekend).
- When the Partner is contacted about what is going to happen with the exception case, the items are processed within 24 hours.
- The CB and the ES can work for at least 90% of the working hours.

5.1.2 Scope of model, assumptions, and simplifications

Scope of model

A simulation model is built to test the performance of different settings within the exception process. In the simulation model, all processing steps provided in the improved exception process in Section 4.3, are included. Like the exception process, the model starts at the Working Station where the items are scanned. The process ends when the items are processed to stock, returned to the Lvb Partner, or destroyed. The focus of the model is on the Lvb 'dummy items'. In the simulation model, all variables that influence the priority of tasks, the necessary working hours of the CB and ES, or the performance are included.

Assumptions & simplifications

The simulation model is a simplified reproduction of reality and cannot exactly replicate the improved exception process. Due to to the human behaviour and unpredictability of various events (arrivals, defects, routes, etc.), the simulation model will always show differences in relation to the actual process. Therefore, we apply validation and verification to *ensure that the model is sufficiently accurate for the purpose at hand* [43] and to *ensure that the model design (conceptual model) has been transformed into a computer model with sufficient accuracy* [44]. To simplify the model, all tasks of an employee that are executed consecutively and independent of other employees, are combined into one processing step. This includes also the movements of employees. The movements are not modeled visually, but the duration of the movement is included in the processing time of the processing step. All items that pass the Working Station are included in the model. At the Working Station, it is determined whether the items are exception cases or 'normal' items that follow the Happy flow. The Happy flow moves after the working station directly to the exit, because these are processed. The exception cases follow the exception process.

5.2 Input of the simulation model

The input variables are set such that they represent the actual process as good as possible. The input variables consist of the arrival rates from items at the WS (Working Station), the characteristics of the employees, the characteristics of the exception cases, and the duration of the tasks in the exception process.

5.2.1 Arrival of items

In the simulation model, all items arrive at the Working Station. From these items, 1.11% is an exception case. This percentage is equal to the current situation. Each day, in two steps the arrival interval of Lvb cases ('Happy flow' and exception cases) is determined. First, we determine how many items should arrive that day. From data from 2019, we concluded that the arrival rate of Lvb cases per day is normally distributed with a mean of **x** and variance of **x**. An arrival rate with this normal distribution is generated. Second, from this arrival rate, the average arrival interval is calculated. The arrival interval over the day has a negative exponential distribution, the average arrival rate is used to generate this arrival interval. The probability is **x**% that the case becomes an exception case, the remaining cases are 'Happy flow' cases.

5.2.2 Characteristics of employees

Table 5.1 shows the input of the employees in the model. The working hours are based on the current working hours.

Table 5.1: Characteristics of the employees

	Exception Specilist	**Coordinator bol.com**	**Other employees**
Start day	07:00	09:00	07:00
End day	23:00	17:00	23:00
Explanation working hours	2 shifts, no breaks are included, because the additional programming complications do not outweigh the impact of breaks.	No breaks included, since the CB always finishes his tasks within the breaks.	Equal to ES.
Productivity	70%	80%	100%
Calculation productivity	Observations from work floor. Less productivity by distraction from other colleagues and much idle time.	Calculations based on theoretical workload and actual workload from calculations current process.	Other employees form no bottle neck, it does not add value to include a deviating productivity rate.

5.2.3 Characteristics of exception cases

When the exception item arrives in the system, the characteristics provided in Table 5.2 are determined. These characteristics define which actions are taken with the exception case and how long the processing steps take. All options within a case characteristics have a specified probability to be selected. For each option within the case characteristic, cumulative ranges are indicated. By use of a uniform distribution a number between the lower and upper bound is generated. The option is selected from the range that covers the generated number.

Table 5.2: Characteristics exception cases

Case Characteristic	**Calculations**	**Distribution**
Case quantity & Solve type 'Small'	Pick random number of list of real case quantities. The list contains 1357 quantities. When an exception case consists of 1 or 2 items (in **x**% of the case), the solve type is set to 'Small'. This solve type impacts the steps of the CB.	Uniform(1,1357)
Frequent Offender (FO)	**x** % of the cases is a FO, this impacts the steps of the CB.	Uniform(0,1)
Exception reason	The case receives an exception reason based on the proportions from the current process. These are: *Confidential*	Uniform(0,1)
Reason partner & duration of call	Dependent on the reason of the exception, the reason that the Partner caused exceptions is calculated. See Table **x** for the probabilities per exception reason. The duration of the call with the partner is dependent on the Partner's exception cause.	Probability: uniform(0,1) Duration: triangular
Answer on Email	The CB sends at Registration 1 an email. In each successive step, the Partner has responded with a probability of 25%. This percentage is set after an analysis to the respond rate of partners.	Uniform(0,1)
Answer on Call	When the CB calls the Partner, there are three ways of answering: 1) Answer the phone, and solve together with the CB the exception case. 41% 2) Answer the phone, but the Partner has to execute after the call some additional tasks to solve the case. 10% 3) Not answering the phone. 49%	Uniform(0,1)
Processing type	At the entrance, each exception case receives a processing way. The probability is determined based on the estimated distribution for the improved exception process. These ratio's are: Process to stock: 86% , Return to Lvb Partner: 12% , Destroy : 2%. At three scenarios the processing way changes. When a case is 'Small': always process to stock. When a case is FO: always return. When a Partner does not respond after four days: return.	Uniform(0,1)

To determine the expected processing time of the call, we first need to determine what went wrong in the process of the Partner, because the duration of the call is dependent on the exception cause of the Partner. We analysed the relation between the exception cause of the Partner and the exception reason that is visible for the Exception Specialist. Table **x** provides per exception reason, the probability that a specific mistake is made by the Partner. By means of the uniform distribution, a random number is generated to determine the exception cause of the Partner. The distribution of the duration of the call is determined based on a triangular distribution. The duration of the call per exception cause is introduced earlier in Chapter 2.2 and is provided in Appendix B.2.

Confidential Table

5.2.4 Duration of processing steps

For each processing step, a distribution is used to generate the duration of the processing step. All processing steps are generated by a triangular distribution. From time measurements, we analysed that the duration of the processing steps have an Erlang distribution. However, we have too little measurements to estimate the parameters for each processing step. We use the triangular distribution as reliable alternative, where each parameter (mode, lower bound, and upper bound) per processing step is determined successfully [45]. All processing times are introduced in Table **x** in Section 4.4.1. The duration per step of the processing unit (employee) is visualised in Table **x**.

Confidential Table

5.2.5 Verification of input data

The verification of the input data consists of examining the correctness of the input parameters used by the model. We verified the average cases per day in the system, the productivity of the employees, the characteristics of the exception cases, and the duration of the processing steps. The verification of the input data is explained in Appendix F.1.
We conclude that the average exception case arrival rate per day matches with the entered arrival rate. Also, the productivity of the employees is exactly modelled as prescribed. The case characteristics are assigned according to the proportions analysed from the actual exception process. The modeled proportions where to completely identical to the input proportions, since these proportions are simulated using random number generators. To improve this, we slightly changed the probability ranges, to minimise the difference between the modeled proportions and the desired proportions.
To verify the duration of the processing steps, we first estimated the average duration of each processing step by calculating the expected frequency and duration of each task in the processing step. We compared this with the modeled duration. From this analyses, we see some probabilities and duration of processing steps that deviate from the expected. However, we can explain the differences. Also, the modeled total throughput time is very close to the expected processing time (1.6% difference), therefore we conclude that the simulation model represents the conceptual model with sufficient accuracy. In conclusion, the model uses all input parameters with sufficient accuracy.

5.3 Logic of the simulation model

The logic of the simulation model is explained in three steps. First, the basic model is provided. Next, the performance indicators are explained. Furthermore, the use of the simulation program is described. At last, the experimental design is introduced.

5.3.1 Basic model

As described in the scope, the process starts at the working station and ends when the items are processed. This process is well known as 'receiving'. At receiving, the process is split in six connected parts: Entrance (item arrives at receiving), registration, storage, solving, processing, and exit (item is processed). All items flow through these parts. The parts are visualised in a flowchart in Figure 5.1. The dark marked blocks and dashed lines represent movements in time. Each separate part of receiving is explained in more detail. Furthermore, the process of selecting the next task for the ES and CB is provided. For each part is explained how that part represents the exception process with sufficient accuracy. At last, we explain the verification of the basic model. In Appendix F.4, the technical report of the simulation model is provided.

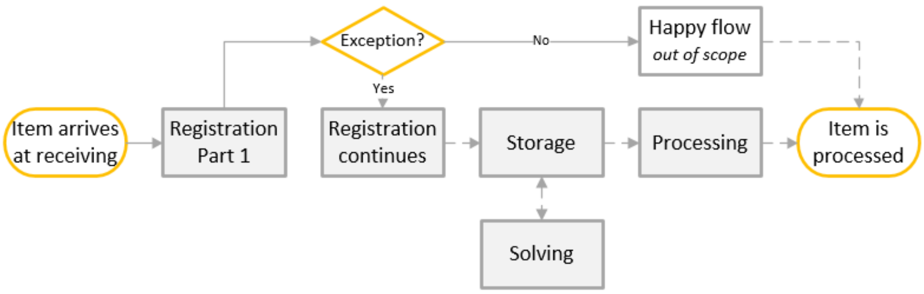

Figure 5.1: Flowchart Receiving

Entrance

At the entrance, all items arrive. All the shipments are created, under which also the exception cases. The inter-arrival time between two cases is determined based on number of cases received that day. The probability is 1.11 % that an exception case arrives.

Registration

The registration process starts when a case arrives at the Working Station, this is visualised in Figure 5.2. When the case is a 'Happy flow', the items are scanned and processed to stock. The case is sent to 'Exit'. When the case is an exception case, the Trouble shooter gets involved. Until the TS is available, the exception case waits at the WS.

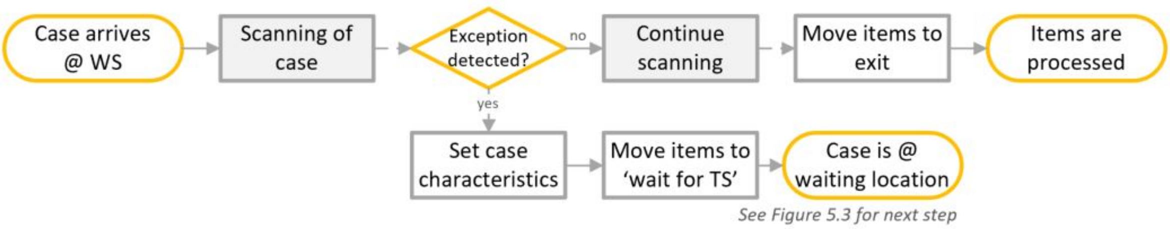

Figure 5.2: Detection of exception case by OWS

When the TS is available, he moves to the case (visa versa in the model). This is visualised in Figure 5.3. After the completion of the task of the TS, the next destination for the case is determined: the registration by the Exception Specialist. This new task is saved to the task list of the ES and the case is moved to a waiting location until the registration task will be performed.

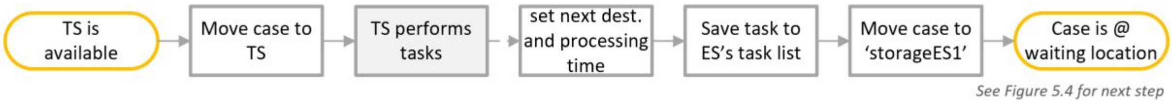

Figure 5.3: Detection of exception case by TS

Before the next task of the ES is determined, there is checked if the ES is available. At the events provided in Figure 5.4 is checked whether it is between the working hours of the ES, if the ES is not performing other tasks, and if he is not 'unproductive' (in failure in the model). When the ES is available, the task list is sorted based on the determined priority rule and the case with the highest priority is selected. If the task is a registration task, the case is moved to ES1 (which performs the registration), otherwise the case is moved to ES2, which performs the preparation of the processing.

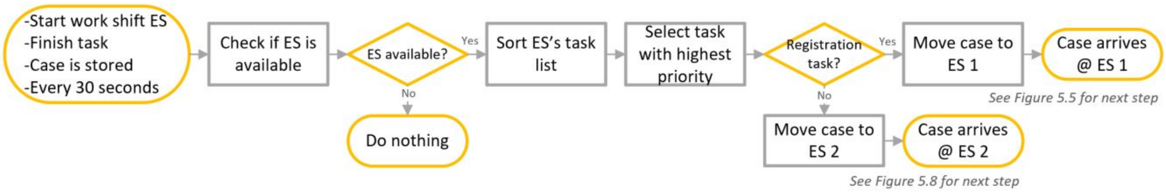

Figure 5.4: Select next task for the ES

When the exception case is ready to be registered by the ES, the ES receives the case, executes the registration, and stores the exception items. This is visualised by the flowchart in Figure 5.5. The exception case receives the information for the next task that is executed by the CB (step: Registration 1). This information is saved to the task list of the CB and the case is moved to the 'storage before solving'.

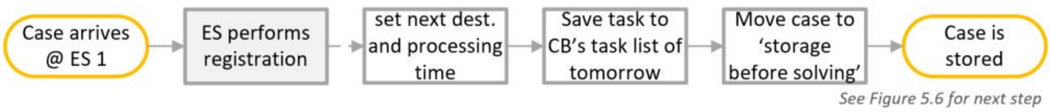

Figure 5.5: Executing the registration of the case by the ES

In this registration process, the movement of tote 7 is omitted, to simplify the process. This waiting time does not lead to different performance results. All other processes are identical to the improved exception process.

Storage

The exception cases remain in storage until the case has the highest priority and the executor of the next task is available. Every time that a case enters the storage location, there is evaluated if a new task can be performed, see Figure 5.4 and 5.6. In the model, we make a distinction in the storage location to visualise the workload per exception step. However, in the actual exception process all items remain at the same storage location.

