UCL
Université catholique de Louvain

LOUVAIN
School of Management

Louvain School of Management

Identification and tracking of Bam Mat equipment

Project Master's Thesis submitted by
André Loïc

With the view of getting the degree in
Master en ingénieur de gestion, à finalité spécialisée

Supervisor(s)
Semal Pierre

Academic Year 2017-2018

Acknowledgments

I would like to thank my supervisor Pierre Semal for his guidance during my thesis and the time he allocated to me. I would also like to thank the ESPO faculty and Louvain School of Management for these five years of studies which helped me acquire new skills and knowledge.

Furthermore, I express my gratitude to Bam Mat and to my internship supervisor David Clement. I have been warmly welcomed inside the company and David gave me a lot of support to the achievement of my project. His work experience helped me to get a better understanding of the management of a company.

Finally, I'm grateful to my family and the support they provided me during the redaction of my thesis.

Abstract

The digitalization and the Internet of things are commonly used concepts and are giving the industry new insight in optimization and collection/exchange of data since the first distributed control system was created in the 70s (Harjunkonsky, Isaksson, & Sand, in press).
These concepts are a real challenge to the development and automation of the construction sector who deals with a lot of different assets and flows. It will help this industry to gain deeper insight about the identification and tracking of the equipment either on construction sites or in the warehouses.

The purpose of this master thesis is to study the feasibility and profitability of an automated identification and tracking system inside a Belgian rental construction equipment company: *Bam Mat*.

This real case application provides a technical and economic feasibility analysis of the project. First, a description of the company and the equipment is assessed. Then, the technical feasibility analyzes three available technologies: RFID, BLE and GPS. Finally, the economic feasibility of this system is studied thanks to a costs benefits analysis and further application to the sector is discussed.

Glossary

BU: Abbreviation of business units. A business unit is a division of the operation department. There are four of them inside Bam Mat: LTD, Equipment, Formwork and Sites.

Bulk equipment: Material that doesn't possess a unique identification number.

CBA: A costs benefits analysis allows to economically identify if a project is viable or not.

CMK93: This is the name of the classification that Bam Mat established for their equipment.

Delivery slip: Summary of the products send to the construction site based on the order. The paper is sent along with the equipment.

ICS: Short for identification, counting and sorting.

ICT: Abbreviation of information and communication technologies.

Intervention sheet: This sheet is made by the repair workshop to explain which operation has been performed on the different pieces (welding, maintenance, repair, …). Then, the sheet is sent to the global administration for encoding.

Mutation slip: When global administration is receiving a *transfer slip*, a mutation slip is created inside Navision which states that material from a specific construction site on a specific day has been received. Later, the *return slip* will be received from the unloading team. This will allow global administration to update the construction site inventory in the database and close the mutation slip.

Order form: Information send to the order picker about the needed products and quantities. It comes from the dispatch team who divide the order form into the different appropriate teams.

PDA: Personal digital assistant is a helping tool/application for the workers to perform their daily activities such as the order picking, inventory management, ...

Pof: Proof of concept. This technique is used to prove the feasibility of a project with a test on a smaller scale.

Purchase order: The purchase order is the paper send to the different picking teams telling them which pieces (and how much) must be prepared and put in the loading area.

PWC: PriceWaterhouseCoopers is a consulting company.

QSE: Department of quality, safety and environment.

Return slip: This contains the information about all the equipment allocated to a specific construction site. Later, this sheet will be filled by the unloading team with the quantities of the returned equipment. Then, the sheet is sent to global administration for encoding.

Transfer slip: This sheet is made by the construction site to inform the unloading team from where the equipment is coming from, when it has been withdrawn from the site and which and how much equipment is coming back. If the sheet has not been filled by the construction site, the driver completes it with only the date and the name of the construction site. Then, it's sent to the global administration.

Navision: This is the name of the ERP used inside the company.

VCA: Inside control performed by Bam Mat to assess the security of the material.

LTD BU: This is the business unit related to the operations of loading, transport and delivery.

Table of contents

Acknowledgments I
Abstract III
Glossary V
Part 1: Company and available technology overview 1
Chapter 1: Introduction 3
Chapter 2: Bam Mat 7
2.1 Introduction of the company 7
2.2 History 7
2.3 Hierarchy 10
2.4 Values 10
2.5 Mission, Vision and Strategy 11
2.6 Corporate Social Responsibility 12
2.7 Future 2021 13
Chapter 3: Equipment Management and Related Issues 15
3.1 Equipment classification 15
3.2 Site Structure 16
3.3 Business Processes 16
3.4 Informatic system 18
3.5 Identification problems and impact 19
Part 2: Technical feasibility study 25
Chapter 4: Inventory Identification and Tracking Method 27
4.1 RFID 28
4.2 Bluetooth Low Energy 31
4.3 GPS 32
4.4 Selection 32
Chapter 5: Application of the Technology 35
5.1 Categorization of the Equipment 35
5.2 Solution to Implement 36
5.3 Conclusion 38
Part 3: Economic feasibility study 41
Chapter 6: Change management 43

6.1 Material return process 43
6.2 Order Preparation Process 45
Chapter 7: Benefits Analysis of an identification system 47
7.1 Stakeholders 47
7.2 Time 48
7.3 Reliability 50
7.4 Environnement 51
7.5 Digitalization 51
Chapter 8: Market analysis 53
8.1 Market Research 53
8.2 Market overview 53
8.3 Selection 57
Chapter 9: Profitability 59
9.1 Cost 59
9.2 Revenue 61
9.3 Profitability 63
Chapter 10: Scalable learning 65
10.1 Shareholders 65
10.2 Belgium 65
10.3 International 66
Conclusion 67
Bibliography 69
Annex 73

Part 1: Company and available technology overview

Chapter 1: Introduction

Bam Mat is a material service company founded in 2010 that mainly rent and deliver construction equipment to the subsidiaries of BAM Group (Bam Contractors, Galère, Bam Track, Interbuild, ...) Beside renting material, they are also selling non-reusable pieces to these companies such as bolts, screws, gasoline, boots or other consumables that are needed when working with one of their equipment.
Bam Mat has other clients than the one listed above (BAM Group) such as external joint venture created to carry out a specific important construction project.

In the past two years, Bam Mat has identified an interesting business opportunity regarding an automated identification and localization of their equipment. This has been made possible thanks to the development of the internet and more recently the internet of things that allows different remote object to communicate with each other's (Krotov, 2017). The focus on automation is strategic for such information-intensive industry and will likely change their processes and contribute to the future growth of the company.
To remain competitive in the long term, Bam Mat must translate this opportunity into a foreseeable scenario with the related cost and revenue. This way, they will be able to decide to undertake the project or not.

This paper is a feasibility study of an automated identification and localization system in the specific area of construction. The purpose of such study is to assess either if the project is feasible or need deeper thinking to be undertaken. The theoretical background is based on a real case written by Christananda & Simanjuntak (2017) where they identify 5 different types of feasibility study when evaluating a project:

-*Legal*: Are there legal constraints that would prevent the project completion?
-*Market*: An estimation of the demand for the new project must be assessed. The company identifies the different customers, competitors, … Two methods are generally used when establishing a market feasibility: Marketing Mix and SWOT analysis.

-*Technical*: This analysis evaluates if the company or the market has the resources to implement the project. Are the available technologies developed enough or is it needed to invest in research and development?
-*Management*: The project needs a clear time structure with different control to perform. Can we reach the completion of the project within the established timeline? Are the resources well allocated?
-*Economic*: Finance is one of the main priorities as, even if the other aspects are feasible but the company hasn't enough funds, the project will not be undertaken. Several methods can be used to assess the economic feasibility such as: Net present value, return on investment, benefits costs analysis, …

This thesis will have a deeper insight on the *technical* and *economic* aspects. In fact, these are the two most important factors as a negative report would be translated into the end of the project. It's highly uncertain if the available technologies are developed enough to meet the project specification and if the project is economically viable. The objective is to take a GO/NO GO decision after having analyzed these two aspects.

