Co-innovation of Small-Scale City Logistics Facilities

Designing a Logistics Solution for Electronic Parcel Lockers at Offices:
The MYPUP case

by

Fokke de Groot

Graduation committee

Chair:	Prof. dr. ir. L.A. Tavasszy
First supervisor:	Dr. W.W.A. Beelaerts van Blokland
Second supervisor:	Dr. J.H.R. van Duin
External supervisor:	Dr. L. van der Wardt

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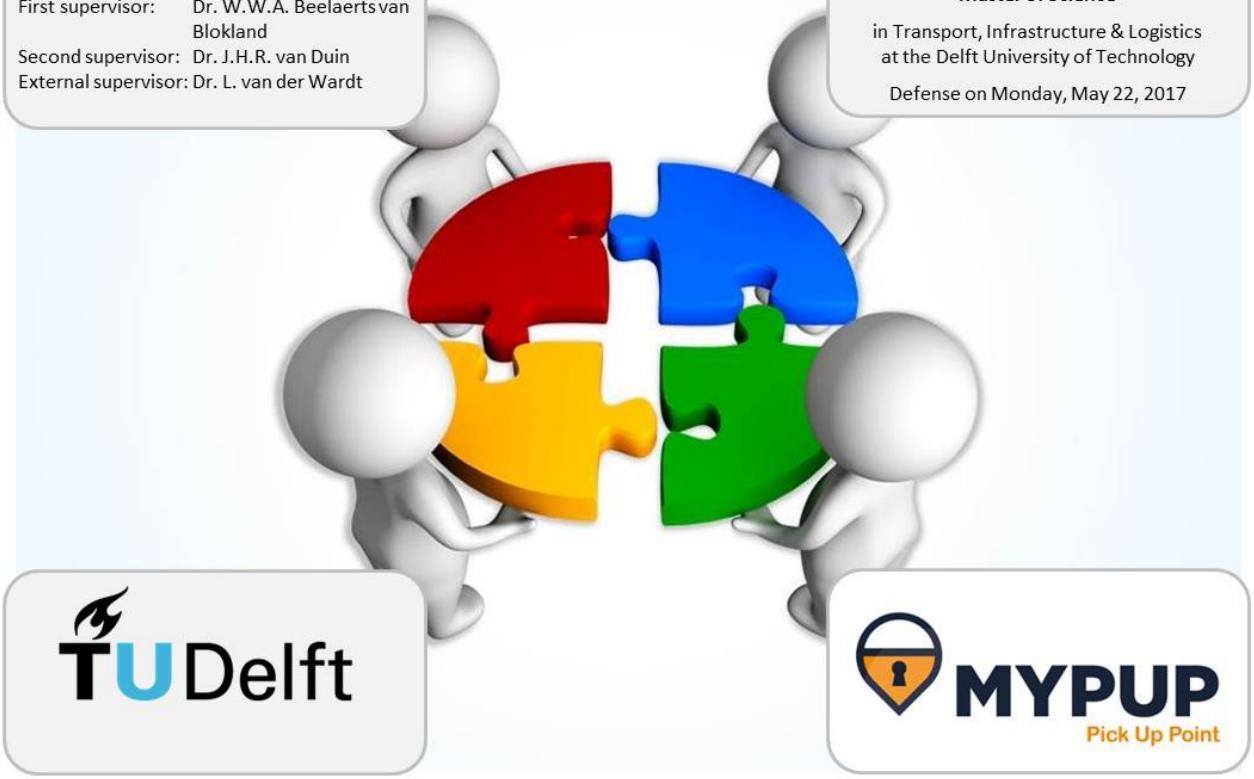

TU Delft

MYPUP
Pick Up Point

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Abstract

The Courier Express Parcel industry is booming business. Final delivery in the business to customer (B2C) parcel market has been one of the main focusses for innovation. The last mile in the B2C market is inefficient and expensive, due to delivery failures, congestion, urban constraints, non-optimum loading rates and regulations. The best solution in solving the last mile problem within B2C logistics is decoupling the presence of the final costumer and the delivery; electronic parcel lockers achieve exactly that.

MYPUP is one of the companies operating in the electronic parcel locker market and their method of operation is unique. MYPUP allows for delivery from all courier services by integrating the last mile of the delivery. The integration of the final delivery resulted in a new logistics process to consolidate, register and redistribute parcels and is the subject of this research. Analysis of the current logistics process exposed that the process involved a fair amount of manual labor, was error prone and reaching its capacity. The aim of this research was to redesign the warehousing process of MYPUP, focusing on the outbound logistics, to be more efficient, less error prone and to increase capacity, within the constraints of the limited available funds.

Solutions were found based on brainstorm sessions with MYPUP executives, MYPUP employees and by consulting experts. A model was developed to show the potential of the proposed solutions and to support the decision-making process of which solutions to implement. The model results showed that introducing optical character recognition (OCR) in the registration process leads to the biggest improvement. A MYPUP specific algorithm was developed to deliver a proof of concept for implementation of OCR in the registration process. This algorithm provided a financially attractive alternative to the expensive, already existing OCR solutions in the market.

The other identified solutions that were modeled all showed that significant improvements can be achieved. The registration process time can be reduced to a third of the current registration process time and a substantial portion of the errors can be eliminated, if all solutions are implemented. Furthermore, the reduction in registration time almost triples the hourly capacity.

It is recommended MYPUP implements all proposed solutions. The software solutions are recommended to be implemented first, in case financial constraints do not allow for immediate implementation of the 3D camera solution. Although using a 3D camera to determine the size of parcels, eliminates errors and saves time, it requires investment in expensive hardware.

It is also recommended to introduce the use of barcodes in combination with a drivers' app to eliminate errors in the registration, sorting and delivery process. The first step is to implement the drivers' app with the scan and OK functionalities. The route optimization algorithm requires further research and is recommended to be added later.

Finally, further research into the consolidation phase is recommended. Consolidating all parcels in time is crucial if the parcels are to be delivered the same day. Quantifying these benefits strengthens the negotiating position of MYPUP in concluding agreements with parcel delivery service companies.

Solutions proposed in this research, although specifically designed for MYPUP, can be adjusted and used to improve logistics processes in small-scale city logistics facilities as well.

Acknowledgements

This Master thesis is the product of the final stage of the Master Transport, Infrastructure and Logistics at the TU Delft. The research focused on the redesign of the outbound logistics of the warehousing process of MYPUP. The creativity required and the simulation of the proposed solutions made the research an enjoyable assignment. I could not have done this without the support of certain people that made the successful completion of this thesis possible.

First, I would like to thank all the people at MYPUP that contributed their valuable time helping me accomplish this research. Their input in the ideation phase, in all the brainstorm and prototype session is invaluable. Special thanks go out to Luke van der Wardt, who guided me throughout the entire process with weekly sessions and extra sessions when needed. He helped structure this research and opened doors to involve other people inside the organization when this was called for. Working closely together from start to finish provided useful insights and input throughout the entire process.

Second, I would like to thank my committee. Wouter Beelaerts van Blokland helped me from the very beginning to get started and help define the problem. When my original chair announced his retirement, he helped me to find another professor, which I did a lot faster with his help. Additionally, his feedback and sparring sessions helped to keep me on the right track; for all his help I am grateful. I would also like to thank Ron van Duin who managed to find time in his busy schedule on the one day per the week he worked at the TU Delft. His insights, advice and expertise allowed for smooth and speedy progression during the entire research. He generously offered to read the entire thesis near the end, to make sure nothing was missing. His dedication inspired and motivated me to work hard and process all feedback to arrive at the research that lies in front of you. I would also like to thank the chair of my committee, Lóri Tavasszy. He provided insights, methodologies and other exiting ideas that I would not have thought of myself. The methodology and co-innovation were both inspired by his suggestions and led to a unique approach for this research. He guided me in the right direction and his input was invaluable to the research. To all my committee members I say a sincere “thank you”.

Third, I would like to thank the people who assisted in the development of the OCR algorithm and their input for improvement. I would like to thank Francisco Miranda for embedding the API in the algorithm, which proved more difficult than expected. I would also like to thank Bob Luppes who assisted in developing the remaining part of the algorithm. His programming skills were extremely helpful to translate the algorithm from words into code.

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Fokke de Groot

Delft, April 2017

Content

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List of Abbreviations & Acronyms

AD	Anderson-Darling
API	Application Programming Interface
B2C	Business to Customer
B2B	Business to Business
BPR	Process Redesign
CEP	Courier, Express & Parcel
DES	Discrete Even Simulation
DSA	Delft Systems Approach
IDTP	IDEO Design Thinking Process
IHCDA	IDEO Human-Centered Design Approach
IT	Information Technology
KB	Kilobyte
KS	Kolmogorov-Smirnov
KSL	Kolmogorov-Smirnov Lilliefors
LID	Location ID
MB	Megabyte
MLS	Microsoft LifeCam Studio
MYPUP	My Pick Up Point
OCR	Optical Character Recognition
POV	Point of View
PTT	Staatsbedrijf der Posterijen, Telegrafie en Telecom
RFID	Radio Frequency Identification
RT	Registration Time
S	Seconds
SCS	Supply Chain Structure
SD	System Dynamics
S-M-L	Small-Medium-Large
STDV	Standard Deviation
SW	Shapiro-Wilk
TU	Technical University

1. Introduction

In this chapter, an introduction to the Dutch parcel market is given. In order to get a clear understanding of the current Dutch parcel market, first an overview of the history of the Dutch parcel market is presented in Section 1.1. Subsequently, the current trends and innovations in the Dutch parcel market are discussed leading up to the research problem in Section 1.2. The research problem and scope form a basis for the research questions formulated to seek a solution to the research problem. Finally, the research questions are presented along with the outline of the report in Section 1.3 and Section 1.5.

1.1 The Dutch parcel market

This section will start by describing the origin and development of the Dutch parcel market Paragraph 1.1.1, followed by highlighting the key developments and recent innovations in the market in Paragraph 1.1.2, and finally explaining the focus on the electronic parcel locker market in Paragraph 1.1.3.

1.1.1 History of the Dutch parcel market

The parcel industry in the Netherlands along with the post market has been a closed market for many years. Until 1881 when dedicated parcel delivery first occurred, parcels travelled along with public transport (PostNL, 2016). More than 100 years, the parcel market, up till a certain weight, remained closed. Only from 1989 when Staatsbedrijf der Posterijen, Telegrafie en Telefonie (PTT) was privatized, were other companies allowed to start delivering parcels above a certain weight. However, it was not until 2009 that the post and parcel industry became a completely open market. (Rijksoverheid, 2016).

The open market was subjected to a false start due to the economic downturn in 2009 as can be seen in the revenue development in Figure 2. The liberalization of the parcel delivery industry resulted in the market entry of worldwide leaders, like FedEx, UPS, DHL and other smaller companies in the Dutch parcel market. Over 90% of the parcel market in 2011 in the Netherlands is covered by the former state company PostNL/TPP and a few internationally operating companies such as DHL, DPD/Kiala, GLS and UPS as shown in Figure 1.

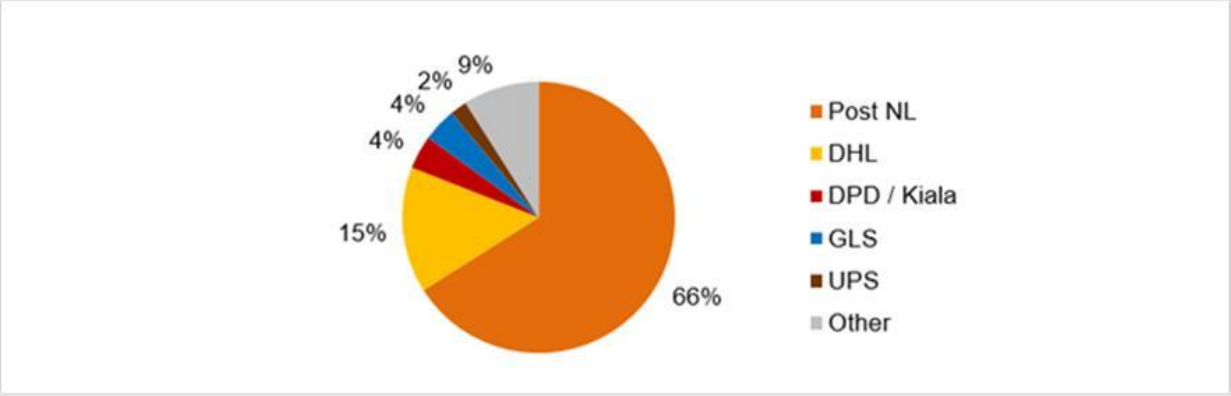

Figure 1: Market Structure X2C parcel segment (Verhagen, 2011)

The economic downturn in 2009 might have influenced the revenues for parcel delivery companies, however the volume continued to rise as can be seen in Figure 2. The reason for this is that the parcel industry is strongly driven by e-commerce (Accenture Consulting, 2015). A worldwide study from 2014 shows that e-commerce has grown in double digits in almost every country (eMarketer, 2014). The share

of online sales as part of the total sales in the Netherlands has increased over the years from 3.8% in 2013 and is expected to grow to 5.1% in 2018 (eMarketer, 2014).

1.1.2 Current trends & innovation

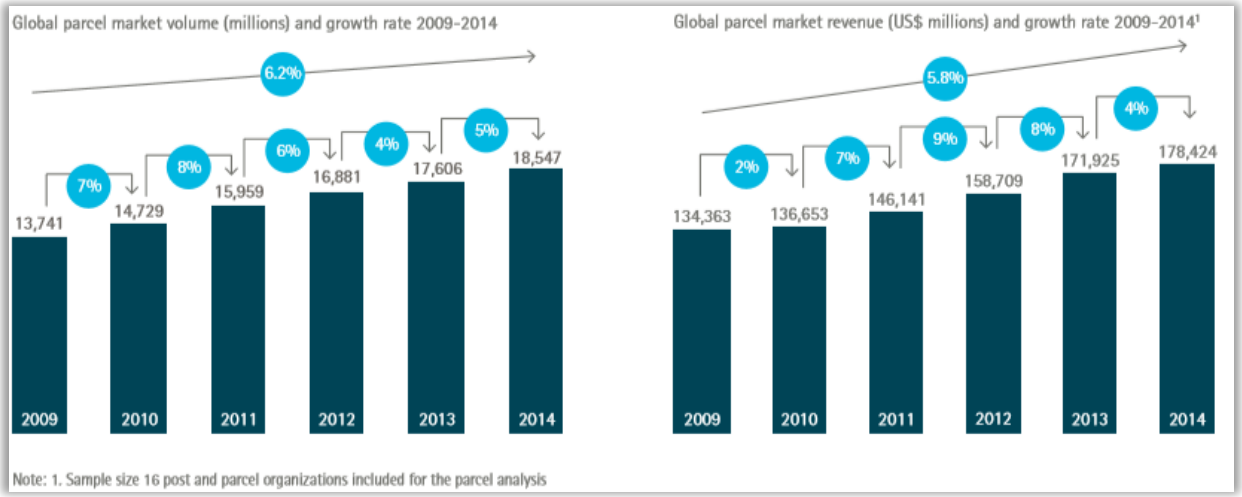

Figure 2: Growth in parcel market (Accenture Consulting, 2015)

The last 20 years have brought some significant and rapid changes in the Courier Express Parcel (CEP) industry, especially in the final stage of the delivery process in cities (Menge & Hebes, 2011) (Savy & Burnham, 2013). This trend of changes is expected to continue, the parcel market is booming business and will continue to grow and develop (Accenture Consulting, 2015). Although the CEP industry developed rapidly over the last years, very little detailed and recent research or publications can be found in academic literature (Ducret, 2014).

One important change that can be seen in the CEP industry is that parcel yields are declining, due to size, weight and travel distance, all getting smaller. This results in a move from air to ground transportation, and the industry is likely to keep moving in that direction (Accenture 2015). (Accenture Consulting, 2015). This change is partly caused by the trend of accelerating e-commerce (PostNL, 2015).

A second trend found in the postal market is moving towards a sustainable society (PostNL, 2015). This trend is mainly driven by government restrictions emerging concerning last mile deliveries (Lindholm, 2012) (Russo & Comi, 2010). Consequently, part of the CEP industry is restructuring itself to adapt to the constraints of urban distribution, creating an urban parcel delivery segment with specific organizations, tools and strategies (Ducret, 2014).

This second trend is one of the drivers for a third trend, the investment in new technological opportunities with innovations like drones, Internet of Things and electronic parcel lockers (PostNL, 2015) (Accenture Consulting, 2015). The trend is driven by the fact that online consumers expect the delivery to be as fast and easy as the ordering (Visser & Lanzendor, 2004). Same day delivery is the next evolutionary step in parcel delivery, but not everybody sees the added value of the service or is willing to pay for it (Hausmann, Herrmann, Krause, & Netzer, 2014). Delivering to the final customer, B2C, is much more difficult than delivering to business, B2B (Ducret, 2014). In fact, the last mile in B2C delivery is more expensive and less efficient due to delivery failures, congestion, urban constraints, non-optimum loading rates and

regulations (Gevaers, Voorde, & Vanelslander, 2011). This results in extra services like evening deliveries and alternative pickup points. According to Holdorf & Haasis (2014) the best solution in solving the last mile problem within the B2C logistics is the decoupling of the presence of the final customer and the delivery. All this has led to rapid movement in the one-to-many B2C segment which has resulted in consolidation points like pickup points, lockers and alternate excess points (Accenture Consulting, 2015) (Ducret, 2014).

1.1.3 Electronic parcel lockers in the Netherlands

In order to counter the expensive and inefficient last mile problem, one of the innovative one-to-many B2C concepts, that has been put to use in many countries is the concept of the electronic parcel lockers (Morganti, Seidel, Blanquart, Dablanc, & Lenz, 2014) (Iwan, Kijewska, & Lemke, 2016).

In the Netherlands 35% of home deliveries fail (MYPUP, 2016), congestion is a daily returning ritual, urban constraints are in place in the majority of the cities and regulations are strict. Electronic parcel lockers tackle most of these problems, or at least partially. For this reason, the electronic parcel market is very much alive in the Netherlands although it is still small. There are several companies that exploit parcel lockers, however the solutions they offer are significantly different. Parcel4Me and De Buren focus on all end consumers providing parcel lockers at convenient locations like gas stations and supermarkets (Parcel4Me, 2016) (De Buren, 2016). PostNL also exploits lockers, but at the moment only at a few train stations and in Almere (PostNL, 2016).

BringMe and MYPUP have a different focus; they target companies, so employees can have their parcels delivered at work (BringMe, 2016). The biggest difference between MYPUP and BringMe is that parcels via BringMe go straight from the logistic service provider into the parcel lockers, where parcels via MYPUP are delivered to a consolidation center and distributed onward. By taking this extra step, MYPUP contributes to better addressing the last mile problem, as less traffic needs to go into the city and ensures the quality of their service by performing the final delivery. At BringMe parcels are often just left outside the lockers instead of securely inside as it is not an intrinsic part of the service of the delivery providers to put the parcels in individual lockers one at the time. From the point of view of logistic service providers, the service of the electronic parcel lockers is a service offered by another company explaining the reluctant attitude to put the parcels in the lockers. Especially when quantities are large, the hurdle to put each parcel in an individual locker is often too big for logistic service providers.

The attitude towards performing a service for another company is also the reason why companies like PostNL, DHL and UPS are unable to compete with a company like MYPUP. Putting a PostNL locker at an office will only result in parcels of PostNL to be delivered into the lockers. Having different parcel lockers from different companies is undesirable as it is more expensive, takes up more space and leaves the receptionist with deliveries from companies that do not provide a locker service.

The MYPUP concept, is the only concept that deals with all issues identified in literature that makes the last mile expensive and inefficient. By consolidating parcels loading rates are optimized and less traffic needs to go into the city contributing to reducing congestion and pollution. The choice to target businesses also reduces traffic into the cities as companies are often located at the outskirts of the city. This fact also means less impact by the urban constraints. Finally, but this goes for all companies using

electronic parcel lockers: the concept of MYPUP knows almost no failed deliveries as the parcels are delivered to parcel lockers.

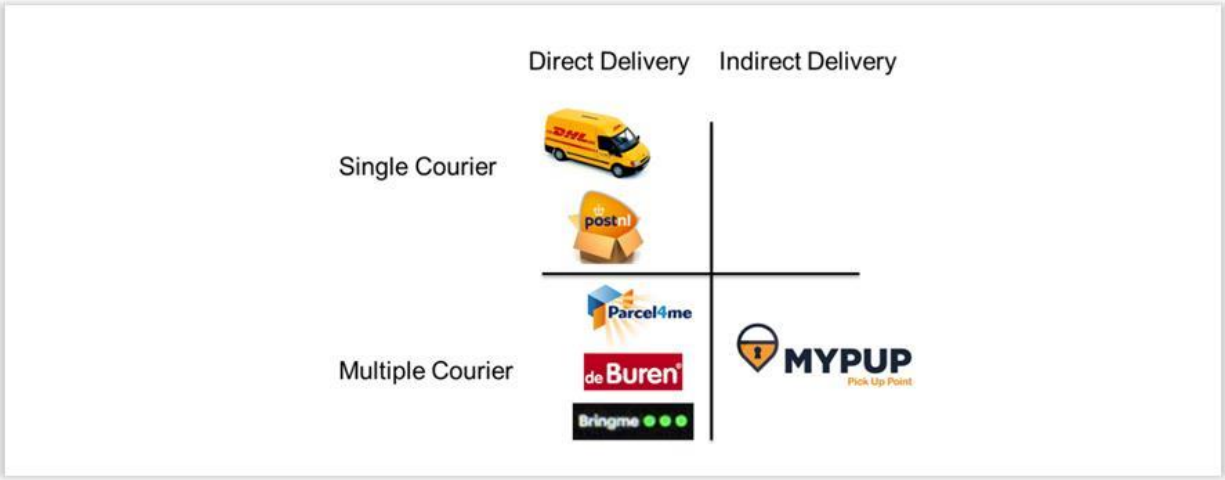

Figure 3: Electronic Parcel Locker Market

1.2 Research Problem & Scope

The research is not concerned with solving the last mile problem, but is focused on one of the solutions to not only the last mile problem, but also to the problems faced with the final delivery of parcels to the customer. The research is focused on MYPUP and its logistics process as this concept deals with different, aforementioned, problems. To understand the research problem, first a description of the system in consideration is given. The research problem and objective follow through which the scope of the problem is further defined.

1.2.1 Description of the system

The system considered in this research is the logistic process of MYPUP. MYPUP is a start-up that has developed a unique concept to have parcels delivered at work. By installing electronic parcel lockers at companies, they enable employees to have parcels delivered at work. However, different companies have already prohibited parcel delivery at the office. One of the reasons for this is that it takes one full time employee per 1.000 employees to deal with all the private parcels that are sent to the office. Another reason why companies do not allow it is for liability reasons. Research done at MYPUP shows 50% of employees go home early to pick up or receive their online purchases. This results in a productivity loss of 3500 hours for an employer with 1000 employees. The research also showed that 85% of employees would like to have parcels delivered at the office. All these facts have led to a solution that satisfies both the needs and wishes of the employer and the employees, electronic parcel lockers at the office. This way the receptionist is no longer bothered with the task of receiving and distributing parcels for the whole office. The employer has less liability and less costly productivity losses due to early departure from work. The promise of same day delivery ensures the satisfaction of the employees as well. Besides using the lockers for B2C deliveries, the lockers can also be used for internal logistics. In Figure 4 a rich picture of the system is shown setting an initial boundary and initial concerns.

The focus of MYPUP on offices leaves only one real competitor with the same target group, BringMe. The two relatively young companies service only a small portion of a potentially huge market. MYPUP is growing rapidly looking to expand internationally and outsource the logistic process. The expansion is not

solely concentrated at one consolidation center, but entails both growth within the current local consolidation centers and the emergence of new local consolidation centers.

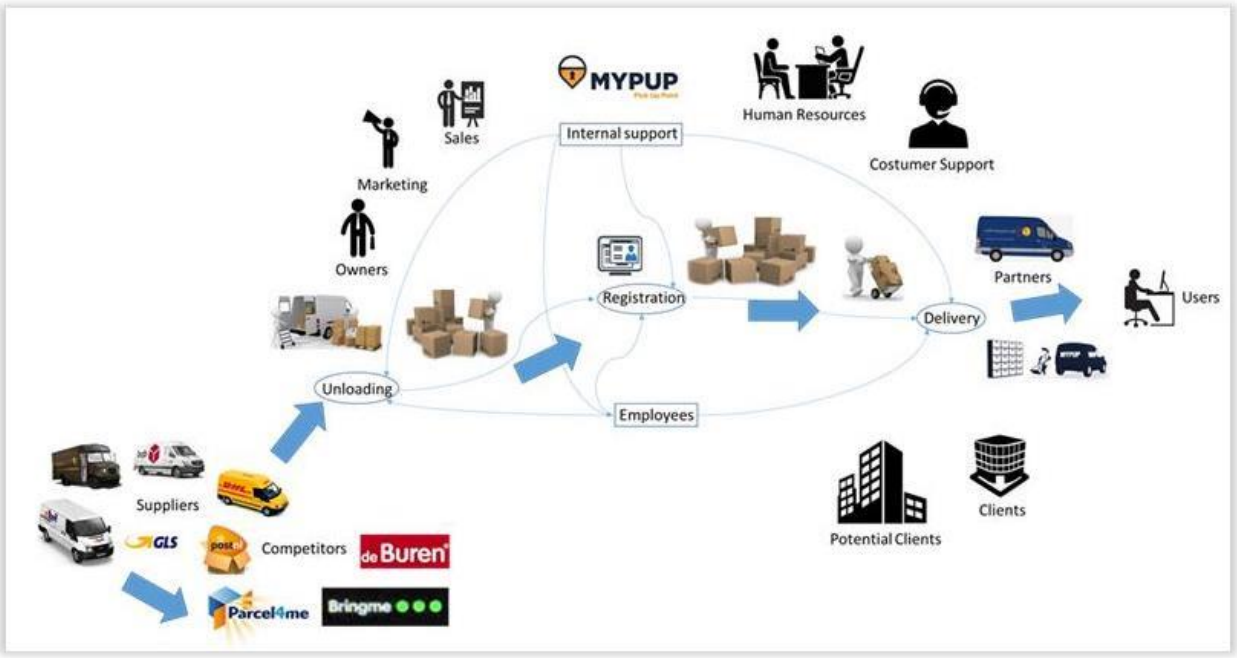

Figure 4: Rich Picture

1.2.2 Research Problem & Objectives

In 2015 MYPUP handled 354 parcels a week on average including the holiday period which had a significant impact on the weekly average. In 2016, the weekly average of parcels handled has risen to 998 In order to be able to handle larger volumes, guarantee same day delivery and outsource the logistic process, the logistic process first needs to be optimized. The main objective of this research is to design a logistics process that is suitable to handle the expected growth in parcel volumes and allows for outsourcing of the logistics process. At one hand this will be contributing scientifically to research for possible solutions to the last mile problem and on the other hand contributing to society, further implementing this concept by creating jobs and reducing environmental impact.

The first step in achieving the objective is defining in which part of the MYPUP logistics process potential room for improvement exists. Identifying bottlenecks and wasteful processes will allow to formulate research questions and design a methodology to optimize parts of the MYPUP logistics process. To this extend the Delft Systems Approach (DSA) is used, which will be elaborated on in the Chapter 2. As a start, black box approach, part of the DSA is used to describe the MYPUP logistics process in Paragraph 1.2.3.

1.2.3 Description of the MYPUP Logistics Process

MYPUP currently has two distribution locations which differ in method of operation. One is at the MYPUP office in Amsterdam and one is outsourced to Van Straaten Post in Nieuwegein. MYPUP strives to outsource the whole logistic process, so both current processes will be taken into account in the

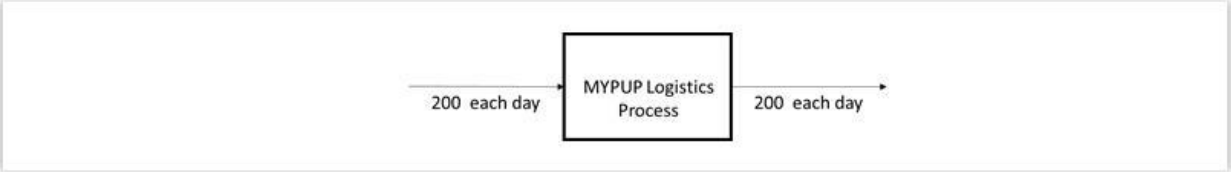

Figure 5: Zoomed out view of the MYPUP Logistics Process

analysis, although the process at both locations should be the same. MYPUP, on average, processes 200 parcels each day; Figure 5 illustrates the most zoomed out overview of the process.

Zooming in on this process it reveals three phases in the logistics process: consolidation, registration and delivery, shown in Figure 6. These phases are identified as they each have their own time windows. The processes that take place within each phase are the areas of interest, therefore zooming in further is required. This is done for each phase separately. A table is presented with a root definition of each phase and the process is discussed at the hand of a zoom of each phase in a conceptual model.

1.2.3.1Consolidation

Between 9:00 a.m. and 5 p.m. parcels are delivered by multiple logistic service providers. However, it is never known beforehand at what time delivery will occur. MYPUP tries to make agreements with the

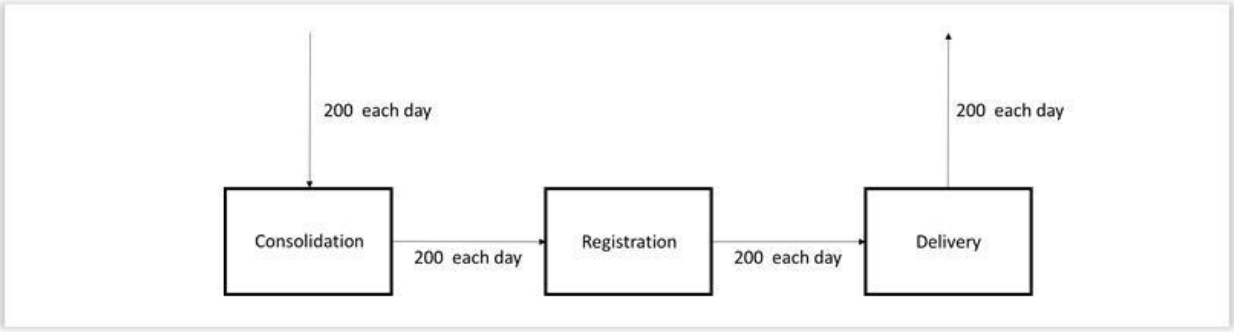

Figure 6: Phases Zoom of the MYPUP Logistics Process

different delivery companies to deliver before 1:00 p.m. to guarantee same day delivery to the end customer. MYPUP would benefit if information was shared about delivery times, where delivery services would benefit from the consolidation of parcels at MYPUP. They no longer have to go to dozens of different addresses, but just to one.

Literature confirms that sharing information within a supply chain can be beneficial for parties involved, at the same time very difficult to achieve. In every supply chain two flows exist: the flow of goods and an equally important flow of information (Power, 2005). The quality, quantity and frequency of information sharing within the supply chain are key if both parties want to benefit (Prajogo & Olhager, 2012). However, information sharing is a sensitive issue. Privacy, security, trust, coordination and interdependence are key to the willingness to share information and success of information sharing once it occurs (Du, Lai, Cheung, & Cui, 2012). To establish a two-way beneficial information sharing relationship it has been found that long term relationships are extremely important in establishing the sharing of information (Prajogo & Olhager, 2012). There are various levels of information sharing. Du, et al. (2012) distinguish operational

information sharing, strategic information sharing and strategic and competitive information sharing. Although the highest level of information sharing in not always possible or even aspired, for sustainable collaboration, effective information sharing and a strong partnership performance, focus on resources and commitment, intra-organizational support, corporate focus (Sabath & Fontanella, 2002), the use of technology, external and internal trust and mutual benefits are required (Du, Lai, Cheung, & Cui, 2012).

Being dependent on different logistic service providers, results in random arrival times of batches of parcels. For this reason, the in-house process of MYPUP will never be a continuous one. Once a logistic service provider arrives, the unloading starts. All parcels have to be scanned by the delivering party one by one and are then handed over to an employee. Depending on customs charges an employee has to sign for or pay and sign for the parcels which wraps up the unloading process.

Table 1: Root Definition - Consolidation

<table>
<tr><th>Consolidation</th><th>Root Definition</th></tr>
<tr><td>Customer – Employees receiving the parcels for registration. The next stage after consolidation of the parcels is registration. So, the receiving party at the end of the process are the actors of the next process.</td><td rowspan="3">The system is owned by the MYPUP owners and investors, who have the power to stop, change and innovate the overall process. The consolidation process is the first step in the MYPUP logistics chain towards the delivery to the end customer. However, between the consolidation, where the sorting of the parcel by size is also done, there are a few more processes to be considered. This means that the end customer in this case is not the customer of the process but the employees at the registration process are. The employees working in the unloading process prepare the parcels for the next stage in the chain. The unloading process is dependent on the volume of the deliveries and their arrival times.</td></tr>
<tr><td>Actors – Employees unloading the parcels, sorting them by size, sign for them, and if necessary pay fees.</td></tr>
<tr><td>Transformation – The change of responsible & liable part and the storing of parcels after which they await registration. The transformation basically entails that a number of different parcels, under different responsible parties, are consolidated and the responsibility and liability of the parcels is transferred to a single party.</td></tr>
<tr><td>Weltanschauung – Consolidating the parcels is the first step towards the redistribution of the parcels, the first step of the logistics process that is under consideration for improvement. It is also the first step towards delivery to the end consumer.</td><td>Owners – MYPUP owners and investors. The owners have the power to shut down or change processes in the MYPUP logistics chain. It could also be argued that the investors are owners of the process, as they also have the power to set demands and conditions when investing in innovation.</td></tr>
<tr><td colspan="2">Environmental Constraints – The first constraint is that parcels have random arrival times, although, verbal agreements are made about the preference of having the parcels delivered early. However due to rotating drivers, having the parcels delivered early is not always easy.

A second constraint is the volume of parcels being delivered each day. There is no communication about how many parcels are coming. The result is a shifting demand for capacity, also caused by possible overlapping unloading arrivals.</td></tr>
</table>

Consolidation - Amsterdam

At the MYPUP office parcels are sorted by size into three different categories, directly upon arrival. The unloading process is combined with the sorting process as the sorting time is less than the time spent waiting until the next parcel is scanned and handed over by the delivering party.

Consolidation – Nieuwegein

At the Nieuwegein location, where the MYPUP process is just part of the Van Straaten Post process, there is one employee who handles the unloading, putting parcels unsorted in roll containers. The containers are moved over to the registry area where they remain until registration. The sorting process does not occur until registration.