Solving

Identically to the ES, at four different events, there is checked if the CB is available. This process is visualised in Figure 5.6. When the CB is available, the task list of today's tasks is sorted and the case with the highest priority is selected. In the model, for each task a different 'machine' is used that performs the task. Since the solving task is always executed by the CB, we modeled that the machines can never work at the same time. When the task is performed, there is checked if a new task can be executed directly. This occurs only when the case is solved and only the task 'Registration 2' has to be performed. If the case has still tasks to undergo before it is solved, the case is moved to 'storage during solving'. By the logic provided in Figure 5.7, new tasks are determined and saved to the CB's task list for tomorrow. When the case is solved, the case is stored at 'storage after solving', the new task is determined and saved to the task list of the ES.

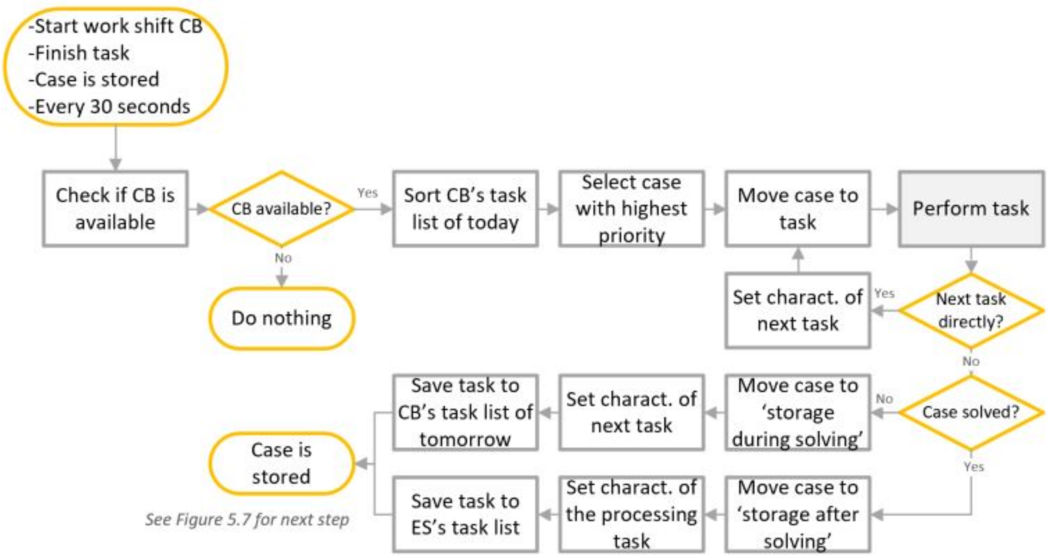

Figure 5.6: Select next task for the CB

When the case is in the solving process, the next task is dependent on the case characteristics. The next task is selected based on the flowchart provided in Figure 5.7. This logic is determined based on the SOP of the CB. This is explained in more detail in Appendix E.2. When the exception case is a 'Small' case, the partner is only informed by mail in 'Registration 1'. The exception case is solved directly after this registration. When the exception case is from a frequent offender (FO), three steps are executed: 'Registration 1', 'Call 1', and 'Registration 2'. Regardless of the Partner's response on the first email (during the first registration) or the call, the exception items are sent return. If the exception case type is 'normal', the Lvb Partner is first informed per mail. Dependent on the response and reaction of the Partner, the partner is called two times and mailed two times. After at most four days, the CB can solve the exception case and finalise the second registration. The CB waits one day before he contacts the Partner again. Step 'Registration 2' follows immediately when the exception case is solved. In the SOP introduced as solution for the improved exception process in Section 4.2, all steps are identical to the steps executed in the simulation model.

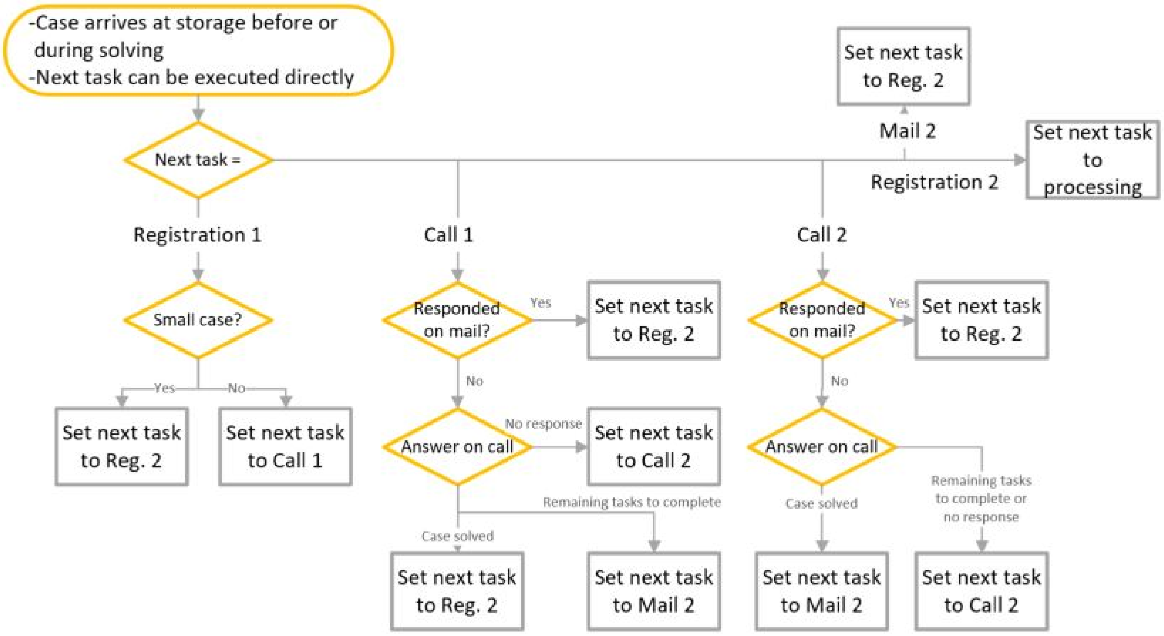

Figure 5.7: Select next task for the exception case

Processing

The processing of the exception cases is simulated as visualised in Figure 5.8.

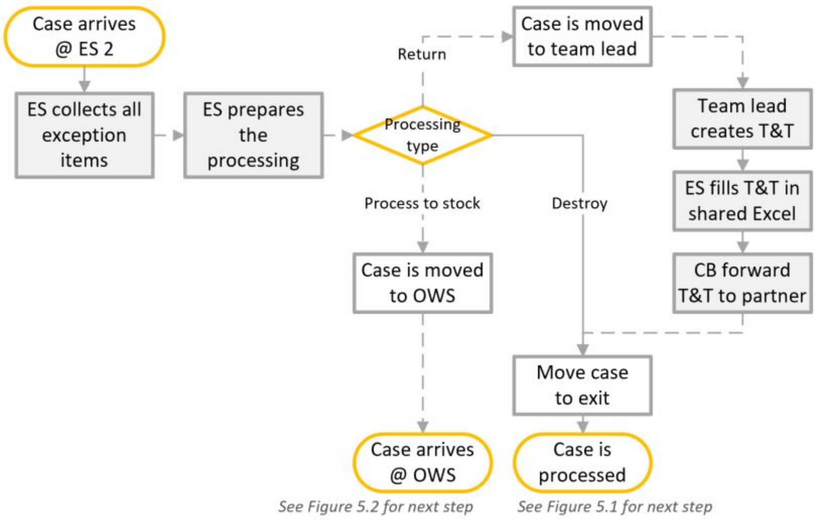

Figure 5.8: Processing exception case

The process starts when the Exception Specialist receives a processing task. The ES collects all exception items and prepares the processing. Dependent on the processing type, the case follows a different route. When the items are processed to stock, the items are handed to the OWS and stored at the other items at the Working Station (See Figure 5.2, the case is now seen as 'Happy flow'). When the items need to be returned to the Partner, the case is waiting for the Team lead to create a Track and Trace code. This code is afterwards forwarded to the Partner. When the case can be destroyed, no additional tasks follow, the items in the case are placed in the destroy box during the preparation of processing. All processing steps are identical to the steps of the improved exception process, except from one task. The forwarding of the T&T is not executed by the same 'machine' that solves the exception process, because this is too complicated to simulate. The benefits of simulating this small task completely identical, does not weight out the created complication.

Exit

At the exit, the Happy flow items and the exception cases leave the system. They are processed.

Verification of the basic model

The flow of the model is verified in four ways. The explanation and results of the performed analyses are provided in Appendix F.2.

1. One exception case and Happy flow case are followed in each step to examine if the cases follow the process correctly. We see that this case follows all steps as expected from the case characteristics. Also, the processing times per processing step are generated as prescribed.
2. Ten exception cases with varying case characteristics are followed in the processing steps to check whether the cases follow the correct logic. From this analysis we conclude that the logic is similar to the conceptual model.
3. We compared the expected frequency of cases per processing step with the analysed frequency from the results of one simulation run. The modeled frequency is in line with the expected frequencies. Therefore, we conclude that the simulated logic is equal to the logic defined in the conceptual model. This is the same analysis performed to verify the processing times and is provided in Appendix F.1.
4. Each method that is written in order to create the logic of the exception process, is evaluated. By debugging we examined that every line of the code worked as expected.

We conclude that the logic of the model works accurately. It simulates the exception process exactly as described by the conceptual model.

5.3.2 Calculating Performance

Multiple performance indicators are calculated per experiment, to compare the result of different configurations. Eventually, we want to select the experiment that has the lowest average throughput time and satisfies the criteria. The criteria are tested by analysing if the cases flow through the process within time and calculating the duration of the idle- and waiting time of the ES and CB. Furthermore, the average costs of an exception case is calculated, since this is one of the KPIs of this research. The performance indicators that are calculated in the simulation model are explained in Table 5.3.

The calculation of the performance is verified to ensure reliable results. We verified the performance by manually calculating the performance of one batch by using the information of the finalised cases, the storage level, and the idle and waiting time. Next, the performance of 254 batches is used to calculate the average performance of one run. We conclude that the simulation model calculates all the performance indicators accurately.

Table 5.3: Performance indicators overview

Performance indicator	Source	Calculation
Throughput time (s)	Average of all finalised cases	Sum of the duration of all processing steps and time in storage.
Avg days in exceptions	Average of all finalised cases	Round up the total days in the system. This measurement method is used, because currently only dates are saved in the Shared excel files.
Criteria 1: % of Partners contacted within 36h	Average of all finalised cases	A case satisfies Criteria 1 if the 'storage before solving' is smaller than 36 hours.
Criteria 2: % of cases solved within five days	Average of all finalised cases	A case satisfies Criteria 2 if the 'storage during solving' is within five days.
Criteria 3: % of cases processed within 24h	Average of all finalised cases	A case satisfies Criteria 3 if the 'storage after solving' is processed within one day.
Total costs (€)	Average of all finalised cases	The costs of one case consists of the handling costs, storage costs, and labelling costs (if the case is processed to stock)
Average cases and items on stock	Stock level at the end of the day	At the end of the day the total cases and exception items in storage are saved.
% Idle time ES and CB	Idle time at every workday	The idle time is the time that the ES or has no tasks to complete. The % idle time is calculated in relation to the total working hours of the ES or CB.
% ES waiting on CB % CB waiting on ES	Waiting time at every workday	Waiting time is the time that the ES or CB has no tasks to complete, but the CB or ES is still working. The % waiting time is calculated in relation to the working hours of the ES and CB.

5.3.3 Simulation software

The simulation program used is *Technomatix Plant Simulation 14*. We selected this program because of the following seven reasons.

1. The author is familiar with the software, since it is part of the Master program.
2. We are able to build a simplified version of the exception process.
3. It is easy to implement logic in the process.
4. The program offers random number generators. These stimulate the use of variability in the process and this is important to generate reliable results.
5. The simulation model provides tools to store and calculate performance.
6. The exception cases are visible in the process, which makes it easy to verify the model.
7. It is a program which can be understood by people who are not familiar with the program. In this case, also employees at bol.com can follow the steps and there is a higher probability that they agree with the results.

Two screen captures of the simulation are provided. In the simulation model, all parts in the receiving process are translated to frames to structure the model. The main frame is the 'Receiving' frame, which is visualised in Figure 5.9. The small green boxes represents the 'Happy flow' cases, the blue marked boxes are exception cases. On this frame, the variables and methods are provided that are involved in the start and ending of the simulation runs.

The reset method sets all variables and tables to the initial settings. The 'Initday' method sets all variables at the beginning of the day correctly. The working hours for the work floor, ES and CB are determined. Furthermore, the simulation runs by following the determined experimental design. The experimental design is explained in the next section.

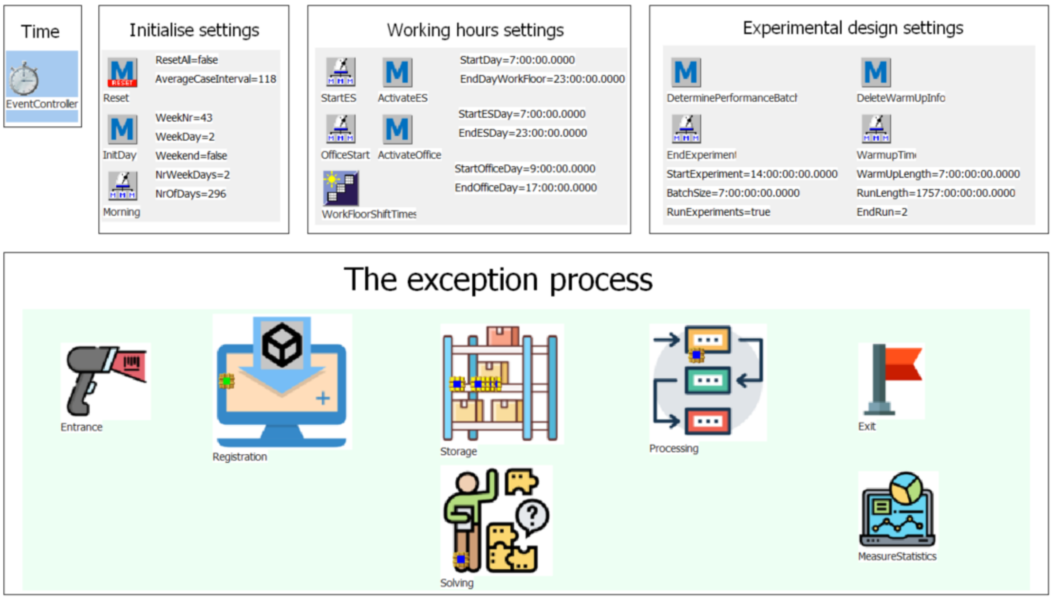

Figure 5.9: Screen capture of the frame Receiving

In Figure 5.10, we zoom in on the frame 'Solving'. In this frame, the tasks of the CB and ES are coordinated. The earlier mentioned flowcharts from Figures 5.4, 5.6, and 5.7 describe the processes in this frame. A description of this frame is provided below the figure.