The market feasibility is also an interesting aspect to study as it analyzes how the demand will change after having undertaken the project. However, this study requires a lot of information regarding the needs of the clients or the predicted growth of the sector and these weren't the main priorities of Bam Mat. Because of these two reasons, the market feasibility will not be part of the thesis.
Nonetheless, a few predictable effects on the market have been identified and analyzed in Chapter 7.

It's worth mentioning that it would still be interesting to study the *legal* and *management* aspects after having assessed the technical, economic and market feasibilities to have a better control on the project. However, this will not be part of the thesis due to their lower importance.

The paper will be structured in three main parts described below:
First, a *general overview* of Bam Mat and the management of its equipment will be analyzed. In this part, the internal problem linked to their material will be presented.

Understanding the company, its processes, structure and equipment is an important step required to understand why Bam Mat needs to implement such automated system; and to study how they can best seize this new business challenge (digitalization) and increase their efficiency.

Second, the paper will focus on the *technical feasibility*. Three wireless technologies capable of automatically identifying and tracking objects will be explored respectively RFID (radio frequency identification), GPS (global positioning system), and BLE (Bluetooth Low Energy). The pros and cons will be assessed for each of them and a selection of the most suitable solution for Bam Mat will be made.
Also, a classification study of the different equipment based on their function and size will be presented. This is needed to know if the different categories of equipment will fit the chosen technology (technical feasibility) and to have an idea about the number of parts to identify per categories (economic feasibility).

Finally, the last part will present the *economic feasibility* based on a costs benefits analysis (CBA). This analysis has been chosen because of its flexibility and ability to integrate all the costs and benefits of a project whether they are tangible or not." CBA is a key component of project appraisal in most OECD countries" (CEEU, 2012, p12).
Meanwhile, a market analysis will be conducted. The main providers on the Belgian market will be identified so that they can give Bam Mat an estimation of the different cost required to achieve the project. Once the quantities and prices established, the profitability of the project will be determined. It's based on these calculations and on several non-financial elements that the GO/NO GO decision will be made.

This should enable Bam Mat to achieve its vision:

"*We will be the preferred multidisciplinary partner adding value to our customers delivering service and equipment.*"

Chapter 2: Bam Mat

This chapter presents a global overview of Bam Mat. This first understanding of the company will allow to figure out how the project is in line with its structure and values and to have a better insight of its management. In fact, it's important for any project to match the strategy of the enterprise and help it achieve its vision.

2.1 Introduction of the company

As explained, Bam Mat is a company founded in 2010 that mainly rent and deliver construction equipment.

Their competitive environment is quite mature with several companies like Boels, Loxam, DK rental, Doka, Hunnebeck, Peri, … Theses companies are all renting construction equipment and this important presence on the market has forced BAM Mat to further develop his role within the Bam Belgium Group as a service provider.

The company is composed of 85 workers responsible for the material management, material repair and counting, delivery, order preparation, … and 30 employees responsible for the central dispatching, technical support & general administration. Bam Mat has three different sites in Belgium: Saint-Trond, Liège and Gand, in order to take care of an impressive equipment fleet of approximatively 390.000 pieces (according to their ERP). This resulted in a turnover of 20 million euro in 2017 and an estimated value of the equipment of 65 million euro (Bam Mat, 2017).

Bam Mat can also count on a strong partnership with companies like Wolftech, Adria, Van Der Speck, … which provide them all the equipment needed when it's not possible to internally fulfill one client's orders.

2.2 History

In this section, the history of Bam Mat is developed. Knowing the background of the company is a required step to fully understand where the values and the vision of the company come from. It's also interesting to avoid past mistakes.

In 1949, Galère, a Belgian family-owned company, is created for the purpose of fixing and repairing the damaged engineering structure caused by the World War II. The company was originally made of two workers but quickly expanded its activities to become sustainable. 40 years later, Arthur Galère (the founder) retired and entrusted his enterprise to the group HGB (65 ans d'histoire et de savoir-faire, n.d.).

In the 80thies, the civil engineering sector was doing very well in Belgium: Galère was part of some important project and it's in this context that they decided to develop a strong equipment service within the company. This allowed them to keep the know-how and become completely independent of any external suppliers.
During this period, another subsidiary construction company of HGB decided to merge with De-Meyer in order to also form their own equipment service located in Gent. This was the creation of the second service material inside the group.

In 2002, HGB is taken over by BAM Group (Royal BAM NBN acquires HBG, n.d.).

Later on, in 2009, BAM Group was facing an important competition between Galère and a road construction company called Betonac on the Walloon market. It was a nice period of cash & acquisitions by then, which drove the group to purchase BETONAC. This allowed Bam Group to reduce competition on civil works and acquire some know-how in roads & asphalt. It's the integration of a third Material service located in Saint-Trond.
All the BAM companies in Belgium were then supplied by 3 different equipment companies.

With 2010 came the vision of one equipment company, merging the 3 apart equipment services of Galère, Betonac & CEI De-Meyer. This is the day *Bam Mat* was founded.

Unfortunately, BAM Mat was created with 3 sites having 3 different culture and 3 different way of working. Each site had his own director with his own vision.
This fusion also took place in a context of tension in Belgium as a lot of political conflict between North and South emerged. This crisis led to the absence of a government for

more than 500 days. Even some politicians were in favor of the separation of Belgium at that moment. Therefore, it was complex to unite the company.

Furthermore, in 2013, Bam Mat lost its car leasing activity. This very profitable activity was all along hiding losses coming from structural & organizational issues. It was time to react and save Bam Mat from these important recurrent losses and a possible closing.

BAM Belgium decided in 2014 to adopt a restructuration plan with a new delegated administrator in charge, Guido De Cock. The structure of the company was modified by grouping the related activities together (up to that moment divided into the three different sites). Four main business units were created to replace the three former directors: Formwork, Equipment, Sites and Logistic Transport & Dispatch.
The loss making metallic construction division was closed. This wasn't a very popular decision and enforced a negative effect between workers and direction on this divided company. The reconstruction of a positive image for the company was needed, a company which is at the service of the construction site.

Resulting from this, it was decided to look for a general manager, having experience on the production side. BAM Mat welcomed David Clément in June 2016 who was before a construction site production manager. David was a former client of BAM Mat and was therefore well positioned to understand the needs of the company.

In September 2016, the mission, the vision and the values of the company were redefined.

In January 2017, a new organigram was defined with a clear definition of "who is who" in the company. Many workers were at that time complaining about having unclear job definition.

Year 2017 was also used to specialize the activities on the 3 sites and avoid double handling. All these efforts helped to create one company with one way of working. Even more it has also been decided to move all the activities of the 3 sites to a new modern site in Hannut (*see section 2.7 Future 2021*).

2.3 Hierarchy

The different department of the companies are briefly listed in this section with a deeper insight of the operation one. This information will be needed when establishing the new classification of the equipment (*see section 5.1 Categorization of the equipment*) and when presenting the different processes of the company (*see section 3.3 Business processes*).

Bam Mat has a vertical structure divided into six different departments:

-HR & Legal
-Finance
-Operations
-QSE
-Procurement
-Administration

The principal department is the operation one and is linked to the management of the equipment. It's divided into the four different business units (BU):

-*Service formwork* is the BU accountable for all the formwork equipment. This unit is also composed of a study desk office to analyze any request coming from the construction site and propose a specification.

-*Service site* includes all the on-site installation such as the tower crane or the electricity and the maintenance of the container.

-*Service LTD* correspond to the loading and unloading of the trucks, sorting and counting the parts and the delivery of the equipment to the construction site.

-*Service Equipment* is related to all the other parts that are not included in the formwork. It goes from large (bulldozer, truck, …) to small equipment (Heras safety collar, screwdrivers, …). The general management of the warehouses and the electrical maintenance are also part of this business unit.

2.4 Values

The project needs to be aligned with the different core values of Bam Mat but also with the mission, vision and strategy assessed in the next section. In fact, the importance of

linking project with business strategy results in an increased performance of the organization (Srivannaboon, 2006).