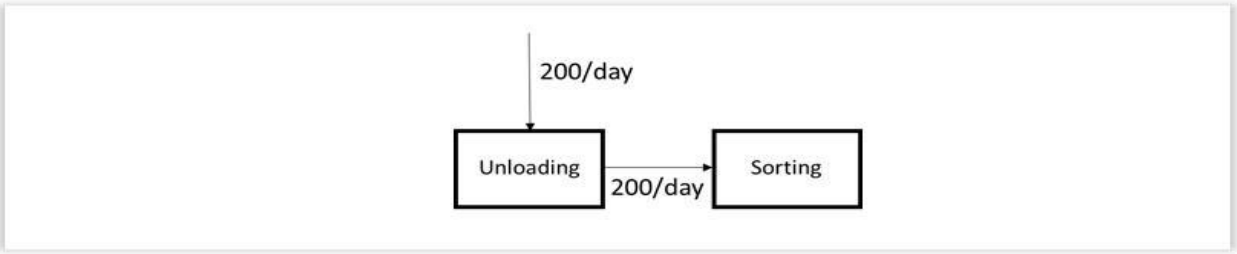

Figure 7: Zoom Consolidation

1.2.3.2 Registration

Table 2: Root Definition - Registration

Registration	Root Definition
Customers – The customers in this process are the delivery truck drivers. They distribute the registered parcels to the end customer.	The system is owned by the MYPUP owners and investors, who have the power to stop, change and innovate the process. The process is crucial in delivering the parcels to the end customer and adds value to the product. The registration of the parcels sets in motion information sharing with the end customer and assigns lockers to each parcel. This is done manually by employees. The customer to this process is the delivery employee. The process is time constraint and limited by capacity.
Actors – The actors in the registration process are the employees who manually register the parcels into the MYPUP database. They provide the parcels with a label containing a pin code and a locker number. The parcels are then sorted by the employees by destination as the parcels await pick-up.	
Transformation – The input situation consists of a large number of parcels sorted by size awaiting registration into the MYPUP database. The output situation consists of the same parcels, registered with assigned lockers and sorted by destination. The parcels then await pick-up to conclude the final step in their journey through the MYPUP logistics chain.	
Weltanschauung – This process is one of the processes where value is added. By registering a parcel, an automatic email is sent to the recipient that a parcel has arrived. Furthermore, by assigning the locker and pin code an automated message is created which is sent as soon as the combination of the locker and pin code are used, notifying the end consumer of the arrival of their parcel.	**O**wners – MYPUP owners and investors. The owners have the power to shut down or change processes in the MYPUP logistics chain. It could also be argued that the investors are owners of the process, as they also have the power to set demands and conditions when investing in innovation.

Environmental constraints – The first constraint refers to the tools and system in place to register the parcels. This is mostly manual labor which puts a real constraint on the capacity of the system.
The second constraint is the limited available time to register the parcels. The registration process does not begin until the latest moment possible, to allow the consolidation of as many parcel deliveries as possible to maintain an efficient process. On the other hand, there is the deadline for the drivers who leave at 14:00 or 14:30 at the latest to ensure same day delivery.

The number of parcels that are delivered on any given day as of 2016 varies between 100 and 300. At 1:00 p.m. the registration process begins. The parcels are registered into the system by hand, one by one and provided with a label containing an access code and a locker number. The parcels are then sorted by hand and distributed to location dedicated crates.

The registration of the parcels into the MYPUP system is a tedious endeavor as presented Figure 8. MYPUP customers are asked to use their username as addressee. This name is typed into the MYPUP system and if found, the origin of the parcel is typed in, the right locker size is selected and the parcel is registered. A label is then printed containing an automatically generated pin code and an assigned locker and is put on the parcel. When the parcels are registered, they are put into designated crates based on their final destination and await pick-up. The time parcels await pick-up is minimized to allow as much time as possible for logistic service providers to deliver their parcels.

Finding the right user can be difficult, since many people wind up using their full name, a username for another service, or misspell their username. Once the addressee does not turn out to be the username, an attempt is done to find the customer by trying to derive the full name. If the system still comes up empty, an account search is done, in which more user information is searched through, increasing the chance of the customer to be found. If the user is still not found the parcel is put aside to find the user at a later moment. Tracing the correct username in case of (spelling) mistakes or unclarity in the addressee information is generally a time consuming and labor intensive activity.

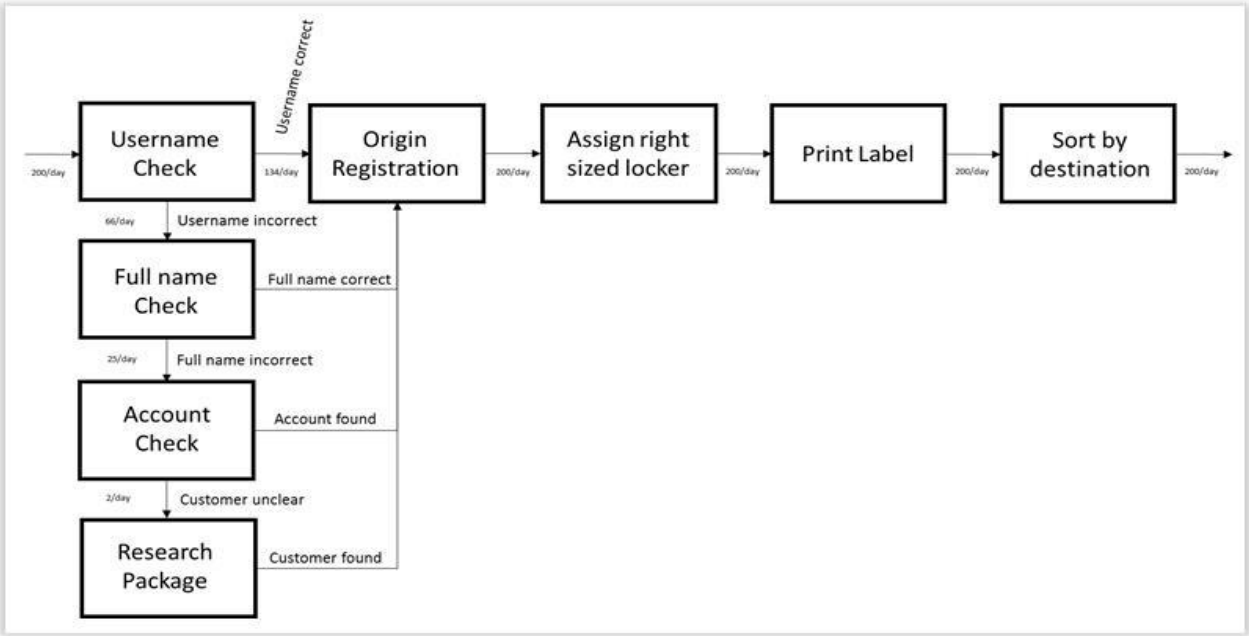

Figure 8: Zoom Registration

Registration – Amsterdam

Whilst the registration takes place by two employees a third is tasked with batching parcels for customers receiving multiple parcels, researching unclear parcels and sorting them by their final destination.

Registration - Nieuwegein

In Nieuwegein the parcel size is determined upon registration adding an extra step to the registration process. The size is determined when the locker size needs to be selected instead of beforehand, resulting in longer process times. Furthermore, the registration is only done by one person so batching parcels for customers receiving multiple parcels, researching unclear parcels and sorting them according to their final destination results in longer process times.

1.2.3.2 Distribution

Table 3: Root Definition - Distribution

Distribution	Root Definition
Customer – The customer in the delivery process is the end customer. This is where the parcel leaves the MYPUP logistics chain.	The system is owned by the MYPUP owners and investors, who have the power to stop, change and innovate the process. It is the final step in reaching the goal of a fast and safe delivery to the end customer. The end customer is also the customer of this system. In the process parcels are placed into individual lockers by MYPUP employees to await pick-up by the end customer. The speed of the delivery depends on the traffic and the location of the lockers inside the building.
Actors – The actors described in this process are the drivers, who load the parcels into their trucks for final delivery to the end customer.	
Transformation – The input to this process are sorted parcels awaiting delivery. In the process the parcels are transported from the distribution center to their final destination. At their final destination, the parcels are delivered and put into individual lockers.	
Weltanschauung – This process fulfills the main goal of the logistics chain, to safely deliver the parcels on time. It is therefore an important process that cannot be ignored.	**O**wners – MYPUP owners and investors. The owners have the power to shut down or change processes in the MYPUP logistics chain. It could also be argued that the investors are owners of the process, as they also have the power to set demands and conditions when investing in innovation.
Environmental constraints – The traffic on the roads is one of the constraints that cannot be influenced, but has a large impact on the delivery times. A second constraint is that the lockers are situated at convenient locations for the users, however not for the delivering, party. This means that it can take quite some time to reach the lockers, making the delivery a hassle.	

Between 2:00-2:30 p.m. the crates are put into the vans for delivery. The delivery to different companies scattered in the greater Amsterdam area take place along two routes a blue route and a grey route. Once an office building is reached, the parcels are moved from the van to the lockers. They are then put into the lockers one at the time using the previously generated locker access code combination printed on the label. The numbers are punched in by hand. Finally, outgoing parcels are retrieved from the lockers and this process is repeated at every location. The parcels should be delivered to the lockers before 5 p.m. to keep to the same day delivery promise.

Distribution – Amsterdam

The distribution in Amsterdam is done by MYPUP's own drivers in MYPUP's own vehicles. This means the deliveries done, are all MYPUP parcels.

Distribution – Nieuwegein

The distribution in Nieuwegein is done by Van Straaten Post, who use MYPUP's parcels to improve their own loading rates. This means that MYPUP deliveries are just part of the route. However, agreements between MYPUP and Van Straaten Post ensure parcels are delivered into the parcel lockers before 5 p.m.

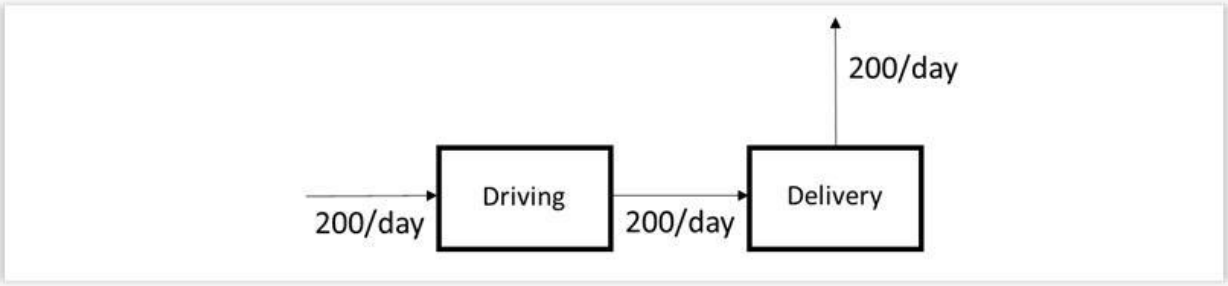

Figure 9: Zoom Distribution

1.2.3.4 Reverse Logistics

Pick-ups from the lockers are also part of the service MYPUP offers. Customers can go online and register their parcel, after which they receive an access code and a locker number to put the parcel in. Once the parcel is in the locker, it awaits pick-up when the other parcels are delivered. The returning parcels are picked up by the MYPUP drivers and at the end of the day collected by Van Straaten Post, for further distribution.

1.2.3.5 Support

The support at MYPUP consists of a wide range of tasks. The support deals with parcels that need to be researched, parcels that need to be bundled in the registration process and parcels that are too big to fit into the lockers. When parcels are too big to fit into a locker it can only be delivered if the user is present at the office to receive the parcel personally. An email is sent to notify the user a parcel has arrived that is too big for the locker. If the user is not present, the parcel is delivered on the first day the user is at the office or the user is given the option to collect the parcel at the distribution location if time is of importance.

Furthermore, when lockers are completely booked at a certain location, parcels that could not be registered are still take by the driver. As soon as the driver has put the parcels in the lockers, customers start to show up to collect their parcel. Waiting a couple of minutes, will often allow lockers to become available and open the opportunity to deploy the excess parcels into the lockers. To make this work the driver calls the support at the MYPUP office to have the parcels registered over the phone. If the capacity of the lockers turns out to be insufficient on a structural basis, the placing of extra lockers is advised. If lockers do not become available fast enough, the customer is called to check if they are able to collect the parcel in person and if not, the parcel will have to be delivered the next day.

The support also plays a role in the distribution and reverse logistics process. The support continuously monitors if lockers are properly closed and if no pick-ups are left behind.

Support is available 24/7 to answer any questions and handle any problems, users, drivers or employees might have. This support is essential to the efficiency of the operation.

1.2.4 Problems & Opportunities

The first thing that becomes apparent looking at the MYPUP logistics' process is that information sharing is of vital importance. Agreements with logistic service providers are essential in guaranteeing the MYPUP service. Logistic service providers are unwilling to cooperate even though they benefit from the parcel consolidation without extra payment. This part of the process falls outside the scope of this research as the improvement of the consolidation is largely dependent on the logistic service providers and the agreements made with them.

The second thing that can be concluded from the current situation is that many processes require a lot of manual labor. Human actions are expensive, time consuming and error prone, so unwanted in the process.

The sorting process is done manually and when there is doubt about the size of a parcel, measuring needs to be done by hand. The sorting of the parcels by size can be done in a matter of a few seconds per parcel by someone with a trained eye. As only manual labor is involved, opportunities present themselves for automation to optimize the process of sorting by size while unloading. Information about the size and weight of the packages is often already known by the delivery services, presenting an opportunity for information sharing.

In the registration process a lot of manual labor is involved as well. On days where 300 parcels need to be processed three employees are needed for an hour and a half to process all parcels. On averages the registration of a parcel at the Amsterdam location takes 31 seconds. This is far longer than any of the other processes, making the registration process the bottleneck of the operation. When volumes increase, the process will become more expensive and time consuming and error prone. On top of that, with an increasing demand, capacity is starting to become a more crucial factor.

In the final phase of the operation parcels are delivered and leave the in-house MYPUP process. The delivery is the most time-consuming part of the operation. Although driving accounts for the biggest part of the delivery process, the last step, putting parcel into the designated lockers, is the tedious part. Punching in numbers by hand is time consuming especially when it needs to be done a couple of hundred times a day

Manual labor is the most important contributor as it comes to waste. Another constraint that contributes to waste is the capacity in the registration process causing idle time in the subsequent processes. In conclusion, the current process of MYPUP is primitive and should be redesigned in order to handle larger volumes. The new design of registration process should be able to handle up to 1500 packages in the same time or less compared to the current situation. There is no need for larger capacity as the expansion of MYPUP does not have to facilitate all new demand flow through the current consolidation centers, but is spread out over local consolidation centers. The delivery should only cover the last mile, and not go across country.

1.3 Research Questions

From the previous section, it has become clear that the MYPUP logistics process needs to be redesigned to be able to handle the intended growth in volume. How this goal can be reached and to what extent solutions will contribute to reach this goal is subject of this research. First it is important to find out what alternatives are available and which are financially realistic. Subsequently, the alternatives are analyzed in different scenarios so the efficiency and capacity of the alternatives can be determined. To tackle the research problem, the following research questions are formulated:

Research Question:

How can the warehousing process of MYPUP, focusing on the outbound logistics, be redesigned to be more efficient, less error prone and to be able to handle increased capacity, constrained by limited available funds?

To keep an open mind and not exclude viable solutions that would be better, the financial constraint is not considered at first. This ensures all practical options are considered and none are overlooked; investing a little extra may even be best in the long run. The sub questions for this research are as followed:

- How do MYPUP employees, users of the system, see and experience the system?
- How do the problems experienced by the MYPUP employees relate to the problem statement formulated based on the black box approach?
- How can the MYPUP process be redesigned, taking into account problems found from both the black box approach and the MYPUP employees?
- What solutions are preferable and most suitable to prototype?
- How can a prototype be developed?
- How can the prototype be improved and developed into a well-functioning solution?
- What solutions that are not implemented can improve the process in the future?

1.4 Research Philosophy

The presented problems and research questions call for a different research approach than is applied by most. The design nature of the problem directs focus to how inspired companies and designer achieve success. The way inspired companies and designer achieve success is through a certain way of thinking identified as the golden circle (Sinek, 2009), show in Figure 10: Golden CircleFigure 10.

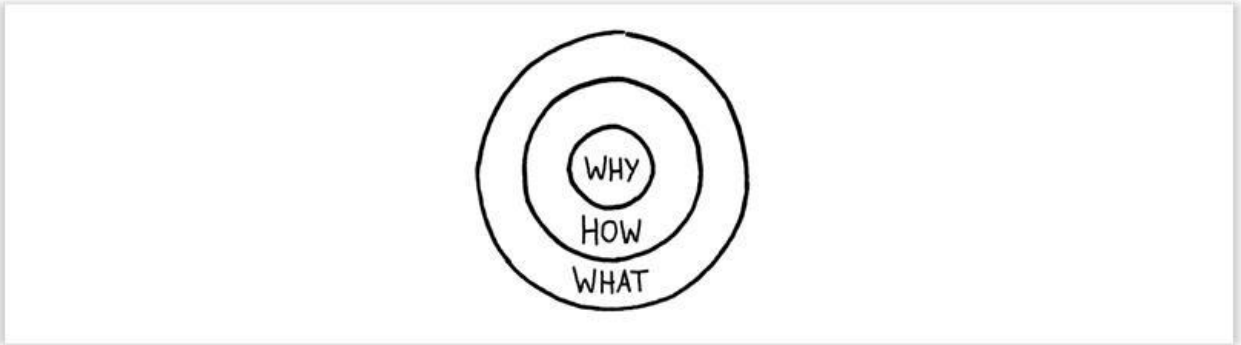

Figure 10: Golden Circle (Gardner, 2017)

This research aims to achieve a create something unique, not just a unique product, but a unique journey to arrive at the product as well. The research challenges the status quo in master thesis methodology through co-innovation with the author in the heart of the operation. The author acts as a project leader throughout the process working closely together with MYPUP employees, TU Delft supervisors and includes experts from different fields to design and develop a successful solution that is tailormade to the needs and wishes of MYPUP.

1.5 Research Outline

The research is outlined as followed. Chapter 1 gives an introduction to the market MYPUP operates in and identifies the problems encountered by analyzing the MYPUP logistics process. In Chapter 2 the chosen methodology is explained, followed by the ideation phase described in Chapter 3. The ideation phase is followed by the prototype phase in Chapter 4. Chapter 5 describes the development of the Optical Character Recognition (OCR) software including the testing and user feedback and finally the proof of concept and its requirements. To decide on further implementation a simulation model is made and described in Chapter 6; the model is verified and validated in Chapter 7. The solutions presented in Chapter 4 are then implemented in the model to test their impacts. The altercations to the model and the results of implementing the solutions into the model are discussed in Chapter 8. The overall conclusions of the research and recommendation for future work are presented in Chapter 9. Finally, parts of the research are reflected upon in Chapter 10.

1.6 Critical Reading Checklist

Before the remainder of the research is done, one of the IDEO tools is used to check if the problem statement and research questions are in line with the users, answering four questions:

What is the point?

A framework has been established to apply focus thus providing a goal to work towards. The focus is on the logistics process starting after the parcels have been consolidated. The driver to redesign this process is to be able to increase capacity, eliminate errors and be able to outsource operations.

Who Says?

The need for redesign is supported by findings from users and personal experience gained in practice. By talking and discussing on the job, problems identified by users were in line with the problems found by analysis.

What is new?

From the problems found after analysis and spending time in practice it can be concluded that there is a need for redesign as the current way of operating will not be good enough to cope with increased volumes in the future.

Who cares?

The users have expressed excitement from the beginning. Starting from the moment of introduction they have been excited to change their ways as the current way of operating since it is very demanding and taking a toll on them as well.

2. Methodology

In this chapter, the choice for the newly created methodology is explained. Section 2.1 starts out with an explanation of the Delft Systems Approach used in de first phases of the research. Section 2.2 and Section 2.3 introduce two IDEO Design approaches. Finally, in Section 2.4 it explained why these three approaches are combined to form the new methodology used in this research.

2.1 Delft Systems Approach

To arrive at the problem statement, the Delft Systems Approach (DSA) was used. This approach was chosen given that for the MYPUP case a capacity analysis combined with an optimization study seemed to be a good fit. To that end in Chapter 1 the first phases of the DSA have been applied. Figure 11 shows the steps in the DSA.

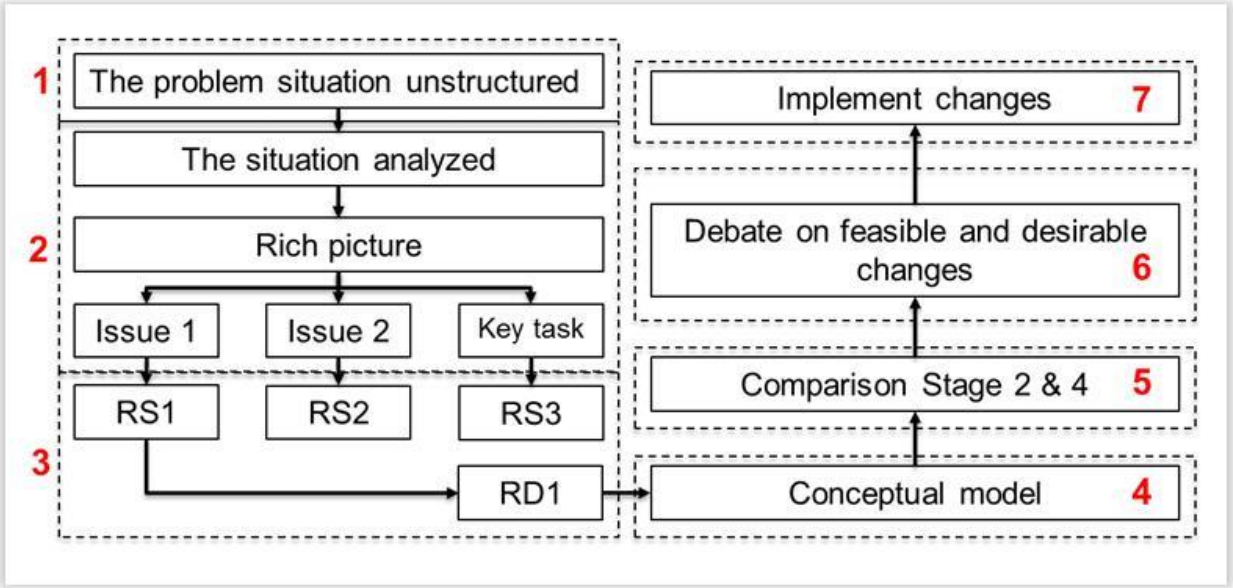

Figure 11: Delft Systems Approach Methodology (Veeke, Ottjes, & Lodewijks, The Delft Systems Approach - Analysis and Design of Industrial Systems, 2008)

The first three stages in the DSA have been presented in Chapter 1 and a black box approach was used to visualize and analyze the initial process. From this analysis, it became clear that optimization of the current process was of little use. A complete redesign of the logistic process was needed to facilitate the growth in demand and expansion plans of MYPUP. Therefore, the first part of the DSA is combined with the IDEO Human-Centered Design Approach (IHCDA).

2.2 The IDEO Human-Centered Design Approach

The original IHCDA consists of six phases as shown in Figure 12: observation, ideation, rapid prototyping, user feedback, iteration and implementation.

The first phase is about observing the end-user, taking lessons from the observation and being open to creative possibilities. The goal is to understand the people for who the design is made. Stepping into the shoes of the end-user can provide great insight in the problems faced in a process.

The second phase is the ideation phase where brainstorming in a team happens, taking what was learned from observations and experiences in the first phase. The goal is to come up with as many ideas as possible, staying focused on the needs and desires of the end-user. The group's ideas will eventually evolve into the potentially best solution.

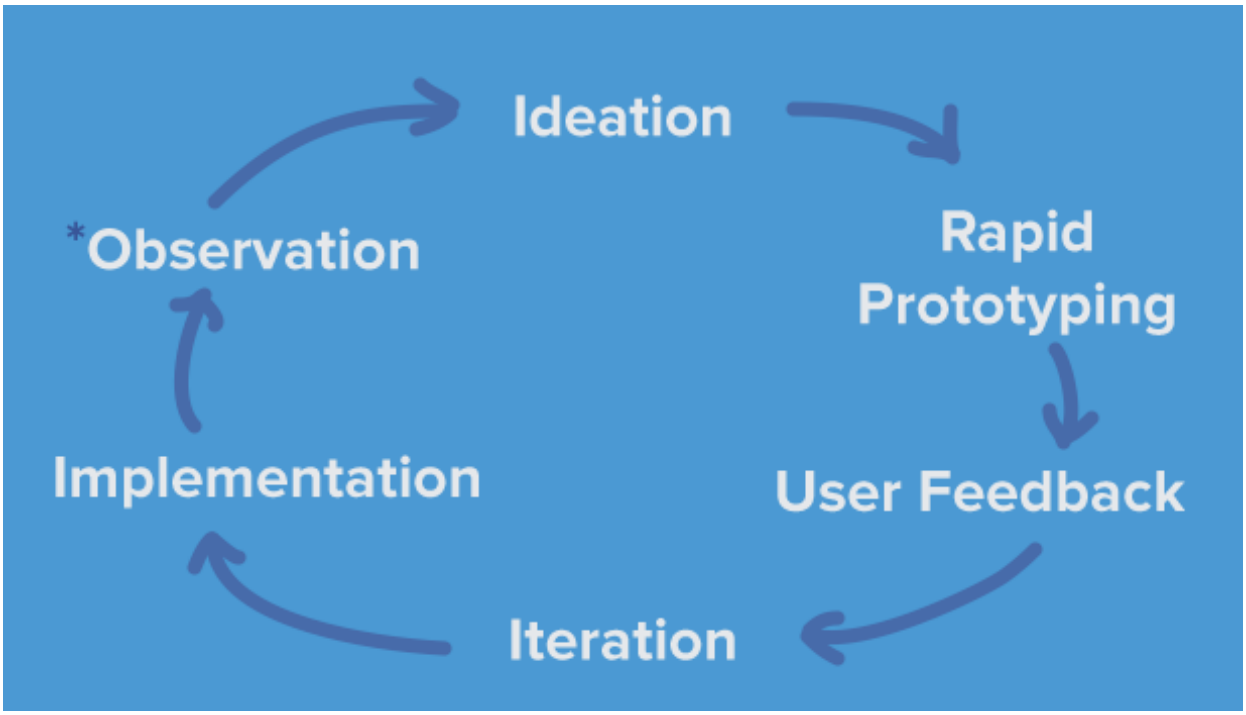

Figure 12: IDEO Human-Centered Design Approach (How IDEO uses customer insights to design innovative products users love, 2016)

The third phase is rapid prototyping, building a prototype in a short time to make the idea tangible and provides something to test with the end-user. A fancy high fidelity prototype is not required at this stage, the goal is to spend minimum time building and getting user feedback as quickly as possible. The goal is not to create the perfect solution, but to make sure the solution is meeting the requirements.

The fourth phase is user feedback. In this phase, the prototype is presented to the end-user, so the end-user can give feedback.

The fifth phase is iteration where improvements are made, new feedback is collected and more improvements are made until a solution is reached that is ready to be used.

The final phase is implementation. As the usefulness of the solution has been validated in phase 5 it is time to get the solution working in practice.

When more improvement is desired even after the first solution the process should start again with the previous solution as a starting point.

In the first phase observations were made, which have been done in Section 1.2 using the black box approach. Solely using this information to move into the ideation phase was not sufficient as this would lead to all sorts of ideas that might be interesting but not useful. Before moving on to the ideation phase direction in needed to ensure ideas relate the problem at hand. Normally the IHCDA is used to design or

redesign a product. In this case however, not just one product is designed but a whole logistics process is the focus of the redesign. Therefore, it is imperative to define a problem statement or direction in which to steer the ideation phase. The IDEO Design Thinking Process offers a solution.

2.3 IDEO Design Thinking Process

The IDEO Design Thinking Process(IDTP) is a variation of the IHCDA adding an extra step between the first and second phase of the IHCDA and focusses more on the design process itself and is less concerned with implementation.

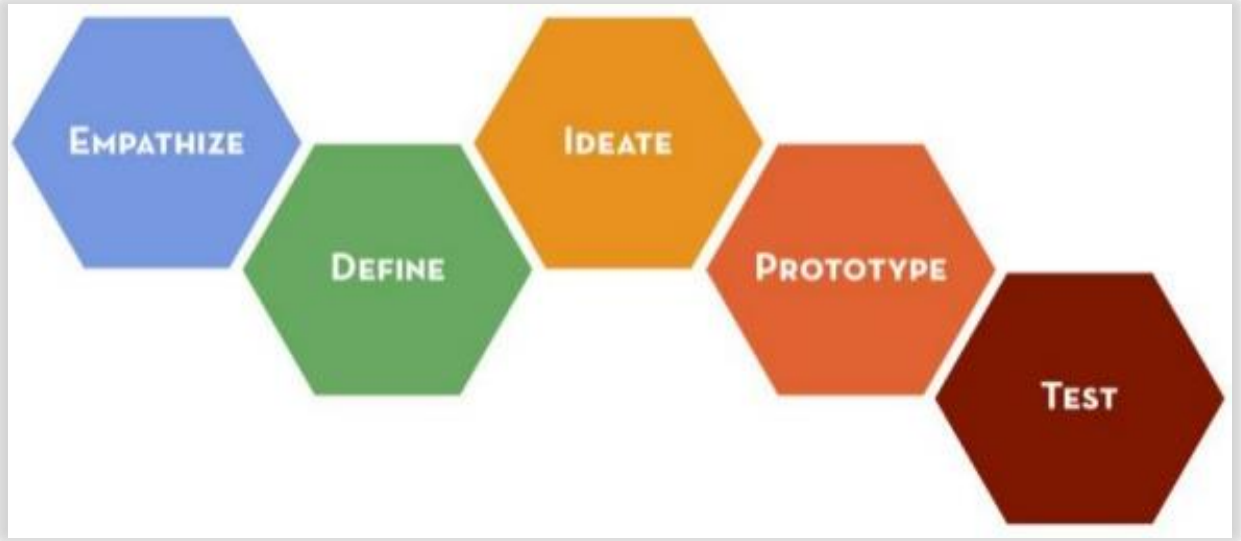

Figure 13: IDEO Design Thinking Process (IDEO, 2016)

The empathize phase corresponds partly with the observation phase in the IHCDA. This phase engages to reveal needs that people might have that they may not be aware of. However, the empathize phase also suggest experience in the use of a product or working in a process can be helpful in furthering the understanding of in this case the process. It provides the insight that forms a basis for the define phase.

The IDTP adds the define phase, as shown in Figure 13, where the findings from the first phase are not directly injected into the ideation phase, but first processed and used to come up with an actionable problem statement. Defining a problem statement, or point of view (POV), does not just provide a problem statement, but can be considered as a design view that inspires the team, and provides a reference for evaluating competing ideas. It gives direction to the solution to prevent solutions concepts that are all things to all people (Plattner, 2013).

The ideation phase is the phase where going wide in terms of ideas is stimulated while keeping focus to the end goal. In the MYPUP case this means stimulating wild ideas while focusing on one part of the logistics process at the time. The phase is initiated to generate alternative solutions beyond the obvious ones. This is to maximize the innovation potential as a result of the generated ideas. During the ideation phase, it is important to keep the generation and evaluation of ideas to avoid that ideas are killed too early and so frustrating the creative process.

The prototype phase is important to gain empathy from the end user, deepen the understanding of the end user, refine solutions in cooperation with the users and to inspire to achieve the best solution for the user. Creating quick and easy prototypes allow for testing of ideas without investing a lot of time and money and sparks conversation as to what solution is desirable. Furthermore, describing solutions in words is a lot harder than showing them through prototypes. A much more constructive and informed discussion will be encouraged. Making several prototypes sequentially results in a product that meets the demands of the end user better than having just one round of prototyping, which is facilitated by IHCDA, but less so in IDTP.

The IDTP calls the phase of prototype iteration the test phase. However, the iterations take place when an actual working prototype has been made. It could result in having to go back to the drawing board, but in contrast to the rapid prototyping approach in IHCDA, here an actual prototype is developed early on. The test phase does not include actual implementation.

2.4 Combining Research Methodologies

This research combines different methodologies as no single methodology seems to be a perfect fit and the initial goal of the research changed, once the problem was defined. At the start of this research it appeared that the logistics process that needed to be optimized was unique in its sort. MYPUP expressed the need for capacity expansion which it hoped to accomplish through optimization of their current logistics process. To this extent, the Delft Systems Approach was chosen as this research's methodology. Applying the first steps of DSA gave insight in the system it surroundings and the working of the logistics process. The use of a rich picture, root definitions and the black box approach helped structure the problem at hand. The problem turned out to be more of a design nature than of a capacity or optimization nature. The DSA is more suitable for a capacity or optimization problem than for a design problem. After considering design methodologies two methodologies of the design company IDEO stood out, the IDEO Human Centered Design Approach and the IDEO Design Thinking Process. The IHCDA is mostly used to design or redesign a product, not an entire process, so any form of direction, when considering a process, in the ideation phase was missing. Another methodology presented by IDEO, IDTP, seemed to have identified the missing step, however in IDTP the implementation step was missing. Combining the two methodologies led to a methodology that fit this research shown in Figure 14.

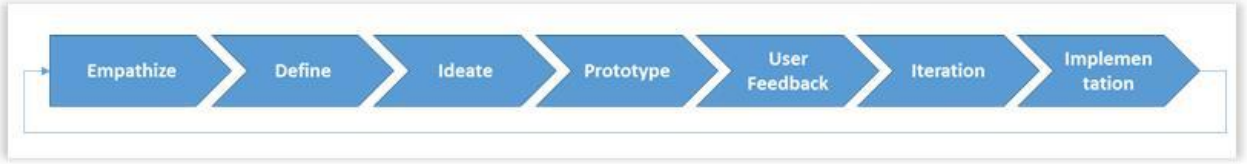

Figure 14: Research Methodology

The empathize and define phases described by IDEO were consistent with methods used in the DSA. Therefore, tools like the rich picture, root definitions and the black box approach from the DSA which were used before switching methodologies served as tools in the empathize and define phase. This led to combining three methodologies instead of two.

2.4.1 Empathize

The empathize phase consists of three main aspects. Observation of the users is important to capture their behavior and the context of their environment. Through observation much valuable information can

be obtained. However, to get a holistic view it is important to engage and interact with the users. Finally, it is important that through a deep-dive you build a good insight in what the users experience. In this study, the observation was done in the first phase using rich pictures, root definitions and the black box approach to document the findings. In addition to the observations, experience was gained in practice, by participation in the entire process over a period of several weeks.

Rich Picture

Rich pictures are used to provide an abstract view of a system, the actors and processes involved and their relationships. A rich picture consists of actors (users of the system), processes (processes needed to execute tasks of system), data storage (data associated with the system), arrows (relationships) and system boundary (focus area, everything outside is ignored). Steps in creating a rich picture are (Veeke, Quick View on The Delft Systems Approach, 2014):

1. Determine the actors involved in the system;
2. Determine the operations each actor is meant to perform;
3. Determine the data requirements; where is the data held; flow of data;
4. Determine the system boundary.

The rich picture was used to be able to identify relevant processes and define root definitions.

Root Definitions

A root definition is the description of a relevant system. To compute a complete root definition CATWOE is used. CATWOE stands for (Veeke, Quick View on The Delft Systems Approach, 2014):

C - Customer of the system;
A - Actor(s) those who do T;
T - Transformation of input to output;
W - Weltanschauung the specific “world view” that makes T meaningful;
O - Owner(s) those who could stop (or change the nature of) T;
E - Environment constraints on the system that are outside its scope.

After identifying the system and its relevant processes the black box approach was used to structure the system and its processes.

Black box approach

The black box approach is used to discover what happens in a system from the input to the output. The system can be seen as a black box. To discover what happens inside the black box one needs to zoom in to arrive at a lower level of black boxes. Often several zoom levels are needed to uncover what happens in a system (Veeke, Ottjes, & Lodewijks, The Delft Systems Approach - Analysis and Design of Industrial Systems, 2008).

The black box approach structured the system in such a way that problems could be identified, providing sufficient information to define the problem statement.

2.4.2 Define phase

In the define phase (Paragraph 1.2.4, Section 1.3 and Section 1.5) a 'good' point of view is formulated. Basically, a point of view consists of a framework, it validates the problem, it addresses a new problem and it is significant. A good point of view (Plattner, 2013):

- Provides focus and frames the problem;
- Inspires your team;
- Provides a reference for evaluating ideas;
- Empowers team members to make decisions in response to the high-level goals of the team;
- Fuels brainstorms by suggesting "how might we" statements;
- Captures the hearts and minds of people you meet;
- Saves you from the impossible task of developing solution concepts that are all things to all people;
- Is revisited and reformulated – learn by doing;
- Guides innovation efforts.