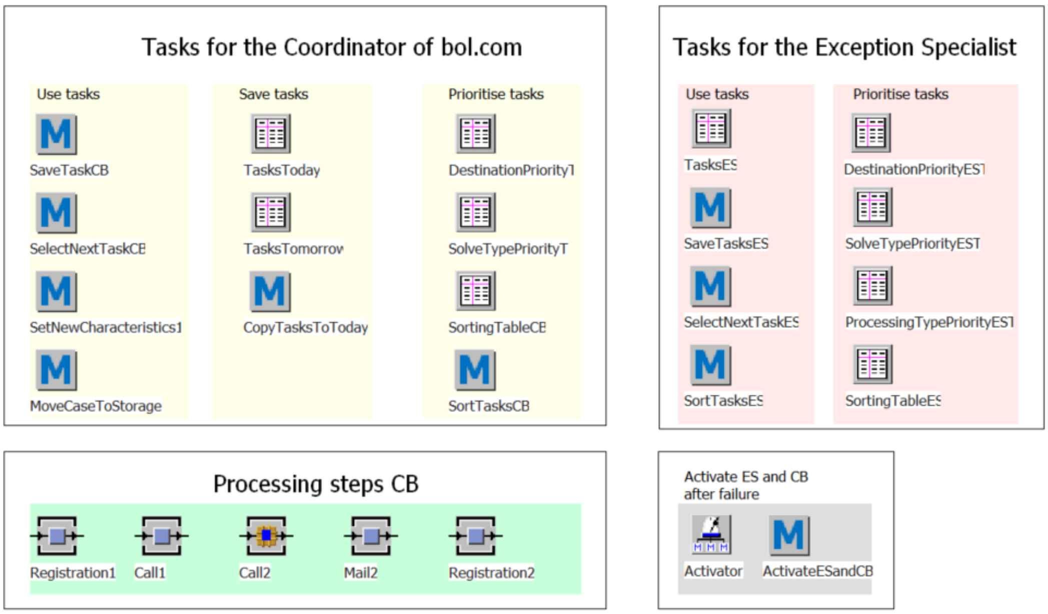

Figure 5.10: Screen capture of the frame Solving

During the solving of the exception case, the CB performs five different tasks. In most cases, the next task is performed after one day, to provide the Lvb Partner time to respond. When a task is finished, the next task is determined based on the case characteristics and the case is moved to the 'Storage during solving'. This follow up task is saved to the task list of tomorrow's tasks. When the CB is free, the task list with tasks that can be performed that day is sorted and the first task is selected. When the exception case is solved, it is sent to the 'Storage after solving', until the ES is able to process the task. The ES has tasks to execute in the Registration frame and in the Processing frame. When the ES is available, the ES's task list is sorted and the task with the highest priority is selected. We evaluated if the the ES or CB is available every time when the ES and CB start their work shift, when they finish a task, and when an exception case arrives in storage. Furthermore, the employees can be in 'failure', which means that they are unproductive. To start a next task when the ES or CB is productive again, every thirty seconds is checked if the ES and CB are available again.

5.3.4 Experimental design

First the experimental settings are explained. Followed by the configuration variables. Lastly, the executed experiments are introduced.

Experimental settings

The exception process is a non-terminating system, since the model has no natural end point. As long as there is enough employee capacity, the system reaches a steady state, with a stable performance. When there is not enough capacity, queues arise and the average throughput time will increase continuously. The simulation is tested with enough capacity, to analyse the performance of the steady state. When the simulation starts, there are no items in the system and the system is in initial transient. It takes a few days to reach the steady state. The initialisation bias is removed to ensure only results from the steady state are included in our analyses.

Before the length of the initial transient (warm-up) period is determined, we have defined a batch size. This batch contains the performance of a specified period such that the batches are independent and identically distributed (i.d.d.). We concluded that a batch of one week is a logical size and subsequent batches are roughly independent; Figure F.1 in Appendix F.3.1 shows that there is no visible correlation between the batches.

The warm-up length is determined by using *the marginal standard error rule (MSER) method*. The MSER is a numerical method that is based on minimising the mean-squared error. This method, in combination with the *Welch approach*, where via a graph the initial transient is estimated, leads to a warm-up period of one batch. This is equal to a warm-up period of one week. In every simulation run, the first week of results is deleted. The calculation of the warm-up period is provided in Appendix F.3.2.

When a system is non-terminating and the measurements are i.d.d., the configuration can be tested by performing a single long run and determine the performance by calculating the average of the measurements. As mentioned earlier, the performance of a batch of one week is i.d.d. and can therefore be used as measuring point. By the *graphical method of Robinson*, we determine at which point in time the run length (in batches) is long enough to provide significant results. We applied the method as follows.

1. Twenty runs are performed with a run length far above the expected required run length. Each replication had a run length of 400 batches in steady state.
2. For every measurement the average performance is calculated over the measurements executed so far. For example, for measurement 5, the average performance is calculated over the first five measurements. One measurement stands for the performance of one batch.
3. For every measurement, the convergence is determined over the twenty runs. The convergence is calculated by Formula 5.1. We set the run length to the measurement number where the convergence reaches below 0.05 (to ensure that the performance of the runs differ at most 5%).

$$C_i = \frac{Max(\bar{Y}_{i1}, \bar{Y}_{i2}, ..., \bar{Y}_{i20}) - Min(\bar{Y}_{i1}, \bar{Y}_{i2}, ..., \bar{Y}_{i20})}{Min(\bar{Y}_{i1}, \bar{Y}_{i2}, ..., \bar{Y}_{i20})} \tag{5.1}$$

   where:
   C_i = convergence at period i.
   $\bar{Y}_{ij}$ = cumulative mean of output data at period i for replication j.

The convergence drops below 0.05 at 251 runs. The length of one single long run is set to a batch size of 251, which is equal to 1757 days.

In the simulation, many random number generators are used to define characteristics and times. All random variable generators use different seed values to ensure that there are no correlations between characteristics and times in the system. For every experiment, the same seed values are used. This guarantees that all configurations are tested under the same conditions.

Configuration variables

Every run, multiple variables are changed. The variables that can be varied are provided in Table 5.4. The sorting criteria are numbered in the order of priority. The working hours of the CB and ES has to be filled in and are initially from 9:00 to 17:00 and 07:00 to 23:00 respectively. There are many variables that can be sorted on many different ways.

The variables of the CB and ES are sorted separately. To determine the full-factorial experimental number, the number of options for CB and ES are determined and multiplied together. We assume that per employee only can be prioritised on at most four criteria, since the effect of prioritising on more criteria is so small that is does not add value. For each employee there are 5*4*3*2+5*4*3+5*4+5 = 205 ways to sort the priority criteria. First,

Table 5.4: Configuration variables

CB		ES	
Sorting criteria	**possibilities**	**Sorting criteria**	**possibilities**
Case Quantity	up - down	CaseQuantity	up - down
Next task	Registration 1 Call 1 Call 2 Mail 2 Registration 2	Next task	Registration Processing
Solve Type	FO Normal Small	Way of processing	Process to stock Return to Partner Destroy
Nr of days in system	up - down	Nr of days in system	up - down
Expected processing time	up - down	Expected processing time	up - down
Start of day	Time	Start of day	Time
End of day	Time	End of day	Time

sorting on four criteria gives 5*4*3*2 options. Next, when we sort on three criteria, there are 5*4*3 options and so on. For every priority criteria, the possibilities of options variate as well. In Table 5.5, the calculation of the full-factorial number of experiments is visualised. To execute all possible priority rules, 89,321,616,000 experiments should be run. This is not possible, therefore we determine in the next section which configurations are tested.

Table 5.5: Calculation full-factorial experiments to determine best performing priority rule

Tasks CB	**options**	**Tasks ES**	**options**
Case quantity	2	Case quantity	2
Next task	205 (5*4*3*2+5*4*3+5*4+5)	Next task	2
Solve type	9 (3*2+3)	Way of processing	9 (3*2+3)
Nr of days in system	2	Nr of days in system	2
Expected processing time	2	Expected processing time	2
205	14760	205	144
Total CB	**3025800**	**Total ES**	**29520**
Total CB & ES	**89321616000**		

Experiments and configurations

Four scenarios are created to test the impact of the priority rules, working hours, and arrival rates.

1. **Initial conditions & priority rule**
   First, the model is tested without any priority rules and under standard working conditions. *1 experiment is executed.*
   Next, the best priority rule is defined for the CB and ES under standard working conditions. In three steps, the best performing priority rule is selected. Each iteration is continued when a better performing priority rule is found.
   (a) Impact of single priority rules.

CB: 14 experiments (Case quantity - 2, Next task - 5, Solve type - 3, Nr of days - 2, Exp. processing time - 2).

ES: 12 experiments (Case quantity - 2, Next task - 3, Way of processing - 3, Nr of days - 2, Exp. processing time - 2). Since there is no impact measured for the ES, the next iterations are only executed for the CB.

(b) Impact of the processing steps and the different solving types of the CB.

i. Processing steps
First the three best performing processing steps resulted from the previous iteration are combined with all other processing steps *(3*4=12 experiments).* Next, the three best performing combinations of processing steps are combined with the to other well performing processing steps *(3*2=6 experiments).*

ii. Solving steps
All combinations with sorting on two solving types are executed *(3*2=6 experiments).*

(c) Impact of a combination of well performing priority rules.
First, the five best performing criteria are sorted with another best performing rule *(5*4=20 experiments).* Next, the best performing rule is tested to sort with a third criteria *1*3 = 3 experiments.* This best performing is tested to sort with a fourth criteria *1*2 = 2 experiments.*

2. **Impact of arrival rate**
The Lvb inbound flow will grow the coming years. This will lead to an increase of exception cases. Therefore, we test the impact of an increased arrival rate, with and without priority rules under standard working conditions.
In total, seven varying arrival rates are tested with and without the use of the priority rule, leading to 14 experiment is total.

3. **Impact of working hours**
As mentioned in the problem statement, the working hours seem to be not aligned with the workload. Therefore is the impact of the exception process tested, under different working hours with and without the use of a priority rule.
In total, 12 varying working hours are tested with and without priority rule. This results in 24 experiments.

4. **Impact of priority rules under stressed environment**
The results show an improved performance when the priority rule is used under less working hours and when the arrival rate is higher. However, the best performing priority rule is not automatically the best priority rule under stressed conditions. Therefore the best priority rules are determined for:

   (a) An environment where the workloads of the CB and ES are decreased.
   (b) An environment where the arrival rate is increased.

   These priority rules are determined by employing the same method as provided at step two. *In both cases, the identical number of experiments are executed as in step 2. This lead to an execution of 150 experiments in this step.*

In total 264 experiments are executed. The exact configurations, results and conclusions are provided in the Section 5.5.

5.4 Validation of the simulation model

Robinson identified six forms of validation [45]. These forms are applied to execute the exception process completely.

Conceptual model validation

From the model introduction, we conclude that the content, assumptions, and simplifications are sufficiently accurate. The simulation model contains the necessary details to to meet the objectives.

Data validation

The data that is used in the model is sufficiently accurate to provide reliable results. By the use of the input data, the exception process is replicated as good as possible. The inter arrival time is specified, all exception case characteristics are simulated based on analysed probabilities, the employee characteristics are taken into account, including productivity, and the duration of the processing steps are determined based on a detailed analysis into the sub processing steps.

In all situations, random number generators are used to create variation in the process, which also occurs in the actual process. We have no insight in the distribution of the processing times, because a lot of measurements per processing step are needed and these are not available for the improved exception process. Therefore, the times are generated based on triangular distributions. The triangular distribution is a reliable method to use, when a small set of measurements is executed [45]. For the simulation model, we assume that the triangular distribution is sufficient accurate to determine the processing steps.

White-box validation

White-box validation consists of determining that the constituent parts of the model represent the corresponding real world elements with sufficient accuracy for the purpose at hand [45]. The standard procedure is to compare the actual way of working with the steps taken in the model. Since, the actual way of working is not implemented yet, we have to validate the model differently.

The improved process is designed based on the current process. All new procedures are described by detailed flowcharts. The expected processing times per processing step are determined by looking into the duration of each small task. These small tasks could already be measured, therefore we assume that the duration of the processing steps are estimated with sufficient accuracy. The designed conceptual model is validated by the involved employees and process experts. Furthermore, in the previous section, the verification of the basic model tells us that the conceptual model is translated by the simulation model correctly. Since the conceptual model is representing the improved exception process sufficiently and the simulation model is verified, we can conclude that the simulation model represent the real world with sufficient accuracy.

Black-box validation

Black-box validation looks into the representation of the overall model and if this represents the real world. As described at white box validation, we cannot compare the simulation output with the performance of the improved exception process, since it is not implemented. Because of the arguments named at white box validation, we assume that all tasks are executed following the procedure for the improved exception process and that processing times are determined correctly.

In Section 4.4.1, the estimated performance of the improved exception process is calculated. We compare the estimated performance of the conceptual model with the results of a test run of the simulation model, using the initial settings. The total modeled handling time and storage time have to match with the throughput times of the improved process, provided in Table **x** in Section 4.4.1. Also, the costs have to be similar as estimated. The complete performance of the initial run is provided in the next section. From the throughput time of the improved exception process, the estimated total throughput time is **x**.

From the simulation model, the total throughput time is **x** days. The handling time, storage time before solving, and during solving is similar to the processing times of the improved process. We can explain the difference in the storage time after solving. In the improved exception process, we estimated that the exception case is processed after 0.7 days, however the results of the model show that this can be realised faster, which we assume is realistic. The estimated costs of the improved exception process are similar to the costs of the simulation model. We explain the difference of €0.19, by the variation in storage time and the small difference in handling time. Also, performance results of the model about idle time and waiting time seem plausible. Since the results of the estimated improved exception process are comparable with the results of the model, the model has sufficient black-box validation.