As mentioned in the history part, Bam Mat has encountered a major turn when switching from one director per site to one director for the three of them. This was the time to unite this company and redefine the ground values the employees wanted to work for. Therefore, in 2016, an important analysis has been established to redefine the essence of the company and its future. It's at that moment that the six core values of Bam emerged: *Customer oriented*, *efficient*, *reliable, sustainable, innovative, without borders* (Bam Mat, 2017).

The foreseeable future challenge for Bam Mat will be to establish a clear communication plan about these values and spread them inside the company so that the employees live with them.

2.5 Mission, Vision and Strategy

The current mission of Bam Mat is the following (Bam Mat, 2017):

-"*Supporting your business*"

And the future vision they want to reach will be (Bam Mat, 2017):

-"*We will be the preferred multidisciplinary partner adding value to our customers delivering service and equipment.*"

By "Supporting your business" Bam Mat mean that the enterprise is more than a classic material services company. In fact, supporting operations are also undertaken to facilitate the daily on-site activities of their clients. Such activities are: Providing the correct license for specific vehicles in specific areas, operating quarterly maintenance controls to check if the material is functioning well and still comply with the usual safety rules, providing on-site installation for certain equipment, …

Their vision represents the future strong position that the company wants to achieve in the market. Their ambition is to be the preferred providers and not the default one as it is now for the other subsidiaries of BAM Group.

To fill the gap between the mission and the vision, Bam Mat has defined a set of strategies to put in place. First, their processes will be redesigned and a correct IT framework will be created. Doing this, every shareholder will know exactly how Bam Mat does things and it will result in an easier communication. Along with the redefinition of these processes, the company is looking for a new appropriate ERP specialized in the renting industry.

Second, the digital follow up will be improved to keep up with the new trends. Bam Mat has not yet invested much in this domain as almost everything is done on paper and then encoded in the database. This would allow the enterprise to give more accurate information to their clients and incur a better/faster internal management. This digital point will be the main purpose of this thesis.

Finally, a reduction of the average lifetime of the equipment is considered in order to improve their quality. The objective is to have a fleet of equipment having a lifetime of approximatively seven years. This should improve the finance and the customer satisfaction as Bam Mat will have less breakdowns and less repair to perform.

2.6 Corporate Social Responsibility

Today, the concern about CSR is well present and every new project undertaken needs to integrate ethics into business to avoid predictable future problems. The CSR concerns of Bam Mat are presented in this section. The major one is security and is directly linked to the identification and tracking project as a material can't be controlled if he doesn't have a unique identification number.

As stated above, the first and major CSR aspect for Bam Mat is the *security*. As you can imagine, Bam Mat's workers are dealing with a lot of heavy or dangerous equipment and their sites are full of vehicle movements. You must always make sure that you are visible to the others. The standard compulsory outfit is made of boots, protection glasses and a fluorescent vest.

Their motto around security is "*don't walk by*" meaning that if you pass next to something that sounds dangerous to you (wobbly stacking, damaged equipment, unidentified containing, …), you must report it independent of your status inside the

hierarchy. Moreover, a safety presentation is made by the QSA manager for every new worker (Bam Mat, 2017).

Adding to this, Bam Mat is operating internal and external (compulsory) *control* on its equipment. The internal one is coming from a growing concern from their clients regarding the safety of the material. Therefore, a quarterly VCA inspection with Vinsotte Company has been implemented which is made of a series of inspection and review to perform on "at risk equipment". These controls assess if the different parts can still be rented or need maintenance/repair.
Then, an annual compulsory legal control about the standard rules and regulation of the construction sector is achieved.
As explained above, all these operations can only be performed on the individual material (the one that have a unique identification number). If a bulk equipment needs to be checked, Bam Mat first must give him a unique id as the company needs to precisely track and record which parts has been controlled. If the project is undertaken, a consequent number of pieces will have its own identification number which will increase the reliability of the equipment.

Besides this security aspect, Bam Mat is also involved in some *sustainable activities* such as the creation of their low-energy new sites (*see next section*), the reduction of the printed paper thanks to the digitalization of their equipment and their eco-container. These have been created by the company to safely store hazardous/polluting products.

2.7 Future 2021

As mentioned in the history part, Bam Mat wants to regroup his three sites into one to gain in coherence and efficiency. This will be the final step of their restructuration engaged in 2016. This site will manage all the present activities of the company and will be designed to take into account enough space for further expansion as the enterprise wants to penetrate the outside market.
Therefore, the automated identification and localization of their equipment needs to be thought in relation with the new site.

This idea was launched end 2016 when the need for restructuration was well present. An external consultant company (PriceWaterhouseCoopers, PWC) has been hired and with Bam Mat, they worked on a benefits analysis of a centered site, a potential location and an estimated budget.
This was presented in June 2017 in front of BAM Group with an investment plan of 10 million euros. The project was approved by the board of management. Then, an estimation of the space required and the flow of movement between the different areas has been established end January 2017.
The future of the project is now to find a logistic architect who will design the site considering all the flows and an appropriate management team with a construction site operator. Bam Mat wants to move in in this new place for at the latest 2021.

Along with this site project, an urgent need to restructure the processes was present as the enterprise had several different ways of working regarding the different sites. Therefore, a second module with PWC has been created on these processes design. All the “as is” processes have been identified as well as the “to be” in relation to the new site. the quick win to put in place right now were established but also the long-term goals (taking place with the new site). At the moment, Bam Mat is looking for a new ERP system to integrate the future “to be” processes but they are likely to be changed with the implementation of the identification project (*see Chapter 6: Change Management*).

Chapter 3: Equipment Management and Related Issues

Managing the equipment is the main business of Bam Mat. Therefore, it's an important dimension to analyze. This chapter will study the internal classification of the material, how the company handles and stores them in the different sites and warehouses (with which information system) and the main problems (internal and external).

3.1 Equipment classification

In order to assess the *technical feasibility*, the initial classification of Bam Mat equipment needs to be presented. This allows to understand the wide and varied range of material and will later help to restructure and align them with the automation project.

The equipment management is the core activity inside Bam Mat and therefore an appropriate classification was needed to facilitate their handling (for both the clients and the internal management). Bam Mat has about 390.000 pieces of equipment according to their ERP. However, it should be lower in reality as their data are subject to several errors during counting and encoding (*see section 3.5 Identification problems and impact*). It is estimated that the formwork equipment accounts for about 3/4 of the total number (in terms of number of pieces).

The equipment is divided into two main categories: *Individual* and *bulk*.

In parallel of these two main categories, the products are subdivided under the CMK 1993 classification (*see annex 1 for the detailed classification*). The initial purpose of this categorization is to provide a helping tool for the companies in the construction sector for calculating the pricing structure of the equipment. As this document was summarizing all the different equipment of the sector and therefore included the one that Bam Mat possesses, this classification has been adopted under some adjustment (confederation construction, n.d.).

3.2 Site Structure

Before seeing the two main business processes of Bam Mat, the different areas within the warehouse and their function needs to be understood. This will allow for an easier understanding of the next section.

As explained in *section 2.1 introduction of the company*, Bam Mat is located in three different sites namely: Liège, Saint-Trond and Gand. These three sites have their own specificity, Liège is mainly responsible for the civil engineering equipment while Saint-Trond is taking care of the road furniture and containers and Gand the cranes. Each site is divided into different areas (*see annex 2 for an overview of Liege site*):

-*Unloading/loading*: This area is used for the loading and unloading of the truck departing/arriving from a construction site.
-*Counting*: Located just next to the unloading/loading area, its purpose is to count the returned material.
-*Preparation*: This is where the workers store the furniture asked by a construction site before loading them on the truck. The area is clearly divided for the different construction site.
-*Depot 1*: This area is dedicated to the storage of the equipment ready to be sent on any construction site if asked. This equipment is characterized by a green label (ready to be shipped). The different depot 1 areas correspond to the different categories of object such as formwork, large equipment, small equipment, …
-*Depot 2*: The equipment in depot 2 is the one who needs reparation whether it concerns electrical maintenance, mechanical and welding reparation or cleaning. Bam Mat possesses several depots 2 areas categorized by the different reparation processes listed above. The equipment in repair can be recognized by a red label (maintenance) to avoid errors.