This is done based on the information found in the empathize phase. This resulted in a problem statement and research questions described in Section 1.3.

Critical reading checklist

To check if the problem statement and research questions are in line with the users, a critical reading checklist method is used. This is a method that in short tries to answers four questions (Plattner, 2013):

1. What is the point?
   - What is the angle?
   - What is the focus or framework?
2. Who says?
   - Is the view supported by findings from users?
   - Is it still applicable outside one colorful interview?
3. What is new?
   - Does it add value?
   - Is something new actually addressed?
4. Who cares?
   - Is your team excited at this point?
   - Do others see the point?

By answering these four questions, in Section 1.6 it becomes clear whether the point of view formulated is meaningful.

2.4.3 Ideate phase

The ideation phase is aimed to generate radical design alternatives, the goal is to generate a wide solution space with a large quantity of ideas and amongst them great diversity. This is done to go beyond the obvious solutions and thereby increase the innovation potential of the solution set. It also helps harness the collective perspectives and strengths of the team members, uncover unexpected areas of exploration, and create fluency and flexibility in the innovation options (Plattner, 2013). In this research brainstorm sessions are organized in the ideation phase, the method and its application are discussed in Chapter 3.

2.4.4 Prototype-user feedback-iteration phases

The ideation phase is followed by the prototype phase, which consists of getting the ideas from the ideation phase into the physical world. Prototypes will allow to learn quickly and investigate a lot of different possibilities. Prototyping can also be used for testing, and also inspire others by showing the vision behind the prototype. It can solve disagreements and reduce miscommunication as ideas and words take shape. At the same time, it can also allow for cost savings as it can fail quickly and cheaply. A prototype can be anything that takes a physical form, whether it is a wall of post-it notes, a story board or an actual working prototype (Plattner, 2013).

In this research, different types of prototypes were used in iterations to take into account and process the user-feedback given during these sessions. The rapid-prototypes allowed for several rounds of feedback, while keeping out of pocket costs at next to zero.

2.4.5 Implementation phase

The implementation phase was initiated as soon as the prototype was considered suitable by the users. It basically consists of two stages, the testing stage and monitoring stage. The solution is implemented and tweaked to remove any glitches and make the solution work seamlessly. After the testing stage, the design should be monitored closely and optimized to tackle bugs that were not discovered in the testing phase.

Within the timeframe of this research part of the design was supposed to be implemented completely, but remains in the testing stage for the moment. Other parts will be implemented in the future, and to be able to make recommendations concerning further implementation of the design a model was developed.

Model development

In this research, the development of the model is part of the implementation phase as it simulates implementation. This will provide insight in the performance of the generated solutions and help determine which solutions to implement. The methodology that is applied for the development of the model and the validation and verification is based from Sargent (2013). Figure 15 shows the steps in model development as well as the real world and simulation world relationships involved in verification and validation.

2.5 Co-Innovation

This thesis is not an individual effort, as several aspects and results were the outcome of a team effort. During the entire process participants from MYPUP have been closely involved in the problem. In all phases their input and experience have contributed to the shaping and direction of this research. Continuous feedback in the design phase helped co-create a solution to their problem. Having the problem owner involved actively from start to finish has resulted in a unique solution that could not have been reached otherwise.

Another reason for this not being a completely individual effort is that parts of the redesign required IT knowledge and skills. For this part of the research two people contributed to solving the IT issues. A former TU Delft student aided in embedding the Computer Vision API (Application Programming Interface) in the OCR algorithm. The rest of the OCR algorithm was co-created with student from the Faculty Electrical Engineering, Mathematics and Computer Science of the TU Delft, who is took care of the programming part of creating the OCR algorithm.

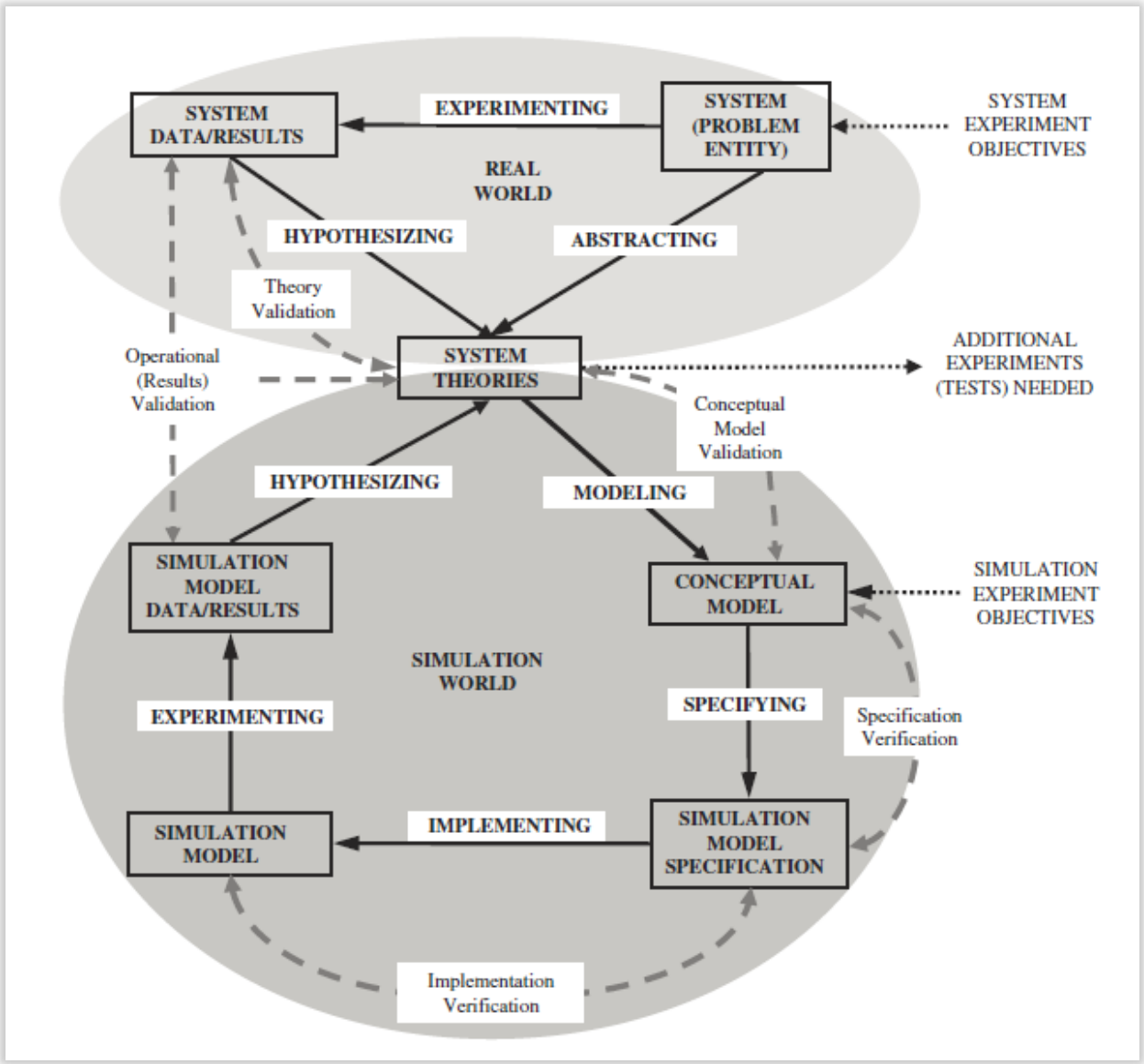

Figure 15: Model Methodology (Sargent, 2013)

3. Ideate

This chapter describes the ideation phase. The method used in this phase is discussed in Section 3.1 followed by the adjustments to the conventional brainstorm method and the setup in Section 3.2. Finally, the course of the brainstorm session and the results are discussed in Section 3.3 and Section 3.4.

3.1 Brainstorm method

Experimental research has lead researchers to conclude that face-to-face brainstorming meetings are less efficient and less effective than generating ideas when working alone (Sutton & Hargadon, 1996). Sutton & Hargadon (1996) question these conclusions, as the research is based on efficient idea generation as the primary effectiveness outcome. They identify six important consequences from brainstorming that are not evident in literature or labeled as such:

1. Supporting the organizational memory of design solutions;
2. Providing skill variety for designers;
3. Supporting an attitude of wisdom;
4. Creating a status auction;
5. Impressing clients;
6. Providing income for the firm.

Sutton & Hargadon (1996) propose a broader perspective for assessing brainstorming effectiveness. Reviews of brainstorming conclude that the productivity loss in brainstorming is observed consistently in brainstorming groups with more than two members. (Mullen, Johnson, & Salas, 1991) (Stroebe & Diehl, 1994).

Although productivity is generally used as the sole outcome measure to review brainstorming, literature rarely addresses the question whether generating ideas should be the primary effectiveness criterion (Sutton & Hargadon, 1996). In their research at IDEO Sutton & Hargadon (1996) found that traditional brainstorming might not be the most effective tool to generate ideas. It appears that the IDEO way of brainstorming adds more value than just creating ideas. It does this by following a set of rules compiled during years of brainstorming. According to the IDEO methodology there are seven rules to brainstorming (IDEO, 2016):

1. Defer judgement;
2. Encourage wild ideas;
3. Build on the ideas of others;
4. Stay focused on the topic;
5. One conversation at a time;
6. Be visual;
7. Go for quantity.

Following these rules is no guarantee for success. Brainstorm participants and organizers get better as they brainstorm more frequently. This has significant impact on the outcome of a brainstorm session (Sutton & Hargadon, 1996).

3.2 Brainstorm Setup

The main goal for the brainstorm was to realize a high level of efficiency and creativity. In light of what had been found in literature brainstorming in the conventional way has not proven to be a great tool.

Therefore, some adjustments were made to the conventional brainstorming approach to accomplish a high level of efficiency and creativity.

The first adjustment made to conventional brainstorming was to only work individually or in pairs. This allowed participants to come up with more ideas as they were not constantly interrupted by their peers. It also stimulated creativity in the sense that there was little or no fear of writing down whatever ideas came out, and judgement was deferred.

A second adjustment made to conventional brainstorming consisted of splitting up the session into sprints with a time limit. The idea for sprinting was inspired by agile scrum. Agile scrum is a method of working in which goals are set over a short period of time and discussed at each interval. Often the interval period is a day, a couple of days or a week. Applying sprinting to the brainstorm session, allowed participants to build on other peoples' ideas in the following round, inspiring each other to be more creative. Secondly, using a time limit puts pressure on the participants to create as many ideas as they possibly can within that limit. Introducing a competitive factor stimulates quantity as nobody wants to be the person who only had two ideas or wanted others to win. It was emphasized intensively that quantity and not quality was important. Furthermore, sprinting allowed for the participants to stay focused on topic, as the entire problem was cut up into pieces. Each sprint was focused on a different topic.

Instead of starting the session off with a problem description, the brainstorm started off with an icebreaker. This consisted of a little game to get the participants laughing, making jokes and clearing their heads to stimulate creativity.

The final adjustment to conventional brainstorming was that the problem at hand was not presented to the participant, but the participants were first asked to come up with the problems themselves. Although the problems for the brainstorm session were already defined, the first round was introduced to see if participants would come up with the same, similar or even different problems. It also gave the participants inspiration to broaden their horizon before starting on the solution brainstorms, stimulating the creative part of their brain.

3.3 Brainstorm Session

This section discusses participant selection, Paragraph 3.3.1, and the course of the brainstorm session, Paragraph 3.3.2, that lead to the results presented in Section 3.4.

3.3.1 Participants

The participants that were selected consist of MYPUP employees from various levels of the organization with diverse backgrounds. Having a diverse group of participants results in different approach to the same problem. It inspires creativity and provides other participants with insight they would not have come to on their own. MYPUP is a start-up and does not employ a large number of people to choose from. The upside to the limited choice of participants was that that selecting people with varying backgrounds from different levels of the organization was a given. Three founders participated in the brainstorm session. The first founder, Managing Director at MYPUP, had a business administration background and had worked in business development, corporate development/strategy and business change. The second founder, Commercial Director at MYPUP, had a background in marketing, management and sales and had work experience in sales and consulting. The third founder, Chief Technical Officer at MYPUP had a background in information technology and had work experience in software development and consulting. Other participants included administrative personnel with supply chain logistics background and

couriers/students, with backgrounds in business administration and economics. This resulted in a group that consisted of participants with diverse backgrounds and experience.

3.3.2 Brainstorm Course

The brainstorm started with an icebreaker, after which the participants, started their individual brainstorm on what the problem was, after a short sketch of the situation. The icebreaker, the problem brainstorm and the presentation of their findings took 20 minutes.

Dividing the problems identified into three categories allowed for three solution finding rounds. Each round different pairs of participants were made to stimulate diversity and quantity. Between each of the rounds participants were asked to present their findings to serve as inspiration to others. During this process, no ideas were judged, in fact in between rounds it was emphasized that they were all good ideas, to maintain a positive atmosphere.

The first round focused on registration, the second round on sorting and the third round on distribution. Each round consisted of 10 minutes of brainstorming. In between rounds participants presented their ideas to serve as inspiration for other to build on. Before ending the brainstorm session, the participants were asked to take a moment to look over the ideas that were generated during the session. They were then paired up once more for the final round. In the final round, participants were asked to take ideas and design, what they thought to be the ideal situation using ideas of others previously shared or their own. This gave insight into the wishes of the people using, exploiting and overseeing the process to be designed. With these designs, the first prototypes were created.

3.4 Brainstorm Results

Sprint 1: Problems

The brainstorm resulted in some interesting insights in the problem owners' perception of the problem and how they thought these problems should be tackled. The problems identified by the people in the field were mostly consistent with the problems found in the initial analyses. Some interesting additional insights became apparent. When presenting the results, problems became visible that did not fit the predefined categories. This showed that the participants were creative and thinking outside the box. Figure 16 shows the results from the first round.

The consolidation of the parcels was conceived to be a problem by all participants. Getting all parcel in house before redistribution was the main concern in this area, which is consistent with earlier observations. However, making agreements with drivers to ensure all parcels can be consolidated in time is not part of the redesign study.

The registration process is where most problems were identified. The problems conceived by the participants were not just limited to the tedious labor intensive, manual process, but also included more practical problems. One example addressed the steps involved when a parcel is oversized. Another problem identified was the situation when users are out of office for a longer period. These problems created opportunities for improvement in the current MYPUP system, which would entail minor software adjustments. Most problems in the registration process conceived by participants were consistent with earlier findings. One important insight that resulted from these perceived problems was the participants' concern about eliminating errors, rather than about speeding up the process.

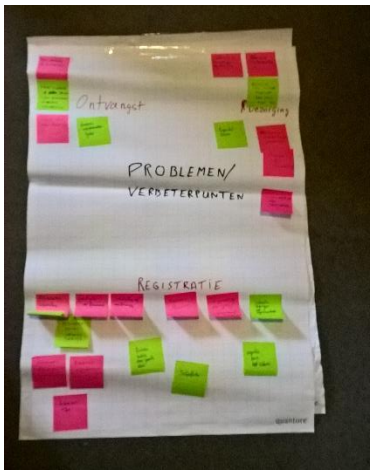

Figure 16: Problems Participants Perspective

Sharing the problems in between rounds gave the participants a scope for their solution finding rounds, or at least a direction. In hindsight, it might have given them too much of a direction no real wild ideas came out of this sprint.

Sprint 2: Registration

As the problems regarding the consolidation of the parcels from external service providers are not part of this study the focus of the second sprint was on the registration process. A small recap of the problems found by the participants and presenting additional problems identified earlier on in this research provided the direction of the sprint. Solutions found in the sprint were interesting and diverse. However, the ideas all remained inside the box. Unfortunately, no real out of the box ideas were generated. Without criticizing, the importance of quantity in contrast to quality was stressed, encouraging participants to be more creative. For the problem concerning the extraction of the username, two main options came out, OCR and scanning the barcodes on the parcels. The same solutions were also considered for determining the size of the parcels. In addition, it was suggested molds could also be used to determine the size of the parcels. For the registration of the sender of the parcel, OCR was suggested, others argued that registration of the sender would no longer be necessary as the OCR picture could be used in case questions around the parcel arose. One pair of participants mentioned the redesign of the label, but without concrete ideas as to what it should look like. The remaining participants considered the label to be part of the sorting process, thus had not taken this into consideration yet.

Sprint 3: Sorting Process

The sorting process was conceived as a problem by almost all participants as it is sensitive for errors. Most participants focused on the label, coming up with color coding or three letter codes to make the label easier to read. Radio Frequency Identification (RFID) was also suggested combined with different sorting approaches. One option suggested using RFID in combination with a conveyor and an automated sorting system. Another application of RFID made an alarm bel go off if the parcel would be sorted to the wrong crate. One solution that stood out was adding another step between registration and sorting, in which the addressee on the address label is confirmed to be the one on the MYPUP label.

Sprint 4: Delivery Process

The fourth sprint focused on the final step in the MYPUP logistics process, the delivery. Continuous route optimization was one of the solutions to make the delivery process more efficient. Other ideas built on the RFID solution from the previous sprint. It was argued that the RFID could be used to open the lockers. The idea that stood out was an app for the driver, which would include route optimization, navigation, a check to see if the driver had delivered all parcel and collected all pick-ups. The app would give the driver an OK or thumps-up and the app would then present the next location.

Sprint 5: Prototype

The final sprint was aimed at getting insight into the preferences of the participants, to be used in designing a prototype. The participants were asked to create an ideal design using the ideas from the previous sprints and new ideas inspired by previous sprints. In Figure 17 and Figure 18 two prototype examples are shown. These prototypes are based on the ideas generated in the brainstorm session.

In Figure 17 the participants included an extra step and added a short-term and long-term vision. On the short-term, the registration process should include OCR for identifying the addressee and the system should detect if an addressee already has a parcel registered to their name so it can be batched and re-registered if needed. On the long-term, the OCR system, or additional camera, should also be able to determine the size upon registration. To improve the sorting process location codes should be used on labels to eliminate errors. The group did not present their design as a process flow, thus the size determination on the short-term was first addressed during the sorting phase. However, a locker is assigned to each parcel depending on the size of the parcel during the registration phase. The use of molds on the short-term presented as part of the sorting phase, actually belongs to the registration phase. Finally, the group decided on having an app for couriers so they receive confirmation when all parcels are delivered and all pick-ups are collected.

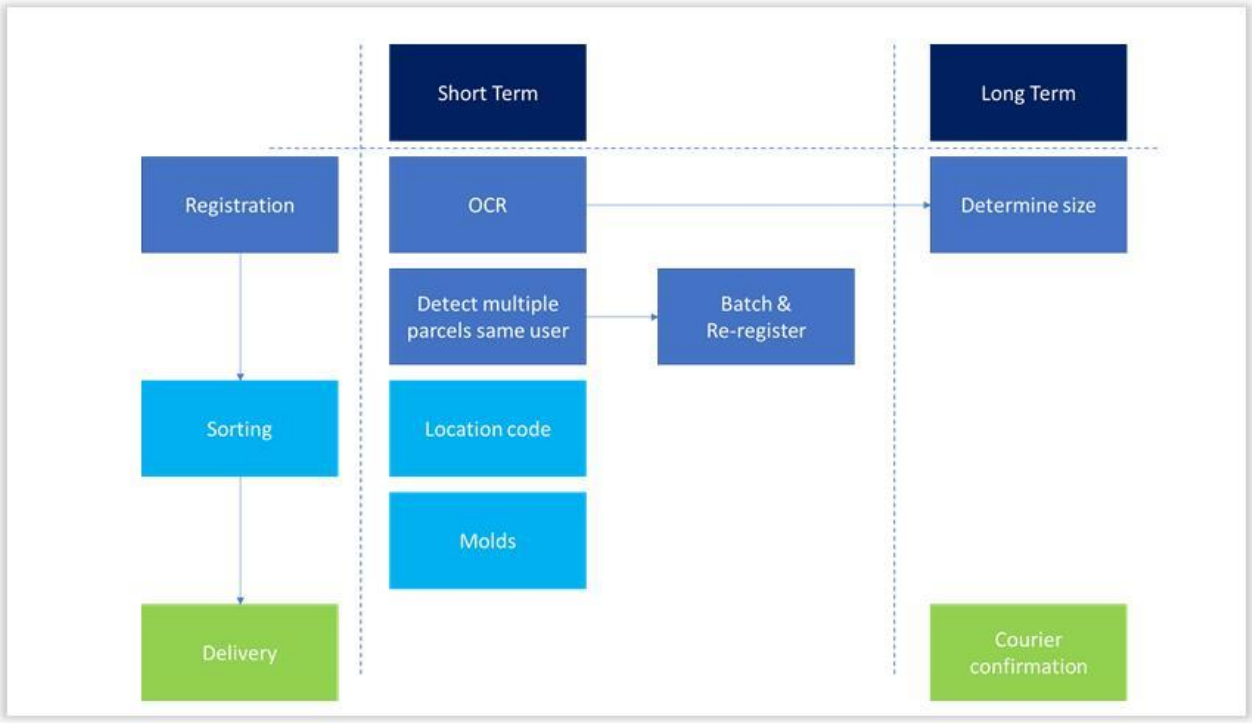

Figure 17: Prototype Example 1

Figure 18 shows a different approach to solving the problems. The registration process is similar to the previous prototype. However, in this prototype the participants also proposed the registration of the sender of the parcel, which is an important aspect in the overall registration process. Make the registration of the sender more efficient it was suggested to use a dropdown menu, with the most common senders and automatic completion upon typing. For improving the sorting process, the participants suggested adding a color code to the label to prevent sorting mistakes and adding a barcode to the label for later. In the delivery phase the participants were quite detailed compared to other prototypes. They proposed the introduction of an app for couriers which would contain the optimal route based on real-time traffic information. Upon delivery, the barcode on the label would be scanned, popping open the door of the designated locker. The courier would get a thumps-up when all parcels were delivered and all pick-ups were collected. Finally, the app would show the courier his next destination.

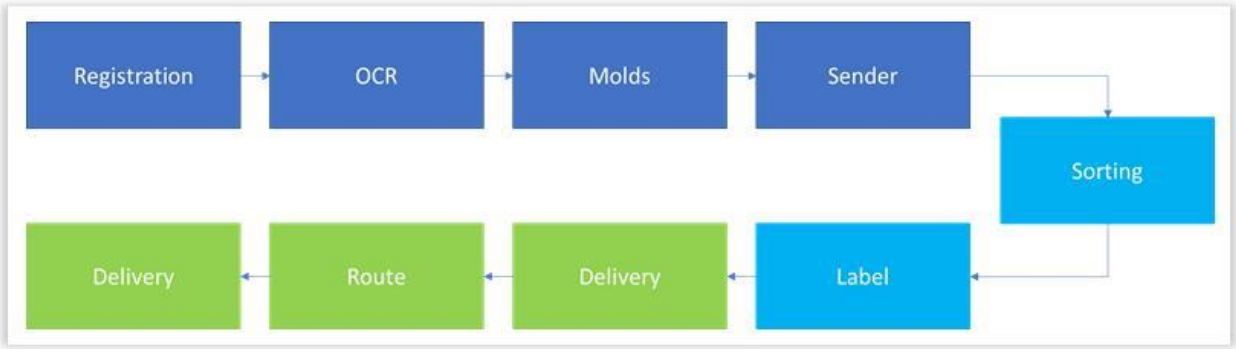

Figure 18: Prototype Example 2

The prototypes resulting from the brainstorm session served as inspiration for developing a first prototype by non-users.

3.5 Conclusion

The brainstorm produced some fruitful results and provided a wide range of input possibilities for designing the prototypes. Even though the results were satisfactory, in hindsight a wider variety of participants could have sparked more out of the box thinking. The participants consisted of MYPUP employees with different backgrounds and positions, outsiders with no connection to MYPUP might have provided some interesting insights. This flaw aside, the outcome of the brainstorm following the adapted IDEO brainstorm method is considered to have produced sufficient input to start the redesign of the MYPUP logistics process.

4. Designing the prototype

This chapter describes the process of designing a prototype based on the input from the brainstorm session. The process involves sessions with the brainstorm participants to create a prototype that can be used to develop the initial design in section 4.2. From this point forward existing designs are taken in consideration disregarding the financial constraint to arrive at a design that near ultimately efficient in Section 4.3. Taking in consideration existing solutions and the solutions produced in the ideation phase a realistic design is developed in Section 4.4, which aims at improving efficiency, increasing capacity and eliminating errors, whilst considering financial constraints.

4.1 Prototype Session I

The first prototypes discussed in Section 3.3 were developed by the participants of the brainstorm session. These prototypes and the other ideas produced at the brainstorm formed the basis for the next prototype. The ideas from the brainstorm were tested on operational/technical and financial feasibility, and compared regarding effectiveness and costs.

From the brainstorm output new prototypes were designed, showing the registration prototypes in Figure 19. The prototypes all use OCR to identify and register the addressee. The OCR pictures are used to register the sender by saving and linking the picture to the registration. The difference between the designs is the determination of the size of the parcel. The upper left design uses a 3D camera, to determine the size of the parcel, which is a quite expensive method. The upper right design uses two photographs to determine the dimension of the parcel. Both the upper left design and the upper right design automatically assign a locker to the parcel. The bottom left design uses molds to determine the size of a parcel, which requires manual labor and manual assignment of the locker. The bottom right in Figure 19 includes additions to the currently used software. By using automated emails, notifications of oversize parcels can be sent to the end user by the click of a button. Furthermore, entering an amount of custom charges clicking the 'send' button should automatically generate a request to pay. Other additions provide for notifications when people are out of office, so parcel can be delivered later, and for notifications in case a user already has a parcel registered, so these parcels can be batched.

For the sorting of parcels the label was redesigned to include a location code rather than using color coding due to financial reasons. The delivery option using barcodes was no included in the first prototype because it would require making expensive hardware changes. The couriers' app makes up the last piece of the process, including route optimization and checks for the completion of tasks at each pick-up-point.

The sessions started off with a recap of the previous prototype identifying the pros and cons of each prototype along the way. Subsequently, the options in Figure 19 were presented to the participants, the same people as the previous session. Each participant was asked to pick one prototype and elaborate on why they preferred that prototype over the others. After each participant had presented their preferred option a discussion was held amongst the participants about which design would best fit the current MYPUP situation.

The main outcome of the first prototype session was insight in the importance and priority of certain aspects of the process. The most time-consuming part of the process, the registration, was found to be most important. Another issue that became apparent was financial awareness. At the end of the session, unfortunately no consensus was reached. However, one of the design did not make the cut, the 2-camera

registration design in the upper right corner of Figure 19. The 3D camera was preferred over the 2-camera option despite the more expensive nature of the 3D camera solution.

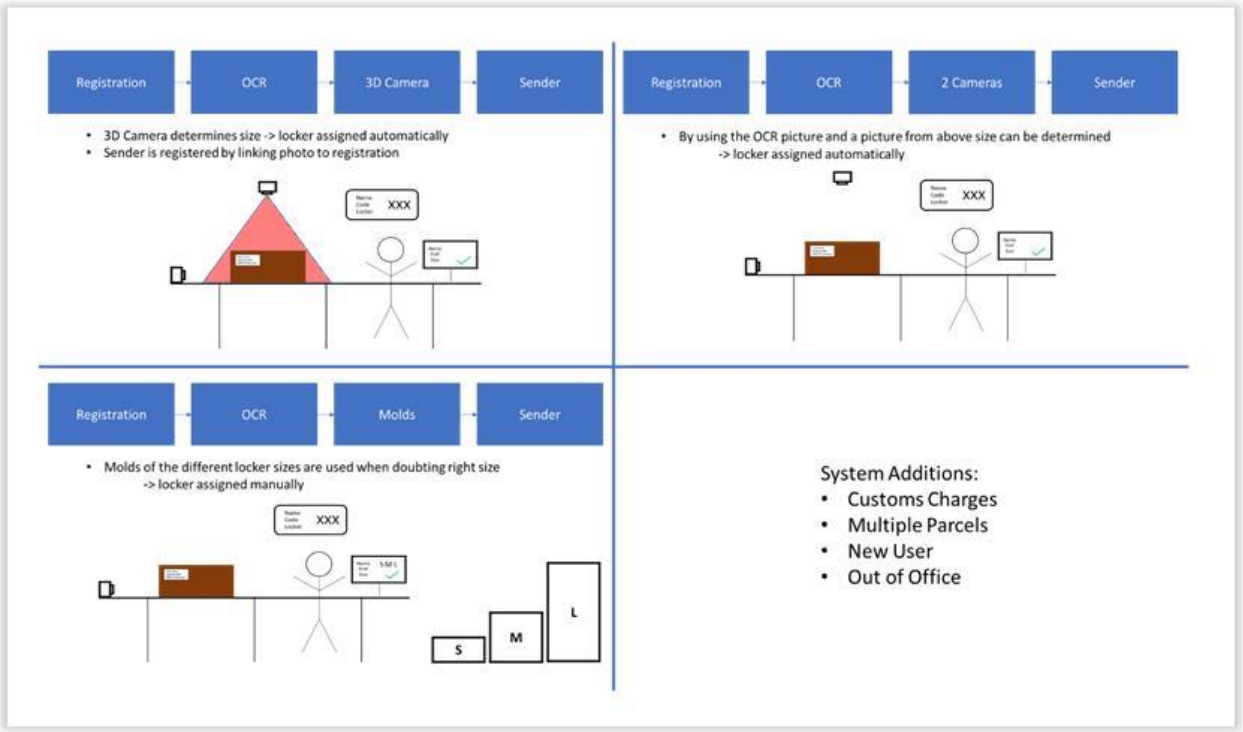

Figure 19: Registration Prototypes

4.2 Prototype Session II: Initial Design

The first prototype session revealed the preferences and priorities of the participants. The session provided inspiration and guidance for the blueprint of the actual design, referred to as the initial design. The initial design takes the ideas and feedback from the previous designs and sessions and forms the foundation to build upon.

The consolidation of parcels will always be the start of the process as it is more efficient to consolidate the parcel and register them all in one go. The registration starts with OCR to register the name. A mold is then used to determine the size of the package, if the user is uncertain about the size. Registering the sender of the parcel should be done by linking the OCR picture to the registration. The new label contains a location code to prevent errors in the sorting process. The routes should be coupled to an app calculating the fastest route for the drivers and acting like a navigation device. To avoid mistakes, the app will give the driver a thumps-up when everything is securely inside the lockers and pick-ups are collected. The final delivery is done the same way as in the current situation, by hand. An abstract layout of this initial design is shown in Figure 20.

Figure 20: Initial Design

Up to this point only ideas generated in the brainstorm and prototype sessions have been used. Sorting parcels is not new and therefore, existing solutions that were overlooked should also be taken into consideration. Often these solutions are built to handle large volumes which is not necessarily applicable in the MYPUP case. To include alternatives that already exist, and could possibly be applied in the MYPUP case, an ideal design is made in Section 4.3, at this stage not taking into consideration financial constraints.

4.3 Description of the Ideal Design

In the ideal situation where costs are not an issue the whole process would be automated. The design is based on visits to postal and parcel distribution centers of PostNL and Van Straaten Post and a meeting with an expert from SICK, a leading sensor intelligence company that has designed and developed many similar solutions.

The consolidation of parcels is no longer needed as parcel are put on a conveyor upon arrival. The parcel is then scanned using OCR and the size is determined using a 3D camera. The pictures are linked to the registration and they are kept for an additional period of time after pick-up for liability reasons. A label containing a barcode and RFID tag are brought on by a labeling machine. The parcel will then continue onto the sorting conveyor that automatically sorts the parcel into the right chute. When the sorting is finished, the system will generate a packing list for the drivers based on distance, number of stops and number of parcels registered, to distribute the workload evenly. The couriers log-in onto the app, load their vans, and follow the instructions on the courier's app. The control function in the app will be triggered when the first parcel at a location is put into a locker. The RFID tag will cause the corresponding locker door to pop open, the parcels is placed inside the locker and the door is closed. The app will then give the OK when all parcels are securely inside, the doors are closed correctly, and all pick-ups are collected. The driver then gets directions to the next destination.

Since this design is hypothetical, the hardware in the design is not specified to make and model. For comparison, some hardware alternatives to the choices made for the actual design are addressed in Section 4.4.

4.4 Actual Design

At first only the OCR part of the process is designed and implemented. However, a realistic future design is made so MYPUP can always decide to implement other parts of the design later. The design made for MYPUP is developed to be affordable, highly efficient and to eliminate human errors.

4.4.1 OCR Method

Different setups to obtain the picture for OCR are offered in the parcel industry. An expert from SICK, the company that is also responsible for the OCR development at Schiphol Airport, was brought in to offer solutions for MYPUP. The following setups to obtain the OCR picture and determine the size of the parcel were suggested. The top of Figure 21 shows the static setups with just one camera to determine size and

read the address label. These solutions start between €20,000 and €40,000. Dynamic solutions shown in the bottom of Figure 21 including conveyors and automatic scanners and cameras start between €40,000 and €65,000.

These setups only include the hardware, the software for OCR is not included. OCR software at the cheapest was estimated to cost between €30,000 and €60,000.

Figure 21: SICK Setups (SICK, 2017)

The setups presented by SICK were too expensive for MYPUP, but provided inspiration for the initial design. Furthermore, the dynamic designs are intended to handle larger volumes than needed in the MYPUP case. For the OCR software two main possibilities seemed to be most realistic: either create the entire OCR from scratch or use an existing Application Programming Interface (API). The first option would entail creating an API that would be able to detect text in pictures and extract that text out of the picture. The second option makes use of an existing API for retrieving the text. In this option, the challenge would be writing an algorithm to incorporate the API and retrieve only the text relevant for MYPUP.

4.4.2 OCR Hardware Design

The requirements for the design of the hardware setup are simple, they should allow for taking a well-lit clear picture. An USB camera, Microsoft LifeCam Studio (MLS), was chosen for taking the pictures. MLS is a camera that takes pictures of a quality high enough to perform OCR on. Besides the quality it provides, it is easily adjustable.

Still there were several issues that needed to be addressed, one of which was the lighting. During tests, it became clear that the lack of lighting caused the camera to have trouble focusing. Simple lighting solutions are already effective to prevent flare and allows for speedy focusing of the camera. Furthermore, in order to keep the cost low preferably only one camera is used. Because repositioning the camera for every parcel is too time consuming, tools are made to be able to handle flat parcels, letters and extremely small parcels.

The OCR software can run on relatively low-budget computer as the computer does not need to process heavy software. Furthermore, for efficiency reasons in the remainder of the registration process the screens need to be touchscreens.

Using this API allowed for writing an algorithm to locate the addressee and read out the usernames. This resulted in working OCR software for less than €300. The design for the algorithm was made by the author, and the actual coding was done by a third party. The IT department of MYPUP eventually embedded the algorithm into the MYPUP system. The algorithm can be found in Appendix A.

4.4.3 Size & Sender

To get the most out of the OCR it should be combined with a menu simple user interface. With just a few touches of the screen the size and sender can be selected, as shown in Figure 22. By taking away the step of a drop-down menu to select the size of a parcel and the need to type in the sender, parcels can be registered much faster.