Experimentation validation

We used theoretical models to determine the batch size, warm-up period, run length, and the method of using random number generators during the experiments. Therefore, we conclude that the experimental validation is sufficient accurate.

Solution validation

No solution validation could be executed, since the improved exception process is not implemented. In future, when all implementation projects are implemented, the performance output of the model can be compared with the actual performance.

Validation conclusion

In summery, the simulation model is validated on five of the six validation types positively, since the solution validation could not be executed. Therefore, we conclude that the model is sufficient accurate to use for the purpose at hand.

5.5 Output of the simulation model

In this section the results of the experiments are given, together with the configuration settings. The results of relevant findings and conclusions are given after each tested scenario. In all steps, the performance of the throughput time is used as key comparison indicator, because in most cases, the increase or decrease of the throughput time is associated with a similar increase or decrease of the other indicators (in comparison with other configurations). Exceptions are duly noticed. The total throughput time in provided in seconds, because this indicator is very detailed. The seconds are converted to days using the notation Days:Hours:Minutes. Eventually, we use the indicator 'Avg days in exceptions' to calculate the final performance, since the performance of the current exception process is calculated in the same way.

5.5.1 Initialisation & Priority rule

The first scenario consists of the current arrival rate of eight exception cases per day and standard working hours. This provides the performance that is shown in Table 5.6.

Table 5.6: Configuration settings without priority rule

Performance	**Output**	**Performance**	**Output**
Throughput time (s)	**x**	Avg days in exceptions	**x**
Throughput time (D:H:M)	**x**	% Idle time ES	95.0%
Criteria 1: % of partners contacted within 36h	80.4%	% Idle time CB	33.5%
Criteria 2: % of cases solved within five days	91.3%	% ES waiting on CB	28.8%
Criteria 3: % of cases processed within 24h	100%	% CB waiting on ES	0%
Total costs (€)	**x**		

The next step is to determine the best working priority rule. The first interventions to determine the priority rule for the CB are provided in Table **x**.

The combined priority rule that decreases the throughput time the most takes **x** seconds. This is equal to **x** (D:H:M). In the execution of prioritising the tasks, first there is sorted on the least important priority criteria, until there is at last sorted on the most important priority criteria. This ensures that eventually, the cases with the highest priority are on the top of the list. However, in the results we show the most important priority criteria as number 1.
We conclude from the priority rule for the CB the following.

- The best priority rule focuses on the cases that are the longest in the solving process.
- The sorting rule on small exceptions seems plausible, because this solving type only requires one task: 'Registration 1'.
- Sorting additionally on the tasks Mail 2, Call 1, and Registration 2 organises the tasks in a way that the probability is the highest that a case is solved after completing these tasks.

Using the priority rule for the ES has no effect at all. Therefore, the best priority rule consists of sorting the CB's tasks only.

5.5.2 Impact of an increased arrival rate

The impact of the arrival rate is tested with and without the use of the priority rule. First, the arrival rate from the expected growth is calculated, see iteration 2 in Table **x**. Increasing the arrival rate, slightly increases the throughput time. However, the exception process performs really well. The arrival rate is increased with 10% until the exception process experiences stress. We conclude from the table that the priority rule impacts the throughput time a lot when the arrival rate is **x** or higher. Figure 5.11 shows the first six iterations, since the seventh and eighth iteration do not fit in the graph.

Confidential Table

Confidential Figure

Figure 5.11: Effect of arrival rate on the throughput time (s)

5.5.3 Impact of decreased working hours

The working hours are varied and the impact, with and without the best priority rule, are visualised in Table **x**. Also, the first measurements are provided in Figure 5.12. The last two measurements are not included in the graph, because the throughput times are too large to see. From Table **x**, we see that the impact of the priority rule increase, when the CB works three hours. We see that decreasing the working hours of the ES has a negative impact on the workload of the CB, therefore we only want to decrease the working hours of the CB. It is optimal when the CB works four hours.

Confidential Table

Confidential Figure

Figure 5.12: Effect of working hours on the throughput time (s)

A test is performed to the necessary working hours of the CB at the end of 2020 (with an arrival rate of **x** exception cases per day). The result is provided in Table **x**. Six hours are necessary to complete the tasks of the CB. However, seven hours are optimal, because the throughput time remains low.

Confidential Table

We conclude the following:

- In the current situation, the working hours of the CB can be decreased with four hours. This results in only an increase of ten minutes on the total throughput time. The working hours can be decreased by two hours without any change in performance.
- End 2020, the CB needs seven hours to complete his tasks and to keep the throughput time low.
- Decreasing the working hours of the ES impacts the throughput time more than decreasing the working hours of the CB (until five hours decrease). However, the exception process is still well performing when the ES has identical working hours as the CB.
- The performance is better when the ES works from 09:00 to 17:00 than when he works from 7:00 till 17:00. These additional hours impacts the workload of the CB negatively.
- The priority rule shows a better performance when the exception process experiences stress in relation to not using the priority rule.
- Multiple priority rules for the ES are tested, but also show no impact when the working hours are decreased.

5.5.4 Priority rules within a stressed environment

As concluded from step 2 and 3, the impact of the priority rule increases when the exception process experiences stress. In this step, we analyse if the selected priority rule in step two is also performing best if the process has to deal with less working hours or more exception cases. The same steps as in part one are used to determine the best performing priority rule. First, to determine the best performing priority rule with a higher arrival rate, the arrival rate is set to a mean of **x** and a standard deviation of **x**. This arrival rate is used, because we see clearly the impact of using the priority rule and with and without the use of the priority rule, the process is still functioning.

Second, we change the initial settings to a situation where the working hour of the CB is reduced to three hours, and the ES works only the first shift (7:00 to 15:00). We set the working hours of the CB to three hours, since we see a larger relative impact of the priority rule, but both processes (with and without priority rule), still flow.

Impact priority rule on increased arrival rate

With the increased arrival rate of **x** exception cases per day, the priority rule clearly has more impact. First, the impact of single priority rules are measured. The results are provided in Table 5.7. From this table we conclude that sorting descending on ‘Numbers of days’ and sorting on ascending on the 'Case quantity' result in an improvement. Important to note is that if there is sorted incorrectly, for example descending on 'Expected processing time', the performance deteriorated with 28.4%.

Table 5.7: Impact of the criteria on the throughput time with an increased arrival rate

Priority rule	**Throughput time (s)**	**Throughput time (D:H:M)**	**Improvement i.r.t. no priority**
Nr of days (down)	x	x	8.8%
Case quantity (up)	x	x	4.5%
Call 1	x	x	2.5%
Mail 2	x	x	2.2%
Call 2	x	x	0.8%
Registration 1	x	x	0.7%
Normal (case type)	x	x	0.6%
Small (case type)	x	x	0.1%
No priority	x	x	0%
FO (case type)	x	x	-1.3%
Case quantity (down) 2	x	x	-1.3%
Expected processing time (up)	x	x	-2.5%
Registration 1	x	x	-20.2%
Nr of days (up)	x	x	-24.5%
Expected processing time (down)	x	x	-28.4%

The results of the best performing iterations are visualised in Table 5.8. The best priority rule selected in Step one, also performs best in case of an increased arrival. The throughput time reduced with seven hours.

Table 5.8: Impact of priority rules on the performance with an increased arrival rate

Best performing priority per iteration	**Throughput time (s)**	**Throughput time (D:H:M)**
1a. Effect single priority		
Small (case type)	x	x
Nr of days (down)	x	x
Call 1 (Next step CB)	x	x
Registration 2 (Next step CB)	x	x
1b1. Effect next steps CB		
Mail2 - Call1 - Reg2	x	x
2. Combining priority criteria		
(1) Nr of days (down) (2) Small (case type) (3) Tasks of CB: Mail 2 - Call 1 - Reg 2	x	x

Impact priority rule on reduced working hours

The best performing priority rule for the reduced working hours is exactly the same priority rule as found in Step 1. Applying the priority rule decreases the average throughput time with seventy minutes. The priority rules for the Exception Specialist has also in this scenario no impact on the performance.

Conclusions from the impact of a priority rule on a stressed environment

In Table **x**, we see that the priority rule has a minimal impact with standard working hours and an arrival rate of on average **x** exceptions each day. As the arrival rate of the exception

cases increases, the priority rule becomes important to use.
From the last interventions, we can conclude the following:

- The priority rule that is best to apply is in every scenario identical, this is:
  1) Descending on number of days at solving
  2) Small cases
  3) Tasks of the CB: Mail 2- Call 2- Registration 2
- It is important to use the priority rule, since sorting on a different criteria causes a negative impact.
- The priority rule contributes more in a stressed environment. Especially, when more exception cases enter the process. Applying the priority rule can lead in a highly pressured process, to a process that still functions, while the process would be exploded when no priority rule was used.

5.6 Solutions for an improved exception process

We recommend to implement two improvement projects. At first, implement the use of the priority rule when the the next task for the CB is selected. Second, align the working hours with the workload. Lastly, the performance improvement is slightly adapted as a result of the modeled output. This is explained in the last section.

5.6.1 Implementation of the priority rule

To be able to prioritise the tasks of the CB, three additional columns have to be added to the Excel.

1. Number of days at solving
   This column provides the number of days that the exception case is registered by the CB. A formula can be added, to provide the number of days since the CB has started with the case.
2. Small items
   Include a column where a '1' is filled in when the exception case quantity is a two or lower.
3. Priority of next step
   This column provides numbers that relate to the priority of the step: Mail 2 (priority 3), Call 1 (priority 2), Registration 2 (priority 1). All other steps do not have a priority number. With a formula, these priority numbers can be filled in automatically when the next step is selected.

At the start of the day when all tasks for that day are clear, sort the priority criteria columns in order from least important to most important, to ensure that the most important priority criteria has the most impact.

5.6.2 Align working hours

When all improvement projects are implemented and the employees are used to the new way of working, the working hours can be aligned with the workload. In the current situation, where eight exception cases enter the exception process each day, the Coordinator of bol.com only has to work for four consecutive hours. When the arrival rate of exception cases increases, we advise to increase the working hours as well to a maximum of seven hours at the end of 2020. For the Exception Specialist it is important to remain available during two shifts to execute the registration and the processing of the exception cases. However, the ES can perform additional tasks to increase the workload. It is important that the priority remains at the exception tasks, to reach identical performance. Determining the working hours is a responsibility of the inbound operation team of bol.com.

5.6.3 Impact on performance

From the simulation model, we observe a shorter storage throughput time (**x** days) than estimated in Chapter 4 (**x** days). This leads to a small decrease in the costs. The storage time reduces with 1,210 minutes, which result in a cost decrease of **€x**. The final costs per exception case are **€x**. Expected costs for 2020 are **€x**. In this case, **€x** is saved (44.6%).

5.7 Conclusion

Four scenarios are simulated with the use of a simulation model, in which multiple priority interventions are tested to find the best working priority rule and working hours to decrease the total throughput and idle time of the employees. The simulation model is validated and verified to ensure that the model is sufficiently accurate for the purpose at hand. In the experimental design, we performed experiments with a batch size of one week, deleted the one week warm-up period at the beginning of a run and run each experiment 254 weeks.
In the first scenario, the improved exception process with the current exception arrival rate (**x** cases per day) and standard working hours (ES works two shifts: 07:00 - 23:00) and CB works from 9:00 to 17:00) is tested. The throughput time of the improved exception process without prioritising, is already reduced to **x** days. Executing multiple priority interventions leaded to the following best working priority rule where only the tasks of the CB are sorted, since sorting the rule of the ES has no impact.

1. Sort on the number of days that the exception case is in the solving process.
2. Execute the cases that are 'small' (contain of 1 or 2 exception items) first.
3. Sort the next steps of the CB such that first the Mail 2 tasks are executed, followed by Call 1, and Registration 2.

The sorting criteria decreases the throughput time by exactly 21 minutes (0.5% improvement). In this scenario, the idle time of the ES and CB are very high. Therefore, there are not many tasks to sort and this leads to a small impact of the priority rule.

In the second scenario, the impact is tested of increasing the number of incoming exception cases per day. The maximum capacity that the CB and ES can handle is **x** exception cases per day. Here, the throughput time can be decreased by 18.7% when the priority rule is applied. Sorting on a characteristic different from the priority rule can lead to negative impact. For example, if sorting is set on smallest processing time, the throughput time is increased by 28.4%.
In the third scenario, the impact is tested of decreasing the working hours of the ES and CB. The working hours of the CB can be reduced to four hours when the priority rule is applied and the idle time of the CB is below 10%. Reducing the working hours of the ES has a negative impact on the throughput time, because it increases the workload from the CB as well. It is impossible to reduce the ES's idle time by decreasing the ES's working hours, without increasing the throughput time significantly. Therefore we advise to only lower the throughput time of the CB to 9:00-13:00.

In the fourth scenario, the arrival rate of exception cases is set to **x**, to create the environment that is expected in Dec' 2020. In this scenario, the working hours of the CB from 9:00 to 16:00 are optimal, under condition that the priority rule is applied. We advise to not change the working hours for the ES, but provide additional tasks to execute during the two working shifts.

Testing many priority rule interventions, we state that the best working priority rule found, works best in all scenarios. Furthermore, we conclude that applying the priority rule improved the throughput time. How more stressed the environment, how larger the impact of the priority rule.

From the simulation model, we observe a plausible shorter storage throughput time than estimated. Therefore we change the expected performance from to a total throughput time of **x** to **x** days. This leads to a decrease of **x** per exception case. In 2020, a total amount of **€x** can be saved (44.6%).

Chapter 6

The implementation of the improved and optimised exception process

To change the current situation to an improved and optimised process, multiple solutions have to be implemented. This chapter is introduced to provide a clear implementation plan for bol.com. In Section 6.1, all projects are scaled on an impact-effort matrix to indicate the priority of the projects. In Section 6.2 an implementation planning is created, in which the project type, implementation time, and priority of projects are taken into account. Section 6.3 provides the conclusion of this chapter.

6.1 Impact and effort of the implementation projects

The proposed solutions from Chapter 4 and Chapter 5 are translated into clear implementation projects. We scaled all projects on an impact-effort matrix to indicate the priority of the projects. The results are visualised in Figure 6.1. The grey marked projects are projects that are already implemented.