3.3 Business Processes

The purpose here is to have a global overview of Bam Mat's activities linked to their equipment (*see annexes 3 and 4 for the detailed order preparation and material return process*). In fact, having a deeper understanding of the process will be useful when

assessing the economic feasibility. The differences with and without the project will be assessed so that the different savings can be calculated.

Two main processes have been analyzed respectively the order preparation process and the material return process (PWC & Bam Mat, 2017). Both of them have differences depending on the kind of material the workers are handling (craves, formwork, small equipment or large equipment) but these are not worth mentioning for the understanding of this thesis.

3.3.a Order Preparation Process

Starting with the *order preparation process*, the dispatch department receives the order. First, a purchase order is created and sent to the different appropriate depot 1 teams. After receiving the purchase order, the teams look if they have everything on stock. If not, they phone the different possible depot 2 areas and ask for the missing pieces. Two scenarios are possible:

-If the depot 2 has the parts, the workers repair it and send it to the depot 1 as soon as possible.

-If it hasn't, a decision must be made of either renting the pieces to an external supplier or buying it.

Finally, the workers put the equipment in the preparation area where it will wait to leave for the related construction site. At the same moment, a delivery slip is printed in their ERP Navision. (with information about the shipment).

Once the material arrives at the destination, the manager has to sign the delivery slip to notify his agreement (otherwise a complaint is introduced) and Bam Mat update the inventory in the database.

3.3.b Material Return Process

For the *material return process*, everything starts when a truck is coming back from a construction site. The workers first unload the truck and put the equipment together by construction site. A red label is associated to them with the site and the date.

Meanwhile, they check if the construction site has sent a transfer slip with the shipment. This paper is made of the name of the construction site, the date of withdrawal at the

site and the list of the returned equipment. If there is none, the driver creates one without the last information.
The transfer slip is then sent to the global administration where a mutation slip is created inside Navision. This one is saying that a request for material return has been opened in the system from a specific construction site.

The dispatch unit also sends a return slip (the entire list of equipment belonging to a specific construction site) to help the workers identify the pieces and write down how many has been returned. Now, it's possible for them to identify, count and sort the material (depending on if the pieces belong to bam Mat or an external supplier).

The filled return slip is then sent to the global administration for encoding in the Navision where some operations need to be performed if there are inventory issues (*see annex 5 for the detailed issues*). Once the issues are solved, the mutation slip is updated, closed and sent to the construction site.

Meanwhile, the material is cleaned and sent to the appropriate depot 2 for another counting (to minimize errors) and possible reparation.
If repair is needed, the workers take some pictures of the damaged equipment, repair it, write down the performed operation on an intervention sheet and then change the status of the equipment to depot 1. This sheet is sent to the global administration where they linked it to the right piece.
Otherwise, they just have to change the status of the equipment to depot 1.

3.4 Informatic system

In this section, it will be analyzed how the employees interact with the informatic system and how they used it for to evaluate different ways of improvements with the new project. In fact, as demonstrated in the previous section, a lot of data are entered manually in the system which is taking a lot of time.

Microsoft Dynamics NAVISION (5,0) is the ERP system used by Bam Mat to store, collect and analyze data since almost 10 years. It's a database that contains information about all their equipment, clients, suppliers, employees, invoices ….

Most of the work is done on paper. The workers register all the asked information on paper sheets and then give them to their superior who will record the information in the Navision system. The administration doesn't want that everyone has access to this database as the impact of mistake is important. In fact, it's used every day and must be as accurate as possible.

Finally, as explained in *Section 2.7 Future 2021*, there's a need for a new ERP with a solid operation unit. This would allow them to automatize the delivery schedule with the trucks or to summarize important information such as the number of orders per week, the quantity moved or the utilization rate. At the moment, there isn't any option in Navision that automatically provides an overview of last week's performance.

3.5 Identification problems and impact

The different internal and external problems linked to the equipment management are presented. Therefore, this section demonstrates the need for implementing an automated identification and tracking system. In fact, the majority of the different issues presented can be solved with the potential new system.

3.5.a Internal problems

A first analysis has been made to evaluate the company's way of working through different formal and informal meetings, interviews, brainstorming, walking around and processes analysis. In this paragraph the different problems (identification, encoding, counting, timing and tracking) and their impact on the company are presented. Bam Mat is working in an old-fashioned way where everything is done manually and written on paper which is taking a lot of time given the size of the company and leads to very redundant jobs. The company is behind the available technology due to all the restructuration issues (*see section 2.2 History*).

Identification Error

One of the main problems is related to the identification of the bulk equipment. In fact, this equipment doesn't have a unique identification number and Bam Mat hasn't set a proper catalog for the workers to base themselves on. When the material is coming back,

they (the workers) only receive a return slip with the inventory of the construction site and a small description. It's based on this list that the returned pieces will be identified and counted (same thing applies when the equipment is put for maintenance in depot 2).

Identification can be tough as Bam Mat possesses a lot of pieces and some of them are similar. It usually happens that at the end of a construction site, they have too many pieces of one kind and not enough of others because of these identification problems.

However, the error related to the identification tend to be smaller with the experience of the workers. They tend to be more familiar with the different particularities of the pieces. Nonetheless, it will always happen that the experienced workers are sick/off-duty leaving the new employees with less supervision and leading to more problems. It's taking at least one year to get used to the different equipment inside the company.

Encoding Error

As everything is done manually, the database is subject to some encoding errors. In fact, the sheet that the manager receives for encoding can be altered by external events such as rain or be hard to read because of the employee bad writing.

Furthermore, the manager has to input all this information in the system which is more subject to typing error when you are tired or when you have a lot of data to enter. This can lead to a returned equipment encoded under another one or a wrong quantity entered.

Finally, the quantity of each piece is generally over evaluated as it happens that the missing pieces from a construction site aren't deleted in the database. Also, some equipment (sold, broken, stolen, …) are still registered which further inflate the total amount of equipment.

Counting error

As the workers have to count a large number of pieces manually, it frequently happens that they make some mistakes and that the quantities count by the two different teams (unloading and depot 2) lead to two different results.

Timing errors

It can take a few days to encode the written information in Navision. This means that a material that has been returned and then moved to depot 2 can still be registered under the construction site location (and not depot 2). This is leading to some problems when a part has to leave depot 2 and be ready to be rented again (depot 1). In fact, the next database movement of depot 2 to depot 1 can only be performed if the piece is classified under depot 2.

A new line has to be created for that piece in Navision because the person who wants to encode the movement from depot 2 to depot 1 can't do the first movement (as stated above). In fact, he doesn't know from which construction site he must withdraw the piece and as they are a lot of construction sites, it's not possible to know from where the piece is coming.

This is over-evaluating the inventory and will lead to problems when the order planner checks in the database if they can fulfill the order.

Tracking problems

The location of the equipment is divided under only 3 categories: depot 2, depot 1 or construction site. The equipment inside the different warehouse (depot 1/depot 2) does not always have a clear place and occasionally the workers have to search for a missing piece quite some time.

Another problem appears when Bam Mat has to perform VCA control on their on site equipment. In fact, most of them doesn't have an inside tracking device and it's therefore not possible to accurately know where the equipment is. Sometimes, the different construction sites move them from one site to another without noticing Bam Mat.

Conclusion

All the above-mentioned problems are related to the database Navision (except for tracking) implying that the data is not accurate.

It's therefore hard to find precise information making it more time consuming. For example, it was a real challenge for PWC to estimate the future growth of Bam Mat based on their current equipment and determine the space needed in the new warehouse.

3.5.b External Issues

On the side of their clients, it happens that a complaint is introduced for a wrong invoice. In fact, identification and counting errors sometimes appeared and are therefore reflected in the bill that Bam Mat is sending to them.