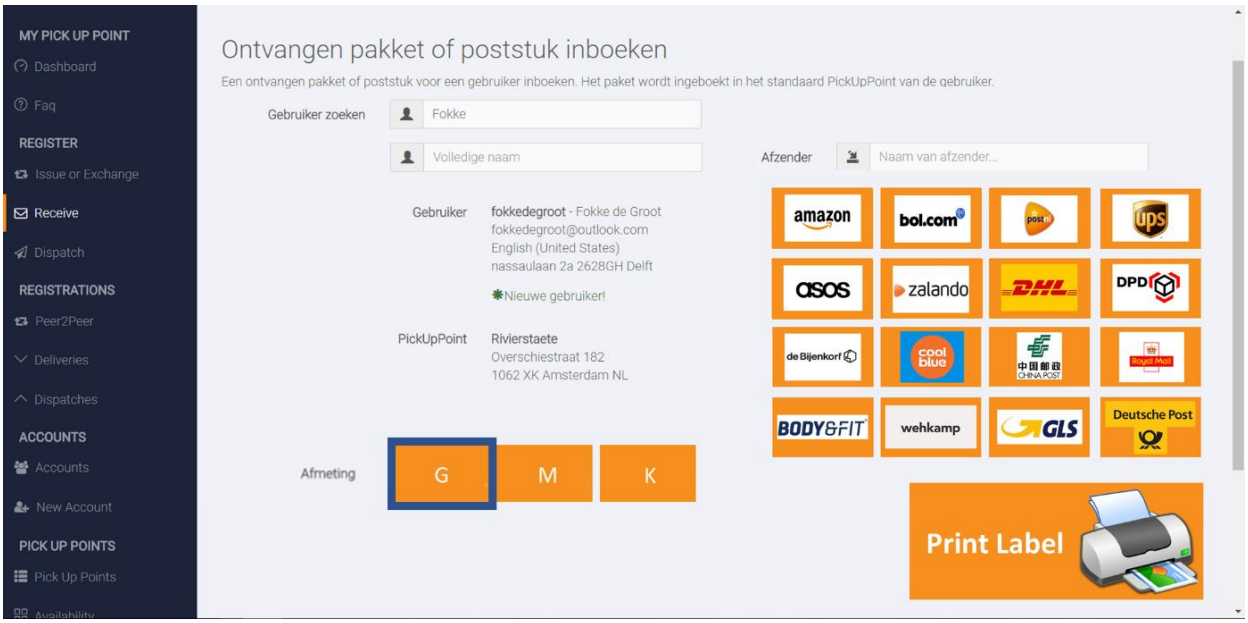

Figure 22: MYPUP Registration Screen

The size is still determined by the trained eye, and a measuring tape. By sorting the parcels by size in the consolidation phase the registration process is made more efficient as size does not need to be determined during this process. On the short-term errors made in the size determination can be eliminated using dummy parcels or molds. On the long term the design of the process includes a 3D camera, as it determines the size of a parcel within split seconds eliminating errors and making the sorting by size beforehand obsolete.

It is also possible to not assign a sender as senders in this step of the process as senders often become clear from the picture taken for OCR purposes. Keeping this picture until collected could eliminate the addition of assigning a sender in the registration process all together.

4.4.4 Label

One part of the process where most errors take place is in the sorting process. Automating this process is very expensive and not an option. Therefore, the only realistic solution that could help prevent mistakes, is redesigning the label to contain all necessary information needed for sorting. Preferably the label contains the following information:

1. Username;
2. Location ID (LID);
3. Address;
4. Locker number (K) with Pin code (P);
5. Barcode.

To prevent mistakes in the sorting process the label is redesigned, as is shown on the right side of Figure 23, which allows for comparison with the current label on the left side of the figure.

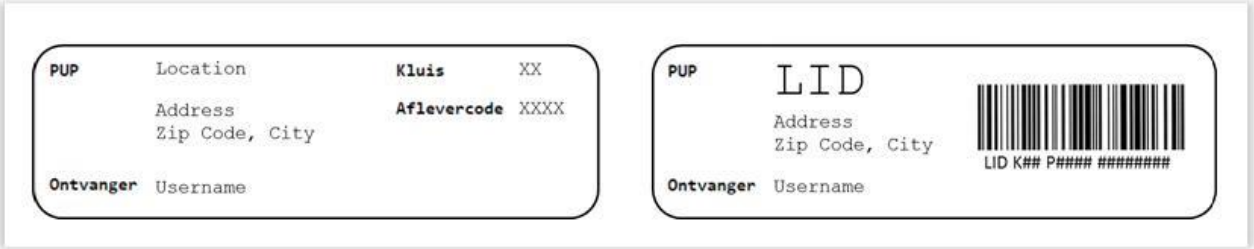

Figure 23: Label

The scanning of the barcode at the designated crate eliminates sorting errors, where the location code sends the sorting employee in the right direction.

4.4.5 Drivers App & Route Optimization

Route optimization should be done considering four factors, the number of locations, the number of parcels, the distance and real-time traffic situation. An app should be developed for the drivers that contains their route and serves as navigation. In this same app, a check should be implemented to make sure the driver has delivered all parcel, the doors are closed correctly and all pick-ups are collected. He should get an OK that he has completed all tasks and that he is ready to head to his next location.

4.4.6 Delivery

The parcel should be able to be placed into the lockers using a barcode and a mobile phone. Once the barcode on the label is scanned the door of the locker pops open and the parcel can be placed in the locker. This works faster compared to punching in the numbers one by one.

4.5 Implementation

The OCR algorithm created, is being implemented with final alterations to improve the success rate further. These alterations were done to make the algorithm compatible and take into consideration the working of the MYPUP currently used software. An example of an alteration is that the search for the

name in the MYPUP system is done more dynamic. This entails that even when one or two letters do not match or cannot be read, the person can still be found using a percentage match-rate. These alterations could not be done without insight into the code of the MYPUP software. Therefore, these final steps could only be done by MYPUP IT. The OCR algorithm is planned to be implemented by the end of the second quarter.

The drivers' app is planned to be implemented by the end of the third quarter. The implementation entails only the part that ensures the driver has delivered all parcels, closed all lockers and collected all pick-ups. The route optimization part will be added at a later stage as this is more complicated than simply embedding navigational software.

5. Developing the OCR Software

Creating an OCR API is more complicated and expensive than using an existing API like the Microsoft Computer Vision API. Furthermore, creating own OCR software requires more powerful, and thus more expensive hardware, to be able to handle the software. Therefore, using an existing API was the path chosen to pursue. Microsoft offers a variety of API's, free to use up till a certain amount of calls, including an API that can be used for OCR called Computer Vison. The Microsoft Computer Vision API allows for 5000 free calls per month charging an additional $1.50 per 1000 additional calls. Using this API, a MYPUP specific OCR algorithm is developed in Section 5.1. The iterations to improve the algorithm result in the proof of concept presented in Section 5.2.

5.1 Developing the OCR Algorithm

To develop the algorithm multiple sessions were organized to develop and improve the algorithm. Outside support was sought for writing the code. A former student of the TU Delft, was consulted for embedding the API in the algorithm, as he is experienced in working with API's. For the remainder of the code writing part a student from the Faculty Electrical Engineering, Mathematics and Computer Science of the TU Delft, experienced in programming was engaged. The progress made in each session is discussed below.

5.1.1 OCR algorithm session 1

The basic working of an API in general is that you sent information to the API, it does whatever it is programmed to do with that information, and sends back information as output. In case of the Computer Vision API a picture is sent to the API, the API performs OCR on the picture and sends back all text in the picture. The first step to creating the algorithm is to get this process working. To use the API a registration key is needed and a way of calling the API by sending a picture. To get this part of the algorithm working, a former student of the TU Delft, who works with API's regularly, was consulted. He explained the working of the API and the algorithm needed to call the API.

For testing, some random pictures with text were sent to the API and text was received. This formed the basis for the OCR algorithm. However, within six hours and around 30-50 test pictures a limit was reached resulting in a 24-hour timeout. Data limits for google script in which the algorithm was developed were reached, presenting a problem to the number of pictures that could be processed. Tests revealed that the quality of the picture could be diminished and be quite low for the API still to work. Resizing the pictures allowed for 2500-3000 pictures to be processed.

5.1.2 OCR algorithm session 2

The next step was to extract the right information from the text that was returned by the API. For programming this part of the algorithm, a student from the Faculty Electrical Engineering, Mathematics and Computer Science of the TU Delft, experienced in programming was consulted. Before the first meeting it was defined what the algorithm needed to do. The goal for the registration was to extract the username from the address label. However, an average picture contains more text than just the address label and most address labels contain more text than just the address. The main goal was to filter out the username.

The first idea for the OCR algorithm is shown in Figure 24. When taking the picture, the picture should be saved immediately in the source folder, where all pictures are stored to be sent to the API. The API would then be called and try to locate the username using the word MYPUP. All users are asked to put "MYPUP –" followed by their username as addressee in order to have it delivered to the consolidation address.

Therefore, searching for MYPUP and taking the next word should produce the username needed to look up the user in the database. Eventually the username should be written away to the username box in the registration screen, but for testing it was written away in a file. This should be the most straight forward and simplistic way to find a username.

Figure 24: Algorithm First Draft

During the imbedding of the API in the algorithm it already became clear that finding a word is case sensitive. So, when locating MYPUP different spelling variations of MYPUP were used shown in Figure 25.

```
if (USERNAME == 'not detected')
  var pupTag1 = 'MYPUP';
  var pupTag2 = 'MyPUP';
  var pupTag3 = 'MyPuP';
  var pupTag4 = 'mypup';
  var pupTag5 = 'Mypup';
```

Figure 25: MYPUP Spellings

Testing

After each session, the code needed to build whatever was agreed upon would be written by the programmer. When it was done, testing took place by the author. The first draft of the algorithm seemed to be working quite well on the pictures the programmer was provided with. However, there were only about 15 pictures to work with, that coincidentally nearly all contained some variation of MYPUP. Testing more pictures resulted in many usernames that could not be found. Beforehand the possibility of searching for the username in another way had also been discussed, however for the first session establishing a basis was important and therefor alternative possibilities were not further explored at that time. Another way of locating the addressee was to look for the street name and take the line above it as the username in case a variation of MYPUP was missing. Testing with more pictures revealed more and more different ways addressees put their name on the parcel. Therefore, the success rate with the new pictures was low.

5.1.3 OCR algorithm session 3

From the tests with the first draft of the algorithm it became clear that there was work to be done. Often MYPUP or a variation was missing or misspelled and the number of variations in spelling MYPUP was astonishing. Adding a search based on the street name made sense as there are less variations in spelling possible and it is never missing. The new setup for the algorithm is shown in Figure 26. The beginning has been left unchanged, but the part after the text was received from the API was largely changed. Once the text is received from the API the algorithm still searches for a variation of MYPUP first and writes not only

the first word, but all words in the same line in a file. Some users use their actual name which can also be found in the MYPUP database. However, to do so all words are needed and not just the first name. If a variation of MYPUP cannot be located by the new algorithm, it then searches for “Overschiestraat” or a spelling variation of it. Once located it takes the line above “Overschiestraat” and writes the words in the file. If words are found the picture is moved to the Finished Folder. This folder was created as testing with larger amounts of pictures called for more structure. For this same reason pictures are moved to the Error Folder if no words were detected using both options of locating the username.

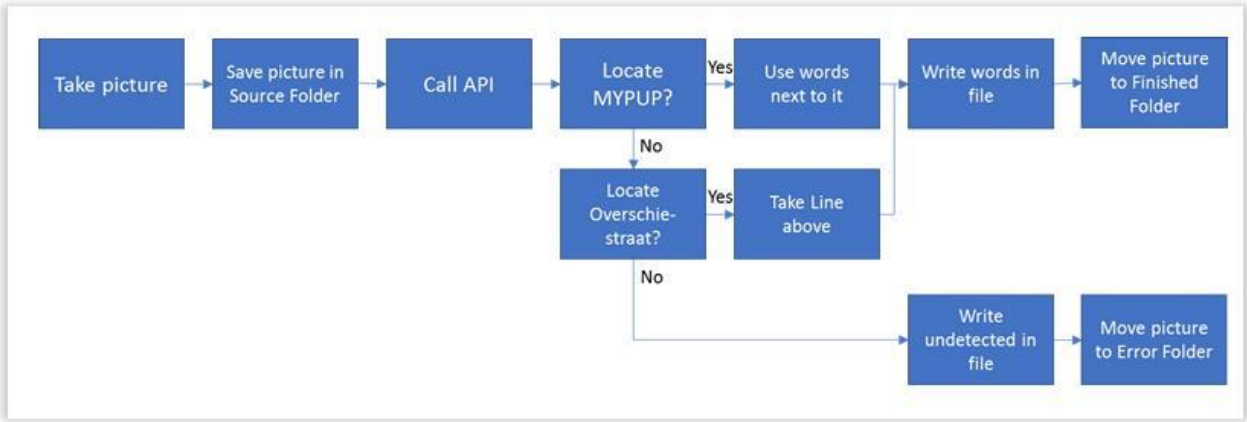

Figure 26: Algorithm Second Draft

Testing

Once the new draft of the algorithm was completed it was available for testing by the author. There were a few altercations made to the original design of the second draft. Testing by the programmer revealed a high success rate if the algorithm just tried to locate “Overschiestraat”, take the line above and remove “MYPUP-“ or variations of this phrase. At first glance it seemed evident that the success rate in detecting words was indeed higher this way. However, further investigation into the test results revealed that even though more words were found, these were not necessarily the right words. In fact, looking at previous results, pictures that were successfully processed before in extracting the name or username, now showed text that was in the line in between the username and “Overschiestraat”. Although the success rate was higher using “Overschiestraat”, it became clear that a combination of looking for “Overschiestraat” and “MYPUP” would provide better results.

Another important finding is that the algorithm was no longer able to process parcel from what looked at first to be parcels from UPS. Further testing however revealed that the problem was not the UPS label, but the Amazon label. Most parcels received from Amazon arrive through UPS. The labels on the parcels that contained the addressee, were as it turned out in fact applied by Amazon. The parcels contained a separate UPS label with a barcode and QR-code but did not contain the addressee. Due to the assumption, that the label containing the addressee was also an UPS design, discovering what was causing the problem was not immediately clear. Some UPS parcels did work and some did not, though al labels were similar. After analyzing more test photos, it revealed more problematic parcels that were sent with TNT Parcel and DHL. These parcels contained the same label containing the addressee as the UPS parcels. It became clear that Amazon labels were the problem, making it easier to look for the common denominator.

When locating “Overschiestraat” the second draft of algorithm only looked for two spelling variations as the misspelling of the street name had not been encountered. One variation started with an upper-case letter and the other variation with a small letter. Amazon uses all capital letters on its address labels, causing the success rate of the second draft to be much lower than expected.

5.1.4 OCR algorithm session 4

By adding the final new features to the design, a draft was created that comes close to being a worthy proof of concept. The new idea for the algorithm is illustrated in Figure 27.

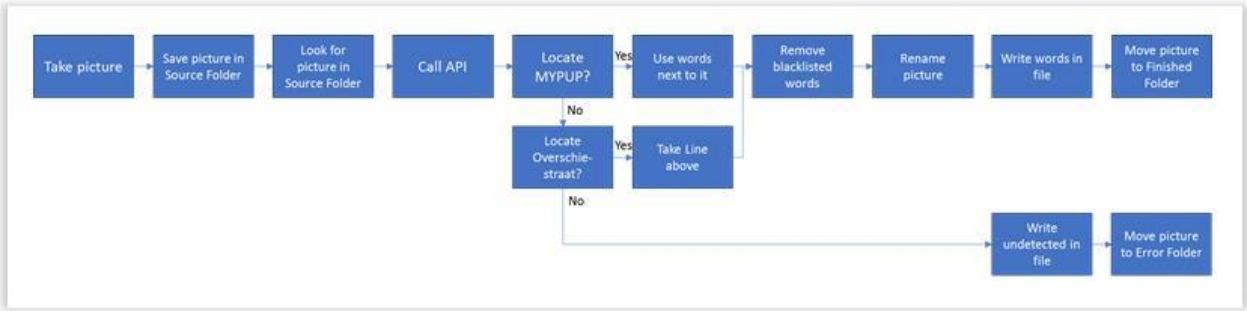

Figure 27: Algorithm Third Draft

In comparison to the first two drafts the algorithm now runs continuously. In the previous versions, the algorithm needed to be run manually once pictures were saved in the Source Folder. The algorithm would then process all pictures in the Source Folder that were present at that moment. Pictures added later would not be processed and the algorithm would stop once the pictures were processed. The new version of the algorithm should continuously check to see if new pictures are added to the Source Folder. This way, during registration, the name is registered with the push of just one button. The text received back from the API will first be searched for MYPUP or a variation. In case this is not found, the algorithm will try locating the username through the “Overschiestraat” option. The order in which this happens is important as looking for the “Overschiestraat”, although always present and less variations in spelling, extracts the incorrect information due to the layout of certain labels. The username and “Overschiestraat” are often separated by another line. Looking for MYPUP first and “Overschiestraat” second is expected to result in a higher success rate. The downside to including all words after MYPUP or the entire line above “Overschiestraat” in order to capture the full name or username, is that there are lot of words and symbols present in the addressee spot that do not belong. Users add the pick-up-point they are located at or fill out the web shop’s information form incorrectly, causing words or symbols other than their full name or username to pop-up on the addressee line. To extract only the full name or username, a blacklist of words is created to filter out words and symbols that do not belong. This list should be updated in the first few weeks, with all words and symbols encountered that are not part of the list yet. This will increase the success rate in the future. The renaming of the picture is done, so MYPUP has evidence of the parcel and information in case a parcel goes missing or something else goes wrong with the parcel. The picture is renamed with the username extracted from the picture, so it can be easily retrieved. Finally, the full name or username is written away in a file and the picture is moved to the designated folder.

Test Session

During the tests the hypothesis that looking for MYPUP first would produce better results was tested. The test showed that this was in fact true and uncovered a minor flaw with running the algorithm in this order. Two of the test labels showed a blank space next to MYPUP and were written away as errors. This was a possibility that had not been considered before. These pictures were written away as errors in the first run, but detected when looking for “Overschiestraat” first. This issue was easily solved by looking for “Overschiestraat” if MYPUP was found, but no words were found.

A bigger issue that occurred is that the run time of the algorithm was limited to six minutes at the time. A problem that had not occurred before as the test pictures were always processed well within six minutes. The algorithm needs to run during the entire registration process which often takes more than an hour. This led to the conclusion that Google Scripts is not a suitable tool to use for implementation.

What became clear after analyzing the results, is that the API sometimes has trouble extracting the text correctly. In a few cases one or two letters were read wrong, making the result completely unusable for the MYPUP system. These often relate to names with accents, which makes it harder to read for the API. The MYPUP system could be adjusted to accept a, for example, 90% match rate if only one user remains as an option. This would increase the success rate significantly.

Taking these observations into account and tweaking the algorithm, fixing minor flaws, has resulted in an algorithm that performs well enough to be made into a proof of concept.

5.2 Proof of concept

The third draft was slightly adjusted to fix small problems, and all problems that could be fixed within the algorithm. This resulted in the proof of concept shown in Figure 28. Higher success rates can only be achieved by alterations in the MYPUP system. The proof of concept shows that OCR can be performed using the Computer Vision API with an algorithm specially designed to extract the information need in the registration process.

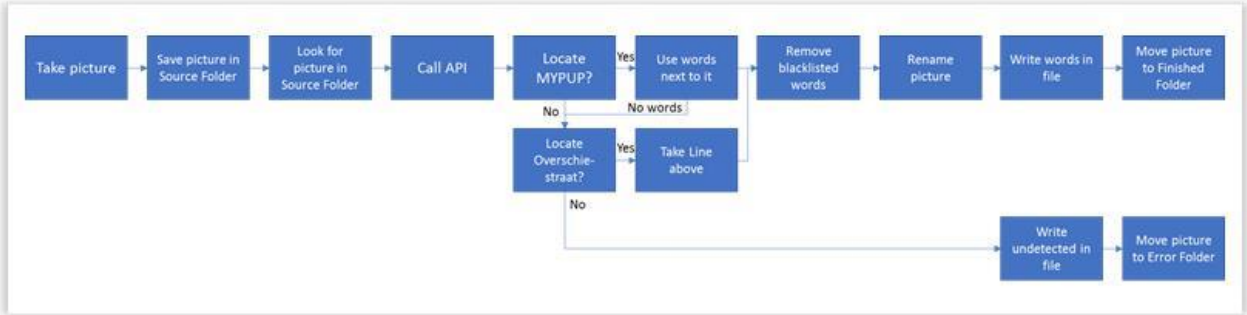

Figure 28: Algorithm Proof of Concept

To implement the algorithm and to make it compatible with the MYPUP system a list of requirements is drafted:

- Google scripts was used to create a proof of concept, and was sufficient for developing the algorithm and testing. However, due to its limitation Google Scripts is not suitable for implementation. The limits are shown in Table 4. The proof of concept was created using a

personal account. A business account would only provide sufficient access looking at the total runtime. Preferably own servers are used to take away restrictions on runtime and data;

- The size of the pictures used for testing ranged between 31-108 KB. The quality of the pictures was sufficient to extract the text from them. Therefore, it is recommended not to use the full potential of the camera and to keep the size of the picture small to ensure a speedy process using the Computer Vision API. Furthermore, it reliefs the servers of having to process larger amount of data than necessary;
- To develop the algorithm multiple computer windows were needed on in the process. One for taking the picture and one to see the result. Switching between windows for every parcel in the registration process is tedious and time consuming. Therefore, the picture taking should be embedded in the MYPUP system, so as soon as the picture is taken the registration screen appears showing the picture and user that are matched;
- Although the Computer Vision API provides a cheap alternative to other OCR software, it is limited to 5000 free calls/month, insufficient for MYPUP. A standard plan consists of limits of 10 transactions per second for $1.50 per 1000 calls (Microsoft, 2017);
- To prevent build-up of large amounts of pictures and inconvenience for the user, it is recommended to not just change the name of the picture once a user is found, but link the picture to the registration. Once a parcel is picked-up the picture can then be deleted automatically after an additional period of time for liability reasons. This can only be done by alterations in the MYPUP system and is not included in the algorithm;
- To make the algorithm compatible with the MYPUP system the algorithm should be translated into the corresponding language. The current language used is a dialect of Java.

Table 4: Google Script Limits (Google Apps Scripts, 2017)

Limit	Personal	Business
Total runtime	90 minutes/day	6 hours/day
Data	100 MB/day	100MB/day
Runtime	6 minutes/run	6 minutes/run

The algorithm will never be able to achieve a 100% success rate. Limitations to algorithm are largely due to external circumstances. Smudged address labels are not readable by the Computer Vision API, neither are hand written address labels. Only one type of labels that could not be read by the API can be influenced; some pictures showed glare of light reflecting. By changing the hardware setup in such a way that the light is good, a higher success rate can be achieved.

6. Model

In Section 6.1 the choice for discrete event simulation (DES) is elaborated. In Section 6.2 the base model is discussed on a conceptual level, which explains the model logic. In Section 6.3 the specifications of the model are discussed by zooming in on the processes, uncovering the process steps and observational steps of the model for each process. The data used for the model and formulas used to measure variables in the model are presented in Section 6.4. Finally, the validation and verification of the model is discussed in Section 0

6.1 Discrete Event Simulation

When it comes to modelling in logistics supply chain management, DES and system dynamics (SD) are widely used tools to model problems of both strategic and operation/tactical level (Tako & Robinson, 2011). Tako & Robinson (2011) analyzed a total of 127 research articles to identify which modelling approach was used and for what reason. Figure 29 shows the results of their research based on

Classification of LSCM issues into domain areas based on the frequency modelled by each modelling approach.

	SD high frequency of use	SD low frequency of use
DES high frequency of use	Common (DES and SD) domain Supply chain integration (SCI) Information sharing (ISH) System performance (SP) Inventory planning/management (IPM) Planning and forecasting demand (PFD) Production planning and scheduling (PP-SCH)	DES domain Supply chain structure (SCS) Replenishment control policies (RCP) Supply chain optimisation (SCO) Distribution and transportation planning (DTP)
DES low frequency of use	SD domain Bullwhip effect (BE)	Less common (to DES and SD) domain Process redesign (BPR) Supplier selection (SS) Facilities/capacity planning (FCP) Reverse logistics (RL) Cost reduction (CR) Dispatching rules (DR) (Pricing policies) (Return policies) (Global supply chain)

Figure 29: Results table (Tako & Robinson, 2011)

frequency. Based on the descriptions of the issues, which can be found in Appendix B, the MYPUP case best corresponds to a combination of the supply chain structure (SCS) and the process redesign (BPR). From Figure 29 it is shown that in SCS issues DES is frequently used and in BPR neither DES nor SD are frequently used. Furthermore, DES is more frequently used when the issue is of operational/tactical nature and SD is more frequently used when issues are of strategic nature (Tako & Robinson, 2011) (Trevisan, Brito, & Botter, 2011). The MYPUP case is of operational/tactical nature, and is focused internally rather than how it is influenced by its environment. Based on literature the choice for DES is made rather than using SD. Simio is the simulation software for DES made available by the TU Delft.

6.2 Conceptual Design

The base model, shown in Figure 30, describes the current logistics process in place at the MYPUP distribution center. The model generates a different number parcels each day. It is assumed that all parcels arrive at once, as the consolidation of parcels falls outside the scope of this research. The parcels are sorted by size and the parcels are then put away for storage until the registration process is ready to begin. Figure 31 zooms in on the process part of the model, in which the previous steps are displayed by the first three blocks.

The registration process always starts at 13:00 and the large parcels are registered first. Once these are registered the registration of the medium parcel is initiated, followed by the small parcels. The Oversized

parcels are registered once all other parcels are registered. This order represents the method of operation that takes place at MYPUP. The large parcels are registered first in case the medium locker capacity at a location is exceeded. A medium parcel can then be booked into a large locker as all large parcels have been registered.

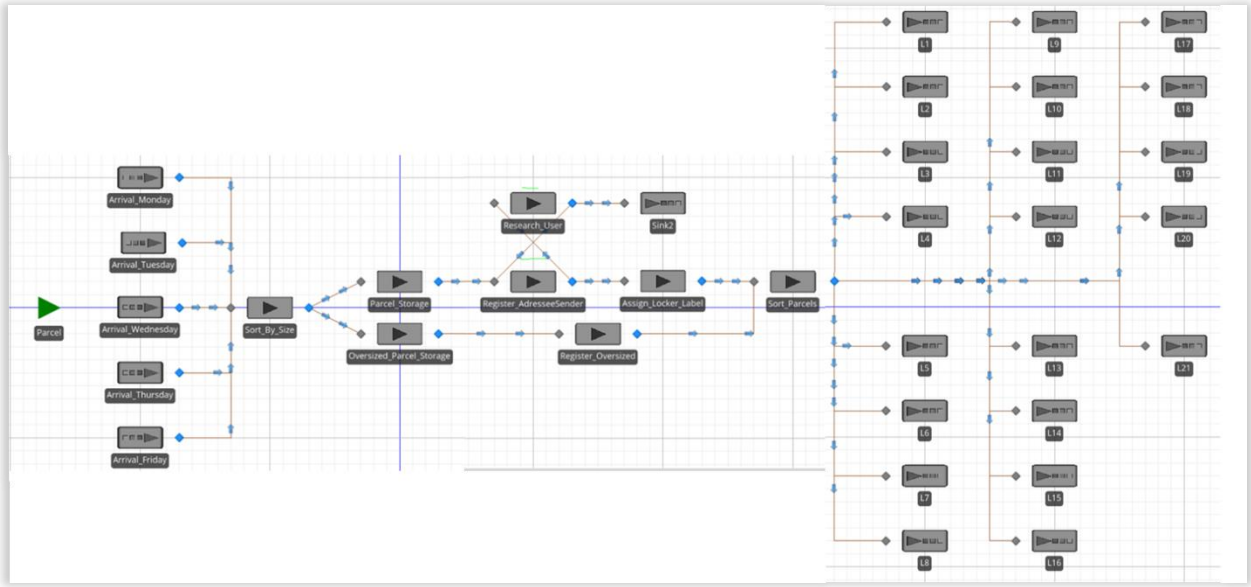

Figure 30: Base Model

The registration process differs for parcels that do not fit into a locker compared to parcels that do. Parcels that fit are registered by identifying the addressee in the MYPUP database and registering the sender. The next step to complete the registration is to assign the right size locker and print and apply the label. The destination is linked to the user, so the locker availability is automatically checked against the available capacity at the designated location. The registration employee then deploys the parcels in the sorting area where a sorting employee sorts the parcels by destination.

Figure 31 shows two more parallel process, the research of a parcel to find the user and registration of oversized parcels. The oversized parcel registration differs from registering parcel that fit into the lockers as no locker needs to be assigned. Oversized parcels are picked-up at the destination by the designated user, in person, once the courier is present. The oversized parcels need to be provided with a label containing the phone number and location.

The names that are encountered on the address labels during registration are supposed to contain the username. However, it often happens that other names are used or the label is misprinted by the sender, making the identification of the user near to impossible. In such an instance the parcel is opened to see if it contains a bill or invoice containing the right information. If the user is identified the parcel is put back into the process for registration. If the user cannot be identified the parcel is kept for three months, to see if someone calls to inform the company they are missing a parcel. These parcels exit the model as they do not play a significant role in the performance of the rest of the model.

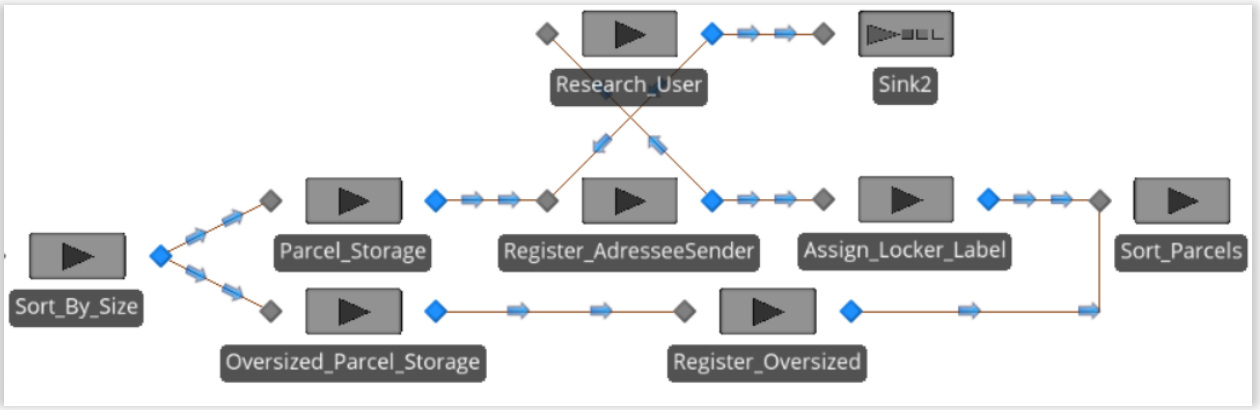

Figure 31: Bases Model Process Zoom

6.3 Process Specification

The parcels are assigned a size variable upon arrival, by checking the value of this variable parcels are sorted and either send to the parcel storage or the oversized parcel storage. The parcels are held in storage until they receive a signal. The large parcels are released at 13:00 by a timer signal. The number of large parcels observed in storage and the number of large parcels that have been registered or put aside are used to send a release signal for medium parcels. The small and oversized parcels are released in a similar way. The process designed to sort, hold and release the parcels can be found in Appendix C as they do not influence the process performance, but are merely in place to model the process accurately.

6.3.1 Registration Regular

The registration process of the base model starts by identifying the user in the system based on the addressee information; Figure 32 shows the steps involved in the identification process. First the parcel seizes a registration employee and then enters the process where the user and sender are registered assigned. Upon entering the process the parcel is assigned “TimeNow” for several entity variables assigned to monitor process times. If it is the first time a parcel enters the process, it has not been researched before. The identification of the user is attempted entering the addressee information to find the corresponding username. If the addressee cannot be identified in the system by attempting to find the corresponding username, the employee attempts to find the corresponding full name. If the user cannot be identified by their full name, the employee attempts to find the users corresponding account. Finally, if the user cannot be found in the system the parcel is put aside for research by another employee.

Once the user has been identified in the system, regardless of the identification method, the parcel’s state variable to monitor process times are updated. The employee is then ready to register the sender and finally, monitor values are updated and registered for analysis purposes.

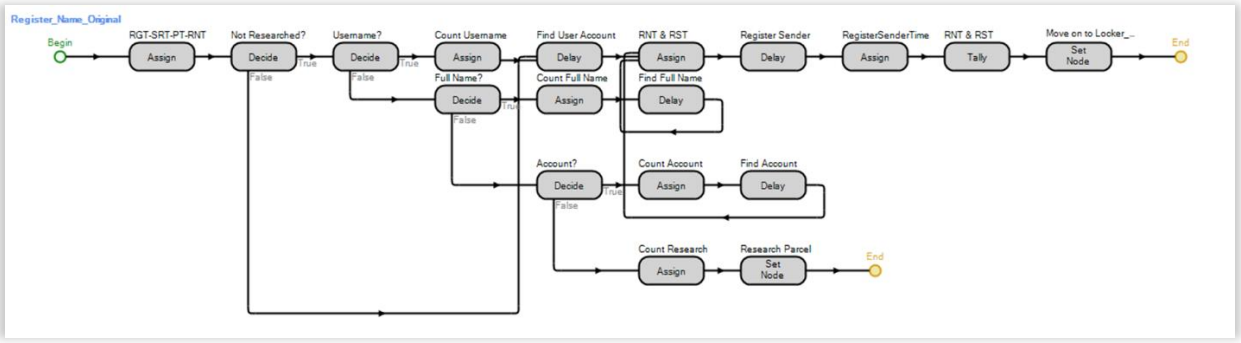

Figure 32: Registration Name & Sender

The parcel moves on to the next step of the registration process which consists of assign a locker to deliver the parcel to, shown in Figure 33. At the beginning of the process another entity variable is updated for analysis purposes. Although the parcels are sorted by size before the registration process starts, the registration employee might still doubt if this was done correctly. The sorting of the parcels by size is done with a trained eye, making it prone to errors. The registration employee is in the end responsible for the parcel fitting into the locker, so when there is doubt the parcel is measured. Once the size of the parcel is clear a locker is assigned and state variables for analyses purposes are updated. The final step for the registration employee is to print and apply the label so the parcel can be sorted.

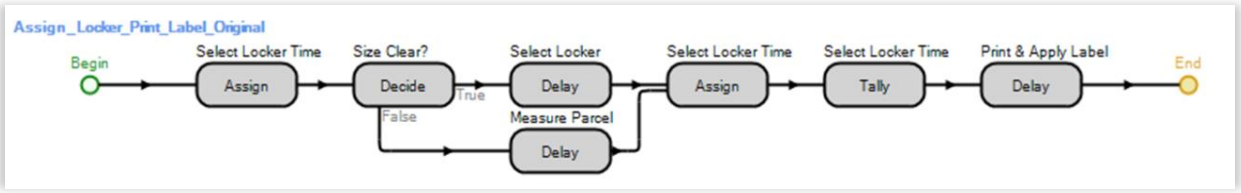

Figure 33: Assign Locker & Label

Upon entering the assign locker server, the parcels are assigned a location. Although each location has a different configuration of locker sizes and a different number of lockers it is assumed that there is always a locker available. The reason for this is that parcel needs to be registered eventually once a locker becomes available. Delaying this process and modelling this accurately requires a large part of modelling and data that falls outside the scope of this research. The delaying of the process of parcels that cannot be assigned to a locker due to lack of capacity, does not influence the performance of the overall process that is of interest. The time and effort required defeats the added value, making it slightly more realistic, of modeling this process. However, for route optimization the number of parcels that are delivered to each destination are of interest. Therefore, once a locker is assigned, the destination and size of the parcel are registered for analysis purposes. The process to acquire this data can be found in Appendix C.

6.3.2 Sorting Parcels

The parcel now continues to the final step in this base model, the sorting of the parcels. The sorting of the parcels is not a process that is redesigned. However, it is part of the process before parcels await transportation and is therefore of interest for the total processing time. The sorting process is illustrated in Figure 34 and sets parcels to a specific node based on their value of the entity variable location. The entire sorting process can be found in Appendix C. Upon exiting the final time-related variables are

updated and registered. The parcel is destroyed in the designated sink, but not before the incrementing state variables for parcel count for verification purposes.