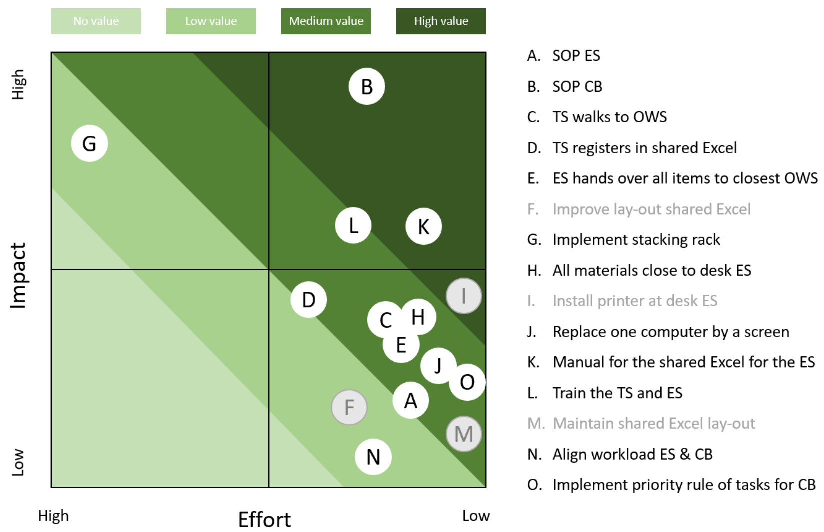

Figure 6.1: Implementation projects scaled on an impact-effort matrix

We indicated the effort for each project based on the workload and lead time and scaled the projects on a scale from one to ten. This is visualised in Table 6.1.

Table 6.1: Effort score of implementation projects

Projects	**Implementation tasks**	**Work load**	**Lead time**	**Condition**	**Effort score**
A - SOP ES	Create manual.	2 days	2 weeks	Expert knowledge	2
B - SOP CB	Create manual, change way of working CB. *Already ongoing*	5 days	2 weeks	Expert knowledge	3
C - TS walks to receiving station	Approval from relevant stakeholders, instructions for TS, execution by TS.	3 days	2 weeks	Cooperation employees	2
D - Let TS register in the Teams Excel	Approval from relevant stakeholders, instructions for TS, execution by TS.	5 days	4 weeks	TS has to be educated	4.5
E - ES hands over all exception items to closest receiving station	Align with lead work floor, ensure the team lead plans experienced OWS to closest WS.	1 day	1 week	In planning Team lead	2
F - Change Excel lay-out	Design new lay-out. *Already implemented*	4 days	3 weeks	Excel knowledge	3.5
G - Stacking Rack	Purchase rack, connect locations with WMS, train ES and TS.	2.5 weeks	12 weeks	IT time	9.5
H - All materials (without IT) close to desk Exception Specialist	Place two pallets, reserve space for return boxes, purchase/move waste bin.	1 day	2 weeks	Space on work floor	2
I - Install printer at desk	Install printer. *Already implemented*	1 day	1 day	IT knowledge	1
J - Replace one of the computers with a screen	Purchase screen / use screen from office, install this screen.	1 day	1 week	Technical approval	1.5
K - Provide a manual for the Shared Excel ES	Create Excel manual.	2 days	2 weeks	Expert knowledge	2
L - Train the TS and ES	Set up introduction program, organise training	5 days	4 weeks	Expert knowledge	4
M - Maintain Excel lay-out and the correctness of information	Align the responsibility of the task with the CB. *Already implemented*	1 day	1 day	Responsible employee	1
N - Workload ES / CB	Agree with lead work floor, change way of working such that remaining hours are spend differently.	3 days	3 weeks of testing	-	3
O - Implement selecting priority rule CB	Include in way of working, add two columns in Excel	1 day	1 day	Excel. columns	1

The projects have impact on the throughput time, handling time, and quality of the process. To determine the total impact, first in Table 6.2, the impact of the throughput time is provided. Second, Table 6.3 gives the impact of the handling time. Lastly, the impact of quality is explained, together with the total impact score. This is visualised in Table 6.4. The storage and handling impact is determined based on the percentuale improvement in relation to the previous way of working and the percentuale improvement of the total storage and handling time.

Table 6.2: Impact storage time

Project and effect	**Impact storage**	**% Decrease**	**% Impact total storage time**	**Cost decrease**	**Impact score**
B - Faster contact between CB and Partner	x days	63%	45%	x	8,5
K - Better overview of tasks and priority of tasks	x days	88%	25%	x	7.5
O - Better use of throughput time	x days	5%	1%	x	2.5

Table 6.3: Impact handling time

Project and impact	Impact handling time	% decrease	% total decrease	Costs decrease	Impact score
B - Less time is spent per task	x	46%	22%	x	9.5
C - Less waiting time	x	29%	1.3%	x	6
D - No double work	x	28%	2.0%	x	7
E - Less searching for operator	x - (freq. 86%)	48%	0.9%	x	5
G - Less searching for items	x	61%	3.6%	x	7.5
H - Less walking	x	70%	0.9%	x	6
I - Less walking	x	92%	6.4%	x	8.5
J - Faster handlings and less mistakes	x	2%	0.1%	x	2
L - Faster handlings and less mistakes	x	11%	0.8%	x	5

In Table 6.4, the quality impact is determined in agreement with the exception process stakeholders. When the quality increases from poor quality to a minimal value level, the grade 5 is given. When the quality is improved even more, a grade higher than five is given. In case of a small increase a grade between one and three is given. The total impact is calculated by summing the quality-, handling-, and storage impact. Next, the total impact is recalculated to a one to ten scale. At last, the impact/effort ratio (I/E ratio) is calculated to indicate which projects can be implemented with the most impact and least effort.

Table 6.4: Impact quality and total impact of implementation projects

Project	Quality impact	Handling impact	Storage impact	Total impact	Impact scale 1-10	Ratio I/Effort
A - Standard Procedure Exception Specialist	5			2.5	1.1	1,4
B- Standard Procedure Coordinator bol.com	5	9.5	8.5	20.5	9.3	3,3
C - Trouble Shooter walks to receiving station	2	6		7	3.2	1,8
D -Let TS register in the Teams Excel	3	7		8.5	3.9	1,0
E - ES hands over all exception items to closest WS	2	5		6	2.7	1,6
F - Change Excel lay-out	6			3	1.4	0,8
G - Stacking Rack	8	7.5		11.5	5.2	0,8
H - All materials (without IT) close to desk ES	2	6		7	3.2	1,8
I - Install printer at desk	1	8.5		9	4.1	4,3
J - Replace one of the computers with a screen	5	2		4.5	2.0	1,8
K - Provide a manual for the Shared Excel ES	5		7.5	10	4.5	3,1
L - Train the TS & ES	7	5		8.5	3.9	1,8
M - Maintain Excel lay-out and the correctness of information	5			2.5	1.1	2,3
N - Workload ES / CB	2			1	0.5	0,3
O - Implement selecting priority rule CB	3		2.5	4	1.8	2,5

6.2 Implementation planning

To implement the projects in a structured and effective way, the projects are clustered based on the impact, effort and type of project. From the impact-effort matrix, we see that all projects add value. Also for the projects that show 'low value', we recommend to implement these projects to make the work of the employees more convenient and to bring the exception process to an acceptable quality level. We already implemented three projects: the printer is installed at the ES's desk (I), we improved the Shared Excel (F), and the CB is currently responsible for maintaining the Excel lay-out (M). In five steps, the remaining projects can be implemented. The overview is provided in Figure 6.2. The planning is based on the longest lead time of the projects within the implementation step. Furthermore, the required available time of the involved employees is taken into account. The responsible project leads and all implementation steps are explained below. Lastly, the implementation risks are provided.

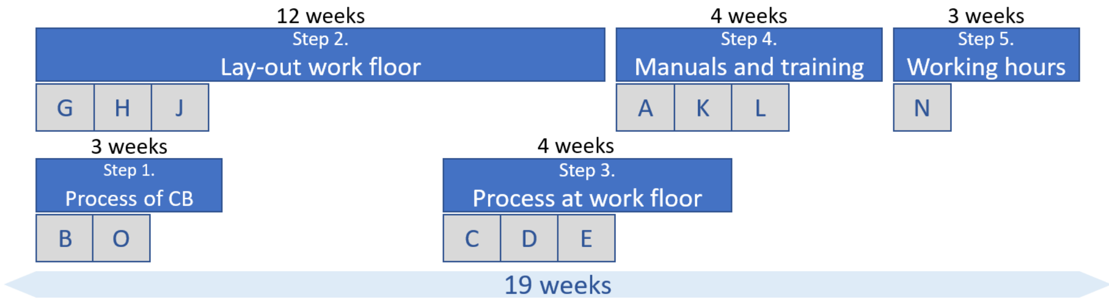

Figure 6.2: Implementation project planning

Responsible employees for the implementation

Two teams within bol.com are responsible for the successful implementation of the projects. These teams are the 'Inbound operations team' and 'Product team inbound' (more tactical and strategic project improvement team) at the logistical department. These teams work together to maintain and improve the inbound processes. Most improvement projects are about the execution of the process and small lay-out changes (projects A-F,H,K-O), these are the responsibility of the 'Inbound operational team'. The implementation of the stacking rack and IT related implementations (projects G,I,J) are the responsibility of the 'Product team inbound'. In both teams, currently one person is dedicated to improve the exception process. It is important that the project leaders include and convince all layers of the organisation and their staff that is involved in the exception process. These consist of the operations manager of the warehouse, the coordinators of the inbound process, the inbound team leads, and of course the employees that work in the exception process.

Step 1. Improve the process of the CB

The project with one of the highest I/E ratio is the 'Standard procedure for the CB' (B). This project contributes to a remarkable lower throughput time, faster handling time and brings the process quality to a standard level. In combination with this project, we advise to implement simultaneously the priority rule for selecting tasks of the CB (O). By changing the CB's way of working, it is easy to directly implement the use of the priority rule. This priority rule shortens the throughput time and will have a large impact when the process is under pressure.

Step 2. Changing the Lay-out of the work floor

To create a changing environment on the work floor, we recommend to execute first the projects that change the lay-out. Most of these projects score high on the I/E ratio. These lay-out changing projects are: implementing the stacking rack (G), move all materials into the exception corner (H), and replace one of the computers with a computer screen (J). Especially the stacking rack will impact the way of working and contributes to bring the exception storage to an acceptable quality level. Implementing the projects ensures less walking time, higher work convenience, less mistakes, and therefore a higher quality as well.

Step 3. Change way of working on the work floor

As the lay-out is changed, the next step consists of changing the way of working of the Trouble Shooter and the Exception Specialist. We advise the 'Inbound operational team' to confer this new way of working with the inbound lead, team coordinator, team leads and the TS, and ES. The TS has to walk to the working station on detection of an exception (C), furthermore we recommend to let the TS register the first information about the shipment of the exception case in the Shared Excel instead of writing this with pencil on the dummy label (D). Besides, the closest working station at the exception desk has to receive all exception cases from the ES that can be processed to stock (E). Each shift, the Team lead has to schedule an experienced OWS at this working station.

Step 4. Train employees and publish the work floor instructions

After all changes at the work floor are implemented, it is important to train the TS & ES (L) and provide them with instructions about the way of working (B) and about the usage of the Shared Excel (K). In this way, the improvements can be controlled and maintain the process quality. We recommend to repeat the training each six months and to use the training program when new employees start working in the exception process.

Step 5. Working hours

When the exception process is stabilised, we advise to look into the working hours of the CB (N). When the number of exception cases remains below 17 exception cases per day, the CB can decrease the working hours spend on the exception process to less than six hours a day. For the ES, we advise to define new tasks, in which the priority of the tasks remains at the registration and processing of the exception cases.

Implementation risks

We identified the following four risks.

1. Unavailability of project leads
   It might occur that the project leads are ill or that responsibilities change within the teams. In this case it is of high importance that the improvement projects are assigned to colleagues. Understanding of the exception process takes some time, and will lead to a delay of probably one or two weeks on the total implementation time.
2. Delay of the implementation of the stacking rack
   The implementation of the stacking rack might get delayed due to a delayed approval of purchasing the stacking racks. Also, IT time is required to implement the storage locations into the Warehouse Management System (WMS). In case of a delay also steps 3, 4, and 5 will delay. Some processes at the work floor can be implemented already,

however it is more efficient to change the way of working at once. The manuals and training programs can be developed already, but we recommend to provide the training only when all processes are changed. The working hours can be adapted only when the improved way of working is completed, therefore this step will be postponed as well.

3. Employees not sufficiently involved
   When not all employees are sufficiently involved, the execution of the new way of working will not be implemented and executed correctly. At every layer, the involved people has to be convinced of the new way of working to improve the performance.
4. Lack of monitoring the execution of the improved exception process
   When the improved way of working is introduced, it is important to monitor the process and ensure that the process is executed as prescribed. Right at the beginning, it is the easiest to teach the new way of working correctly at once. It is hard to change a bad executed process at a later stage. Therefore supervision of the team leads play an important role in the implementation to improve the performance.

6.3 Conclusion

For each improvement project, the impact and effort are determined. Based on these scores, we clustered the projects into implementation steps. We implemented already three projects during this research. In the first step, the projects that change the way of working of the CB. Second, the projects regarding the lay-out change are implemented. The stacking rack is placed, all necessary items are moved into the exception corner, and a computer is replaced by a computer screen. Placing the stacking rack is the largest project, but will improve the lay-out notably. In the third step, the projects are implemented that change the way of working on the work floor. These projects take less effort to implement and can be executed simultaneously. Directly after the new processes at the work floor are introduced, the employees need to be trained and all manuals need to be introduced. These can be developed during the implementation of the prior projects. At last, there can be experimented with decreasing the working hours of the CB and select additional tasks for the ES to execute next to the exception tasks.