Figure 3.1 shows the two possible invoicing errors:

-The first one would be that Bam Mat didn't correctly *identify* or encode the returned/leaving pieces. This *internal* problem is captured with the complaints introduced by the construction sites and can be tracked.

-The second one appears when the *quantity* at the end of the contract is not the same as the equipment delivered. This can be because of several reasons: the construction site is sending back too much/not enough pieces, the workers didn't count/identify them properly, … This problem is discussed at the end of the construction site with the two parties as the errors can come from both sides.

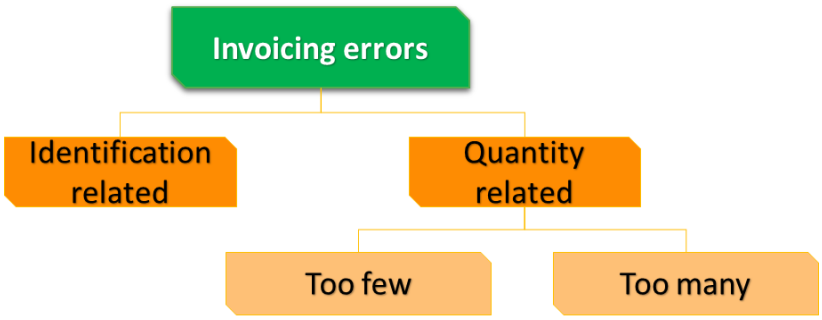


Figure 3.1: Invoicing related problem – Source: Author of the paper

In 2017, Bam Mat received 49 complaints (under 347, 14%) about wrong invoices where 21 of them led to a refund for a total number of 3.855 euros. These complaints follow a strict agenda under Bam Mat Policy and must be answered within 10 working days.

Besides that, still in 2017, they also recorded 52 cases of too many pieces accounting for 144.504 euros. This can sometimes not be linked to an internal error but to the construction site sending back too many pieces so this information has to be handled more carefully.
In the case of too few pieces, Bam Mat will receive money.

Finally, it's difficult at the moment for Bam Mat to justify their invoices as it's not possible to precisely track the inventory. How to prove that they in fact receive 120 pieces when the construction site is claiming that they sent 140 back? The requested equipment has certainly left the counting area for the different depot 2 and can't be found anymore.

3.5.c Conclusion

It's because of all these well-known problems that Bam Mat decided to analyze the feasibility and profitability of an identification and tracking system of their inventory. The next part will assess the technical feasibility of the project.

Part 2: Technical feasibility study

Chapter 4: Inventory Identification and Tracking Method

In order to assess the technical feasibility of the project, the available wireless identification and tracking solutions on the market and their features have been identified. This will demonstrate if the current technologies are powerful enough to meet the requirement.

This chapter presents a global overview of three wireless technologies used in identification and tracking: *RFID, BLE and GPS* (Bauer, Henkel & Samie, 2016). Bam Mat is already using GPS devices to locate its vehicles and will keep this technology as "GPS coordinates is the most practical approach for mobile objects tracking due to its precise data acquisition, robust hardware implementation and cost effective" (Ahmad & Wanglin, 2016, p.76).

However, RFID and BLE still need to be compared in order to implement the most efficient solution. These have been chosen among the different wireless communication protocols established in *figure 4.1* as they both present a low data rate and a short range. There is no need for a higher rate since Bam Mat only wants to transmit small messages and this will allow for a longer battery life-cycle.

Regarding the range, 10 meters is enough to easily identify the equipment. Choosing for a wider option would be more expensive because of the added infrastructure and the cost of data management.

Finally, WBAN technology will not be analyzed as it's used for human body sensors.

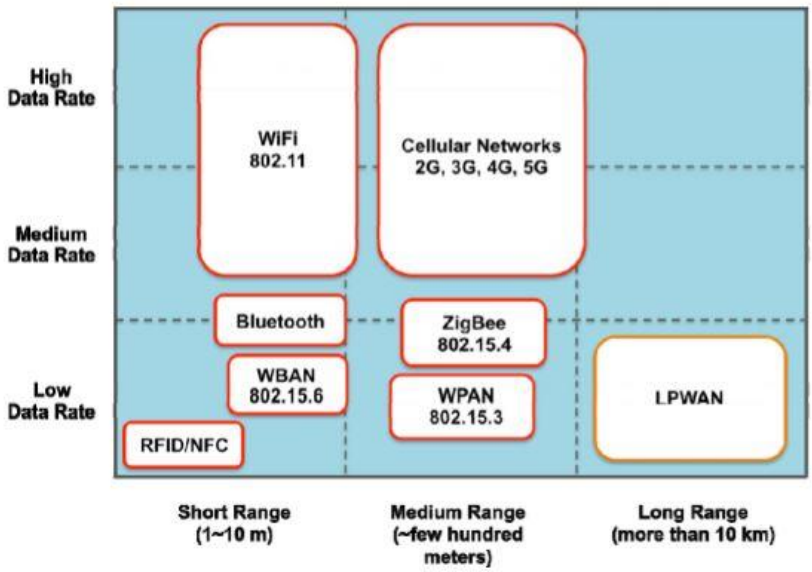


Figure 4.1: Distribution of wireless communication protocols – Source: Ahmad & Wanglin, 2016

The last section will determine the most suitable technology for Bam Mat.

4.1 RFID

Radio frequency identification (RFID) is an identification and tracking solution system that uses radio waves to send and capture information. This technology was first studied by Harry Stockman in 1948 but it's only in the 80s that researchers started to implement it. Nowadays, RFID is used in a lot of industrial applications (Landt, 2005; Robert, 2006).

4.1.a Component

"A basic RFID system is generally made of the following components:

-RFID tags fixed to entities with unique electronic product code (EPC) per entity (wireless RFID network).

-Networked RFID readers, and real-time database.

-RFID antennas for information exchange between the tags wireless network and middleware/control platform" (International Federation of Automation Control [IFAC], 2015, p. 2).

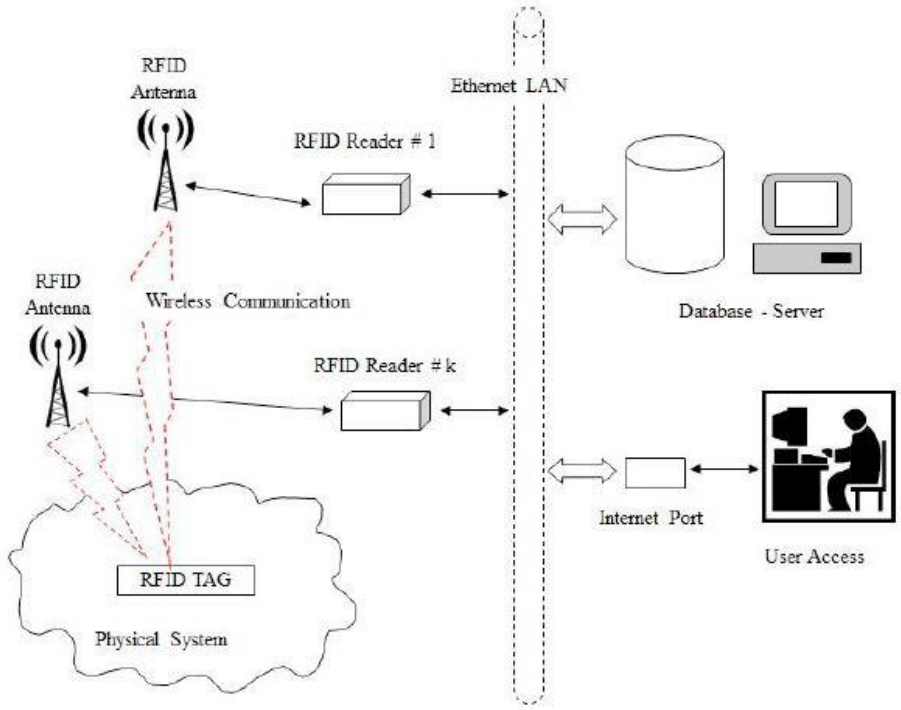


Figure 4.2: RFID generic architecture - Source: IFAC

Figure 4.2 provides an overview of the RFID architecture. The readers scan the tags and collect their EPC generally without a line of sight needed. The antennas allow to retrieve information about the position of the tags within their range which can only be achieved with active tags (explained in next subparagraph). Both of them (readers and antennas) are connected to the enterprise system and the users can retrieve the information he needs.