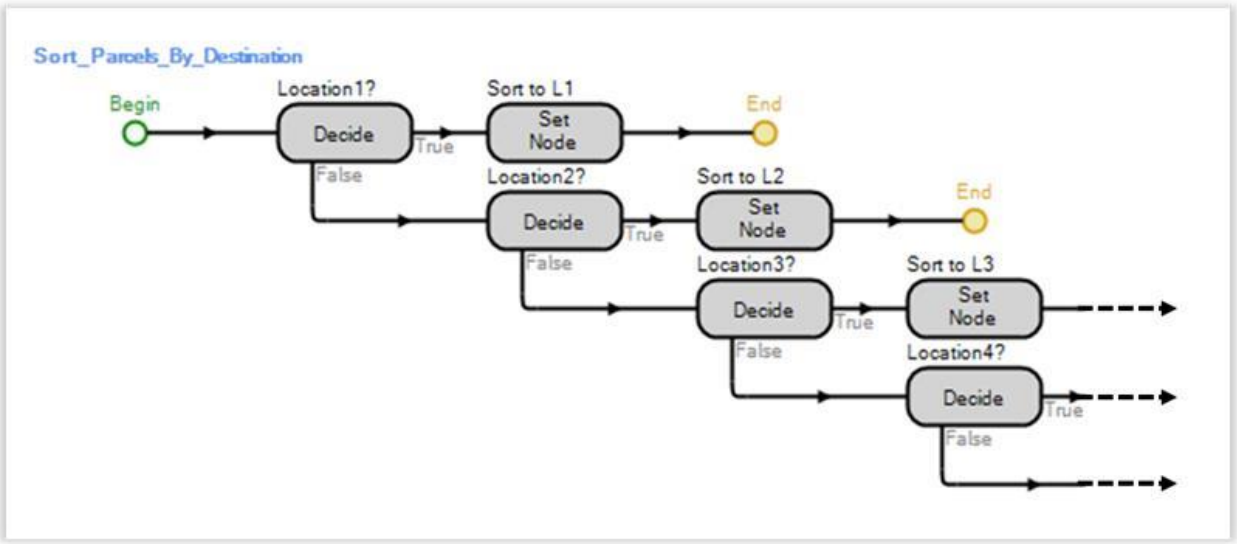

Figure 34: Sorting Parcels by Destination

6.3.3 Oversized Parcel Registration

The registration of oversized parcels is a separate issue, as the parcels do not fit in a locker, no registration in the system is required. Figure 35 shows the steps involved in the registration of oversized parcels. An oversized parcel is first assigned time-related state variables for analysis purposes. An employee must then attempt to identify the user by trying to find the corresponding account. Identifying the user by username or full name is of no use, as the more detailed information necessary is only shown in the account search. The employee then writes a label by hand, containing the destination and phone number of the user. Once the parcel has been provided with a label, an email is sent to the user stating MYPUP has received a parcel that is too big to fit into a locker and that the courier will contact the user, when at the location, to ask to personally collect the parcel directly from the courier. Upon exiting state variables are updated and registered for analysis purposes and parcels are sent for sorting.

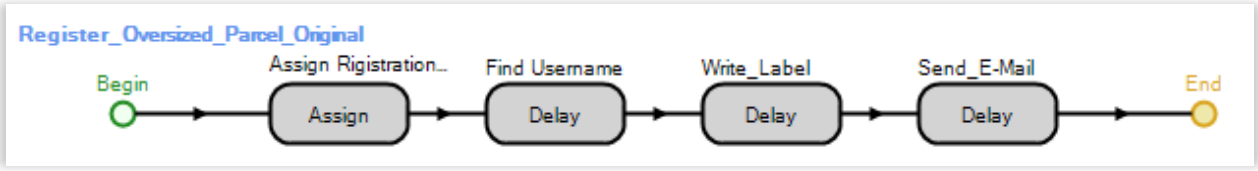

Figure 35: Registration Process Oversized Parcels

6.3.4 Research Parcel Process

The research process is a process that is of little interest as the process can in no way be improved or made more efficient. It is not possible to identify all users by researching the parcel. Based on probability a user is either identified and the parcel put back in the process or no user can be identified and the parcel is sent to a sink and destroyed. The sink represents a storage where parcel remains for three months and if still not identified, it is discarded.

6.4 Data & Calculations

Part of the data used in the model was obtained from the MYPUP database providing reliable data obtained over the course of a year, 2016. Historic data going back further than a year was also available, however since MYPUP is young and growing rapidly data older than a year results in lower values, different distributions and incomplete datasets. This would lead to the use of data that is no longer representative for the current situation.

Most of the data used in the model was obtained through observation, by measuring current process times and counting occurrences for distribution and probability calculations. All data can be found in the appendices. Not all process times and data could be obtained through observation or derived from the MYPUP database. Therefore, in some instances assumptions were made. The data used in the model and calculation related steps are discussed for each step were data or calculations were required.

6.4.1 Arrival Data

Arrival of parcels is based on data obtained from the MYPUP database and can be found in Appendix D. The parcel arrival distribution over the year 2016 is shown in Figure 36, showing a skewed right distribution. The data does not look to be normally distributed as is confirmed by results of the normality tests in *Table 5*. The data fails the both the Shapiro-Wilk (SW) test and the modified Kolmogorov-Smirnov test with the significance correction of Lilliefors (KSL). The SW test is considered the most powerful normality test when compared to the Anderson-Darling (AD), Kolmogorov-Smirnov (KS) and KSL test (Razali & Wah, 2011) (Saculinggan & Balase, 2013). The SW test is also better to use for small numbers and skewed distributions (Saculinggan & Balase, 2013) (Yap & Sim, 2011). The AD test is comparable in performance to the SW test but is not available in SPSS. The KSL test is available in SPSS and performs better than the KS test (Razali & Wah, 2011) (Saculinggan & Balase, 2013).

To determine if a gamma distribution or other distribution fits the data better a tool called EasyFit was used. The EasyFit tool uses the AD and KS tests to determine which distribution fits the data best. The performance of the AD test is considered better than the KS test and is therefore leading in the determination of the best distribution fit. The data was tested against all distributions offered in Simio plus variations of some distributions that cannot be excluded from the analysis. Therefore, the highest-ranking distribution that was available in Simio was chosen.

A three-parameter log-logistic distribution fit the arrival data over the entire year best. This suggests that the arrival data for the separate weekdays will probably also not be normally distributed.

Table 5: Normality Test Parcel Arrival Data Year

	SW-STATISTIC	SIG.	KSL-STATISTIC	SIG.
Year	0.881	0.000	0.114	0.000

When looking at the arrival distributions for each weekday the skewedness is in some cases even more extreme. For other weekdays, the skewedness is less compared with the data over the entire year. As the arrival data for each weekday is quite different from another. The model uses different arrival data for each day.

From the normality test results, obtained using SPSS, shown in Table 6, it can be concluded that none of the weekday distributions pass both normality tests. All arrival distributions, like the distribution over the entire year, are skewed right.

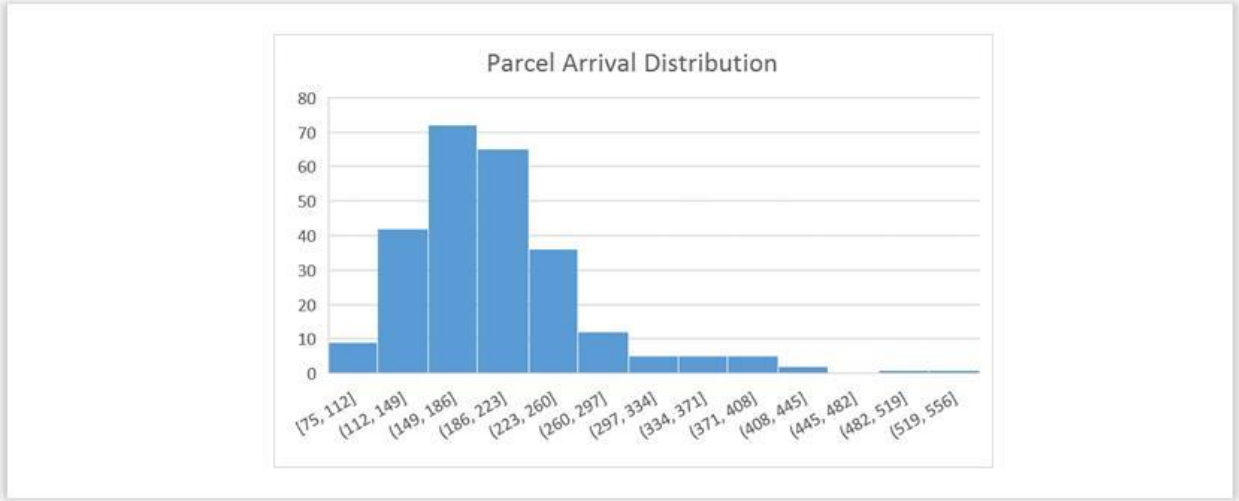

Figure 36: Parcel Arrival Distribution Skewed Right

Table 6: Normality Tests Parcel Arrival Data Weekdays

	SW-STATISTIC	SIG.	KSL-STATISTIC	SIG.
Monday	0.808	0.000	0.197	0.000
Tuesday	0.805	0.000	0.178	0.000
Wednesday	0.749	0.000	0.207	0.000
Thursday	0.857	0.000	0.189	0.000
Friday	0.948	0.024	0.121	0.054

The datasets for Monday through Friday have were tested with EasyFit; the results for Monday through Thursday are displayed in Table 7. Monday, Tuesday, Wednesday and Thursday data sets are log-logistically distributed. The corresponding parameters, shown in Table 7, were calculated in the distribution fit tests, where α is a continuous shape parameter and β is a continuous scale parameter. The values for the number of parcels on Monday through Thursday are drawn at random from their corresponding log-logistic distributions with the parameter values presented in Table 7.

The Friday dataset turned out to be log-normally distributed with a mean of 5.07 and a standard deviation of 0.281. The values for the number of parcels on a Friday are drawn at random from a log-normal distribution with the previously mentioned parameter values.

Table 7: Parcel Arrival Data Distribution Fit Tests

	TEST	KS-RANK	AD-RANK	A	B
Monday	Log-Logistic	2	3	6.1447	163.17
Tuesday	Log-Logistic	2	4	7.7197	235.72
Wednesday	Log-Logistic	4	4	7.4315	201.83
Thursday	Log-Logistic	6	2	6.8218	188.93

6.4.2 Registration data

The data used for the registration process is obtained through observation. The underlying data can be found in appendices E through J. The number of observations differ per process time as some processes occur more frequently than others. Once the number of around 50 observations was reached for each process time the data collection was seized. The process times within one process are expected to be similar, thus the data sets are expected to be normally distributed. Table 8 shows the number of observations and the outcomes of the normality tests.

Table 8: Normality Tests Internal Data

PROCESS	OBSERVATIONS	SW-STATISTIC	SIG.	KSL-STATISTIC	SIG.
Username	279	0.980	0.001	0.059	0.019
Full Name	86	0.980	0.219	0.080	0.200*
Account	47	0.986	0.834	0.074	0.200*
Sender	126	0.953	0.000	0.087	0.020
Measurement	51	0.956	0.056	0.094	0.200*
Writing Label	56	0.992	0.977	0.049	0.200*
Send Email	56	0.963	0.081	0.074	0.200*

*This is the lower bound of the true significance

The results from the normality tests show that most process time data are distributed normally. Only the username process time and the sender process time show significant P-values for both normality tests. Even though the SW-Statistic in both cases is high, which suggests a normal distribution, the P-values suggest otherwise. The sender process time data is skewed right, while the username process time data is skewed left. The username process time data and the sender process time data were tested against all distributions available in Simio using the EasyFit tool. The Johnson SB distribution is the best fit for the username process time data as it ranks first in both the AD and KS test. The log-normal distribution fits the sender process time data best. The Johnson SB distribution is relatively unknown, but is related to the normal distribution. However, the Johnson SB has four parameters which allows to better deal with skewedness than a normal distribution.

The distributions and corresponding parameters used for the process times in the model are summarized in Table 9. The parameters used in a Johnson SB distribution are α_1, α_2, the minimum value and the maximum value in the data set where α_1 and α_2 are continuous shape parameters. The normal mean and standard deviation are the parameters for the log-normal distribution of the sender process time.

The values for the process times are drawn at random from their corresponding distributions with the parameters presented in the table above. The process times for selecting a locker and printing and applying a label are assumed to be constant. There are no variables in play that can cause delay or cause a speedier completion of the process. Through observation the process time for selecting a locker is estimated at two seconds and the process time for printing and applying the label is estimated at seven seconds.

Table 9: Process Time Data Distributions & Parameters

	DISTRIBUTION	MEAN	STDV.	A_1	A_2	MIN	MAX
Username	Johnson SB	8.2	1.1	2.39	2.64	4.3	11.4
	DISTRIBUTION	MEAN	STDV.	NORMAL MEAN		NORMAL STDV.	
Sender	Log-Normal	9.4	2.1	2.09		0.14	
	DISTRIBUTION	MEAN	STDV.				
Full Name	Normal	18.5	3.0				
Account	Normal	32.9	4.2				
Measurement	Normal	11.9	3.4				
Writing Label	Normal	15.3	2.0				
Send Email	Normal	61.4	5.9				

6.4.3 Decision probabilities

In the many processes decide modules are found, which can either be condition-based or probability-based. The condition-based decide modules base their decision on variable values assigned to the entities to ensure the entity follows the right path through the model. The probability-based decide modules are based on probabilities that were calculated using the obtained data from the MYPUP database and through observation. Other distributions for assigning entity variable values are also calculated in the same way.

Size

The size distribution is based on the average configuration of lockers at all locations as no data is available. These average configuration is shown in Table 10. The share of the small and medium parcels seems to in line with the rough counts observed. However, the share of large parcels is not in line with these numbers. As counting the large parcels is much simpler and can be done in a reliable manner, large and oversized parcels are counted to correct for the misrepresentation of the share of large parcels and the absence of oversized parcels.

Table 10: Average Locker Configuration

SIZE	SHARE
Small	53%
Medium	38%
Large	9%

Over a period of twelve days the large and oversized parcel were counted. In total 56 oversized parcel were counted and 143 large parcels. The total number of parcels registered over those twelve days sums up to 2907 parcels. The total number of parcels equals the sum over the total registered parcels and the oversized parcels, 2963. By calculating the shares of large and oversized parcels, the remaining share can be used to calculate the new size distribution shown in Table 11.

Table 11: Size Distribution

SIZE	SHARE	SIZE	SHARE
Small	54.3%	Large	4.8%
Medium	39%	Oversized	1.9%

Registration path

The probabilities for the registration path, deciding if a username, full name or account can be found, are based on observed data shown in Table 12.

Table 12: Registration Path Probabilities

PATH	OBSERVATION	SHARE
Username	279	67.2%
Full Name	86	20.7%
Account	47	11.3%
Research	3	0.7%
Total	415	100%

Location

A location is assigned to the parcel using an empirical distribution defined by a set of value and cumulative probability pairs, that define a stepwise linear cumulative distribution function for a discrete random variable. The probabilities are calculated based on the average number of parcels delivered to each location. The averages can be found in Appendix K, the distribution is shown in Table 13.

Table 13: Location Distribution

LOCATION	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11
Probability	0.031	0.093	0.004	0.106	0.003	0.056	0.076	0.198	0.015	0.121	0.002
Cum. Prob.	0.031	0.124	0.128	0.234	0.237	0.293	0.369	0.567	0.582	0.703	0.705
LOCATION	L12	L13	L14	L15	L16	L17	L18	L19	L20	L21	
Probability	0.012	0.013	0.001	0.112	0.038	0.030	0.044	0.006	0.028	0.013	
Cum. Prob.	0.717	0.730	0.731	0.842	0.880	0.910	0.954	0.960	0.987	1.000	

Measurement

The probability that a parcel is measured by the registration employee is calculated based on observed data. Observing 623 registrations a total of 51 were measured by employees that were not sure if the parcel would fit in the locker. The probability that the parcel does not have to be measured equals to 0.918.

6.4.4 Capacity Data

The leftover count is increased based on decisions to see if the capacity at a certain location has been met; the capacities per location are the real capacities and can be found in Appendix L. The configurations

of the locations are included in the capacity check, so the results show the distribution of parcels by size per location.

The capacity of the servers in the registration process are set to two, as two employees can register parcels simultaneously. The number of employees that can work in the registration is limited by the number of available printers. The current number of available printers in the setup is two, thus the capacity of the registration process servers equals two.

7. Verification & Validation of the Base Model

Chapter 7 describes the steps that were taken to validate the process. Section 7.1 discussed the techniques derived from literature to verify and validate the model. The techniques are then applied and the results are discussed in Section 7.2. Finally, the results of the base model are presented and discussed in Section 7.3. All time values presented in this chapter and the next are in seconds.

7.1 Techniques

Model verification and validation is a big concern when developing models, as models often aid in decision making it is imperative that the model produces correct results (Sargent, 2013). Sargent (2013) defines verification as "ensuring that the computer program of the computerized model and its implementation are correct" and validation as "'substantiation that a model within its domain of applicability possesses a satisfactory range of accuracy consistent with the intended application of the model." Sargent (2013) recommends the minimum of an 8-step process based on research into verification and validation of simulation models. Not all steps are applicable in every situation, as is the case in this research; the steps that are taken consist of applying several validation techniques. From the validation techniques presented by Sargent (Sargent, 2013) appropriate techniques for the base model are chosen. The chosen techniques and a short description are shown in Table 14.

Table 14: Verification & Validation Techniques

TECHNIQUE	BRIEF DESCRIPTION
Data Relationship Correctness	Data must have correct values regarding the relationships that occur within a type of data
Degenerate test	Appropriate selection of input and internal parameters
Event validity	'events' occurrences are compared to those of the real system
Extreme condition test	Setting parameters to 0 or extreme values
Fixed values	Input and internal parameters are fixed, compare output with hand calculations
Internal Validity	Several replications are made to check consistent behavior
Parameter Validity	Sensitivity analysis to see the effect on the output
Traces	Behavior of different entities is followed through the model

7.2 Results

The techniques described in Section 7.1 have been applied and the results of the tests are discussed for each technique.

7.2.1 Data Relationship Correctness

Data relationship correctness is concerned with the correctness of the distributions of the data as well as computations made inside the model where different types of data are involved. In Section 6.3 the distributions of the data are discussed, ensuring the distribution fits the data correctly. Within the model several model state and entity state variables are assigned values and these values are changed along the way. The time values are calculated using the old value and the TimeNow values which all have the same

unit of time. Count variables are only incremented or decremented and do not interact with other variables, they are either used for verification and validation purposes or used to compare values with available capacity. Through manual inspection it can be stated that no unit errors exist in the base model.

7.2.2 Degenerate test

Degenerate tests are done to see if internal values change as expected when altering the input parameters. To this extent, a daily arrival pattern of 500 parcels was compared to an arrival pattern of 100 parcels per day. The tests showed that the average number of parcels waiting for the registration server is 6.83 and the maximum number waiting in queue is 293 parcels with 500 parcels arriving daily. While the average number of parcels waiting with a daily arrival of 100 parcels is 0.26 and the maximum number of parcels waiting equals 58. As expected the average number of parcels in queue and the maximum number of parcels in queue are significantly lower for the 100 parcels per day arrival pattern.

7.2.3 Event Validity

One way of testing if the probabilities in the model have been modeled correctly is to assess the location distribution. Over 50 replications with a run length of 4 weeks the location distributions produced quite similar values as the observed distribution. The results are shown in Table 15. The models' probabilities of events occurring in the model match the observed probabilities of events happening almost perfectly.

Table 15: Location Distribution Validation

	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11
Estimated	120	362	15.2	408	10.9	220	296	779	59.0	473	7.90
Observed	110	334	13	380	12	200	273	710	54	433	8
Est. Share	3%	9%	0%	10%	0%	6%	8%	20%	2%	12%	0%
Obs. Share	3%	9%	0%	11%	0%	6%	8%	20%	2%	12%	0%
	L12	L13	L14	L15	L16	L17	L18	L19	L20	L21	
Estimated	46.7	50.3	3.96	429	146	114	171	23.5	105	51.1	
Observed	44	46	2	400	135	107	157	22	99	46	
Est. Share	1%	1%	0%	11%	4%	3%	4%	1%	3%	1%	
Obs. Share	1%	1%	0%	11%	4%	3%	4%	1%	3%	1%	

7.2.4 Extreme Conditions test

An extreme condition test is done changing the server and resource capacities to zero and to 5000. From Table 16 it becomes clear that then no capacity is available the model is overloaded due the creation of too many entities that are created without entities being destroyed. As expected no parcels are registered in the no capacity scenario resulting in the absence of throughput time and process time. When the capacity for all servers and resources is set to 5000 the throughput time of the parcels decreases by over 1400 seconds. The throughput time cannot get much lower as the parcels arrive at 9:00 and are held till 13:00 or longer (14,400 seconds). On average a parcel is held up about 200 seconds past 13:00 before being released for registration, as different sizes are held till the previous size is completely registered. The Process slightly improves as the only time spent waiting during the registration process is when the parcel is waiting to be sorted; a process that is assumed to take one second as it is not of interest in this research.

Table 16: Extreme Condition Test Results

	BASE	CAPACITY 0	CAPACITY 5000
Throughput Time (s)	16,071	-	14,641
Process Time (s)	38.75	-	37.89
Number Entered	3898	2568	3918
Number exited	3898	0	3918

7.2.5 Fixed Value Analysis

The fixed values used for the analysis are the means that were previously determined based on the obtained data. The parcel counts per path in the registration process allows for the manual calculation of the average registration time; the values used for the manual calculation are presented in Table 17. The registration time for each path and the distribution along the paths is shown in Equation 1.

Equation 1: Average Registration Time

$$Average\ Registration\ Time = \frac{T_u * N_U + T_f * N_f + T_a * N_a + T_r * N_r + T_o * N_o + T_{al} * N_{al} + T_m * N_m + T_p * N_p}{N_{Total}}$$

Table 17: Fixed Value Analysis Data

REG. PROCESS	$T_X N_X$	TIME (S)	OBSERVATIONS	TOTAL TIME (S)
Username	$T_u N_u$	8.2	2723	22328.6
Full Name	$T_f N_f$	18.5	799	14781.5
Account	$T_a N_a$	32.9	445	14640.5
Research	$T_r N_r$	180	24	4320
Oversized	$T_o N_o$	84.9	92	7810.8
Sender	$T_s N_s$	9.4	3967	37289.8
Measure	$T_m N_m$	11.9	302	3593.8
Assign Locker	$T_{al} N_{al}$	2	3665	7330
Print Label	$T_p N_p$	7	3967	27769
Total				135544

The average registration time produced by the model equals 33.3934, where the manual calculation of the registration time average equals 33.3945. The averages are nearly identical and only differ a little less than one thousandth of a second.

7.2.6 Internal Validity

For the validation of the internal validity the statistical analysis for terminating simulation proposed by Law (2010) is applied. The method determines the confidence interval at a 95% confidence level and compares the half width to the estimated average. Table 18 shows the time averages over 50 replications with their corresponding standard deviations, half widths and minimum and maximum values. The model produces no strange minimum and maximum values and the standard deviations are relatively low.

Furthermore, the confidence interval is quite precise, for all times recorded less than 0.5% of the corresponding estimated average.

Table 18: Replication Results

TIME (S)	AVERAGE	STD. DEV.	HALF WIDTH	MIN	MAX
Process Time	38.75	0.1567	0.0448	38.36	39.13
RT Overall	30.88	0.1705	0.0487	30.40	31.28
RT S-M-L	29.88	0.1365	0.0390	29.46	30.19
RT Oversized	82.97	0.7357	0.2102	80.83	84.43
RT Username	11.89	0.1355	0.0387	11.50	12.27
RT Sender	8.16	0.0190	0.0054	8.11	8.20
Set Locker Time	2.82	0.0492	0.0141	2.72	2.95

7.2.7 Parameter Sensitivity Analysis & Traces

Sensitivity analysis and traces were used through the construction of the model. Unexpected values in the output data were regularly the trigger to identify the entities that produced these values and trace their steps through the model. Entities producing minimum and maximum values for the time variables were traced to check if these values were feasible and were computed in a correct manner. The process was repeated until all values could be explained.

7.2.8 Conclusion

The verification and validation tests all produced positive results validating the model in different ways. The base model is considered to be validated and it performs as intended. The base model is serves as a basis from which modifications can be made to model the new design and its parts.

7.3 Base Model Results

To test the performance of the model and the improvements introduced in Chapter 4 several criteria are defined. The criteria are concerned with the process times within the registration process to give insight in how the overall registration time is computed.

7.3.1 Process Time Indicators

The process time is the time from the moment the parcel is picked by the registration employee until the moment the parcel is sorted in the designated crate. However, the focus of this research in on the registration process in particular. This is the time from the moment a parcel is picked by the registration employee until the moment the parcel is put aside by the registration employee to be sorted. The process time is of interest as the sorting of the parcels could become a bottle neck if the average registration time becomes less than twice the average sorting time. This would mean parcels would spent time waiting for the sorting employee to be sorted. The registration time for small, medium and larger parcels is of interest to see the effect of improvements to the registration process without the influence of the registration time of oversized parcels. The registration time of oversized parcels is about 2.5 times as long on average than the registration of small, medium and large parcels. The remaining time data provide insight into which part of the registration process contributes to the improvements to the overall registration time.

7.3.2 Results Process Time Indicators Base Model

The results produced by the base model are presented in Table 19 and are used to test if improvements from the new design have a significant effect. The validity of the results has been previously discussed. The run length is four weeks and no warm-up time is necessary as the process is a terminating system and the system is empty at the start in reality as well. All results that are obtained from here on forward are obtained from 50 replications.

Table 19: Base Model Results

TIME (S)	AVERAGE	STD. DEV.	MIN	MAX
Process Time	38.75	0.1567	24.26	105.85
RT Overall	30.88	0.1705	19.80	97.89
RT S-M-L	29.88	0.1365	19.80	72.85
RT Oversized	82.97	0.7357	67.99	97.89
RT Username	11.89	0.1355	4.99	45.71
RT Sender	8.16	0.0190	4.88	13.42
Set Locker Time	2.82	0.0492	2.00	27.10

To see if the distinction between the overall registration time and the small, medium and large registration time is just, a paired sample t-test is performed. The results that can be found in Appendix N show that the difference in mean is significantly different as the p-value is smaller than 0.001.

8. Experiments

At first MYPUP will only implement OCR, other parts of the redesign may be implemented later. To uncover which parts of the new design have the most impact on the criteria different variations the model consisting of different combinations of parts of the redesign are tested. In Section 8.1 the effects of all parts are tested separately. Combinations of OCR and other registration process related parts are tested in Section 8.2, where the complete design is tested in Section 8.3.

8.1 Separate Part Testing

All parts of the redesign are tested separately to see if parts have a significant impact on the before mentioned criteria. Parts that do not have a significant impact need to be reconsidered. Furthermore, these tests will allow for prioritizing parts of the design for implementation.

8.1.1 OCR Only

At first only the implementation of using OCR in the registration process is modeled. The new process, shown in Figure 37, is vastly different from the original manual approach. In the new process the first step is to take a picture and send it to the OCR API by the click of a button. The API processes pictures within a second so the entire process of taking the picture and returning the text is assumed to take 2 seconds. If a user is identified the parcel is ready to be assigned a locker; if not the parcel must be registered manually and is sent to the original registration process shown in Figure 32. There is no longer need for registering the sender as the picture, containing the enough information to identify a parcel, is assigned to the registration. The results of the addition of OCR in the registration process are shown in Table 20.

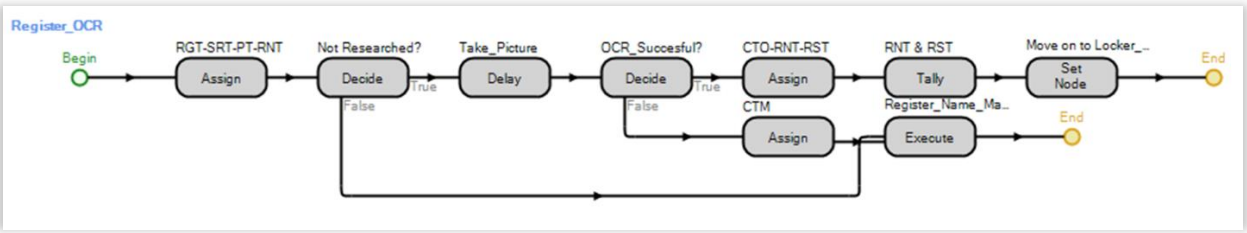

Figure 37: Registration Process OCR

An independent t-test comparing the means of the base model to the means of the OCR only model shows the oversized registration time and the set locker time are not influenced by the altercation to the model, with a p-value larger than 0.05. A complete overview of the results can be found in Appendix N. As expected the time to register the name and sender of a parcel both show a big decrease in averages. As the majority of parcels can be registered using OCR the reduction in time to register the name and sender influences the overall registration time and the process time greatly. The differences in time to register the name and sender, the overall registration and the process time were expected to be significant and the independent t-test confirms this as the p-values were smaller than 0.001. The registration time for small, medium and large parcels has also been reduced significantly with a p-value smaller than 0.001. The reduction in registration time for small, medium and large parcels is slightly larger than the reduction in overall registration time as the implementation of OCR does not affect the registration time of oversized parcels. The reduction in the total process time of the parcel is lower than the reduction of the overall registration time. This is caused by an accumulation of the parcels at the sorting process.

Table 20: Results OCR Only

TIME (S)	AVERAGE BASE MODEL	STDV. BASE MODEL	AVERAGE OCR ONLY	STDV. OCR ONLY
Process Time	38.75	0.1567	33.32	0.9735
RT Overall	30.88	0.1705	17.09	0.2232
RT S-M-L	29.88	0.1365	15.82	0.1752
RT Oversized	82.97	0.7357	83.19	0.6422
RT Username	11.89	0.1355	3.99	0.1071
RT Sender	8.16	0.0190	3.22	0.0412
Set Locker Time	2.82	0.0492	2.82	0.0566

As part of the parcels still need to be registered manually, two solutions to improving the manual registration process are also tested.

8.1.2 New Layout only

The new layout of the registration screen shown Figure 22, will make it easier to register parcels manually. To test the sole effect of the new layout a model was created where the registration process in Figure 32 is replaced by a modified version of the process. Figure 38 shows the part of the process that was modified on the left and its modification on the right. In the original situation, the sender is registered manually by typing the name of the sender manually. The new situation decides whether the parcel sender is one of the eight most frequent web shops or eight of the most frequent courier services. The decision is based on a probability that was calculated using sender data obtained from MYPUP database of 45,637 parcels. In 43% of the cases the sender of the parcel is one of the 16 largest senders. Instead of having to type the senders name manually, 43% of the time a simple mouse click will register the sender. The mouse click is assumed to take two seconds as it is as simple as clicking a button. The employee does however have to locate the right button first assuming it takes two seconds instead of one. No real data can be obtained through observation as the new layout of the registration screen has not been implemented yet. The remaining 57% of the parcel sender are registered in the same way as in the old situation. The results of implementing this new layout are shown in Table 21.

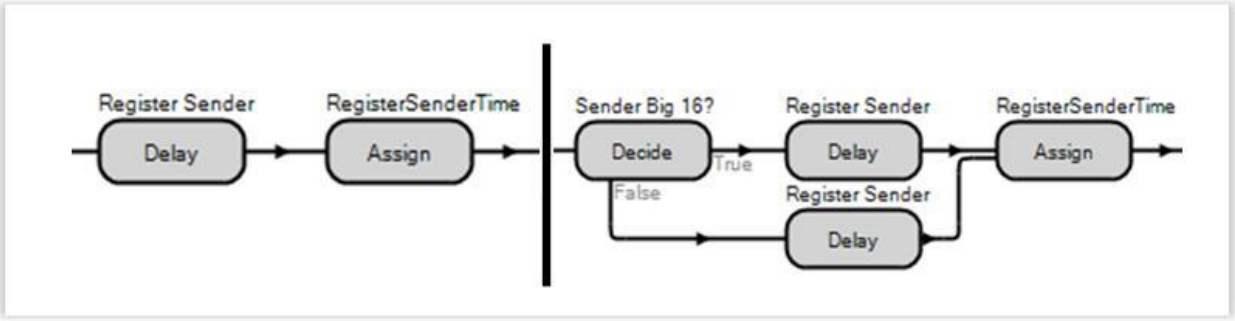

Figure 38: Registration Process Layout Alteration

An independent t-test comparing the means of the base model to the means of the layout only model shows the username registration time, the oversized registration time and the set locker time are not influenced by the altercation to the model, with a p-value larger than 0.05. A complete overview of the

results can be found in Appendix N. As expected the sender registration time is significantly different from the base model, with a p-value smaller than 0.001, as the new layout allows for easier selection of the sender. The impact of the change in sender registration time is big enough to produce significantly different values for the average process time, overall registration time and the small, medium and large parcel registration time; all showing p-values smaller than 0.001.

Table 21: Results Layout Only

TIME (S)	AVERAGE BASE MODEL	STDV. BASE MODEL	AVERAGE LAYOUT ONLY	STDV. LAYOUT ONLY
Process Time	38.75	0.1567	36.28	0.1961
RT Overall	30.88	0.1705	28.28	0.2097
RT S-M-L	29.88	0.1365	27.22	0.1534
RT Oversized	82.97	0.7357	83.04	0.7218
RT Username	11.89	0.1355	11.90	0.1399
RT Sender	8.16	0.0190	5.51	0.0553
Set Locker Time	2.82	0.0492	2.82	0.0434

8.1.3 Search Query Only

The search query redesign is one that will allow for faster identification of the user. Instead of having to enter the username first, if not found the full name and if that is not found do an account search the search query is adjusted to incorporate all in one. Starting to type the name will not just search for the user by username but at the same time compare the information with full names and account information. If multiple accounts match, then the account that corresponds with the information can be chosen by the employee manually. The process prevents employee of having to type the name on the address label into three different search boxes, like in the original registration process show in Figure 32. The adjustment of the search algorithm incorporated in the registration process is shown in Figure 39. The time it takes to find a user in the database is assumed to be equal to the time it takes to find a user by username as only one entry of the name is required. The results of adjusting the search algorithm are shown in Table 22.

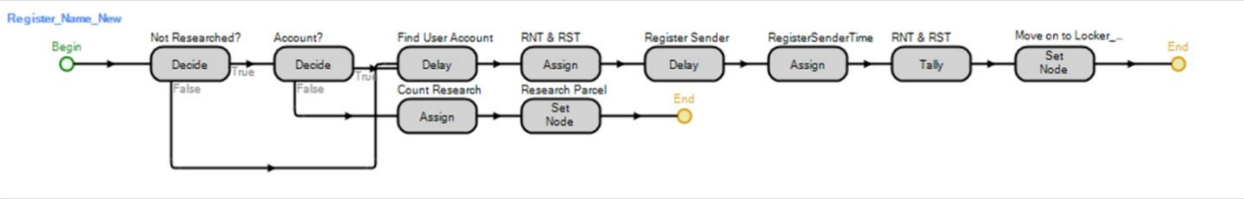

Figure 39: Registration Process Search Query

An independent t-test comparing the means of the base model to the means of the search query only model shows the sender registration time, the oversized registration time and the set locker time are not influenced by the altercation to the model, with a p-value larger than 0.05. A complete overview of the results can be found in Appendix N. As expected the username registration time is significantly different from the base model, with a p-value smaller than 0.001, as the search query only requires entering information to find the name once. The impact of the change in username registration time is big enough

to produce significantly different values for the average process time, overall registration time and the small, medium and large parcel registration time; all showing p-values smaller than 0.001.