The two responsible teams within bol.com for the successful implementation of the projects are the ‘Inbound operations team’ and ‘Product team inbound’ at the logistical department. It is important that the project leaders include and convince all layers of the organisation and their staff that are involved in the exception process, consisting of the warehouse operations manager, the inbound process coordinators, the team leads, and the exception employees. We identified four implementation risks: (1) Unavailability of the project leads and (2) delayed implementation of the stacking rack, leading both to a delay at all subsequent projects. (3) Insufficient involvement of stakeholders & employees and (4) lack of monitoring the execution of the new process lead both to a less improved performance. The implementation of all improvement projects require full attention to achieve the desired improved performance.

Chapter 7

Conclusions and recommendations

First, the conclusions of this research are provided in Section 7.1. Second, recommendations to bol.com for further research are explained in Section 7.2.

7.1 Conclusions

The research goal is to answer the following research question.

> *"How can bol.com design their Lvb exception process to improve their performance on throughput time, costs, and partner dissatisfaction?"*

On average, **x** exception cases arrived each weekday in 2019. Due to forecasted inbound growth and a higher share of Lvb sales, this will grow approximately to **x** cases in 2020. This is equal to **x** exception items each day in 2019 and **x** exception items in 2020 respectively. In the current situation, the total throughput time per exception case is **x** days. The total costs per exception case are **€x** and **€x** per exception item. The total costs for 2019 result in **€x** and will increase to **€x** in 2020. The dissatisfaction of Lvb Partners is expressed by the following performance. The questionnaires' results show that **x**% of the exception Lvb Partners are dissatisfied. **x**% of the exception Lvb Partners contacted Partner Service about delayed items on stock.

Using a literature research, we selected Lean as the best process improvement methodology to apply. The inefficiencies in the current exception process are identified by applying different Lean tools. For each inefficiency, solutions are identified. The three solutions with the largest impact are:

1. The replacement of the tote storage and separate storage of identical exception items with a stacking rack that stores all exception items of a case together.
   This solution brings the exception storage to an acceptable quality standard. It avoids searching to exception items, the ES can walk directly to the right exception case. Furthermore each case is registered to a location, which prevents that items get lost.
2. All materials are placed at the exception corner.
   This reduces the time that the ES spends on movements with 70%. It also leads to

higher employee satisfaction when unnecessary work is minimised.

3. Introducing the SOP for the CB leads to the highest performance improvement. *It ensures a faster throughput time of exception cases (63% decrease), also the handling time of the CB is reduced with 46%.*

By including all improvement solutions, we designed the improved exception process. To test the improved exception process, a model is used to simulate the process and calculate the performance of four scenarios. At first, the improved exception process with initial settings (**x** exception cases per day, standard working hours) has an average throughput time of **x**days. Performing tests to multiple priority interventions, we conclude that in all scenarios the following priority rule is best to apply. Sort on:

1. Case that is the longest in the solving process
2. Small exception items
3. Next processing steps CB : Mail 2 - Call 1 - Registration 2

Second, the impact of the priority rule depends on how full (stressed) the exception process is. In a more stressed environment, the priority rule has a larger impact and can make the difference between a still functioning process and a process that has more incoming exceptions than processed exceptions. Applying the priority rule under the standard working hours, an average rate of **x** exception cases per day can be handled, while keeping performance sufficient. Third, at the arrival of eight exception cases per day, the working hours of the CB can be reduced from eight to four hours. However, in a fourth scenario, when the arrival rate increases to **x** exception cases each day, the optimal working hours of the CB is from 9:00 to 16:00. We advise not to change the working hours of the ES, but expand the set of tasks. Reducing the working hours of the ES influences the CB's workload negatively and results in longer throughput times. In 2020, the expected impact of the priority rule is a decrease of one hour (1.1%) on the total throughput time.

The changed processing steps lead to less storage- and handling time, which improves the performance. For the improved exception process, the expected total throughput time of an exception case is estimated to **x** days, corresponding with a reduction of 74% compared to the current situation. The total costs will decrease approximately by 44%. The costs in the improved exception process are reduced to **€x** per exception case. Therefore, in 2020, the improved exception process has a savings potential of **€x**. Furthermore, we expect a decrease of partner dissatisfaction, because 80% of the Lvb Partners are contacted by bol.com within 36 hours (from the arrival in the exception process). This fast contact ensures more insight in items that are delayed on stock and prevent partners to contact bol.com first.

To realise the improved and optimised exception process, fifteen improvement projects are identified. Based on the impact, effort, and project type, the projects are clustered into five implementation steps. During this research, three projects are already implemented. The five implementation steps are: 1) Change the process of the CB, 2) Change the work floor lay-out, 3) Change the process at the work floor, 4) create work floor manuals and train the employees, 5) align the working hours more effectively.

The two responsible teams within bol.com for the successful implementation of the projects are the 'inbound operations team' and 'product team inbound' at the logistical department. It is important that the project leaders include and convince all layers of the organisation and their staff that are involved in the exception process. These are the warehouse operations manager, the inbound process coordinators, the team leads, and the exception employees. We identified four implementation risks: (1) Unavailability of the project leads and (2) delayed implementation of the stacking rack, leading both to a delay at all subsequent projects. (3) Insufficient involvement of stakeholders and employees and (4) lack of monitoring the execution of the new process, lead both to a less effective improved exception process. The implementation of all improvement projects require full attention to achieve the desired improved performance.

7.2 Recommendations

We formulated eight recommendations that can contribute to a better performing exception process. All recommendations are listed below.

1. The 'Operational inbound team' and 'Product team inbound' have to implement all projects recommended in Chapter 6.
2. Improve monitoring the execution of the exception process.
   The 'Operational inbound team' has to stimulate the inbound team leads to pay more attention to the supervision of the exception process, to gain more control of the execution of the process and improve the process quality.
3. Be more strict towards frequent offenders
   Currently, exception cases from a single partner are accepted and processed to stock up to four times. When causing an exception case has more consequences, Lvb Partners would probably be more careful to create one. The 'operational inbound team' and 'Product team inbound' has to collaborate and define a more strict protocol for Lvb Partners.
4. Combining the role of TS and ES
   We advise the 'Operational inbound team' to perform a research combining the roles and tasks of the Exception Specialist and the Trouble Shooter. It might be beneficial to fulfill the complete registration of the exception case at the working station when this is just detected. This can be realised when the ES walks to the OWS or when there is one more TS available. Which solution works best and how this registration will be executed, needs to be investigated.
5. Improve the dashboard
   We advise the 'Operational inbound team' to improve the dashboard to be continuously aware of the performance of the exception process, the reasons of exceptions and the frequent offenders, to control the process quality.

6. Decrease the percentage of incoming exception cases

   We recommend the 'Product team inbound' to start a project to decrease the number of exceptions by informing Lvb partners upfront. Bol.com is not strict enough in educating Lvb partners to send their shipment correctly. On three points improvements can be made:

   (a) Explanation to partners. Explain in a video which activities have to be performed to ship correctly.
   (b) Pay more attention to the mistake that is made often: 'Labelling via bol.com'. In many cases, the Partner assumes that 'labelling via bol.com also means that no EAN is required, while this is not the case. Many exception cases arise because there is no label on the product.
   (c) Always provide feedback on first shipment. A solution could be to print the HD form in a different color of a Partner that delivers for the first time an Lvb shipment. In this case, it is immediately visible that the shipment belongs to a new Partner and the correctness of the shipment can be evaluated. When the shipment is not completely correct, feedback can be given to the Partner to prevent the partner from causing exceptions any more. The feedback loop at the first shipment has probably more impact than after multiple shipments.

7. Role of tote 7

   We recommend the 'Product team inbound' to collaborate with the 'operational inbound team' and perform a research to the role of using tote 7 for sending exception cases to the exception desk. Currently, also new items are sent via this tote, which makes it difficult to detect the exceptions directly by the ES, which delays the registration of the exception cases. It might help to split the totes for new items and exception cases, register the exception case directly at the exception desk, or send a tote with an exception case directly to the exception desk instead of waiting until tote 7 is full.

8. DOA (dead on arrival) items and items that are nearly expired

   Although the DOA items and nearly expired items were no part of this research, we noticed that there is a lack of clarity about the destinations of these items. Because the items are owned by the Lvb Partners, bol.com is not allowed to make profit of these items. Therefore, most items are destroyed. This is a waste, since a lot of products are still valuable. We advise the 'operational inbound team' to investigate how this process can be more sustainable by providing these items a second life.

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Appendix A

Process flows

A.1 Impact on problem bundle

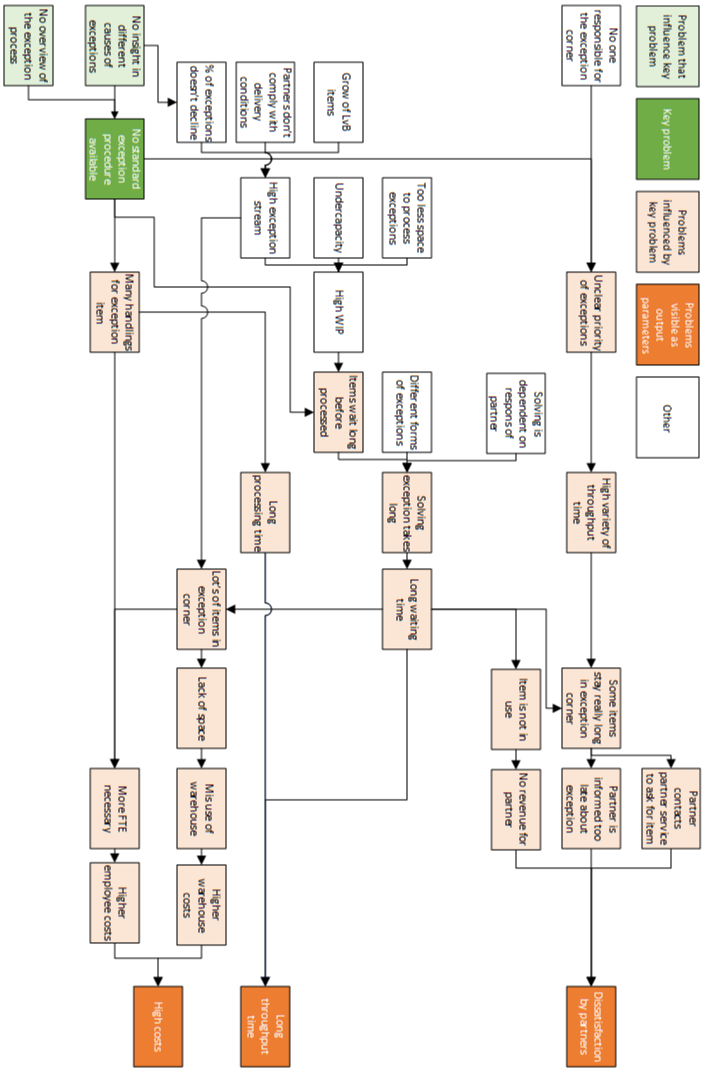

Figure A.1: Impact of improving the key problem on the problem bundle

Appendix B

Data analysis

B.1 Analysis flow inbound, Lvb, and exceptions

With data from one year (week 40 2018 - week 39 2019) the average inbound stream is measured. A division of Own and Lvb products is made and the average share of Lvb products is calculated each week.

Confidential information

B.2 Duration of solving an exception case

Solving the exception case consists of four steps: Registration, unanswered calls of partners, solving the cause, and updating the registration. The third step, solving the cause is variable and dependent on the cause.
The time spend on the registration and updating of the registration is fixed for every exception case. In 14% of the cases a partner does not answer a call. The average time spend on unanswered calls is calculated by multiplying the average time of calling a partner with 0.14. The time spend to solve a cause is variable. For each cause is measured how long it takes to solve the cause and calculated how often this cause occurs. The causes are categorised based on the duration from category A to E and given in column Category.
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The average time spend on solving the exception case results from the average time spend per category multiplied by the share of that category. This is *Confidential information*.

B.3 Analysis total throughput time

The average total throughput time (time between registration and processing of an exception case) is x days. A detailed analysis is executed to provide more insight in the spread of the throughput time per case.

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A histogram is created to provide insight in the division of the total throughput time of the exception cases.

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Appendix C

Literature review

C.1 The occurrence of process improvement methodologies

A research is performed in the field of process improvement methodologies. All articles that provided an overview or compared multiple methodologies in three search therms are listed in Table C.2. Other search therms are filled in, but did not give useful results. Table C.1 provides an overview of the occurrence of the methodologies that are named more than once. The first five methodologies occur in fifty or more per cent of the researched articles. These methodologies are used in the comparison.

Table C.1: Occurrence of process improvement methodology

Methodology	Occurrence
Lean (Thinking)	10
Sig Sixma	9
Total Quality Management (TQM)	6
Business Process Re-engineering (BPR)	5
Kaizen	5
ISO (9000)	3
Benchmarking	2
Lean Sig Sixma	2
MIPI	2

Table C.2: Research to the occurrence of process improvement methodologies

Nr	Search Therm in Google Scholar	Name	Author	Year	Methodologies
1	Process improvement methodologies	Review of Business Process Improvement Methodologies in Public Services	Dr Zoe Radnor	2010	Lean Thinking, Six Sigma, Lean Six Sigma, BPR, Process Improvement Techniques (TQM, ISO9000, EFQM, Kaizen and Benchmarking)
2	Process improvement methodologies	Quality Improvement Methodologies PDCA Cycle, RADAR Matrix, DMAIC and DFSS	M. Sokovic, D. Pavletic, K. Kern Pipan	2010	PDCA Cycle, RADAR Matrix, DMAIC and DFSS
3	Process improvement methodologies	Business process improvement methodologies: an overview	O. A. Rashid, M.N. Ahmad	2013	Model-Based Integrated Process Improvement (MIPI), Super Methodology , PCDA, Benchmarking, Six-Sigma, Lean Thinking, Kaizen, TQM
4	Process improvement methodologies	Total Quality Management and Business Excellence	Tony Bendell	2005	ISO9000, Lean, Sig Sixma, Investors in people, Process mapping and simple improvements
5	process improvement methodologies comparison	A decision aid for selecting improvement methodologies	N. Thawesaengs-kulthai, J.D.T. Tannock	2008	TQM, Lean, Sig Sixma, Iso
6	process improvement methodologies comparison	Choosing Which Process Improvement Methodology to Implement	Mark Gershon	2010	Six Sigma, Lean Management, Lean Six Sigma, Agile Management, Re-engineering, TQM, Just-In-Time, Kaizen, theory of constraint
7	process improvement methodologies comparison	An integrated multidimensional process improvement methodology for manufacturing systems	K.K. Chan, T.A. Spedding	2003	BPR, TQM, IMPIM, JIT, TPM, production cells, Kaizen, set-up time reduction, Kanban, Poke-yoke, six Sigma
8	process improvement methodologies warehouse	Advances in Manufacturing	A. Hamrol, O. Ciszak	2017	Own method, looks like PDCA / DMAIC
9	Process improvement methods	A Critical Evaluation and Framework of Business Process Improvement Methods	R.J.B. Vanwersch, K. Shahzad	2015	BPR, Business Process Improvement, Workflow Engineering, Lean, Service Engineering
10	Process improvement paradigms	A The barriers to realising sustainable process improvement: A root cause analysis of paradigms for manufacturing systems improvement	B. J. Hicks, J. Matthews	2010	Lean, Kaizen, Six sigma, TQM, BRP, Total Productive Maintenance (TPM), Overall Equipment Effectiveness (OEE)

Appendix D

Identification of waste

All waste that is identified is classified at one or multiple types of waste. This is provided with a letter of T-I-M-W-O1-O2-D-S. (Transport, Inventory, Motion, Over-production, Over-processing, Defects, Skills unused).