4.1.b Categories

The RFID technology can be divided in two main categories namely active and passive:
Passive RFID doesn't have a battery inside the tags. They are activated only when a radio waves from the reader is received. This wave is then reflected in a certain way regarding the tag's characteristics allowing the reader to identify the equipment. The price of a passive tags is between 1€-5€/tag. Also, "[they] have unlimited life" (Roberts, 2006, p. 2) as long as the tags aren't damaged by some external factors (IFAC, 2015).

This passive technology has some drawbacks as the range interval where the tags can be detected is short and depends on the frequencies band they are operating (Juels 2006; Roberts 2006):

-Low-frequency LF tags (124–135 kHz) can have a range going up to 0, 5 meters.
-High-frequency HF tags (13,56 MHz) operate up to 1 meter and have a good ability to work with metal objects. This frequency is the same for the *NFC* (Near field Communication) technology which is a subcategory of the RFID and uses peer to peer communication. It was created to allow for a smaller range detection (a few centimeters) and is mostly used for contactless banking payment (Kantner, Langer, & Madlmayr, 2008).
-Ultra High-Frequency UHF tags (860–960 MHz) can be read up to 10 meters. They are faster than the first two categories in terms of tag identification but have more trouble to pass through material. Therefore, a path between the reader and the tags can be needed.

Active RFID is using tags having batteries included whom can be detected at a wider range. In fact, "[they] provides sufficient energy to allow independent communication capabilities within greater range (approximately 90 meters)" (IFAC, 2015, p. 383). The lifetime of the battery varies depending on their size and the frequency of emission of their signal. An average of 5-6 years is usually considered. These tags are usually bigger than the passive one as the battery is taking more space and are also more expensive: 20€-50€.

4.1.c Limitations

The RFID technology has some limitations. In fact, "The RFID system is … affected by many factors such as RF power, the speed of tag, target size, shape, material, surface structure" (Tan, Wang & Xie, 2017, p. 465). If the tag is surrounded by metal elements (Bam Mat possesses a lot of them*)*, the reader will not be able to detect it and will miss the information (Faraday cage blocking the waves). Also, the wave will have more trouble to spread in certain liquid environment.

4.1.d Further Readings

Some authors examined the use and impact of RFID technology on the specific field of construction projects. Kassim (2015) presents an application of a material tracking system. El-Misalami & Jaselskis (2003) provides an RFID implementation flow diagram and analyzes potential gain of time. Other studies (Caldas & Al., 2010; Sardroud, 2012;

Adan & Valero, 2016) have integrated the use of RFID with other technologies such as GPS, GPRS, cameras, microcomputers, …

In conclusion, it can be claimed that the passive tags are useful for material identification while active one can also perform some tracking within a certain range. Active tags could be used to approximately track the inventory within Bam Mat warehouse or in the construction site.

4.2 Bluetooth Low Energy

Bluetooth is a wireless communication (2.4Ghz) which was originally designed to eliminate the wire's limitation/issues while delivering a significant data rate. The communication is done automatically when two devices are within the range of each other but an initial connection (pairing) has to be created with a pin code in order for them to exchange information. The technology also allows to read several information at the same time (limited by the transfer rate) as once devices are paired, they automatically detect each other. Finally, the Bluetooth protocol is widely used and integrated in every smartphone. Therefore, it's not needed to buy external expensive reader to scan the object. However, due to its band frequency, the Bluetooth protocols suffers several interferences with metal, water or even human bodies (Dursch, Shih, & Yen, 2004).

One weak point of this technology is the power consumption which leads to the creation of *Bluetooth Low Energy* (BLE). This subcategory was merged with the standard of Bluetooth 4.0 in 2010. Therefore, the main advantage of BLE is low power consumption. In fact, it's staying in sleeping mode when data is not transmitted while classical Bluetooth constantly stays on. This allows for a lifetime up to 40 years which is generally far more than the average life of the product. Also, the range is approximately the same as the active RFID one: 10-100m (Hugues 2015).

The price of a BLE tags is between 5$ and 25$ (Mohtat, 2016).

4.3 GPS

The global positioning system is a technology that can provide real-time information about the location of an object (altitude, latitude and longitude). It was developed in the end 60's by the US Department of Defense. The system is composed of 24 orbiting satellites so that any object on earth is visible by at least 4 satellites at any time and its location can be calculated accurately within 2 cm. It's used in many applications such as traffic management, timing (for electrical system), logistics, farming, weather forecasting, … (Ku, Thiess, & Yen, 2005; MacNeff, 2002).

The data are transmitted using L band frequencies (1575,42 MHz and 1227,6 MHz) in order to minimize the interaction with earth's atmosphere and the other higher-powered frequencies (MacNeff, 2002).

This system is really helpful to accurately locate assets but has some limitations. In fact, "because the satellites are in a high orbit, and broadcasting over a large area the signal is very weak" (Bilchev & D'Roza, 2003, p. 3). Hence, the signal is unable to retrieve data when under some construction such as bridges or inside a building. The path between the satellites and the tracked object must be unobstructed. (Bilchev & D'Roza, 2003)

Also, the devices need a source of power to function and send data regularly. This can be a problem for Bam Mat if a position is needed and the machine isn't working. Hybrid devices with internal batteries can then be used to solve this problem but are more expensive.

4.4 Selection

First, comparing the two RFID categories, the analysis showed that passive tags are less expensive than active one as they don't have an inside battery and doesn't need extra infrastructure such as antenna's. The difference between these two technologies lies in the detection range as active tags can be found within 100 meters which allows for an approximate localization within the covered area. Passive RFID signal doesn't exceed 10 meters.

Bam Mat has to deal with a lot of parts (390.000) and they don't need a read range >10 meters to identify the pieces has the workers still need to visually check if they aren't

damaged. Therefore, passive RFID is the most suitable and affordable solution compared to active tags.

Regarding BLE, it's similar to the active RFID technology in terms of detection rang and data rate. The main advantages are its long-lasting battery, its affordable price, its growing importance on the market (comprised between active and passive RFID) and that an external reader isn't needed to scan the tags.
However, the impressive battery-life that makes BLE so special isn't needed as the average lifetime of a product inside Bam Mat is between 5-10 years. Also, the technology still suffers interference with metallic object, water or even human bodies and its range of 100 meters isn't necessary.

Because of all the above-mentioned reasons and its cheaper price, passive RFID (coupled with GPS) will be the chosen solution for implementing an automated identification and tracking system inside Bam Mat.

Chapter 5: Application of the Technology

The RFID technologies will behave differently depending on the size of the pieces as different tags will be needed. In fact, if the pieces are too small, it will technically not be feasible to put a tag on them. Therefore, a new classification of the equipment was needed (different from the one explained in *section 3.1*) *based on the size and function* to determine if the RFID solution can be applied to every single piece inside the company. Moreover, the classification gives information about the estimated quantities of each category which will be needed for the economic feasibility.

5.1 Categorization of the Equipment

A study has been made to identify the different categories of equipment depending on their identification or tracking needs and the available technology which lead to a classification of the equipment by size and function. *Figure 5.1* shows an overview of the classification that has been established; the quantities are based on the data retrieved from Navision (*see annex 6 for the detailed classification*).

The equipment is already classified under *individual* and *bulk* inside Bam Mat.

For the individual material, Bam Mat must clearly and accurately identify all the pieces as, as explained in *Section 2.6 CSR*, the material is subject to several controls during the year. This material has only been classified based on their function as they will need different treatments depending on what they are used for. In fact, they already have an identification number attached and it's therefore possible to put a tag on them (they are not too small).