Table 22: Results Search Query

TIME (S)	AVERAGE BASE MODEL	STDV. BASE MODEL	AVERAGE SEARCH QUERY ONLY	STDV. SEARCH QUERY ONLY
Process Time	38.75	0.1567	33.67	0.1548
RT Overall	30.88	0.1705	25.50	0.1571
RT S-M-L	29.88	0.1365	24.38	0.0522
RT Oversized	82.97	0.7357	82.97	0.6518
RT Username	11.89	0.1355	6.39	0.0079
RT Sender	8.16	0.0190	8.16	0.0202
Set Locker Time	2.82	0.0492	2.83	0.0489

8.1.4 3D Camera Only

The addition of a 3D camera to the new design ensures no errors can be made in determining the size of a parcel. Furthermore, there is no longer need for employees to measure parcels when they doubt the size or select a locker size as all this is determined by the 3D camera. This results in a simplified version of the original process, shown in Figure 33, where the new process excludes all steps associated with assigning the locker as the 3D camera is triggered automatically when a user is identified. The sole process that remains is printing and applying the label as is shown in Figure 40. The results from implementing a 3D camera are shown in Table 23.

Figure 40: Assign Locker & Label 3D Camera

An independent t-test comparing the means of the base model to the means of the 3D camera only model shows the username registration time, the sender registration time and the oversized registration time are not influenced by the altercation to the model, with a p-value larger than 0.05. A complete overview of the results can be found in Appendix N. As expected the set locker time is significantly different from the base model, with a p-value smaller than 0.001, as the use of a 3D camera automatically assigns a locker, triggered by and simultaneous to registering the username. Selecting a locker no longer causes a delay and this impact is big enough to produce significantly different values for the average process time, overall registration time and the small, medium and large parcel registration time; all showing p-values smaller than 0.001.

Table 23: Results 3D Camera Only

TIME (S)	AVERAGE BASE MODEL	STDV. BASE MODEL	AVERAGE 3D CAMERA ONLY	STDV. 3D CAMERA ONLY
Process Time	38.75	0.1567	36.13	0.1737
RT Overall	30.88	0.1705	28.14	0.1784
RT S-M-L	29.88	0.1365	27.06	0.1698
RT Oversized	82.97	0.7357	83.10	0.7536
RT Username	11.89	0.1355	11.89	0.1538
RT Sender	8.16	0.0190	8.16	0.0145
Set Locker Time	2.82	0.0492	0	0

8.1.5 Oversized Parcel Registration

The redesign of the registration process of oversized parcels, basically allows for the parcels to be registered in a more analogous way to the other parcels. An employee can try to identify the user by using the new search query and select an oversized locker. By hitting the print button an automated email is sent to the user and the phone number and location are printed on the label. The handwritten label and manual sending of the email in the original process, shown in Figure 35, are eliminated. The new process is illustrated in Figure 41 and the corresponding results are shown in Table 24.

Figure 41: New Registration Process Oversized Parcels

An independent t-test comparing the means of the base model to the means of the new registration process for oversized parcels model shows the small, medium and large parcel registration time, the username registration time, the sender registration time and the set locker time are not influenced by the altercation to the model, with a p-value larger than 0.05. A complete overview of the results can be found in Appendix N. As expected oversized parcel registration is significantly different from the base model, with a p-value smaller than 0.001, as manual actions have been automated in the new design. The impact of the change in oversized parcel registration time is big enough to produce significantly different values for the average process time and overall registration time; both showing p-values smaller than 0.001.

Table 24: Results Oversized Registration Process Redesign

TIME (S)	AVERAGE BASE MODEL	STDV. BASE MODEL	AVERAGE NEW OVERSIZED	STDV. NEW OVERSIZED
Process Time	38.75	0.1567	37.47	0.1570
RT Overall	30.88	0.1705	29.57	0.1587
RT S-M-L	29.88	0.1365	29.88	0.1682
RT Oversized	82.97	0.7357	13.89	0.0585
RT Username	11.89	0.1355	11.89	0.1495
RT Sender	8.16	0.0190	8.17	0.0189
Set Locker Time	2.82	0.0492	2.82	0.04736

8.1.6 Results based on part separate part implementation

The averages that have change by the separate parts are shown in Table 25. The solution that shows the biggest reduction for each time measure is colored dark green, the second best light green, third best yellow and fourth best orange. Averages that were not affected have be left out of the table. The implementation of OCR in the registration process shows the biggest reduction in registration times in most categories. Therefore, OCR should be implemented first based on the individual reductions of the overall registration time. To The search query and layout implementations suggest that a further reduction in registration time can be accomplished by improving the username and sender registration processes. However, the reduction will be less compared to the results from when they are implemented with no other alterations. The reduction in impact is expected, because a substantial portion of the parcels will be registered using OCR in which the search query and layout solutions are obsolete. However, the parcels that cannot be registered using OCR are still registered manually and will be affected by the search query and layout improvements to the manual registration process. To test if these additions still impact the average process and registration times significantly the two solutions will be tested separately in combination with OCR 0

The impact of the 3D camera is expected to increase as the average overall registration time is almost half of the base scenario. The new design for registration of oversized parcels has a significant impact on the process and registration times as well. This impact is expected to increase when compared to a lower average overall registration time.

Table 25: Changed Averages by Separate Parts

TIME (S)	BASE	OCR	LAYOUT	SEARCH QUERY	3D CAMERA	NEW OVERSIZED
Process Time	**38.75**	**33.32**	**36.28**	**33.67**	**36.13**	**37.47**
RT Overall	**30.88**	**17.09**	**28.28**	**25.50**	**28.14**	**29.57**
RT S-M-L	**29.88**	**15.82**	**27.22**	**24.38**	**27.06**	
RT Oversized	**82.97**					**13.89**
13.RT Username	**11.89**	**3.99**		**6.39**		
RT Sender	**8.16**	**3.22**	**5.51**			
Set Locker Time	**2.82**		**0**			

8.2 OCR Registration Combinations

The parts that were tested separately are tested again to see if their impact is still significant in combination with OCR. A combination of the registration process parts is also tested to see the effect of the combination of the parts. If the parts separate impact is not significant the combination of parts might have a significant impact. The parts separate impacts are of interest in prioritizing the parts for implementation.

8.2.1 OCR & New Layout

This model replaces the registration process in Figure 32: Registration Name & Sender Figure 32 by a combination of the processes presented in Figure 37 and Figure 38. The users that are not identified using OCR are sent to the manual registration process with the new layout of the registration screen. The rest of the process remains unaltered. The results from this configuration are shown in Table 26. Only the processes known to be influenced by the combination of solutions are displayed; a complete overview of the results can be found in Appendix N.

Table 26: Results OCR + New Layout

TIME (S)	AVERAGE OCR ONLY	STDV. OCR ONLY	AVERAGE OCR + LAYOUT	STDV. OCR + LAYOUT
Process Time	33.32	0.9735	34.83	1.4790
RT Overall	17.09	0.2232	16.60	0.1937
RT S-M-L	15.82	0.1752	15.32	0.1428
RT Sender	3.22	0.0412	2.70	0.0375

As expected the sender registration time decreased and found to be significant with a p-value smaller than 0.001. The impact of the new layout on the average process time, overall registration time and small, medium and large parcel registration time is still big enough to cause significant differences in their averages; all showing p-values smaller than 0.001.

8.2.2 OCR & Search Query

In this model, the registration process in Figure 32 is replaced by a combination of the processes presented in Figure 37 and Figure 39. The users that are not identified by OCR are sent to the manual registration process with an adjusted search algorithm. The results from the OCR and search query combination are shown in Table 27. Once again only the relevant criteria that are influenced by the search query adjustment are displayed; a complete overview of the results can be found in Appendix N. The impact of the adjustment to the search query on the username registration time and on the process time, overall registration time and small, medium and larger parcel registration time is significant. All average comparisons are significant with p-values of less than 0.001.

Table 27: Results OCR + Search Query

TIME (S)	AVERAGE OCR ONLY	STDV. OCR ONLY	AVERAGE OCR + SEARCH QUERY	STDV. OCR + SEARCH QUERY
Process Time	33.32	0.9735	36.17	1.8917
RT Overall	17.09	0.2232	15.99	0.2026
RT S-M-L	15.82	0.1752	14.72	0.1173
RT Username	3.99	0.0412	2.87	0.0307

8.2.3 OCR & 3D Camera

The registration process combining the OCR process from Figure 37 and the assign and print label process from Figure 40 are used in combination with the original manual registration process from Figure 32. There is no longer need for the employee to measure or assign a locker as this is done automatically. The results from this configuration are shown in Table 28. The table only displays the relevant criteria that whose differences in averages was found to be significant with p-values of smaller than 0.001. The impact of the 3D camera on the change in average process time, overall registration time and has increased as the average values are smaller compared to the base model.

Table 28: Results OCR + 3D Camera

TIME (S)	AVERAGE OCR ONLY	STDV. OCR ONLY	AVERAGE OCR + 3D CAMERA	STDV. OCR + 3D CAMERA
Process Time	33.32	0.9735	85.34	8.8579
RT Overall	17.09	0.2232	14.30	0.2161
RT S-M-L	15.82	0.1752	12.98	0.1772
Set Locker Time	2.82	0.0412	0	0

8.2.4 OCR & New Oversized Parcel Registration Design

The registration process combining the OCR process from Figure 37 and new oversized parcel registration process from Figure 41 are used in combination with the original manual registration process from Figure 32. This configuration is run to be able to assess the impact of a new oversized parcel registration process with OCR as a reference case. Table 29 shows the relevant results; a complete overview of the results can be found in Appendix N.

Table 29: Results OCR + New Oversized Parcel Registration Design

TIME (S)	AVERAGE OCR ONLY	STDV. OCR ONLY	AVERAGE OCR + OVERSIZED	STDV. OCR + OVERSIZED
Process Time	33.32	0.9735	32.16	0.9808
RT Overall	17.09	0.2232	15.78	0.1356
RT Oversized	83.19	0.0412	13.39	0.0621

8.2.5 OCR Combinations Results Comparison

The results of the OCR combinations are compared in Table 30. The solution that shows the biggest reduction for each time measure (row) is colored dark green, the second best light green, third best yellow and fourth best orange. Averages that were not affected have be left out of the table.

Table 30: Results OCR Combinations

TIMES (S)	OCR	LAYOUT	SEARCH QUERY	3D CAMERA	NEW OVERSIZED
Process Time	**33.32**	**34.83**	**36.17**	**85.34**	**32.16**
RT Overall	**17.09**	**16.60**	**15.99**	**14.30**	**15.78**
RT S-M-L	**15.82**	**15.32**	**14.72**	**12.98**	
RT Oversized	**83.19**				**13.89**
RT Username	**3.99**		**2.87**		
RT Sender	**3.22**	**2.70**			
Set Locker Time	**2.82**			**0**	

The first thing that stands out is that the process time starts increasing when the small, medium and large parcel registration time decreases further. This is caused by an accumulation of parcels that are registered and await sorting. The registration process can continue while the parcels await sorting as enough space is available.

The second thing that stands out that the reduction of the average overall registration time is caused in a different part of the registration process for each solution. Implementing one solution will therefore not affect the relative impact of reduction of the other solutions. The solution that shows the biggest time reduction in overall registration time and small, medium and large parcel registration time is the 3D camera. The second biggest impact on time reduction in overall registration time is achieved by redesigning the oversized parcel registration process, closely followed by the third biggest impact achieved by the search query solution. The least reduction in overall registration time is achieved with the new layout solution. However, the reduction has proved to be significant.

8.3 Complete Design

The complete design is a design where all previous described solutions are implemented in the model. The original registration process is replaced with a combination of the OCR process from Figure 37 and a new manual registration process combining the new layout and search query as presented in Figure 42. Additionally, it also replaces the assign locker label process from Figure 33 with the modified process shown in Figure 40 representing the use of a 3D camera. The results are compared in Table 31; a complete overview of the results can be found in Appendix N.

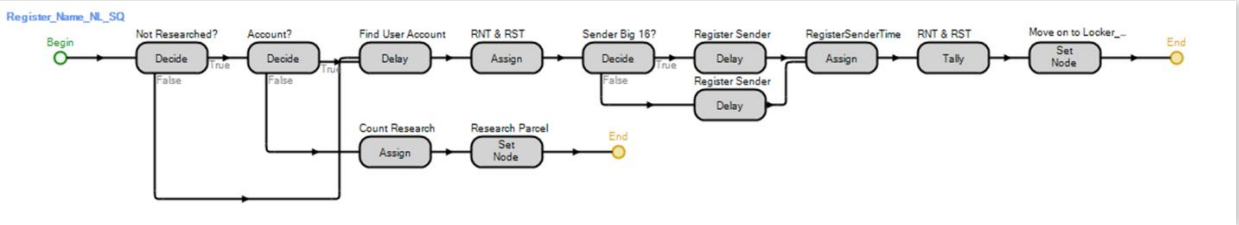

Figure 42: Manual Registration Process New Layout & Search Query

The process time in the complete design has increased as the overall registration time has become so low that the parcels pile up awaiting sorting. The substantial increase in process time suggests enough room is needed to temporarily store the parcels. The overall registration time and the small, medium and large parcel registration time hardly differ anymore as the oversized parcel registration time has substantially reduced to nearly the overall registration time. The small volume of oversized parcels causes the overall registration time to approach the small, medium and large parcel registration time whose value is determined by 98% of the parcel volume.

The username registration time and sender registration time have moved closer to each other as the registration of the name and sender using OCR is done simultaneously and only takes two seconds. The average username registration time and sender registration time are higher than two as not all parcels can be registered using OCR. These parcels follow the manual registration process which has also been improved, by layout and search query adjustments.

Table 31: Results: Base Model, OCR Only & Complete Model

TIME (S)	AVERAGE BASE	STDV. BASE	AVERAGE OCR	STDV. OCR	AVERAGE COMPLETE	STDV. COMPLETE
Process Time	38.75	0.1567	33.32	0.9735	155.86	14.15
RT Overall	30.88	0.1705	17.09	0.2232	11.40	0.0776
RT S-M-L	29.88	0.1365	15.82	0.1752	11.36	0.0793
RT Oversized	82.97	0.7357	83.19	0.6422	13.41	0.0828
RT Username	11.89	0.1355	3.99	0.1071	2.87	0.0270
RT Sender	8.16	0.0190	3.22	0.0412	2.70	0.0339
Set Locker Time	2.82	0.0492	2.82	0.0566	0	0

The complete implementation of the design can reduce the overall registration time to almost a third as to what it is now. The time that is saved in the registration process increases the capacity per hour almost three time. The results show that the 3D camera is the best solution after OCR is implemented followed by the redesigned oversized parcel registration process, the new search query, and the new layout of the registration screen.

All solutions that were offered can be implemented to improve the MYPUP process and are tailored specifically for the MYPUP process. Similar processes that deal with consolidation, registration and redistributions of goods can however look to the solutions that were tested. The alternative approach to OCR has been found to be a cheap and feasible alternative to the expensive existing OCR solutions. Parties interested in extracting text from an object can use this approach in combination with a case specific

algorithm. The 3D camera is only of interest to parties interested in the size of an object contributing to time reduction and error elimination. Other software related solutions in the model were very specific for MYPUP. However, they showed that the layout of a system, the algorithms behind search queries and standardized digital actions can present opportunities to make a process more efficient. Opportunities for improving efficiency do not just lie in the physical processes, but also in the digital world. Any process that requires input into digital systems or digitally performed tasks can benefit from the proposed solutions.

9. Conclusions & Recommendations

This chapter summarizes the findings of the research and the conclusions that follow from the results. It also presents recommendations for future work. The findings throughout this research and the conclusions drawn from the model results are presented in Section 9.1. Section 9.2 then reverts to the main research question and the sub questions formulated at the beginning of this research. Finally, recommendations to MYPUP and direction for general research are presented in Section 9.3.

9.1 Main Findings & Model Results

This section presents the main findings that have been identified and discussed throughout the report. Furthermore, it outlines the conclusions based on the results obtained from the models.

9.1.1 Main findings

The CEP market is a rapidly developing market which is expected to follow a trend of rapid changes. These changes are driven by the continuing volume growth of parcels showing an average growth of 6.2% over 2009-2014 (Accenture Consulting, 2015). The innovation in the CEP market is also driven by the trend shown in the market of moving towards sustainability. This movement towards sustainability is mainly driven by emerging government restrictions, concerning the last mile deliveries (Lindholm, 2012) (Russo & Comi, 2010). The best solution to solve the last mile problem within B2C logistics is decoupling the presence of the final customer and the delivery (Holdorf & Haasis, 2014). A solution like electronic parcel lockers manages to do exactly that. Many different approaches to using electronic parcel lockers exist, although in the Netherlands, no approach stands out and is applied on a large scale yet. One approach that is picking up and growing rapidly is the approach where electronic lockers are installed at the workplace. MYPUP is one of the companies who implements this approach and is confronted with new challenges as they grow. The logistics process especially, is becoming a challenge as volumes increase.

The MYPUP approach is found to be unique in its sort as MYPUP consolidates all parcels from all parcel delivery services, registering them and delivering the parcels into the lockers themselves. Disregarding the sole purpose of delivering parcels and delivering them into electronic parcels lockers, the consolidation and redistribution of goods show similarities with urban distribution centers. The reliability and responsibility of safely delivering the parcels to the end-consumer transfers from the parcel delivery services to MYPUP upon delivery at the consolidation center. This research was first approached as an optimization study of the logistics at a small-scale city logistics facility. However, it turned out the logistics process was not in need of optimization, but in need of redesign. To this extent, a new methodology was developed resulting in redesigning the MYPUP logistics process and co-innovation in the process. Combining the findings of the author with problems identified in brainstorm sessions led to several problems to be addressed.

One of the main problems MYPUP is faced with is collecting all parcels in time to ensure same day delivery. Information sharing and making agreements with parcel delivery services would greatly help in addressing this problem. However, this part of the system is not subject of this research. MYPUP is also faced with a logistics process in which a substantial amount of manual labor is involved. Manual labor is prone to errors, it is often considered time inefficient and the output capacity is constrained by the number of employees available. Financial restrictions did not allow for already existing solutions, implying significant investments and therefore called for the need for creativity.

Brainstorm sessions with owners, office employees, drivers and outsiders with IT background contributed to the design of the preliminary prototypes. The sessions that followed gradually improved and developed the preliminary prototype until the prototype was found to be good enough to use as basis for the initial design. The brainstorm sessions gave insight into the possibilities and the wishes of the owners and users of the system.

By consulting experts in the field of automated registration and sorting systems, research was done for the ideal design. This provided new insights to develop the initial design into the actual design. The actual design intended to make the registration process more efficient and less error prone within the financial boundaries. Only the OCR part of the actual design was chosen to be implemented at first. Standard OCR systems were found to be extremely expensive, so an alternative OCR system was developed. Using the Microsoft Computer Vision API, a proof of concept for a unique, specially developed to the MYPUP needs, OCR system was co-created. The proof of concept is being slightly upgraded and modified so it can be embedded in the current MYPUP system. The impact of OCR on the process, and the impact of potential future implementation of other parts of the redesign, was tested by developing a model that represented the MYPUP logistics process.

9.1.2 Model Conclusions

The base model was validated and verified in several ways and proved to match the observed behavior in real life. The alteration to the model provided insight into the individual impacts of all solutions that were modeled. Comparing the impact of different solutions regarding the registration time, OCR proved to show the biggest reduction in the overall registration time. Based on these findings it can be concluded that the decision of MYPUP to first implement OCR was the right one. As OCR influences parts of the registration process that are also influenced by other solutions, the impacts of the remaining solutions had to be reassessed to allow for comparison. The remaining solutions all contributed to different processes within the registration process, so the relative impact comparing the solutions to each other will not change after implementation of one of the solutions. The results of the combinations of each separate solution with OCR can be used to determine which solution will lead to the biggest reduction in overall registration time. The results show that the 3D camera is the best solution after OCR is implemented, followed by the redesigned oversized parcel registration process, the new search query, and the new layout of the registration screen.

The OCR reduces the average username registration time almost three times and the average sender registration time more than 2.5 times. The small, medium and large parcel registration time is almost twice as low when OCR is implemented, where the overall registration time shows slightly less improvement as it is also influenced by the oversized parcel registration time.

The complete design including all modeled solutions shows even further reductions in process times. All additions are proved to have a significant impact on the overall registration time. The username registration time is more than four times less than in the base scenario and the sender registration time is more than three times less than in the base scenario. The small, medium and large parcel registration time is nearly the same as the overall registration time as the oversized parcel registration is only about two seconds more than small, medium and large parcel registration time. The overall registration time is almost three times shorter than in the base scenario, translating into almost tripling the capacity per time unit.

9.2 Research Conclusion

At the start of this research the following research question was formulated:

How can the warehousing process of MYPUP, focusing on the outbound logistics, be redesigned to be more efficient, less error prone and to be able to handle increased capacity, constrained by limited available funds?

In order to assess if this originally defined research question was answered adequately, this section focuses on relating the actual research conclusion with the original research question and sub questions. The preliminary problems, found using the black box approach, which led to the problem statement turned out to correspond with the problems conceived by the MYPUP employees. These problems formed the foundation to develop at a wide range of solutions that could be used to redesign the MYPUP logistics process. The solution that turned out to be most suitable, to develop from an abstract design into an actual prototype, was the OCR software. Implementing existing OCR software modified to the needs of MYPUP was too expensive and therefore own OCR software was co-created. Requirements and recommended improvements, that could only be accomplished by having access to the MYPUP system, were formulated so the proof of concept could be developed into a well-functioning solution in the MYPUP environment. A model was created to assess which proposed solutions could improve the MYPUP logistics process in the future. The 3D camera proved to achieve the biggest improvement followed by the new oversized parcel registration process, the new search query and finally the new layout of the registration screen. Furthermore, the 3D camera also ensured no more errors were made in selecting the right locker size. Other solutions were not modeled like, the redesigned label with barcode, scanners in the sorting process to eliminate sorting errors, the drivers' app to eliminate errors in delivery and the barcode scanners at the locker to speed up the final delivery. The redesigned label with barcode in combination with scanners in the sorting process and the drivers' app will contribute to eliminating human error. No definite conclusion can be made about the barcode scanners at the lockers or the effect of the route optimization embedded in the drivers' app as this was not part of the model.

From the testing of the model can be concluded that the complete redesign presented in Chapter 4 improves efficiency in the MYPUP logistics process. The more efficient registration process reduces throughput time significantly, increasing the capacity of registration process. Solutions that were not modeled contribute to reducing and sometimes eliminating errors all together. Only financially feasible solutions have been included in the design. The methodology used in this research has proven to work and to provide answers to all sub questions. Moreover, the methodology lead to a design that is in compliance with all aspects formulated in the main research question and thereby answering it.

9.3 Recommendations

This section first presents recommendations to MYPUP regarding implementation and further research. These recommendations will be followed by recommendations for general future research.

9.3.1 MYPUP Recommendations

The OCR solution is already being developed from a proof of concept into a well-functioning solution embedded in the MYPUP system. Plans are in place to develop and out the drivers' app and have it functioning at the end of quarter three of 2017. Although, the implementation of these two solutions contribute to both making the in-warehouse logistics process more efficient and reducing or even eliminating errors in the final delivery stage, it is recommended to use the design presented in this

research as the future goal. The design presents solutions that could reduce the overall registration time further, while also further reducing errors and in some processes, eliminating errors all together.

The solution that reduces the overall registration time most and simultaneously eliminates errors in selecting the right size, locker is the 3D camera. Therefore, it is recommended that implementing the 3D camera is the next step in improving the logistics process. It should be noted that the remaining modeled solutions also contribute to making the registration process more efficient and do not require investment in hardware. If MYPUP chooses not to make an investment in the hardware it is recommended the new oversized parcel registration process, the new search query and the new layout are considered. Because of the fact that the solutions only need software adjustments, the investments are limited to labor costs. Priority in implementation should be based on the impacts discussed in Section 8.2.

The implementation of the drivers' app to reduce errors in the final delivery originally also included a route optimization algorithm. This algorithm would first determine the routes based on the number of parcels, the location of the lockers at the destination and real-time traffic information. On route the app would update the routes based on the continuously changing real-time traffic information. It is recommended that before this feature is added to the app, the final delivery of the parcels at each destination is researched. Information is needed on time spent from arrival at the unloading dock to the arrival at the location of the lockers, time spent placing the parcel inside the lockers and the number of trips to be made from the van to the lockers. This information can then be used to develop a modified time-based shortest path algorithm considering the travel time and in addition the final delivery time based on the number of parcels.

Introducing a barcode and barcode scanners in the sorting process is recommended in order to eliminate sorting errors. Furthermore, the introduction is recommended as it can save time in the final delivery of the parcels. If using the barcodes in the final delivery is considered, it is recommended to implement this before designing the route optimization algorithm as it is expected to significantly reduce the time spent placing parcels in lockers.

It is also recommended that further research is done into all solutions that are not planned to be implemented at first. Outcome of this research will allow for comparing the solutions based on more than only their improvement in efficiency and error reduction.

Finally, research into the consolidation phase of the MYPUP system is highly recommended. Consolidating all parcels in time is crucial if the parcels are to be delivered the same day. With plans to expand and open more consolidation centers, this forms a key factor in their success. One of the areas that could be of interest in this research is to determine the benefits parcel delivery service companies enjoy, as a result of delivering a large number of parcels to one address instead of many addresses. Quantifying these benefits strengthens the negotiating position of MYPUP in developing agreements with these delivery companies.

9.3.2 General future research direction

Previous research showed that the movement towards sustainability in the CEP industry is mainly driven by government restrictions concerning the last mile. Furthermore, previous research showed that the best solution to solving the last mile problem within B2C logistics is the decoupling of the presence of the final customer and the delivery. The MYPUP case tackles both issues and therefore presents research possibilities into the social and environmental impact of the MYPUP concept to determine if it is a

sustainable solution to the last mile problem. The environmental impact and the impact of the MYPUP concept on city center traffic could be of interest to city governments.

10. Discussion

This chapter looks back on the conducted research and discusses several topics. In Section 10.1 the development of a new methodology, its performance and the concept of co-innovation in a master thesis are discussed. Section 10.2 discusses the data collection, its completeness and the implications of the used data for interpretation of the results. Section 10.3 looks addresses the proposed solutions and the uncertainty about their performance because of their innovative nature. Section 10.4 addresses the generalization of the research and finally Section 10.5 discusses the role of the author throughout the process.

10.1 Reflection on the Methodology

This researched started out as an optimization study of the logistics of a small-scale city logistics facility. The MYPUP case uncovered that the logistics process was not in need of optimization, rather it needed to be redesigned completely. The chosen methodology to assess the logistics process and to form a problem statement, the Delft Systems Approach was no longer suited for the research. A methodology used in design studies was more appropriate. A Silicon Valley based design company, IDEO, has developed two different approaches for design studies that have been applied by them any many others over the world. The methodologies have been adjusted and improved based on years of application of both methodologies. The IDEO Human Center Design Approach used user insights to redesign a product, however it moves straight from the observation phase to the ideation phase. The methodology focusses on product redesign where the focus is already clear, as the product to be redesigned is known. Applying this methodology on a design of an entire process results in a wide range of ideas in the ideation phase that might not even be relevant to the issue at hand. Furthermore, the IHCDA methodology is often applied when a new product needs to be redesigned without the need for improving its technical performance, rather it is used to make it more user-friendly or add features user might enjoy.

In a process, it is easier to identify problems or opportunities for improvement than in a product. The redesign of the MYPUP logistics process called for more focus and a clear view of the problem at hand. The IDEO Design Thinking Process contained the phase that was missing, the define phase where a problem and scope are defined. Furthermore, the definition of the empathize phase seemed more appropriate and complete than the observation phase in IHCDA. The downside to the IDTP methodology is that it did not contain the implementation step. Combing the two methodologies resulted in a new unique methodology, where in addition, techniques from the DSA were used in the empathize and define phase.

In the end the newly created methodology, which had not been used before, however based on two proven methodologies and using techniques of a third, worked perfectly. The methodology fit the research well as it allowed all research questions to be answered and inspired much needed creativity in the redesign process. The switch in methodology caused a temporary setback in the progress of this research. Looking back, the need for a different methodology could have been identified sooner which could have saved time. Unfortunately, the case and the perceived problem were unclear at the start of the research and the road taken clunked to for too long. I would recommend making sure that the assignment from the problem owner is clear at the beginning, if it is vague, try to uncover the real wishes first. This will still not guarantee you choose the right approach the first time, but it improves your chances. Furthermore, I would recommend more frequent contact with supervisors in the beginning of

your research to get on the right track and make sure you have something concrete to show or ask every time.

10.2 Reflection on Data Collection

The data used in this research was mostly obtained through observation or acquired from the MYPUP database. For some data used in the base model assumptions were made. These assumptions, were based on data or observations so are likely to be close the actual data. The assumptions were made because data was either not available or too complicated or too time-consuming to obtain. The base model contains very little assumptions that influence the process times of interest. Furthermore, the base model arrived at an average overall process time that matched the observed value.

The data used for the solutions that were modeled are all assumptions. Therefore, it is important to be careful with the interpretation of the results. Although the assumed process times for the different solutions are not completely random, the values might differ in reality. The values are realistically and rationally chosen, and although they cannot guarantee to produce the same results as observed values, they are assumed to be estimated well enough to allow for interpretation of the results. Unfortunately, the implementation of OCR and other solutions was not accomplished in the timeframe of this research. In the future, the model and its values can be validated or adjusted when the solutions are implemented.

The data collection could have started earlier allowing for more reliable and more complete data. Unfortunately, the data that was thought to be registered already in the MYPUP database turned out not to be present. As a result, very little time remained to collect all the data necessary for the simulation. Attempting the access the data at an earlier stage, when it was not needed yet, could have uncovered the missing data at an earlier stage. I recommend that even if it is said to be registered, check it right away to see if this is actually the case.

10.3 Reflection of the Solutions

Given the design nature of the study and innovation in solutions, most solutions presented do not find precedence in known literature. Furthermore, the technical nature of the solutions calls for focus on technical performance and specifications, rather than reverting to the literature about the creation of the hardware or its applications elsewhere. The lack of precedence in known literature does not depreciate the quality of the solutions that were presented. Although one should keep in mind that although solutions involve existing hardware and, for the OCR solutions existing software, all solutions require customized software development. The need for development of own software, or adjustments to existing software, can result in solutions not reaching their full potential if not done properly. I would recommend building in plenty of time if software needs to be developed, because it is an iterating process and should not be rushed.

10.4 Generalization of the Research

The generalization of this research has two sides. On the one hand, there is the generalization of the research process and on the other hand the generalization of the solutions. The generalization in both cases depends on the environment of future problems. MYPUP is a small company, a start-up that has financial constraints, small-scale city logistics facilities and a small number of employees. The innovative mind-set of the people at MYPUP, creates an environment and workplace that is interactive through all levels of the organization. The research method is most suitable in a similar environment where the

researcher operates inside the company as a project leader, instead of on the sidelines in the role of an outside consultant.

The generalization of the solutions presented in this paper is not uniform. Although the solutions can all be of interest for companies that have limited available financial resources, the scale of the operation plays a key role as well. MYPUP uses local distribution centers, which means that volumes will remain relatively low compared to large logistics facilities. The smaller volumes make the need for high tech automated solutions unsuitable and instead simpler solutions suffice. In Section 8.3 the usefulness for other parties is also discussed per solution.

10.5 Co-Innovation

One of the things that created a challenge in this research was the inclusion and close cooperation with a large number of people. Part of the research was the actual design and implementation of the solutions. This in combination with the small-scale of the company put me in a role that can be described as a project leader in redesigning the MYPUP logistics process. Although the research can be perceived as co-innovation it was driven and for the most part executed by me. I analyzed the system and identified the problems and opportunities for improvement. I injected myself into all parts of the process and talked to employees to uncover their perceptions and the problems they encountered. I led brainstorm sessions including MYPUP employees and founders from all levels of the organization, with diverse backgrounds. The input of these sessions was invaluable and contributed greatly to the direction and design of the actual solutions. The actual design was developed by me using the input of the brainstorm sessions, comparison of existing solutions and experts' consult.

Part of the design has been developed within this project and will be implemented at the end of quarter two. The OCR solution required certain skills that were not part of my skill set, which was not a problem as long as it got done. I looked for people who had these skills and could help develop the OCR algorithm. Using a company to develop the OCR solution cost between 30.000-50.000 euros for the software alone. I looked for alternatives and found it in the form of the Computer Vision API. To embed this API into a to be developed algorithm I reached out to my network and found someone who works with API's regularly in his line of work. Together, we made the API work in a simple algorithm that could be used as a base for the next phase. This phase consisted of extracting the username from all the text the API send back. I designed the logic of the algorithm and found someone to program my wishes so the algorithm would perform the right tasks. The programmer would complete his assignments and I would test the new algorithm, identify and formulate improvement and assign new tasks to the programmer until a version was reached that was good enough for a proof of concept. I then presented the proof of concept to the IT department of MYPUP and they are developing it for implementation. Other solutions that are not implemented at first were modeled and their results analyzed.

A lot of different people were involved in the process and contributed their share which I could not have done myself. Throughout the entire process, I facilitated and led the project; I was in charge as it was my project. It gave me a unique chance to lead a team of people and bring them together to accomplish the redesign of the MYPUP logistics process. It was a great learning experience and I am glad I was able to bring it to a great end, where MYPUP, the problem owner, is extremely satisfied with the result. A proactive and enthusiastic attitude is important if you have to assume the role of project leader. Furthermore, you have to take all the advice you can get, from supervisors at the university, the company, and many others.