D.1 Define phase of Lean

This section provides the identified waste from the Analysis phase of Lean. This is originated from three sources; the Swimlane Diagram, the Spaghetti Diagrams, and from observations.

D.1.1 Swimlane Diagram

All waste that is identified from the Swimlane Diagram in Figure 4.2 is explained below.

1. Dummy label (O2-D)
   At the dummy label, the number of identical exception items, supplier ID and shipment date is notated. All this information has to be written on a very small piece of paper, which is mistake sensitive. The information has to be registered in the Excel. This is double work.
2. Walking of Operator at working station (M-O2)
   The Trouble Shooter (TS) and Operator at the working station (OWS) walk both the same route, which is not necessary if the trouble shooter walks directly to the OWS.
3. The shared Excel (D-S)
   The Exception Specialist (ES) works in a shared Excel. This Excel does not work optimally. Sometimes information is not saved and gets lost. Different ES use sometimes different notation methods, which gives errors in dates and names. The field 'Reason for exception' is not always filled in properly.
4. Double system registration (O2)
   Information is transported between many systems and information is saved double. The Coordinator of bol.com (CB) has to paste information in his own excel and he has to make a case in another program.

5. Lay-out problems Excel (02)
   The shared Excel does not provide a good overview. Multiple scrolling is necessary to gather the correct information. It requires searching for cases that can be processed.
6. Storage of dummy items in totes (M-O2)
   The dummy items are located in a tote, but all numbers on the totes need to be checked to see if it is the correct tote number. The tote numbers are not located at the front, but at the side of the tote. Also, the totes are stacked in three levels. If the dummy is placed in the lowest tote, it is too have (and dangerous) to pick the dummy. An operator needs to help, or the ES needs to move all totes. Lifting a tote can be very heavy, especially the highest tote, because the tote is placed above shoulder height.
7. Storage of identical exception items (M-O2-D)
   It is a chaos at the boxes. It is hard to find the right box, because all boxes need to be opened to check if it are the right items. There are many boxes stored. Also, it is easy to loose items, because of the lack of overview.
8. Copying items between Excel sheets (O2-D)
   If the ES has processed the items, the status needs to be set on 'Finalised', All the 'Finalised' items are copied to another sheet in order to keep the working sheet only for exception cases that need to be processed. This copying is executed by an employee that is not involved in the exception process. Mistakes are made with this copying and information gets lost.
9. Gathering information to print HD form (O2)
   The HD code needs to be written down, because the ES has to walk to the docking stations to print the HD form. This is over-processing work.
10. Printing HD form (M) Walking to the docking stations to print a form is wasting time by too far walking. Also, the HD code does not have to be written down if a working printer is available at the desk of the ES.
11. Checking destroy items with the Team lead (O2) A double check with the team lead if exception items can be destroyed is not necessary. If the process is followed correctly, the items can be destroyed if this is the processing solution given by the CB.

D.1.2 Spaghetti Diagram

This section starts with the two Spaghetti Diagrams. The first Spaghetti Diagram visualises the movements of the Trouble Shooter (red) and the Operator at the Working Station (black).

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Detected waste from all movements All waste identified is from the waste type 'Motion'

1. Printer (ES)
   The printer is placed at the other end of the hall, which is a walk of five minutes back and forth.

2. Destroy box (ES, exception item)
   The destroy box is placed in the middle of the hall, which is a quite far walk.
3. Return items to work floor office (ES, exception item)
   The exception items that are processed as a return need to be moved to the work floor office, which is far.
4. Return items that require a new box (ES)
   In some cases if items need to be returned, the exception items require a new shipment box. This box is not always present at the desk of the ES. The ES has to walk the stairs and pick a box at the outbound floor.
5. Waste bin (ES)
   The waste bin is five meters walking, which leads to unnecessary steps and leads to collecting waste before it is thrown away.
6. Searching for exceptions (ES)
   The ES has to search for the right tote and right box with identical exceptions. This result in many steps around the totes and boxes.
7. Double walking (TS & OWS)
   The TS stands on a fixed place in the middle of the Working Stations. The OWS walks first to the TS, it handovers the exception items and walks back. If the TS has labeled the exception item, he walks to the OWS and gives the dummy item. This leads to double walking.

D.1.3 Waste from observations

The following waste is identified from own observations.

1. Stocking method is undesirable (M-O2-D-S)
   The searching of exception items in totes and the identical exceptions in the exception storage is a time consuming and unsatisfying task. The separation of the dummy item and the identical items result in over-processing and lost items.
2. Shared excel is inefficient (O2-D-S)
   As already mentioned at the waste identified from the Swimlane Diagram, the shared Excel works not optimal. The added value of columns need to be determined. Also, the ES makes mistakes with filling the Excel.
3. Multiple exception specialists work differently (D-S)
   There is no standard procedure followed. All Exception Specialists have their own way of working. No feedback is given when mistakes are made.
4. Waiting on Lvb partner (I-W)
   The Coordinator of bol.com has to wait for information about the exception items from partners. It can take very long before partners respond. In this time, the exception items remain in storage.
5. No clear insight in priority of exceptions cases (I-W)
   There is no priority rule determined and therefore also not visible. For the Coordinator of bol.com and for the Exception Specialist is it valuable to provide insight in which

actions they need to execute.

6. Two computers (O2-D)
   Two computers are in use at the desk of the Exception Specialist. The computers are not connected. Copying of numbers between the computers is not possible. Also, only one computer is connected with a code scanner. This both lead to manually filling in codes. This is time and mistake sensitive.

D.2 Measure phase of Lean

This section provides all measurements that need to be executed in the measurement phase of Lean. This gives input for the current state Value Stream Map, explained in the next section, Section D.3.1.
The following performance indicators are measured:

- Takt time
  The exception input rate is equal to the output range. There can be concluded that the customer demand is equal to the exception input because the exceptions need to be processed as fast as possible. Input is the same as output. On average x exception items arrive at the exception corner every day, consisting of on average x exception cases. The available work time of the exception specialist is x s (2 shifts of 7h 15 minutes). This results in a takt time for cases of x s (x minutes).
- Cycle time
  The number of value added activities is the sum of the processing steps where the item is not in storage. The is x s (x min).
- lead time
  The total time of all processing steps: x s (x minutes and x days).
- Processing time
  The processing times of each individual processing step are shown in Section 2.2.3 in Table **??**. To simplify the process, processing steps are combined if they can be executed contiguously and by one employee. This leads to an input step, four processing steps, and an output step. These steps are:

  I Input: detection of an exception
  1. Registration of an exception by the exception specialist
  2. Registration of a case by the coordinator of bol.com
  3. Solving a case by the coordinator of bol.com
  4. Processing a case by the exception specialist

  O Output: Finalising the processing by the team lead and operator at the working station

  This result in the following processing times.

  1. x s - Registration of an exception
  2. x s - Registration of a case
  3. x s - Solving a case

4. x s - Processing a case

- Queue time
  This is the waiting time between to processing steps. This measurement results from the calculated storage time from Section 2.2.3, Table **??**.

  I-1 Time exception stays in tote 7 - x s (x min)
  1-2 Time between registration by the exception operator and the registration of a case by the coordinator of bol.com x s - (x min - x days)
  2-3 Time between registration of a case and solving of a case x s (x min - x days)
  3-4 Time between solving of the case and processing - x s
  4-O Time between the processing actions executed by the exception specialist and finalising activities - x s
  T Total queue time: x s

- Work In Progress (WIP)
  The work in progress is the average amount of cases and exceptions from step 1 till 4. From a weekly analysis are there on average x exception items on stock and x exception cases.
- Completion rate
  The amount of work completed in a week is on average 1483 exception items. This result in x exception items a day, which is equal to x exception cases.

D.3 Analysis phase of Lean

This section provides firstly an explanation of the current state VSM and the corresponding identification of waste. Subsequently, an analysis of levelling the processing times, standardisation, and type levelling is given.

D.3.1 Current state Value Stream Map

This section explains how the current state Value Stream Map (VSM) is created, how the information is gathered and which waste is identified.
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In the following eight steps, the aspects and numbers in the VSM are explained.

1. Processing steps
   As mentioned in the measurement phase in Section D.2, there are four main processing steps; Dummy registration, case registration, solve case, and prepare to process case. The detection of the exception is used as input step, because this is not the only task of the Trouble Shooter and Operator at the Working Station. The output is that the exception case is processed (either to stock, as a return to the partner, or destroyed). Between the fourth process step and the output is a step placed where the processing of

the case is finalised. No definition is used, because these tasks are executed by different employers as a side task.

2. Input of processing steps

   The dummy registration and the prepare to process case are executed by the Exception Specialist (ES), the Case registration and Solve case are executed by the Coordinator of bol.com (CB).

   - C/T: The cycle time is equal to the cycle time calculated in the measurement phase.
   - C/O: There is no changeover time in the processing steps.
   - Step one and four share one employer (ES). The employer share is calculated based on the processing time of the steps. Step four takes two times longer than step one. Step two and three share one employer as well.
   - The ES has two breaks during the shift and works two shifts. The up time is set to x% because the ES does not work totally productive. During work there is time for chatting and working slower than necessary.

     The CB works one shift without breaks (this is outside working hours). The productivity is set to 80% because some other meetings or tasks require some time.

3. Inventory

   The average amount of cases stored in the exception corner is x. This is the total inventory between steps one and four. The cases are divided based on the throughput time between the steps. On average two cases are placed in tote 7 before it arrives by processing step one. Also, two cases are waiting before the processing of the case is finalised.

4. Output

   As mentioned in the measuring phase, the output is equal to the input. All the exception cases need to be processed as fast as possible. Therefore each day ten cases are processed with on average x exception items. This is equal to x cases per month. The items can be received during two shifts, five days a week. The flow is continuously, because the parts can be handed over to output directly and it is done by an employee.

5. Input and flow

   On average arrive each day ten cases. This is equal to x cases a month. The cases are detected at the Working Station and they are handed over by the Trouble Shooter continuously.

6. Exception control & flows

   The Exception items are controlled by the Logistics Inbound Group. The main file used is the Shared MS Teams Excel file. Here, all cases are stored. In step one, the information is stored in the file. This is used by the CB in step two. Next, the CB enters additional information in step three in the file, which the ES uses in step four. Between each processing step, the cases are pushed to the next step.

7. Timeline

In the timeline the storage time is placed at the upper line, the processing time (value adding time) of the processing steps is placed at the lower line. The times are provided from the measurements phase.

8. Production lead time & value added time

   The total production lead time is x day and the value adding time is only x seconds. The value added time is equal to 0.24% of the total time. This is really small.

Detected waste from the current state VSM

1. MS Teams Excel (O2-D-S)

   Information updates not continuously and some Excel functions does not work. Use of Macro's is not possible.
2. The inventory is too high (I-W)

   The inventory between process steps is too high. A lot of items are stored constantly.
3. Up time of Exception Specialist is low

   Around thirty percent of the time, the Exception Specialist cannot work or does not work. In this time, the Exception specialist is chatting, bored, or waiting for work.
4. The exception specialist is two shifts available

   It might not be necessary to work two shifts, looking into the workload of the other process steps.
5. The completion rate of each step is unequal (W)

   The number of cases that can be completed each day, differs per process step. This disturbs the flow and causes unnecessary waiting and inventory.
6. The total inventory time is very high (W)

   Total inventory time is very high, especially in relation to the total cycle time.

   Total value added time $= \frac{xs}{xs} \cdot 100\% = 0.24\%$

D.3.2 Analysis processing time levelling

From the current state Value Stream Map given in Figure 4.4 there can be concluded that the processing times variate. Step three (solving the exception case) takes the longest. Therefore, it slows down the processes prior to step three. To create a flow, it is important that for every process step the completion rate is the same.

D.3.3 Standardisation

As mentioned earlier, there is no standardised process for the exception specialists. There is no manual available. Each exception specialist works differently. This causes mistakes in the shared Excel file. Also the Exception specialists executes some tasks in a different order. This makes the process error sensitive. The coordinator of bol.com is always the same person, which makes the execution of work more standardised. The employee uses his own manual, to follow steps in the same order. However, there are no strict rules about waiting before a partner is approached for the second time or which priority is required to take up cases.

D.3.4 Type levelling

Processing exception cases that variate in processing times in a row can lead to a more fluent process. If a cycle of cases with varying processing times is formed and this is repeated constantly, the cycle is stable. This is not the case right now, but it might be a solution in the future. The solving time of a case can be estimated and based on the excepted duration, a 'production schedule' can be created. The order of solving the cases can be determined. For example, create a cycle where the expected solving time is first 5 min, then 8 min, followed by 10 min, 15 min and 30 minutes and repeat this cycle.