For the collective category, the purpose is to convert as much equipment as possible into individual as it will allow Bam Mat to precisely track them. However, this is not possible for every part of them because of the technology's limitations. The classification that has been established is based on the function of the material with subcategories based on the size.

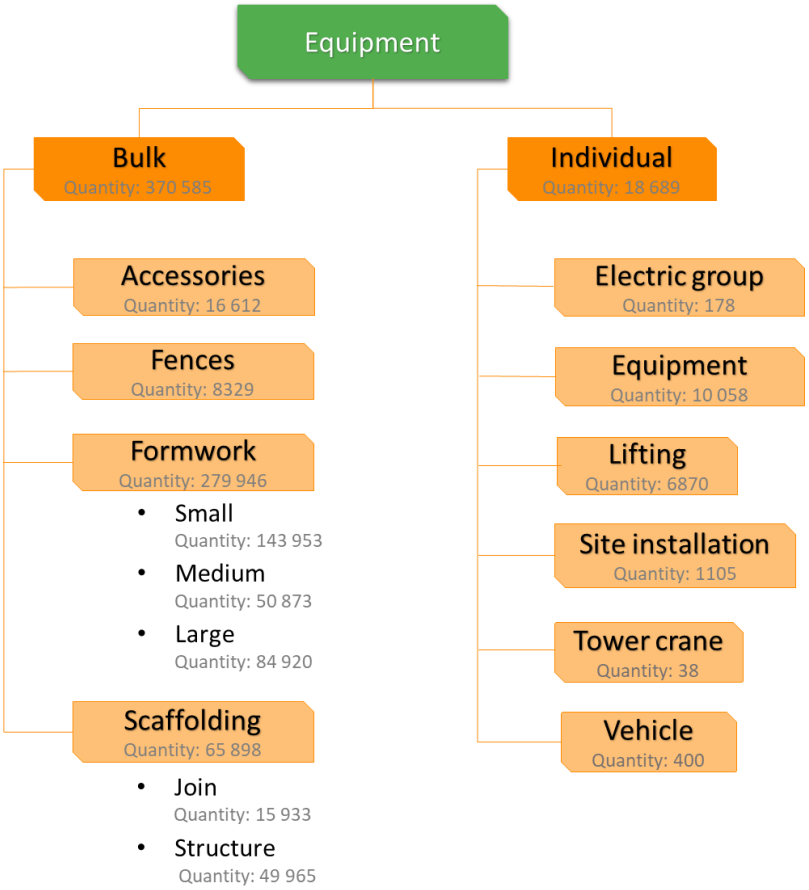


Figure 5.1: Equipment classification based on the needs – source: author of the paper

5.2 Solution to Implement

A hybrid solution has been chosen to identify/track the equipment as Bam Mat is composed of too many different pieces to implement only one solution. In fact, it would be too expensive and sometimes, the available technology doesn't allow it. As stated in *Chapter 4: Inventory identification and tracking*, Bam Mat will implement a GPS tracking along with a passive RFID identification.

5.2.a GPS

Under this solution, the *vehicle*, *electric group and tower crane* categories can be found (656 pieces). The vehicles already have a tracking system but Bam Mat is reaching the end of contract period.

Regarding the electric group and tower crane, there is a growing need from the clients to accurately track the utilization hours which can be achieved with a GPS device. However, these two categories don't have an inside battery to turn on the device, Bam Mat will

need a hybrid solution for them with a GPS housing that contains a battery. The devices will then still be able to send their signals daily.

5.2.b Passive RFID

This RFID solution will be applied to the following categories (228.732 pieces). These are all the categories where the pieces aren't too small to have a tag attached and don't need accurate tracking:

-Individual→lifting
-Individual→equipment
-Individual→site installation
-Bulk→formwork→large
-Bulk→Fences
-Bulk→formwork→medium
-Bulk→scaffolding→structure

However, the last three categories will have a special treatment as passive RFID sticker (barcode with a RFID antenna) will be used for them (109.167 pieces). In fact, RFID sticker are less resistant but are also cheaper. As, the equipment of these 3 categories are less subject to damage when utilized, it will be profitable for Bam Mat to use this solution.

Finally, it will be possible to paint Bam Mat's color or logo on the stickers/tags. This will allow for an easy-on-site identification when the workers have to sort the equipment that will return. This should eventually facilitate the return process as Bam Mat will have fewer pieces from other companies.

5.2.c Others

Two categories remain: bulk→formwork→small and bulk→scaffolding→join. These pieces (159.886) are small and sometimes contain metal, an RFID identification would be too expensive or impossible and a barcode identification would take too much time to process (scan the pieces one by one) and be too easily damaged.

This material will therefore remain in bulk inside the company but the process can still be improved thanks to a tablet catalog with pictures of the different pieces or with a visual recognition system when they are coming back from a construction site. The visual solution is uncertain regarding its feasibility and will not be integrated in the scope of this project. However, a brief presentation is showed in *figure 5.2*.

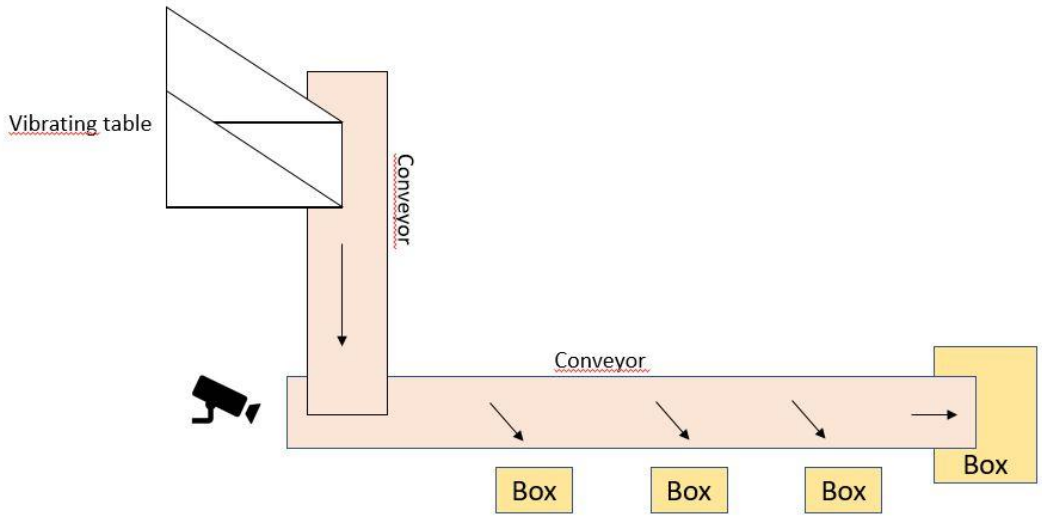


Figure 5.2: visual recognition process – source: author of the paper

The pieces would be put into a vibrating table to separate them as much as possible. Then, they would fall on a first conveyor. A second conveyor place beneath the first one will be faster so that all the pieces are clearly separated from each other. A visual recognition system would then identify and sort the pieces in the different boxes thanks to a diverter (not represented in the picture). Finally, a large box would be put at the end of the second conveyor for the unidentified pieces.

5.3 Conclusion

As demonstrated, the project is technically feasible for some categories of the equipment. In fact, it would allow to give a unique identification numbers to about 229 388 parts which is a significant improvement but 159.886 pieces will still need manual or semi-automated treatment because of the technology limitation.

Figures 5.3 and 5.4 show the difference between the bulk and individual equipment before and after an automated identification and tracking system. It demonstrates that 54% of the total equipment (390.000 parts) is converted.