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Appendix A: OCR Algorithm

The part of the algorithm in Figure 43 is references the folders and spreadsheet in which pictures are stored or need to be moved to after processing and information is written to. The bottom part is to make the connection to the Microsoft Computer Vision API with a valid subscription key.

```
function autoRun() {
  var source_folder = '0B5BAIMdCzTWsSzIzeHl5dkZ0MEE';
  var finished_folder = '0B5BAIMdCzTWsZFp1dmx6ZUZoRmM';
  var error_folder = '0B5BAIMdCzTWsNUZGMm5Cc0UwRU0';
  var spreadsheet = '1FqM_sFNf6eQjXN9I_1btRWhBBAO0PSDQBkKfPPPocw8';

  var files = DriveApp.getFolderById(source_folder).getFiles();
  while (1) {
    if (files.hasNext()) {
      readMyPUPLabels(source_folder, finished_folder, error_folder, spreadsheet);
    }
  }
}


function readMyPUPLabels(source_folder, finished_folder, error_folder, spreadsheet) {

  var OCRURL = 'https://api.projectoxford.ai/vision/v1.0/ocr?language=unk&detectOrientation=true';
  var headers = { "Ocp-Apim-Subscription-Key" : "175d8ac6ea23471494e941a38fc23b41", "Content-Type":"application/octet-stream" };

  var files = DriveApp.getFolderById(source_folder).getFiles();

```

Figure 43: Algorithm Setup

The part of the algorithm show in Figure 44 shows assures the information that is written away does not overwrite previously obtained results.

```
//  Fix row to append instead of overwrite
row = 1;
while (SpreadsheetApp.openById(spreadsheet).getActiveSheet().getRange(1+row, 1).getValue() != "") {
  row ++;
}

while (files.hasNext()) {

  var file = files.next();
  Logger.log('--------------------------------');
  Logger.log(file.getName());

  var image = DriveApp.getFileById(file.getId());

  var options = {
    "headers" : headers,
    "method" : "POST",
    "payload" : image.getBlob().getBytes()
  };

  var response = UrlFetchApp.fetch(OCRURL, options);

  var content = JSON.parse(response);

  var allTheWords = [];
  var currentWord = '';
  var USERNAME = 'not detected';

  for (var r = 0; r < content.regions.length; r ++){
    for(var l = 0; l < content.regions[r].lines.length; l ++){
      for(var w = 0; w < content.regions[r].lines[l].words.length; w ++){


        currentWord = content.regions[r].lines[l].words[w].text;
        allTheWords.push(currentWord);

      }
    }
  }
```

Figure 44: Algorithm get information

Figure 45 and Figure 46 show the part of the algorithm that tries to filter out the username by location a variation of MYPUP.

```
        // Filter out username using MyPuP tag
    if (USERNAME == 'not detected') {
      var pupTag1 = 'MYPUP';
      var pupTag2 = 'MyPUP';
      var pupTag3 = 'MyPuP';
      var pupTag4 = 'mypup';
      var pupTag5 = 'Mypup';

      for (var r = 0; r < content.regions.length; r++){
        for (var l = 0; l < content.regions[r].lines.length; l++){
          for (var w = 0; w < content.regions[r].lines[l].words.length; w++){

            currentWord = content.regions[r].lines[l].words[w].text;

            if (currentWord.indexOf(pupTag1) > -1 || currentWord.indexOf(pupTag2) > -1 || currentWord.indexOf(pupTag3) > -1 || currentWord.indexOf(pupTag4) > -1 || currentWord.indexOf(pupTag5) > -1){
              var wordLen = content.regions[r].lines[l].words.length;
              if(currentWord.length == pupTag1.length && wordLen > w+1){
                if (content.regions[r].lines[l].words[w+1].text != '-'){
                  //USERNAME = content.regions[r].lines[l].words[w+1].text;
                  USERNAME = [];
                  for (var i = w; i < wordLen; i++) {
                    USERNAME.push(content.regions[r].lines[l].words[i].text);
                  }
                  var USERARRAY = USERNAME;
                  USERNAME = "";
                  for (var i = 0; i < USERARRAY.length; i++) {
                    USERNAME = USERNAME + USERARRAY[i] + " ";
                  }
                }
```

Figure 45: Algorithm Find Username MYPUP 1

```
                else {
                  //USERNAME = content.regions[r].lines[l].words[w+2].text;
                  USERNAME = [];
                  for (var i = w; i < wordLen; i++) {
                    USERNAME.push(content.regions[r].lines[l].words[i].text);
                  }
                  var USERARRAY = USERNAME;
                  USERNAME = "";
                  for (var i = 0; i < USERARRAY.length; i++) {
                    USERNAME = USERNAME + USERARRAY[i] + " ";
                  }
                }
              } else {
                //USERNAME = content.regions[r].lines[l].words[w].text;
                USERNAME = [];
                  for (var i = w; i < wordLen; i++) {
                    USERNAME.push(content.regions[r].lines[l].words[i].text);
                  }
                  var USERARRAY = USERNAME;
                  USERNAME = "";
                  for (var i = 0; i < USERARRAY.length; i++) {
                    USERNAME = USERNAME + USERARRAY[i] + " ";
                  }
              }
            }

          }
        }
      }
    }
```

Figure 46: Algorithm Find Username MYPUP 2

Figure 47 show the part of the algorithm that tries to find the username by location the word Overschiestraat.

```
123     //  Filter out username using adress
124     if (USERNAME == 'not detected') {
125       var adressTag1 = 'Overschiestraat';
126       var adressTag2 = 'overschiestraat';
127       var adressTag3 = 'OVERSCHIESTRAAT';
128
129       for (var r = 0; r < content.regions.length; r ++){
130         for(var l = 0; l < content.regions[r].lines.length; l ++){
131           for(var w = 0; w < content.regions[r].lines[l].words.length; w ++){
132
133             currentWord = content.regions[r].lines[l].words[w].text;
134
135             if ( currentWord.indexOf( adressTag1 ) > -1 || currentWord.indexOf( adressTag2 ) > -1 || currentWord.indexOf( adressTag3 ) > -1) {
136               Logger.log('Use adress tag');
137
138               if(currentWord.length == adressTag1.length){
139                 var userlen = content.regions[r].lines[l-1].words.length;
140                 USERNAME = [];
141                 for (var i = 0; i < userlen; i++) {
142                   USERNAME.push(content.regions[r].lines[l-1].words[i].text);
143                 }
144                 var USERARRAY = USERNAME;
145                 USERNAME = "";
146                 for (var i = 0; i < USERARRAY.length; i++) {
147                   USERNAME = USERNAME + USERARRAY[i] + " ";
148                 }
149               }
150               Logger.log(USERNAME);
151             }
152
153           }
154         }
155       }
156     }
157
```

Figure 47: Algorithm Find Username Overschiestraat

Figure 48 shows the part of the algorithm where part of the blacklist is defined. The real list is much longer.

```
159
160     //  Blacklist
161     var blackList1 = '-';
162     var blackList2 = 'PUP';
163     var blackList3 = 'TO';
164     var blackList4 = 'MYPUP';
165     var blackList5 = 'MyPUP';
166     var blackList6 = 'mypup';
167     var blackList7 = 'MY';
168     var blackList8 = 'my';
169     var blackList9 = ':';
170     var blackList10 = 'To ';
171     var blackList11 = 'Naar';
172     var blackList12 = 'Mypup';
173     var blackList13 = '–';
174     var blackList14 = 'Booking.com';
175     var blackList15 = 'Mevr.';
176     var blackList16 = 'mevr';
177     var blackList17 = 'MyPuP';
178     var blackList18 = 'Ship';
179     var blackList19 = 'dhr';
180     var blackList20 = '*';
181     var blackList21 = '(';
182     var blackList22 = ')';
183     var blackList23 = '•';
184     var blackList24 = 'N.v.t.';
185     var blackList25 = 'ABN';
186     var blackList26 = 'AMRO';
187     var blackList27 = 'GML';
```

Figure 48: Algorithm Part of Blacklist

Figure 49 shows the part of the algorithm that removes blacklisted phrases from the results written away. Figure 50 and Figure 51 correct other flaws in location the username.

```
197     if (USERNAME.indexOf(blackList1) > -1){
198       Logger.log('blacklist');
199       var start = USERNAME.indexOf(blackList1);
200       var lenmod = blackList1.length;
201       var stop = start + lenmod;
202       var TEMP1 = '';
203       var TEMP2 = '';
204       for (var i = 0; i < start; i++){
205         TEMP1 = TEMP1 + USERNAME[i];
206       }
207       for (var i = stop; i < USERNAME.length; i++){
208         TEMP2 = TEMP2 + USERNAME[i];
209       }
210       USERNAME = TEMP1 + TEMP2;
211     }
```

Figure 49: Algorithm Blacklist Example

```
738     //  Remove space at beginning username
739     if(USERNAME[0] == ' '){
740       var TEMP1 = '';
741       for (var i = 1; i < USERNAME.length; i++){
742         TEMP1 = TEMP1 + USERNAME[i];
743       }
744       USERNAME = TEMP1;
745     }
746     if(USERNAME[0] == ' '){
747       var TEMP1 = '';
748       for (var i = 1; i < USERNAME.length; i++){
749         TEMP1 = TEMP1 + USERNAME[i];
750       }
751       USERNAME = TEMP1;
752     }
753
754     //  Correct empty username
755     if(USERNAME == "" || USERNAME == " "){
756       USERNAME = 'not detected';
757     }
```

Figure 50: Algorithm Residue Removal 1

```
759     //  Resolve double names
760     var usernameLength = USERNAME.length;
761     var word1 = [];
762     var word2 = [];
763     var word3 = "";
764     var word4 = "";
765     var word = 1;
766     for (var i = 0; i < usernameLength; i++){
767       if (USERNAME[i] != " " && word == 1){
768        word1.push(USERNAME[i]);
769       }
770       if (USERNAME[i] == " " && word == 1){
771        i++;
772        word = 2;
773       }
774       if (USERNAME[i] != " " && word == 2){
775        word2.push(USERNAME[i]);
776       }
777     }
778     var len = word1.length;
779     for (var i = 0; i < len; i++){
780       word3 = word3 + word1[i];
781     }
782     var len = word2.length;
783     for (var i = 0; i < len; i++){
784       word4 = word4 + word2[i];
785     }
786     if (word3 == word4){
787      USERNAME = word3;
788     }
```

Figure 51: Algorithm Residue Removal 2

Figure 52 is the part of the algorithm that writes away the information and moves the picture to the correct folder.

```
        Logger.log('THESE ARE ALL THE WORDS IN THE IMAGE');
    //
        Logger.log(allTheWords);
    //
        Logger.log('THIS IS THE USERNAME');
    //
        Logger.log(USERNAME);


    //    Output data into spreadsheet
    SpreadsheetApp.openById(spreadsheet).getActiveSheet().getRange(1+row, 1).setValue(file);
    SpreadsheetApp.openById(spreadsheet).getActiveSheet().getRange(1+row, 2).setValue(USERNAME);
    if (USERNAME != 'not detected'){
      SpreadsheetApp.openById(spreadsheet).getActiveSheet().getRange(2, 4).setValue(SpreadsheetApp.openById(spreadsheet).getActiveSheet().getRange(2, 4).getValue() + 1);
    } else {
      SpreadsheetApp.openById(spreadsheet).getActiveSheet().getRange(2, 5).setValue(SpreadsheetApp.openById(spreadsheet).getActiveSheet().getRange(2, 5).getValue() + 1);
    }

    row ++;

    //    Move file to other folder
    if(USERNAME == 'not detected'){
      DriveApp.getFolderById(error_folder).addFile(file);
      DriveApp.getFolderById(source_folder).removeFile(file);
    }
    else{
      file.setName(USERNAME);
      DriveApp.getFolderById(finished_folder).addFile(file);
      DriveApp.getFolderById(source_folder).removeFile(file);
    }
  }
}

```

Figure 52: Algorithm Wrap-up

Appendix B: Issue descriptions

Figure 53 contains the descriptions used by Tako & Robinson (2011) to categorize the analyzed articles. Based on these descriptions similarities and characteristics can be compared with the MYPUP case.

LSCM issues	Brief explanation
Supply chain structure	Designing the supply chain structure refers to the configuration of the chain, the sequential links between different activities or processes. Typical decisions made are related to the flow of materials between stages, involvement or not of intermediaries, pull versus push configurations, etc.
Process redesign	Supply chain redesign or re-engineering involves changes in its structure (facilities, production processes, transportation) and processes. An emerging stream of work in this category explores the streamlining of physical transformation processes to simplify the decision-making and control to eradicate waste, such as: Total Quality Management, Just-in-Time, Kaizen etc. Supply chain redesign is associated with strategic management as it requires an overall understanding of business processes.
Supplier selection	Related to procurement that is the process of purchasing raw materials needed to make finished goods or to support the operations of a firm. The selection of intermediaries or suppliers is made based on the evaluation of procurement bids for multiple products or suppliers.
Facilities/capacity planning	Typical decisions are the determination of the facility role and processes to be performed, facility location and capacity allocation, etc. These decisions are usually linked with the objectives and long term vision of the firms or partners in the chain and hence considered a strategic issue.
System performance	The performance of the supply chain is evaluated using a number of criteria, such as transportation cost, resources utilisation, inventory level, order cycle time, delivery performance, etc.
Bullwhip effect	The phenomenon of upstream order magnification in the supply chain. Due to the fluctuations, supply chain partners do not receive a reliable picture of inventory levels which results into a poor alignment between demand and production patterns across echelons.
Supply chain integration	Supply chain integration enables the cooperation of two or more systems in pursuit of complementary objectives. This category includes a number of coordination mechanisms such as: vendor managed inventory, quantity discounts, quantity flexibility, allocation rules, quick response, strategic partnerships, etc.
Information sharing	Information sharing strategies are introduced as a sub-set of supply chain integration mechanisms, which aim to reduce the bullwhip effect and to improve the supply chain performance. Some of the hurdles encountered in operationalising these strategies are the reluctance of firms to share information on sales, demand, production and delivery, inventory levels, etc. This is considered as a separate category, due to the large number of papers on information sharing.
Supply chain optimisation	Supply chain optimisation is mainly concerned with the identification of optimal policies that optimise key performance indicators, such as profits, costs, product flows, etc.
Cost reduction	Cost reduction is often the incentive of various policies undertaken such as electronic data interchange, inventory management, etc.
Replenishment control policies	These policies deal with the control of stock levels in the echelons of the supply chain and the ordering policy. The aim is to have the right product quantity at the right location and at the right time. The choice of inventory replenishment policies aims to achieve low inventory while maintaining high delivery performance.
Inventory planning/management	Deals with the management and movement of goods throughout the supply chain. Studies on inventory planning and management focus on optimisation of service levels or process time by varying the location or quantity of inventory. In each echelon, a decision is made to manage the inventory based on inventory levels, holding and backlog costs and replenishment control policies.
Planning and forecasting demand	It can be the primary or secondary focus of simulation studies, where the objective is to anticipate or to mitigate the risks involved. These models generate forecasts of the expected future demand and investigate the impact of major demand changes on supply chain echelons.
Production planning and scheduling	Production planning and scheduling deals with the management of manufacturing processes and the policies that determine the configuration of the production sequence and resource allocation, material handling, scheduling of machines and work centres. Simulation models are often concerned with the effect of different production planning rules on supply chain performance.
Distribution and transportation planning	Deals with the physical movement of inventory (products, materials) from one stage of the supply chain to another. Some decisions made are: the design of the transportation network, choice of transportation models, the management of vehicle fleet (routing and scheduling), etc.
Dispatching rules	Dispatching rules deal with decisions made regarding the fulfilment of specific customer orders, considering on one-hand delivery dates and on the other hand utilisation of the manufactures' shop floor.
Reverse logistics	Reverse logistics is concerned with the recovery of products as spare parts or recycled products at the end of their life cycle. Product recovery is driven by economical and environmental incentives, which at the same time affects companies' manufacturing and collection activities.

Figure 53: Issue descriptions (Tako & Robinson, 2011)

Appendix C: Base Model Processes

Assign Size

The parcels are assigned a size upon arrival which is used to separate the oversized parcels from the rest using the process shown in Figure 54.

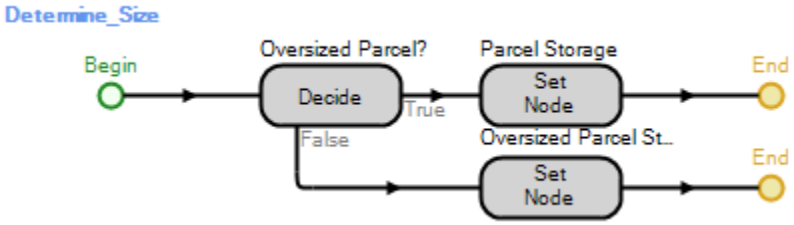

Figure 54: Determine Size Process

Sort by Size, Store and Release

In real life, the small, medium and large parcels are all stored separately and registered in order from large to small once registration commences. Within the parcel storage this separation is illustrated, shown in Figure 55, and designed to release the medium parcels only after all large parcels are registered, and release small parcels only after all medium parcels are registered.

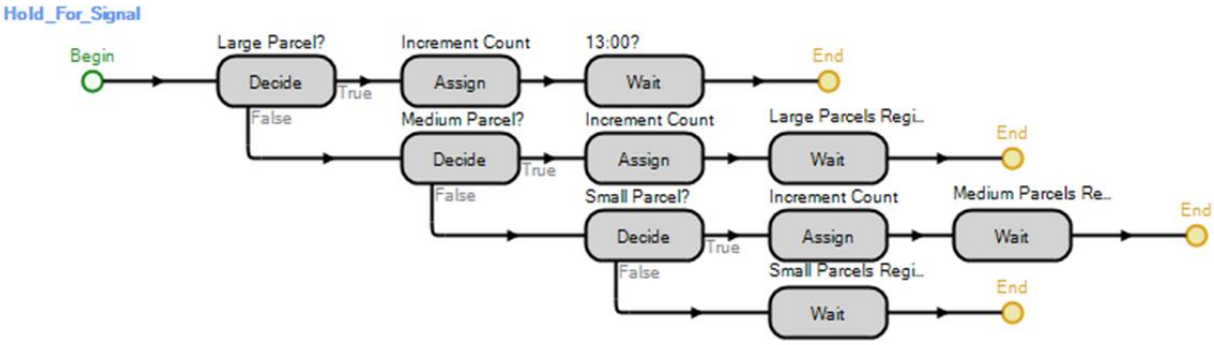

Figure 55: Parcel Storage Hold

The process decides the size of the parcel based on the condition of an entity variable. It then increments the count of the parcels of that size for release signal purposes. The parcels are held until a signal is received from the release process shown in Figure 56. This process is initiated after a parcel has been assigned a locker and a label has been applied. Once again, the size of the parcel is determined after which it decrements the count for the parcels of that size. Once the large parcel count is decremented to zero the signal to release the medium parcels in given. Once the medium parcel count is decremented to zero the signal is given to release the small parcels. Once the small parcel count reaches zero the signal is given to release the oversized parcels.

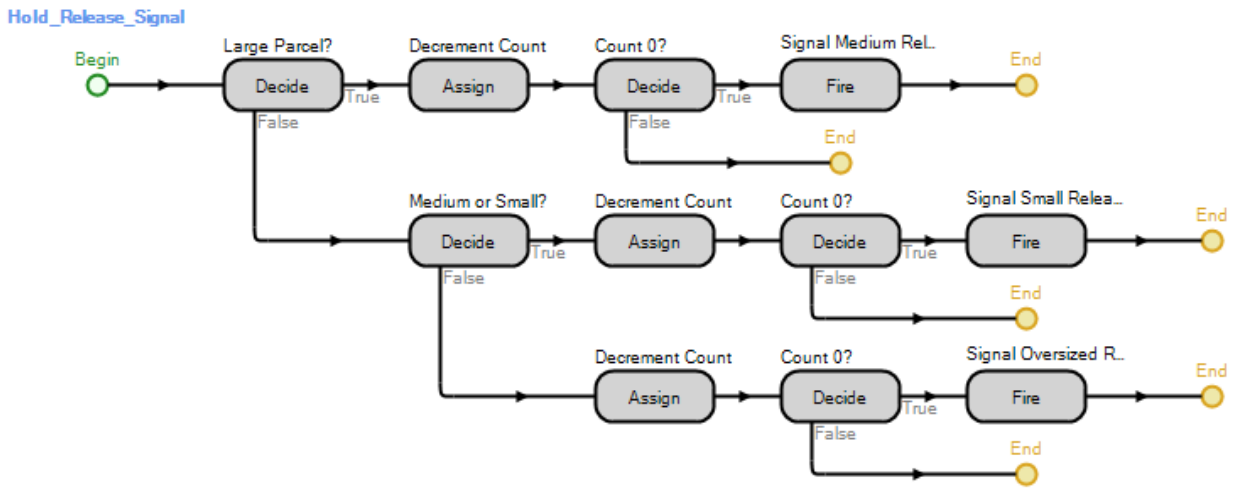

Figure 56: Parcel Storage Release

Capacity Check

The first step in this process is to identify the destination of the parcel, which is done by checking the value of the entity variable location. Based on the destination the parcel is sent to a location specific process, shown in Figure 57. The process, in logic, is identical for all locations, however the capacity and the state variables that are updated are location specific. Therefore, the model contains a separate capacity availability check for each location. The process sending the parcel to the corrected process is shown in Figure 58 and Figure 59

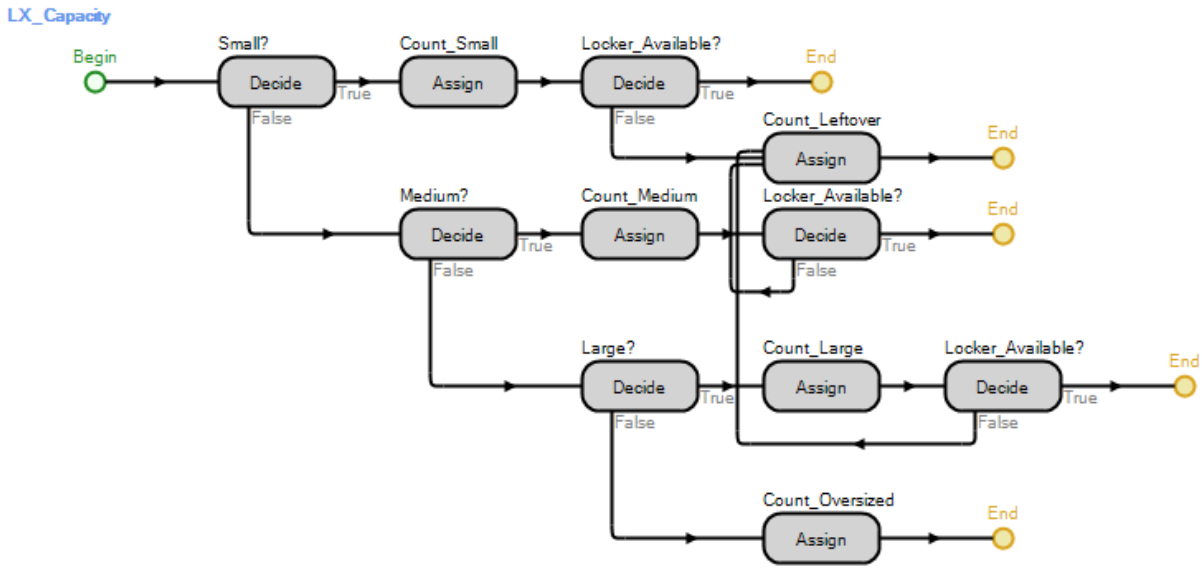

Figure 57: Capacity Check

First, the size of the parcel is determined. If the parcel is small, a state variable is to count the small parcels at location X is incremented by 1. The decide step then decides if the count for small parcels at location X is lower or equal to the location specific capacity. If the count is larger the parcel will increment the

leftover count by 1. Medium and large parcels follow the same logic, where the oversized parcels, that are too big for the lockers and thus not capacity bound, are just counted for analysis purposes. For the same reason as counting the oversized parcels, time-related state variables are updated and registered upon exiting the server.

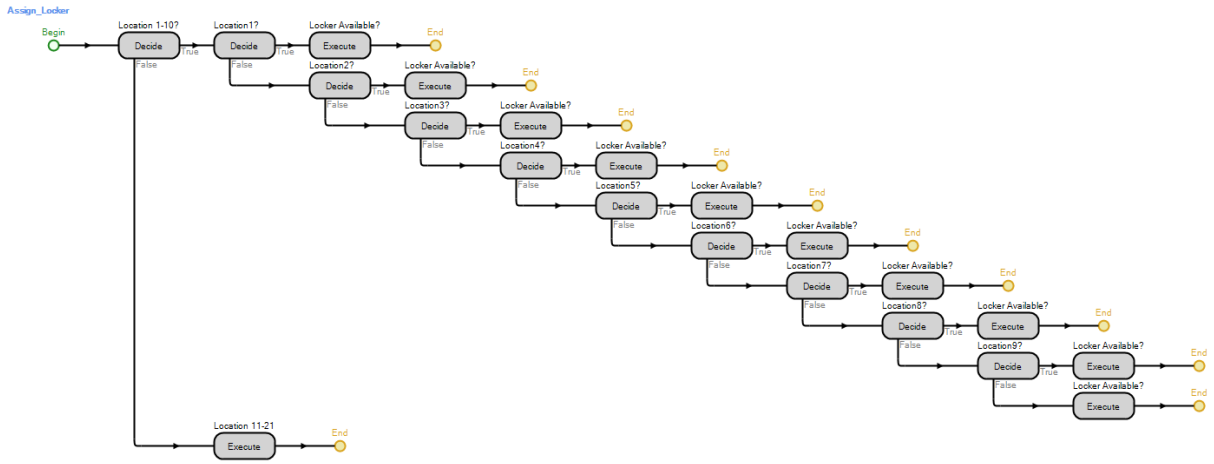

Figure 58: Assign Locker Process 1

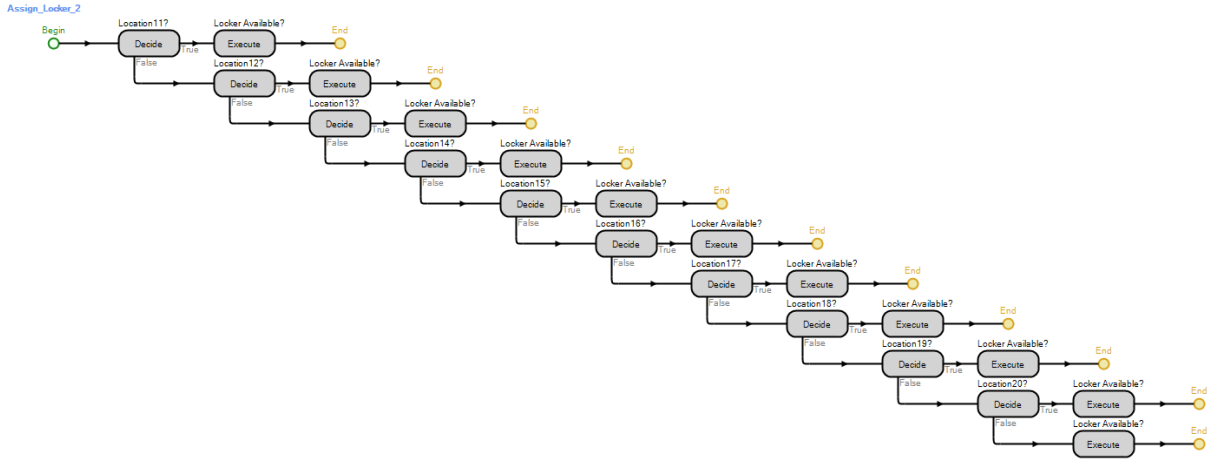

Figure 59: Assign Locker Process 2

Sorting Locker Process

Figure 60 illustrates the sorting process. Depending on the location assigned to each parcel, a parcel is sent to the corresponding node or location.

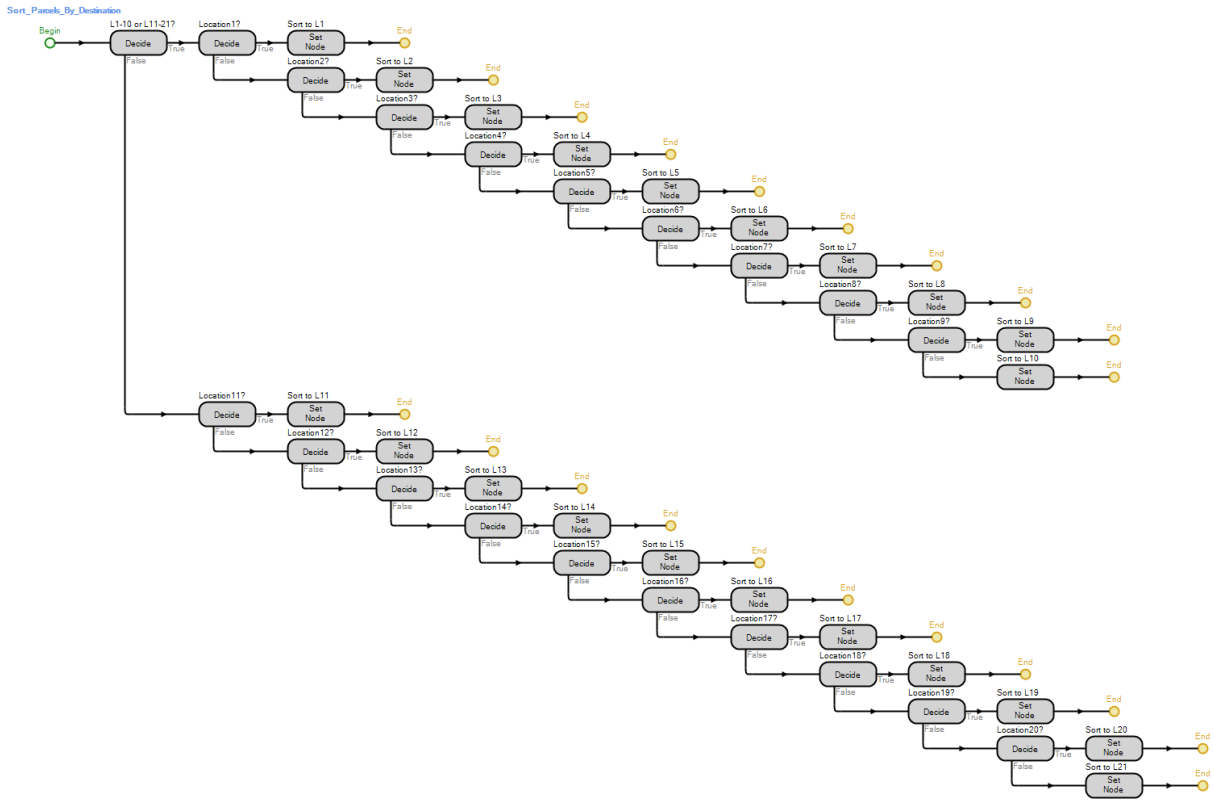

Figure 60: Sorting Process

Figure 61 and Figure 62 show process created to record data for analysis purposes.

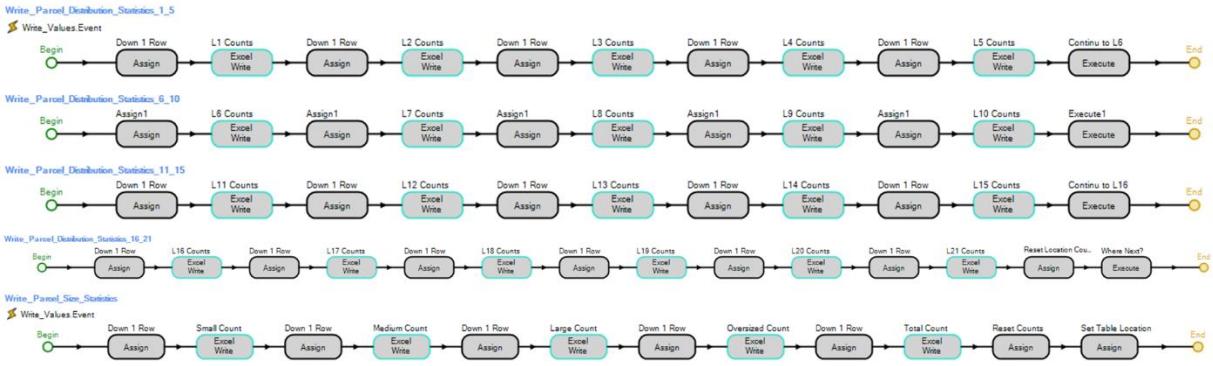

Figure 61: Write Away Data 1

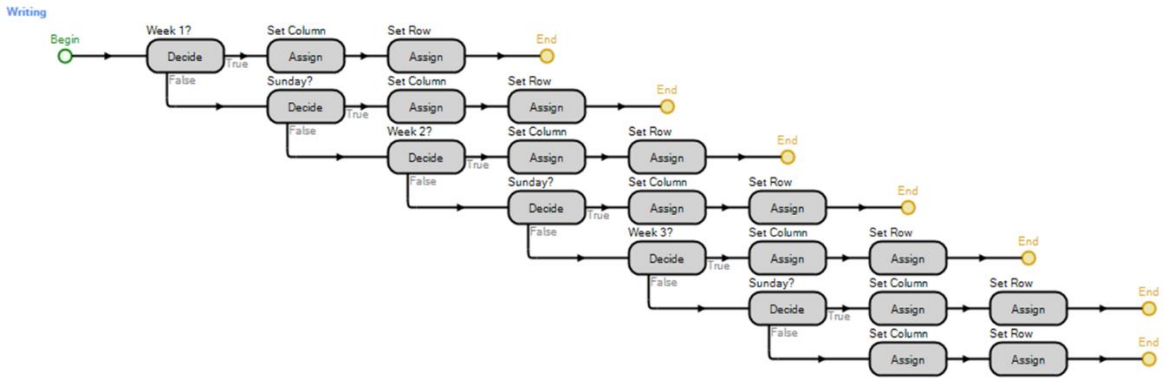

Figure 62: Writing Away Data 2

Appendix D: Arrival Data

Mondays			Tuesdays			Wednesdays		
Month	Day	Parcels	Month	Day	Parcels	Month	Day	Parcels
January	4	82	January	5	174	January	6	148
January	11	125	January	12	198	January	13	144
January	18	127	January	19	186	January	20	139
January	25	134	January	26	176	January	27	178
February	1	144	February	2	224	February	3	183
February	8	156	February	9	215	February	10	185
February	15	140	February	16	178	February	17	160
February	22	113	February	23	192	February	24	189
February	29	142	March	1	247	March	2	159
March	7	129	March	8	191	March	9	153
March	14	136	March	15	186	March	16	153
March	21	134	March	22	190	March	23	202
April	4	123	March	29	165	March	30	216
April	11	168	April	5	218	April	6	181
April	18	148	April	12	211	April	13	194
April	25	179	April	19	246	April	20	168
May	2	146	April	26	189	May	4	168
May	9	198	May	3	229	May	11	159
May	23	144	May	10	234	May	18	211
May	30	164	May	17	194	May	25	186
June	6	177	May	24	259	June	1	169
June	13	177	May	31	255	June	8	211
June	20	134	June	7	246	June	15	218
June	27	177	June	14	278	June	22	207
July	4	192	June	21	235	June	29	229
July	11	176	June	28	213	July	6	237
July	18	139	July	5	231	July	13	229
July	25	146	July	12	290	July	20	176
August	1	144	July	19	259	July	27	243
August	8	164	July	26	237	August	3	213
August	15	166	August	2	264	August	10	185
August	22	174	August	9	252	August	17	195
August	29	142	August	16	235	August	24	195
September	5	121	August	23	220	August	31	200
September	12	136	August	30	233	September	7	239
September	19	160	September	6	295	September	14	178
September	26	178	September	13	224	September	21	218
October	3	168	September	20	231	September	28	228
October	10	194	September	27	228	October	5	200
October	17	209	October	4	238	October	12	181
October	24	187	October	11	274	October	19	202
October	31	208	October	18	220	October	26	269
November	7	237	October	25	254	November	2	208
November	14	208	November	1	276	November	9	222
November	21	220	November	8	298	November	16	251
November	28	389	November	15	272	November	23	274
December	5	339	November	22	350	November	30	514
December	12	316	November	29	528	December	7	352
December	19	292	December	6	395	December	14	356
			December	13	378	December	21	373
			December	20	433	December	28	207
			December	27	181			

Thursdays			Fridays		
Month	Day	Parcels	Month	Day	Parcels
January	7	143	January	8	151
January	14	155	January	15	104
January	21	88	January	22	75
January	28	138	January	29	138
February	4	142	February	5	117
February	11	151	February	12	105
February	18	168	February	19	109
February	25	138	February	26	110
February	3	161	February	4	148
March	10	161	March	11	118
March	17	185	March	18	110
March	24	195	March	25	100
April	31	218	April	1	182
April	7	161	April	8	130
April	14	138	April	15	148
April	21	186	April	22	127
April	28	203	May	29	205
May	12	150	May	6	126
May	19	185	May	13	159
May	26	181	May	20	147
June	2	196	June	27	143
June	9	194	June	3	168
June	16	209	June	10	161
June	23	183	June	17	164
June	30	190	July	24	165
July	7	231	July	1	178
July	14	230	July	8	183
July	21	159	July	15	164
July	28	191	August	22	150
August	4	191	August	29	140
August	11	194	August	5	159
August	18	195	August	12	205
August	25	195	August	19	165
September	1	182	August	26	160
September	8	198	September	2	150
September	15	146	September	9	185
September	22	186	September	16	116
September	29	198	September	23	156
October	6	235	September	30	155
October	13	207	October	7	195
October	20	208	October	14	177
October	27	217	October	21	195
November	3	205	October	28	205
November	10	196	November	4	228
November	17	234	November	11	203
November	24	273	November	18	216
December	1	411	November	25	269
December	8	312	December	2	329
December	15	338	December	9	233
December	22	325	December	16	273
December	29	242	December	23	224
			December	30	194