Appendix E

Performance of the improved exception process

E.1 Average item quantity in Tote 7

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E.2 Standard Operating Procedure for the Coordinator of bol.com

The standard operating procedure for the Coordinator of Bol.com is explained.
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For each case type, we made a different procedure. Small cases are cases that contain of 1 or 2 exception items. These items are only registered. The required information can be found in the Supply Chain portal. When an Lvb partner has caused more than four times an exception case, the Partner always receives his items return. One day after the first registration, the Partner is called, to remind the Partner to correct shipment conditions. Regardless to the response of the call, the second registration is executed.
The remaining exception cases ('Normal' cases) follow a different procedure. First, 'Registration 1' is executed. In this registration, the case is registered in the systems, all information about the case is gathered and the Partner receives an email about the exception case and information about the correct shipment conditions. There is asked to complete the missing information. The next day the partner is called. Three options are possible: (1) the Partner does not answer the call, (2) the Partner answers the call and the case is solved, or (3) the Partner answers the call, but has to execute follow up tasks.
When the case can be solved due to the call, the second registration follows immediately. In case that the Partner has still tasks to execute, the next day is checked if those tasks are executed. If not, a reminder email is sent. In case of no response, the CB calls the next day again. When there is still no response, there is sent an email to inform the Partner about the contact attempts. The next day is sent a last reminder email, the items are sent return to

the Partner. Every day, the CB checks if the Partner did respond on the first email. If this is the case, the remaining steps are passed and directly the second registration is executed. By this procedure, the exception case spend at most five days in the solving process.

An analysis is performed to calculate how much time is spend on the registration of the exception case and the contact with the Lvb partners. The duration of the different tasks and the frequency that those occur are provided in Table x.
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From these frequencies and duration, the total time spend per processing step and total probability that the processing step is executed is calculated. This is provided in Table x.
For each sub process step within solving, the response of the Partners result in the total frequency and the corresponding average duration of the processing step, provided in Table x. The weighted average duration is calculated by multiplying the frequency with the average duration.
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Appendix F

The simulation model

F.1 Verification of input data

The verification of the input data consists of examining if the input parameters actually are being used in the model. We verified the average cases in the system, the productivity of the employees, the characteristics of the exception cases, and the duration of the processing steps.

Average exception cases in system
We included in the calculation of the performance also the calculation of the average arrival rate of the exception cases per day. From the performance of an experiment, we see automatically the average arrival rate. This corresponds exactly with the set mean arrival rate. Since there are tested multiple arrival rates, we can conclude that the arrival rate is verified.

Productivity of the exception employees
After each simulation run, the percentage of failure of each 'machine' can be checked. This percentage of failure corresponds with the set productivity (70% for the ES, 80% for the CB).

Case Characteristics
For each option of a case characteristic, a probability is determined in which the case receives the specified characteristic. The different options that one case characteristics can take are classified in ranges between 0 and 1. A random number is selected between 0 and 1, the exception case receives the characteristics of the range of the random number. After one run with the initial interventions, the case characteristics of the finalised cases are analysed. For each case characteristic with probabilities, the actual frequencies of the different options are determined, to check if the input is verified. From Table F.1, we conclude that all frequencies are executed with sufficient accuracy, since the deviation is in most cases smaller than 2%. Only the average case quantity deviates 3.2% from the expected average case quantity. To reach these frequencies, some probability scales are adjusted to let the modeled probabilities be more similar to the expected probabilities. The probability of the way of processing is only provided from the part that is distributed by a probability. The cases that obtain a standard way of processing based on their case characteristics are not taken into account in

the results.

Table F.1: Comparison of the expected and modeled probabilities of case characteristics

Input variables	**Expected results**	**Measured from cases**	**% Standard deviation**
Case quantity			
Avg case quantity	37	37.2	3.2%
Case type			
% Real Normal	81.4%	80.2%	1.2%
% Real Small	15.1%	16.2%	2.8%
% Real FO	3.5%	3.5%	0.2%
Answer on mail			
Mail day 1	25.0%	24.6%	0.8%
Mail day 2	25.0%	25.0%	0.0%
Mail day 3	25.0%	25.4%	0.8%
Mail day 4	25.0%	25.1%	0.2%
Total	25.0%	25.0%	0.1%
Answer on call			
Call 1 - Answer 1	41.0%	40.7%	0.5%
Call 1 - Answer 2	10.0%	10.6%	1.9%
Call 1 - Answer 3	49.0%	48.7%	0.4%
Call 2 - Answer 1	41.0%	40.5%	0.8%
Call 2 - Answer 2	10.0%	10.3%	0.9%
Call 2 - Answer 3	49.0%	49.2%	0.3%
Exception reason			
x	11.7%	12.0%	0.8%
	44.3%	43.5%	1.3%
x	37.1%	37.5%	0.6%
x	4.1%	3.9%	0.9%
x	1.8%	2.1%	1.9%
x	0.4%	0.4%	0.3%
x	0.2%	0.2%	1.4%
x	0.3%	0.4%	0.8%
Exception cause Partner			
x	11.7%	12.0%	0.8%
x	2.8%	2.6%	1.5%
x	22.8%	23.4%	1.2%
x	21.3%	21.3%	0.2%
x	4.1%	3.9%	0.9%
x	16.3%	16.2%	0.3%
x	8.0%	8.1%	0.6%
x	12.0%	11.5%	1.3%
x	0.4%	0.4%	0.3%
x	0.2%	0.2%	1.4%
x	0.3%	0.4%	0.8%
Way of processing			
Process to stock	86.0%	85.6%	0.4%
Destroy	2.0%	2.0%	0.3%
Return to Lvb Partner	12.0%	12.4%	1.1%

Processing Times

Per processing step, the tasks that are executed variate and depend on the case characteristics. In three steps the processing times are verified. First, per option in the processing step, the expected probability that this option is executed is compared with the actual ratios analysed from the output of the model. Second, for each option in the processing step, the mean processing time is calculated using Formula F.1. Using the probability per option and the mean processing time per option, the expected processing time per processing step is determined.

$$mean = \frac{min + max + mode}{3} \tag{F.1}$$

Lastly, the expected processing times are compared with the average modeled processing time measured from the processing steps from the finalised cases of one run (1450 cases). The results are provided in Table x.

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From these results From Table **x**, we conclude that almost all modeled processing step probabilities are in line with the expected probabilities. We see a difference for Registration 1 and the percentage of different tasks. Absolute is this difference very small. Furthermore, we see a difference at the probabilities at 'Call 2'. However, the eventual average processing step is close to the expected duration. Due to a difference in the distribution of the way of processing, the average duration of the preparation of processing deviate from the expected duration. If we look at the sub processing steps, we conclude that the steps have a duration in line with the expectation. In conclusion, we see some probabilities and duration of processing steps that deviate from the expected. However, we can explain the differences, also the modeled total throughput time is very close to the expected processing time (1.6% difference), therefore we conclude that the simulation model represents the conceptual model with sufficient accuracy.

F.2 Basic model verification

The flow of the model is verified in two ways. First, one exception case and Happy flow case are followed in each step to examine if the cases follow the process correctly. Second, ten exception cases are followed in the processing steps to check whether the cases follow the correct logic. At the start the path that the exception case is going to follow is predicted based on the characteristics of the exception case. The path is examined during the simulation run.

Add the results of the exception process that is followed completely

First, a 'Happy case' is followed. As expected is this case moved after the working station to the exit. Next, an exception case is followed. This case followed the complete exception procedure as prescribed in the conceptual model. In each step, the changed characteristics are evaluated and where identical as expected. The determined duration for each processing step where followed. The logic to determine the next task where followed completely. Therefore, we can conclude that the logic is followed as prescribed.

Add the results of the 10 exception cases with their case characteristics

In Table F.2, we evaluated the case characteristics and determined the path that the case should have followed. We select exception cases with different characteristics. From the duration per processing step, we see that all expected paths are followed. Based on the duration of the processing step, we also analysed if the correct handling is executed. For example, if the Partner did not answer the phone, if the processing time is around 60 seconds. From this analysis, we conclude that all processing times are in line with the prescribed processing step.

Table F.2: Evaluation of the tasks of exception cases

Exception case	Quantity	Case type	Exception Reason	Cause Partner	Processing type	Answer Call 1	Answer Call 2	Response on mail 1	Response on mail 2	Response on mail 3	Response on mail 4	Expected path
1	24	Normal	IncorrectCodeShipment	OldEAN	Return	3	3	FALSE	FALSE	FALSE	FALSE	Reg 1- Call 1- Call 2 - Mail 2 - Reg2
2	35	Normal	IncorrectCodeShipment	WrongArticle	Destroy	1	3	TRUE	FALSE	TRUE	FALSE	Reg 1- Call 1-Reg2
3	33	Normal	IncorrectCodeShipment	WrongArticle	Return	2	2	FALSE	TRUE	FALSE	FALSE	Reg 1- Call 1- Mail 2 - Reg2
4	45	Normal	MissingCodeShipment	ForgotPreRegistration	ProcessToStock	1	3	TRUE	FALSE	FALSE	FALSE	Reg 1- Call 1-Reg2
5	2	Small	IncorrectCodeShipment	WrongArticle	ProcessToStock	3	1	FALSE	FALSE	TRUE	TRUE	Reg 1
6	2	Small	NoLabel	ExternLabelMistake	ProcessToStock	1	3	FALSE	TRUE	TRUE	TRUE	Reg 1
7	10	Normal	NoLabel	PartnerLabelAlsoEan	Return	3	1	TRUE	FALSE	FALSE	FALSE	Reg 1- Call 1-Reg2
8	3	FO	IncorrectCodeShipment	OldEAN	Return	3	1	FALSE	TRUE	FALSE	TRUE	Reg 1- Call 1-Reg2
9	71	Normal	NoLabel	InternLabelMistake	ProcessToStock	3	1	FALSE	FALSE	FALSE	TRUE	Reg 1- Call 1- Call 2-Reg2
10	5	Normal	NoLabel	PartnerLabelAlsoEan	ProcessToStock	3	3	TRUE	FALSE	FALSE	TRUE	Reg 1- Call 1-Reg2

Furthermore, each method that is written in order to create the logic of the exception process are all checked. By debugging we checked if every line of the code worked as expected. We can conclude that the logic of the model works accurately. It simulates the exception process exactly as the conceptual model is described.

F.3 Experimental validation

F.3.1 Batch size

In Figure F.1 is visualised that there is no visual correlation when a batch size of seven days is used.

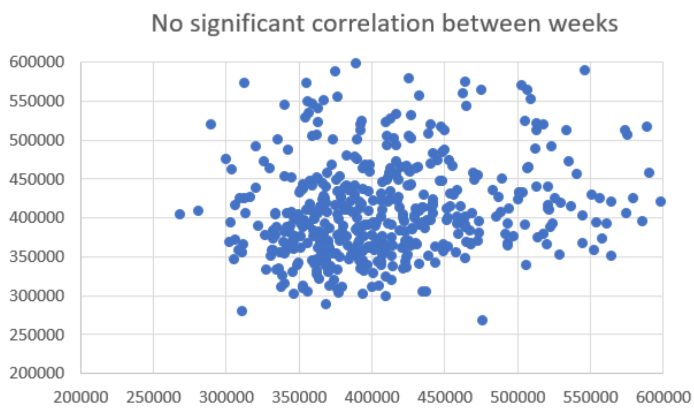

Figure F.1: Correlation between batch sizes of seven days

F.3.2 Warm-up length

The warm-up period is calculated as follows. First, the average throughput time batch is calculated using five simulation runs. Second, for each batch the variance is calculated from that batch until the last batch. Third, the marginal standard error rule (MSER) is calculated by using the following formula.
The warm-up length is defined by the batch number of the batch with the lowest MSER. This is a warm-up period of one as seen in Table F.3 . In Figure F.2, we also observe from with the Welch method that a one week warm-up period is plausible. In week two, the mean throughput time is at the same level as the weeks after week two.

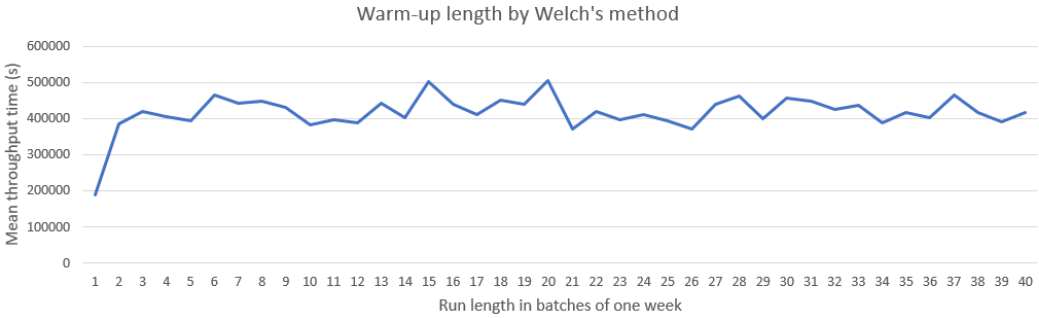

Figure F.2: Welch's method to estimate the warm-up length

Table F.3: Calculating the warm-up period by the MSER-rule

Day	Run1	Run2	Run3	Run4	Run5	Mean Runs	Warm-up	Variance	MSER
1	172508	151131	206702	198740	216830	189182	0	1348753148	4510829
2	422471	412921	352335	399984	338062	385155	1	1174558159	**3941426**
3	338465	500139	450671	432622	380484	420476	2	1174328622	3953923
4	358459	404467	424709	441191	395926	404950	3	1178295948	3980684
5	378452	358759	467536	330287	434569	393921	4	1181471302	4004941
6	692223	387964	454846	373861	416799	465139	5	1183075357	4024019
7	435112	484428	391894	422862	473794	441618	6	1180322661	4028358
8	567366	519303	389430	393035	368521	447531	7	1182826147	4050727
9	373808	419280	397080	457870	513647	432337	8	1184349816	4069882
10	368754	352508	344395	357732	489772	382632	9	1187931770	4096267
11	433822	356350	353216	377150	464752	397058	10	1187128734	4107662
12	336989	411708	349846	386559	451827	387386	11	1189355502	4129656
13	434642	327358	464236	426677	561274	442837	12	1189674556	4145157
14	526338	344646	389674	346408	400531	401519	13	1192095526	4168115

F.4 Technical Report

In this section, the technical background of the simulation model is described. For every part of the process a Frame is build. Furthermore, a frame is build to save the performance; Measure Statistics. Every frame is explained in detail.

Confidential information