Appendix E: Username Registration Time Data

Instance	Time	Instance	Time	Instance	Time	Instance	Time
1	7.5	51	8.9	101	8.7	151	8.6
2	8.6	52	8.7	102	9.4	152	8.9
3	6.6	53	8.6	103	9	153	6.7
4	8.5	54	6.2	104	7.2	154	7.4
5	9.1	55	7.9	105	7.7	155	8.9
6	4.8	56	7.8	106	9	156	9
7	8.8	57	7.5	107	7.8	157	7.6
8	9	58	6.5	108	9.3	158	9.8
9	8.8	59	7.3	109	7.4	159	7.8
10	8.2	60	9.7	110	9.7	160	8.3
11	7.7	61	6.8	111	8.9	161	9.5
12	6.6	62	9.1	112	8.8	162	6.7
13	8.3	63	7.9	113	8.5	163	8.4
14	9.2	64	9.5	114	7.3	164	9.9
15	8.3	65	7.5	115	7.6	165	9.4
16	8.1	66	7.2	116	7.5	166	7.7
17	9.6	67	7.1	117	7.6	167	6.6
18	7.7	68	7.4	118	9.1	168	9.5
19	7.1	69	7.7	119	6.3	169	7.5
20	6.2	70	7.1	120	9.3	170	8.9
21	9.3	71	6.6	121	7.1	171	9.2
22	8.9	72	8.7	122	5.3	172	8.6
23	6.8	73	9.4	123	8.3	173	9.7
24	7.2	74	6.1	124	9.9	174	8.9
25	8.1	75	9.2	125	8.2	175	7.4
26	8.3	76	9.7	126	6.8	176	6.8
27	9.1	77	6.6	127	8.1	177	4.3
28	7.5	78	7.9	128	9.3	178	9.5
29	9.5	79	7.9	129	8.7	179	6.4
30	8.1	80	9.2	130	8	180	7.3
31	9.5	81	9.5	131	8.4	181	8.2
32	9.2	82	6.1	132	7.1	182	9.3
33	9	83	8.3	133	7	183	7.5
34	9.6	84	8.5	134	9.9	184	11.4
35	8.5	85	9.1	135	9.5	185	6.9
36	8	86	7	136	8.3	186	8.4
37	7.2	87	8	137	6.3	187	6.7
38	9.3	88	9.6	138	8.9	188	7.9
39	7	89	9.8	139	8.1	189	9
40	8.3	90	8.4	140	7.5	190	7.1
41	7.7	91	7.5	141	8.3	191	9.2
42	7.8	92	7.5	142	7.9	192	7.1
43	8.7	93	6.4	143	8.6	193	9.5
44	8.3	94	8.9	144	10.4	194	8.7
45	8.8	95	7	145	8.6	195	8.1
46	8.9	96	7.7	146	9.9	196	7.2
47	9.5	97	8.8	147	7.6	197	6.6
48	9.8	98	8.4	148	8.9	198	8.1
49	8.2	99	6.7	149	6.4	199	7.3
50	7.6	100	9.9	150	9.4	200	7.9

Instance	Time
201	8.5
202	8
203	8.2
204	8.6
205	9.6
206	9.4
207	8.1
208	8.6
209	9.5
210	8.7
211	7.3
212	7.9
213	8.5
214	9.6
215	9.1
216	7.6
217	6.1
218	6.4
219	7.8
220	6.6
221	9.6
222	8.7
223	7.3
224	8.2
225	9.1
226	9.7
227	8.5
228	9.3
229	8.1
230	8.3
231	9.3
232	7.1
233	7.6
234	9.8
235	8.6
236	9.4
237	6.7
238	7.8
239	8.6
240	7.4
241	9.7
242	7.7
243	8.3
244	8.6
245	9.3
246	8.5
247	9.2
248	9.8
249	8.6
250	8.3

Instance	Time
251	5.2
252	9.2
253	7.7
254	6.6
255	8.2
256	8.4
257	9.8
258	9.3
259	8.3
260	5.8
261	7
262	9.8
263	8.6
264	7.9
265	6.3
266	7.8
267	9.2
268	7.2
269	8.5
270	9.9
271	8.2
272	6.1
273	8.5
274	9.4
275	7.6
276	8.1
277	7.2
278	9.3
279	8.4

Appendix F: Full Name Registration Time Data

Instance	Time	Instance	Time
1	20.4	51	16.7
2	15.8	52	22.3
3	14.1	53	18.7
4	15.9	54	19.8
5	14.5	55	20.4
6	22	56	16.5
7	14.5	57	21.2
8	19.9	58	25.6
9	21.8	59	23.8
10	23.5	60	21.2
11	20.8	61	16.4
12	16.7	62	19.8
13	18.8	63	18.4
14	23.1	64	17.4
15	20.6	65	18
16	14.9	66	20.4
17	19.4	67	14.9
18	16.7	68	18.8
19	15	69	15.8
20	27.4	70	12.8
21	22.2	71	16.3
22	15.4	72	17.6
23	21.1	73	21.4
24	21.5	74	20.3
25	13.7	75	19
26	19.6	76	22.1
27	18.3	77	15.8
28	21.1	78	17.9
29	13.1	79	16.7
30	14.5	80	13.5
31	18.6	81	17.3
32	17.3	82	16.7
33	21.7	83	17.7
34	17.2	84	19.8
35	22.1	85	14.7
36	15.4	86	20.9
37	17.8		
38	19.7		
39	19.1		
40	16.2		
41	20.7		
42	15.7		
43	16.8		
44	17.4		
45	15.1		
46	14.8		
47	16.2		
48	18.4		
49	19.7		
50	24		

Appendix G: Account Registration Time Data

Instance	Time	Instance	Time	Instance	Time
1	28.6	21	37.3	41	36.8
2	34.6	22	26.1	42	35.4
3	36.2	23	33.7	43	37.5
4	29.8	24	31.9	44	41.2
5	30	25	28.3	45	30.8
6	32.9	26	34.9	46	34.7
7	38	27	31.5	47	33.9
8	28.2	28	32.8		
9	33.8	29	33		
10	29.1	30	27.3		
11	33.8	31	25.5		
12	33.2	32	28.8		
13	30.9	33	36.4		
14	36.6	34	39.7		
15	29.6	35	33.8		
16	42.3	36	35.1		
17	29.5	37	36.5		
18	26.6	38	24.8		
19	29.9	39	40.1		
20	30.9	40	33.8		

Appendix H: Sender Registration Time Data

Instances	Time	Instances	Sender	Instances	Time
1	9.7	51	11	101	11
2	7.8	52	8.6	102	9.7
3	9.3	53	13	103	7.7
4	8.3	54	10.1	104	9.8
5	6.9	55	9.7	105	7.5
6	8	56	11.4	106	9.1
7	7.4	57	9	107	6.4
8	10.9	58	7.5	108	13.1
9	5.6	59	12.3	109	11.4
10	7.4	60	9.8	110	13.9
11	9.6	61	9.9	111	6.6
12	11.3	62	10.6	112	7.2
13	12.1	63	7.3	113	9.2
14	7.1	64	9.3	114	7.5
15	7.9	65	8.6	115	6.4
16	8.5	66	8.1	116	13.5
17	7.8	67	13.4	117	9.5
18	11.1	68	10.2	118	9.1
19	12.6	69	9.6	119	9.3
20	7.1	70	7.8	120	7.6
21	8.5	71	6.5	121	12.3
22	8	72	12.1	122	8.6
23	13.2	73	12.6	123	9.8
24	8.9	74	10.1	124	14.2
25	12.1	75	11.7	125	9.5
26	12.3	76	7	126	6.8
27	6.4	77	6.8		
28	7.1	78	9.7		
29	7.2	79	7.4		
30	7.9	80	11.4		
31	8.5	81	10.5		
32	7.8	82	8.7		
33	10.2	83	13.1		
34	8.8	84	6.8		
35	8.9	85	9.7		
36	13.8	86	7.4		
37	12.1	87	11.5		
38	9.9	88	10.9		
39	7.5	89	8.7		
40	7	90	13.8		
41	8.2	91	6.8		
42	7.1	92	9.8		
43	10.3	93	8.7		
44	7.8	94	8.9		
45	9.2	95	6.8		
46	8.9	96	11.1		
47	7.4	97	8.2		
48	7.6	98	11.3		
49	8.5	99	12.6		
50	15.2	100	9.3		

Appendix I: Measurement Process Time Data

Instances	Time	Instances	Time	Instances	Time
1	10.9	21	10.4	41	10.5
2	8.9	22	14.4	42	17.3
3	6.5	23	9.6	43	12.4
4	11.8	24	18.5	44	17.8
5	8	25	13.7	45	11.4
6	15	26	7.1	46	6.9
7	7.3	27	13	47	11.5
8	13.6	28	6.9	48	12.2
9	17.6	29	13.2	49	17.4
10	12.7	30	9.5	50	13.4
11	18.4	31	10.8	51	8.9
12	13.6	32	17.1		
13	12.6	33	6.9		
14	10.4	34	9		
15	8.7	35	12.7		
16	12.5	36	13.7		
17	17.1	37	10.6		
18	8.5	38	10.1		
19	15.2	39	7.6		
20	12.5	40	12.5		

Appendix J: Oversized Parcel Registration Time Data

Instance	T_{write}	$T_{e\text{-}mail}$	Instance	T_{write}	$T_{e\text{-}mail}$	Instance	T_{write}	$T_{e\text{-}mai}$
1	12.6	62	21	15.9	64.5	41	16.1	61.9
2	13.5	66.1	22	18.2	51.6	42	12.6	52.3
3	15.8	63.9	23	11.9	55.5	43	17	55.4
4	13.4	59.1	24	14.6	56.1	44	13.9	57.7
5	15.6	56.9	25	16.7	59.3	45	17.5	55.9
6	17.6	81.6	26	14.1	60.3	46	16.7	60.3
7	15.7	64.1	27	13.1	52	47	15.4	69.7
8	13.5	60.2	28	16	56	48	16.5	55
9	14.8	66.7	29	11.2	52.6	49	13.2	61.6
10	14	62.4	30	15.7	60.3	50	11.9	57.6
11	19.3	59.4	31	16.4	69	51	15	61.6
12	15.4	63.7	32	14.7	57.5	52	16.1	66.2
13	14.2	58.9	33	19	66.5	53	13.9	56.5
14	17.4	62.2	34	13.6	59.1	54	17.9	63.3
15	16.3	67.2	35	15.1	55.9	55	15.6	67.8
16	16	51.3	36	15.1	69	56	13.7	65.6
17	11.5	64.6	37	16.9	69.7			
18	15.1	56.8	38	17.2	65.8			
19	20.3	64.4	39	15.3	58.2			
20	18.7	70.7	40	14.8	68.7			

Appendix K: Location Distribution Data

Location	Average	Share	Cumulative share
	110	0.031	0.031
	334	0.093	0.124
	13	0.004	0.128
	380	0.106	0.234
	12	0.003	0.237
	200	0.056	0.293
	273	0.076	0.369
	710	0.198	0.567
	54	0.015	0.582
	433	0.121	0.703
	8	0.002	0.705
	44	0.012	0.717
	46	0.013	0.730
	2	0.001	0.731
	400	0.112	0.842
	135	0.038	0.880
	107	0.030	0.910
	157	0.044	0.954
	22	0.006	0.960
	99	0.028	0.987
	46	0.013	1.000
	3,584	1.000	

Appendix L: Capacity Data

Location	Small	Medium	Large	Total
L1	12	9	2	23
L2	17	14	3	34
L3	12	4	2	18
L4	12	9	2	23
L5	6	4	1	11
L6	18	9	3	30
L7	18	14	3	35
L8	18	14	3	35
L9	12	9	2	23
L10	24	9	4	37
L11		9		9
L12	6	4	1	11
L13	6	5	1	12
L14	6	4	1	11
L15	18	14	3	35
L16	12	9	2	23
L17	2	4	1	7
L18	8	4	2	14
L19	6	4	1	11
L20	12	9	2	23
L21	12	9	2	23

Appendix N: Results

Base vs OCR

Group Statistics

	ModelID	N	Mean	Std. Deviation	Std. Error Mean
ProcessTime	1.00	50	38.7545	.15675	.02217
	2.00	50	33.3322	.97353	.13768
RegistrationTime	1.00	50	30.8810	.17048	.02411
	2.00	50	17.0914	.22320	.03157
NameRT	1.00	50	11.8919	.13552	.01917
	2.00	50	3.9859	.10711	.01515
SenderRT	1.00	50	8.1625	.01901	.00269
	2.00	50	3.2240	.04120	.00583
SMLRT	1.00	50	29.8755	.13646	.01930
	2.00	50	15.8216	.17522	.02478
OversizedRT	1.00	50	82.9678	.73574	.10405
	2.00	50	83.1890	.64222	.09082
LockerRT	1.00	50	2.8211	.04919	.00696
	2.00	50	2.8196	.05659	.00800

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
ProcessTime	Equal variances assumed	63.923	.000	38.883	98	.000	5.42233	.13945	5.14559	5.69906
	Equal variances not assumed			38.883	51.539	.000	5.42233	.13945	5.14244	5.70222
RegistrationTime	Equal variances assumed	3.000	.086	347.174	98	.000	13.78959	.03972	13.71076	13.86841
	Equal variances not assumed			347.174	91.654	.000	13.78959	.03972	13.71070	13.86848
NameRT	Equal variances assumed	.924	.339	323.635	98	.000	7.90595	.02443	7.85748	7.95443
	Equal variances not assumed			323.635	93.033	.000	7.90595	.02443	7.85744	7.95447
SenderRT	Equal variances assumed	25.209	.000	769.679	98	.000	4.93850	.00642	4.92576	4.95123
	Equal variances not assumed			769.679	68.961	.000	4.93850	.00642	4.92569	4.95130
SMLRT	Equal variances assumed	5.651	.019	447.453	98	.000	14.05391	.03141	13.99158	14.11624
	Equal variances not assumed			447.453	92.453	.000	14.05391	.03141	13.99153	14.11628
OversizedRT	Equal variances assumed	.209	.649	-1.602	98	.112	-.22119	.13811	-.49527	.05289
	Equal variances not assumed			-1.602	96.243	.113	-.22119	.13811	-.49533	.05295
LockerRT	Equal variances assumed	.272	.603	.143	98	.886	.00152	.01060	-.01952	.02256
	Equal variances not assumed			.143	96.133	.886	.00152	.01060	-.01953	.02257

Base vs Layout

Group Statistics

	ModelID	N	Mean	Std. Deviation	Std. Error Mean
ProcessTime	1.00	50	38.7545	.15675	.02217
	3.00	50	36.2759	.19612	.02774
RegistrationTime	1.00	50	30.8810	.17048	.02411
	3.00	50	28.2790	.20966	.02965
NameRT	1.00	50	11.8919	.13552	.01917
	3.00	50	11.8979	.13991	.01979
SenderRT	1.00	50	8.1625	.01901	.00269
	3.00	50	5.5087	.05528	.00782
SMLRT	1.00	50	29.8755	.13646	.01930
	3.00	50	27.2228	.15342	.02170
OversizedRT	1.00	50	82.9678	.73574	.10405
	3.00	50	83.0440	.72183	.10208
LockerRT	1.00	50	2.8211	.04919	.00696
	3.00	50	2.8162	.04341	.00614

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
ProcessTime	Equal variances assumed	4.306	.041	69.808	98	.000	2.47861	.03551	2.40815	2.54907
	Equal variances not assumed			69.808	93.459	.000	2.47861	.03551	2.40811	2.54911
RegistrationTime	Equal variances assumed	1.941	.167	68.089	98	.000	2.60205	.03822	2.52621	2.67789
	Equal variances not assumed			68.089	94.084	.000	2.60205	.03822	2.52617	2.67793
NameRT	Equal variances assumed	.039	.845	-.219	98	.827	-.00604	.02755	-.06070	.04863
	Equal variances not assumed			-.219	97.901	.827	-.00604	.02755	-.06070	.04863
SenderRT	Equal variances assumed	34.550	.000	320.998	98	.000	2.65381	.00827	2.63741	2.67022
	Equal variances not assumed			320.998	60.428	.000	2.65381	.00827	2.63728	2.67035
SMLRT	Equal variances assumed	1.093	.298	91.354	98	.000	2.65267	.02904	2.59505	2.71030
	Equal variances not assumed			91.354	96.686	.000	2.65267	.02904	2.59504	2.71031
OversizedRT	Equal variances assumed	.023	.879	-.523	98	.602	-.07622	.14576	-.36548	.21305
	Equal variances not assumed			-.523	97.964	.602	-.07622	.14576	-.36548	.21305
LockerRT	Equal variances assumed	1.014	.316	.528	98	.599	.00490	.00928	-.01352	.02331
	Equal variances not assumed			.528	96.510	.599	.00490	.00928	-.01352	.02331

Base vs Search Query

Group Statistics

	ModelID	N	Mean	Std. Deviation	Std. Error Mean
ProcessTime	1.00	50	38.7545	.15675	.02217
	4.00	50	33.6737	.15484	.02190
RegistrationTime	1.00	50	30.8810	.17048	.02411
	4.00	50	25.4968	.15712	.02222
NameRT	1.00	50	11.8919	.13552	.01917
	4.00	50	6.3862	.00794	.00112
SenderRT	1.00	50	8.1625	.01901	.00269
	4.00	50	8.1632	.02022	.00286
SMLRT	1.00	50	29.8755	.13646	.01930
	4.00	50	24.3785	.05216	.00738
OversizedRT	1.00	50	82.9678	.73574	.10405
	4.00	50	82.9701	.65179	.09218
LockerRT	1.00	50	2.8211	.04919	.00696
	4.00	50	2.8290	.04889	.00691

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
ProcessTime	Equal variances assumed	.092	.762	163.060	98	.000	5.08082	.03116	5.01899	5.14266
	Equal variances not assumed			163.060	97.985	.000	5.08082	.03116	5.01899	5.14266
RegistrationTime	Equal variances assumed	.173	.678	164.218	98	.000	5.38422	.03279	5.31916	5.44929
	Equal variances not assumed			164.218	97.355	.000	5.38422	.03279	5.31915	5.44929
NameRT	Equal variances assumed	58.394	.000	286.772	98	.000	5.50562	.01920	5.46752	5.54372
	Equal variances not assumed			286.772	49.336	.000	5.50562	.01920	5.46705	5.54420
SenderRT	Equal variances assumed	.308	.580	-.176	98	.861	-.00069	.00393	-.00848	.00710
	Equal variances not assumed			-.176	97.627	.861	-.00069	.00393	-.00848	.00710
SMLRT	Equal variances assumed	19.575	.000	266.065	98	.000	5.49697	.02066	5.45597	5.53797
	Equal variances not assumed			266.065	63.018	.000	5.49697	.02066	5.45568	5.53826
OversizedRT	Equal variances assumed	.085	.771	-.016	98	.987	-.00222	.13901	-.27807	.27364
	Equal variances not assumed			-.016	96.596	.987	-.00222	.13901	-.27812	.27369
LockerRT	Equal variances assumed	.031	.860	-.811	98	.419	-.00796	.00981	-.02742	.01150
	Equal variances not assumed			-.811	97.997	.419	-.00796	.00981	-.02742	.01150

Base vs 3D Camera

Group Statistics

	ModelID	N	Mean	Std. Deviation	Std. Error Mean
ProcessTime	1.00	50	38.7545	.15675	.02217
	5.00	50	36.1337	.17372	.02457
RegistrationTime	1.00	50	30.8810	.17048	.02411
	5.00	50	28.1367	.17838	.02523
NameRT	1.00	50	11.8919	.13552	.01917
	5.00	50	11.8926	.15284	.02161
SenderRT	1.00	50	8.1625	.01901	.00269
	5.00	50	8.1639	.01448	.00205
SMLRT	1.00	50	29.8755	.13646	.01930
	5.00	50	27.0564	.14983	.02119
OversizedRT	1.00	50	82.9678	.73574	.10405
	5.00	50	83.0952	.75356	.10657
LockerRT	1.00	50	2.8211	.04919	.00696
	5.00	50	.0000	.00000	.00000

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
ProcessTime	Equal variances assumed	.570	.452	79.199	98	.000	2.62077	.03309	2.55511	2.68644
	Equal variances not assumed			79.199	96.982	.000	2.62077	.03309	2.55510	2.68645
RegistrationTime	Equal variances assumed	.097	.757	78.646	98	.000	2.74430	.03489	2.67505	2.81355
	Equal variances not assumed			78.646	97.800	.000	2.74430	.03489	2.67505	2.81355
NameRT	Equal variances assumed	.457	.501	-.024	98	.981	-.00070	.02889	-.05803	.05662
	Equal variances not assumed			-.024	96.616	.981	-.00070	.02889	-.05804	.05663
SenderRT	Equal variances assumed	3.099	.081	-.398	98	.692	-.00134	.00338	-.00805	.00536
	Equal variances not assumed			-.398	91.534	.692	-.00134	.00338	-.00806	.00537
SMLRT	Equal variances assumed	.228	.634	98.359	98	.000	2.81904	.02866	2.76216	2.87591
	Equal variances not assumed			98.359	97.156	.000	2.81904	.02866	2.76215	2.87592
OversizedRT	Equal variances assumed	.749	.389	-.855	98	.395	-.12736	.14894	-.42293	.16821
	Equal variances not assumed			-.855	97.944	.395	-.12736	.14894	-.42293	.16821
LockerRT	Equal variances assumed	109.593	.000	405.570	98	.000	2.82108	.00696	2.80728	2.83489
	Equal variances not assumed			405.570	49.000	.000	2.82108	.00696	2.80711	2.83506

Base vs New Oversized Registration Process

Group Statistics

	ModelID	N	Mean	Std. Deviation	Std. Error Mean
ProcessTime	1.00	50	38.7545	.15675	.02217
	6.00	50	37.4689	.15703	.02221
RegistrationTime	1.00	50	30.8810	.17048	.02411
	6.00	50	29.5712	.15869	.02244
NameRT	1.00	50	11.8919	.13552	.01917
	6.00	50	11.8921	.14951	.02114
SenderRT	1.00	50	8.1625	.01901	.00269
	6.00	50	8.1675	.01887	.00267
SMLRT	1.00	50	29.8755	.13646	.01930
	6.00	50	29.8832	.16821	.02379
OversizedRT	1.00	50	82.9678	.73574	.10405
	6.00	50	13.3888	.05851	.00827
LockerRT	1.00	50	2.8211	.04919	.00696
	6.00	50	2.8236	.04736	.00670

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
ProcessTime	Equal variances assumed	.064	.801	40.973	98	.000	1.28564	.03138	1.22337	1.34791
	Equal variances not assumed			40.973	98.000	.000	1.28564	.03138	1.22337	1.34791
RegistrationTime	Equal variances assumed	.512	.476	39.768	98	.000	1.30986	.03294	1.24450	1.37522
	Equal variances not assumed			39.768	97.501	.000	1.30986	.03294	1.24449	1.37523
NameRT	Equal variances assumed	.377	.541	-.007	98	.994	-.00020	.02854	-.05683	.05643
	Equal variances not assumed			-.007	97.069	.994	-.00020	.02854	-.05684	.05644
SenderRT	Equal variances assumed	.130	.719	-1.322	98	.189	-.00501	.00379	-.01253	.00251
	Equal variances not assumed			-1.322	97.995	.189	-.00501	.00379	-.01253	.00251
SMLRT	Equal variances assumed	2.279	.134	-.251	98	.802	-.00769	.03063	-.06847	.05310
	Equal variances not assumed			-.251	94.004	.802	-.00769	.03063	-.06851	.05313
OversizedRT	Equal variances assumed	54.050	.000	666.603	98	.000	69.57905	.10438	69.37191	69.78618
	Equal variances not assumed			666.603	49.620	.000	69.57905	.10438	69.36936	69.78874
LockerRT	Equal variances assumed	.535	.466	-.257	98	.798	-.00248	.00966	-.02164	.01668
	Equal variances not assumed			-.257	97.860	.798	-.00248	.00966	-.02164	.01668

Group Statistics

	ModelID	N	Mean	Std. Deviation	Std. Error Mean
ProcessTime	2.00	50	33.3322	.97353	.13768
	7.00	50	34.8383	1.47902	.20916
RegistrationTime	2.00	50	17.0914	.22320	.03157
	7.00	50	16.5980	.19365	.02739
NameRT	2.00	50	3.9859	.10711	.01515
	7.00	50	3.9857	.08864	.01254
SenderRT	2.00	50	3.2240	.04120	.00583
	7.00	50	2.7038	.03747	.00530
SMLRT	2.00	50	15.8216	.17522	.02478
	7.00	50	15.3186	.14284	.02020
OversizedRT	2.00	50	83.1890	.64222	.09082
	7.00	50	82.8507	.62469	.08834
LockerRT	2.00	50	2.8196	.05659	.00800
	7.00	50	2.8306	.04712	.00666

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
ProcessTime	Equal variances assumed	4.069	.046	-6.015	98	.000	-1.50615	.25041	-2.00308	-1.00922
	Equal variances not assumed			-6.015	84.749	.000	-1.50615	.25041	-2.00406	-1.00825
RegistrationTime	Equal variances assumed	1.708	.194	11.808	98	.000	.49346	.04179	.41053	.57639
	Equal variances not assumed			11.808	96.087	.000	.49346	.04179	.41051	.57642
NameRT	Equal variances assumed	3.649	.059	.011	98	.991	.00023	.01966	-.03879	.03924
	Equal variances not assumed			.011	94.689	.991	.00023	.01966	-.03881	.03926
SenderRT	Equal variances assumed	1.182	.280	66.060	98	.000	.52022	.00788	.50460	.53585
	Equal variances not assumed			66.060	97.130	.000	.52022	.00788	.50459	.53585
SMLRT	Equal variances assumed	4.304	.041	15.733	98	.000	.50300	.03197	.43955	.56644
	Equal variances not assumed			15.733	94.174	.000	.50300	.03197	.43952	.56647
OversizedRT	Equal variances assumed	.000	.985	2.670	98	.009	.33835	.12670	.08691	.58979
	Equal variances not assumed			2.670	97.925	.009	.33835	.12670	.08691	.58979
LockerRT	Equal variances assumed	1.407	.238	-1.056	98	.294	-.01100	.01041	-.03166	.00967
	Equal variances not assumed			-1.056	94.889	.294	-.01100	.01041	-.03167	.00968

Group Statistics

	ModelID	N	Mean	Std. Deviation	Std. Error Mean
ProcessTime	2.00	50	33.3322	.97353	.13768
	8.00	50	36.1651	1.89173	.26753
RegistrationTime	2.00	50	17.0914	.22320	.03157
	8.00	50	15.9886	.20263	.02866
NameRT	2.00	50	3.9859	.10711	.01515
	8.00	50	2.8705	.03072	.00434
SenderRT	2.00	50	3.2240	.04120	.00583
	8.00	50	3.2203	.04356	.00616
SMLRT	2.00	50	15.8216	.17522	.02478
	8.00	50	14.7166	.11734	.01659
OversizedRT	2.00	50	83.1890	.64222	.09082
	8.00	50	83.0005	.65582	.09275
LockerRT	2.00	50	2.8196	.05659	.00800
	8.00	50	2.8351	.05513	.00780

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
ProcessTime	Equal variances assumed	18.848	.000	-9.416	98	.000	-2.83293	.30088	-3.43001	-2.23584
	Equal variances not assumed			-9.416	73.253	.000	-2.83293	.30088	-3.43255	-2.23331
RegistrationTime	Equal variances assumed	.381	.538	25.868	98	.000	1.10280	.04263	1.01820	1.18740
	Equal variances not assumed			25.868	97.097	.000	1.10280	.04263	1.01819	1.18741
NameRT	Equal variances assumed	49.157	.000	70.787	98	.000	1.11544	.01576	1.08417	1.14671
	Equal variances not assumed			70.787	57.006	.000	1.11544	.01576	1.08388	1.14699
SenderRT	Equal variances assumed	.034	.853	.436	98	.664	.00369	.00848	-.01313	.02052
	Equal variances not assumed			.436	97.695	.664	.00369	.00848	-.01313	.02052
SMLRT	Equal variances assumed	12.113	.001	37.048	98	.000	1.10492	.02982	1.04573	1.16410
	Equal variances not assumed			37.048	85.590	.000	1.10492	.02982	1.04562	1.16421
OversizedRT	Equal variances assumed	.038	.846	1.452	98	.150	.18855	.12981	-.06906	.44615
	Equal variances not assumed			1.452	97.957	.150	.18855	.12981	-.06906	.44615
LockerRT	Equal variances assumed	.024	.877	-1.388	98	.168	-.01551	.01117	-.03768	.00666
	Equal variances not assumed			-1.388	97.933	.168	-.01551	.01117	-.03768	.00666

OCR Only vs OCR + 3D Camera

Group Statistics

	ModelID	N	Mean	Std. Deviation	Std. Error Mean
ProcessTime	2.00	50	33.3322	.97353	.13768
	9.00	50	85.3384	8.85787	1.25269
RegistrationTime	2.00	50	17.0914	.22320	.03157
	9.00	50	14.2969	.21605	.03055
NameRT	2.00	50	3.9859	.10711	.01515
	9.00	50	3.9529	.10477	.01482
SenderRT	2.00	50	3.2240	.04120	.00583
	9.00	50	3.2314	.05341	.00755
SMLRT	2.00	50	15.8216	.17522	.02478
	9.00	50	12.9785	.17719	.02506
OversizedRT	2.00	50	83.1890	.64222	.09082
	9.00	50	82.9839	.70930	.10031
LockerRT	2.00	50	2.8196	.05659	.00800
	9.00	50	.0000	.00000	.00000

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
ProcessTime	Equal variances assumed	86.349	.000	-41.267	98	.000	-52.00620	1.26023	-54.50710	-49.50531
	Equal variances not assumed			-41.267	50.184	.000	-52.00620	1.26023	-54.53723	-49.47518
RegistrationTime	Equal variances assumed	.002	.962	63.612	98	.000	2.79452	.04393	2.70734	2.88169
	Equal variances not assumed			63.612	97.896	.000	2.79452	.04393	2.70733	2.88170
NameRT	Equal variances assumed	.009	.923	1.559	98	.122	.03304	.02119	-.00901	.07509
	Equal variances not assumed			1.559	97.952	.122	.03304	.02119	-.00901	.07509
SenderRT	Equal variances assumed	4.040	.047	-.771	98	.443	-.00735	.00954	-.02628	.01158
	Equal variances not assumed			-.771	92.065	.443	-.00735	.00954	-.02630	.01159
SMLRT	Equal variances assumed	.025	.874	80.672	98	.000	2.84304	.03524	2.77310	2.91298
	Equal variances not assumed			80.672	97.988	.000	2.84304	.03524	2.77310	2.91298
OversizedRT	Equal variances assumed	.274	.602	1.516	98	.133	.20511	.13532	-.06342	.47365
	Equal variances not assumed			1.516	97.048	.133	.20511	.13532	-.06345	.47368
LockerRT	Equal variances assumed	76.784	.000	352.303	98	.000	2.81957	.00800	2.80368	2.83545
	Equal variances not assumed			352.303	49.000	.000	2.81957	.00800	2.80348	2.83565

Group Statistics

	ModelID	N	Mean	Std. Deviation	Std. Error Mean
ProcessTime	2.00	50	33.3322	.97353	.13768
	10.00	50	32.1621	.98081	.13871
RegistrationTime	2.00	50	17.0914	.22320	.03157
	10.00	50	15.7836	.13564	.01918
OversizedRT	2.00	50	83.1890	.64222	.09082
	10.00	50	13.3894	.06205	.00878
NameRT	2.00	50	3.9859	.10711	.01515
	10.00	50	3.9798	.08315	.01176
SenderRT	2.00	50	3.2240	.04120	.00583
	10.00	50	3.2327	.03533	.00500
LockerRT	2.00	50	2.8196	.05659	.00800
	10.00	50	2.8188	.04738	.00670
SMLRT	2.00	50	15.8216	.17522	.02478
	10.00	50	15.8296	.13815	.01954

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
ProcessTime	Equal variances assumed	.195	.660	5.987	98	.000	1.17013	.19544	.78230	1.55797
	Equal variances not assumed			5.987	97.995	.000	1.17013	.19544	.78230	1.55797
RegistrationTime	Equal variances assumed	10.305	.002	35.406	98	.000	1.30780	.03694	1.23450	1.38110
	Equal variances not assumed			35.406	80.848	.000	1.30780	.03694	1.23430	1.38130
OversizedRT	Equal variances assumed	71.729	.000	764.959	98	.000	69.79966	.09125	69.61859	69.98074
	Equal variances not assumed			764.959	49.915	.000	69.79966	.09125	69.61638	69.98295
NameRT	Equal variances assumed	4.241	.042	.320	98	.750	.00613	.01918	-.03193	.04418
	Equal variances not assumed			.320	92.325	.750	.00613	.01918	-.03196	.04421
SenderRT	Equal variances assumed	2.557	.113	-1.125	98	.263	-.00863	.00768	-.02386	.00660
	Equal variances not assumed			-1.125	95.777	.263	-.00863	.00768	-.02387	.00660
LockerRT	Equal variances assumed	1.173	.281	.076	98	.939	.00079	.01044	-.01992	.02151
	Equal variances not assumed			.076	95.065	.940	.00079	.01044	-.01993	.02152
SMLRT	Equal variances assumed	4.964	.028	-.255	98	.799	-.00806	.03156	-.07068	.05456
	Equal variances not assumed			-.255	92.939	.799	-.00806	.03156	-.07073	.05460

Group Statistics

	ModelID	N	Mean	Std. Deviation	Std. Error Mean
ProcessTime	2.00	50	33.3322	.97353	.13768
	11.00	50	155.8646	14.15319	2.00156
RegistrationTime	2.00	50	17.0914	.22320	.03157
	11.00	50	11.4018	.07755	.01097
OversizedRT	2.00	50	83.1890	.64222	.09082
	11.00	50	13.4082	.08278	.01171
NameRT	2.00	50	3.9859	.10711	.01515
	11.00	50	2.8727	.02704	.00382
SenderRT	2.00	50	3.2240	.04120	.00583
	11.00	50	2.6980	.03389	.00479
LockerRT	2.00	50	2.8196	.05659	.00800
	11.00	50	.0000	.00000	.00000
SMLRT	2.00	50	15.8216	.17522	.02478
	11.00	50	11.3645	.07930	.01122

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
ProcessTime	Equal variances assumed	71.804	.000	-61.074	98	.000	-122.53242	2.00629	-126.51384	-118.55099
	Equal variances not assumed			-61.074	49.464	.000	-122.53242	2.00629	-126.56326	-118.50158
RegistrationTime	Equal variances assumed	31.448	.000	170.264	98	.000	5.68961	.03342	5.62330	5.75593
	Equal variances not assumed			170.264	60.659	.000	5.68961	.03342	5.62279	5.75644
OversizedRT	Equal variances assumed	67.223	.000	762.010	98	.000	69.78086	.09157	69.59913	69.96259
	Equal variances not assumed			762.010	50.628	.000	69.78086	.09157	69.59698	69.96474
NameRT	Equal variances assumed	53.683	.000	71.256	98	.000	1.11317	.01562	1.08217	1.14417
	Equal variances not assumed			71.256	55.219	.000	1.11317	.01562	1.08187	1.14448
SenderRT	Equal variances assumed	1.768	.187	69.727	98	.000	.52600	.00754	.51103	.54097
	Equal variances not assumed			69.727	94.485	.000	.52600	.00754	.51102	.54098
LockerRT	Equal variances assumed	76.784	.000	352.303	98	.000	2.81957	.00800	2.80368	2.83545
	Equal variances not assumed			352.303	49.000	.000	2.81957	.00800	2.80348	2.83565
SMLRT	Equal variances assumed	29.350	.000	163.863	98	.000	4.45710	.02720	4.40312	4.51108
	Equal variances not assumed			163.863	68.266	.000	4.45710	.02720	4.40282	4.51137