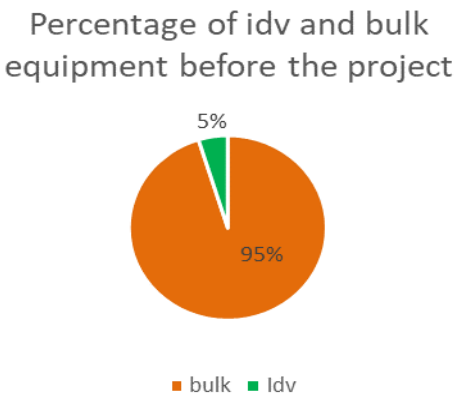


Figure 5.3: Percentage of idv and bulk equipment before – Source: Author of the paper

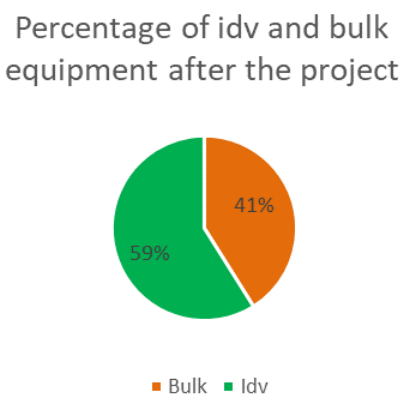


Figure 5.4: Percentage of idv and bulk equipment after – Source: Author of the paper

Part 3: Economic feasibility study

Chapter 6: Change management

In the following chapters, the economic feasibility will be studied thanks to a costs benefits analysis (CBA). “A well-planned CBA can tell a policy maker everything they need to know about a project, breaking down the relevant costs and benefits in such a way as to give the decision maker the most comprehensive set of information” (Williams, 2008, p.67). This analysis compares the most relevant cost and benefits of the project to assess its viability. Those have been established based on a paper written by CEEU (2012) were they developed a guide to identify them.

The identification and tracking of Bam Mat’s assets will change the current way of running the company in several ways. This chapter analyze the impact of the new system on the company. This analysis will be useful when assessing the different benefits of the project (next chapter).

6.1 Material return process

6.1.a New system

The return process will be significantly facilitated and accelerated for the identification part as every product number will be retrieved and encoded automatically. *Annex 7* shows an overview of the process.

It starts when a truck arrives. The equipment is unloaded and a red label is attached with the name of the construction site and the date.

When a worker starts to work on a specific construction site, he must first input in the system the data written on the red label. After this, he has to identify if the equipment has a RFID tag or not.

-If not, the equipment is managed manually with a worker (same as before).

-If yes, the tagged equipment is scanned with the reader. A visual check is made along with the RFID scan to assess if all the tags have been identified.

Finally, the worker validates the return shipment in the system and the information are automatically sent to the global administration for automatic encoding in the database. At the same time a mutation slip is created.

The system deals automatically with the inventory issues except for the consumable return (the workers must check with the warehouse) and the unidentified pieces (the workers have to check with the workshop).

-If the equipment is not coming from the right site, a mutation slip is automatically created to allocate the machine to the right site.

-If the number of items coming back is too high, the system automatically updates the construction site inventory.

Then, the mutation slip is validated by global administration while the material is cleaned and sent to depot 2 for reparation. The procedures for repairs are the same as before except that the workers don't have to count the equipment a second time and that the intervention sheet can be automatically linked to the right equipment on the system.

6.1.b Comparison

There are several major differences compared to the initial process explained in *section 3.3.b Material return process* which will significantly facilitate and accelerate the return of the equipment:

-There is no need to ask the construction site to fill a transfer slip as the system is automatized and less subject to errors.

-Most of the data is automatically entered in the informatic system meaning that significant time can be spared for those operations.

-The identification part is focusing only on identifying the tagged/non-tagged pieces.

-One new procedure is introduced: RFID scan.

-The inventory issues are handled semi-automatically by the system. A manual intervention is sometimes still needed.

-The material doesn't need to be counted a second time at the workshop.

-The LTD dispatch has no more implication in the process as he was in charge of sending the return slip which is not needed anymore. As a recall, this slip was used to help the workers identify the pieces and to write down the counted quantities.

6.2 Order Preparation Process

Regarding the order preparation process, the main impact is during the encoding. In fact, in the current system, the workers receive an order that they have to send back to the global administration to update the database. Now, they will receive the order form on their readers and will be able to confirm each picking so that the movements are automatically recorded on the database.

These changes apply only to the individual equipment (RFID tagged). The same procedures as before will apply for the bulk equipment.

Also, the dispatch team will not have to call the warehouses to ask them how many pieces do they have in inventory. In fact, the employees will be able to trust their database again.

Chapter 7: Benefits Analysis of an identification system

The focus now is on the advantages of a potential automatized system. The following sections have been identified thanks to the CEEU guide and brainstorming/analysis linked to the five internal problems (identification, encoding, counting, timing and tracking) assessed in *section 3.5 Identification problems and impact* that the system would solve. These advantages will then allow to calculate the profitability of the project (*chapter 9*).

7.1 Stakeholders

7.1.a Client

As stated in *Section 2.4 Values*, customer satisfaction is one of the main priorities to Bam Mat. Being able to identify and track their inventory is therefore a major point to improve their relationship with them. In fact, the automation of identification and counting will result in fewer errors and more transparency for the delivered and returned material.

There will be no need anymore for their client (construction site) to count the returned equipment prior to send them back as they will be able to trust Bam Mat's automatized process. This is a *significant* gain of time for them as they are dealing with thousands of different pieces.

Also, this will lower the complaints to handle every year about returned equipment. In fact, Bam Mat will be able to accurately track the returned material and confirm or deny more easily the construction site complaints. As explained in *section 3.5.b External Issues*, Bam Mat can't at the moment verify that the equipment indeed came back or not.

7.1.b Employees

On the sides of the workers, some formal and informal conversations showed that an identification system would facilitate their daily operation in several ways.

First, it will facilitate their work when starting in the company. As explained in *section 3.5 Identification problems and impact*, the major part of the equipment identification is done by acquiring experience inside the company. Given the impressive number of different pieces in Bam Mat, it's taking some time to get familiar with all of them resulting in frequent questions to the manager that can be avoided.

Also, fewer errors will be done on the counting and identification part resulting in less control and more trust from their supervisor. In fact, he sometimes recounts the equipment after his employees to see if their job is well done; this is a waste of time.

7.2 Time

The system will allow to earn time on several aspects listed below.

7.2.a Identification, counting and sorting (ICS)

First, in order to assess the potential gain of time during the identification, counting and sorting operations (denoted as ICS), an analysis of the time required for this process has been made. A sample of 54 SKU (1152 pieces) has been collected and correspond to a one-week period analysis (*see annex 8 for the detailed sample*).

Figure 7.1 shows the operations that are included in the timing analysis. As observed, the movement of the equipment such as the unloading and the storage in the appropriate depot 2 areas are not taken into account as they will not be influenced by the potential new system. Also, as explained in *Section 3.3.b Material return process*, the ICS operations are performed twice: once after unloading and once in depot 2.

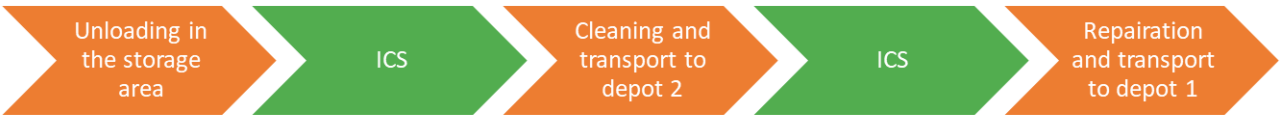


Figure 7.1: Return process overview – Source: Author of the paper

The total amount of time needed for the ICS operations is 2,87 hours/week which needs to be multiply by two (as the operation are performed twice) = 5,74 hours/week.

The passive RFID tag will allow to accelerate the process as they are able to read several tags at the same time. However, a quick visual check will still be needed to validate if the tags are functioning well and if the reader scanned them all. It has been estimated, based on the process redefinition in *chapter 6: Change management*, that the total time needed with the new system can be reduced by at least 40% and that the second counting can be eliminated as the system will be much more accurate:

$$2{,}87 - 2{,}87 * 0{,}6 + 2{,}87 = 4{,}02\ hours\ saved\ per\ week.$$

And as the construction calendar is made of 220 days:

$$4{,}02 * \frac{220}{5} = 176{,}8\ hours\ saved\ per\ year$$

7.2.b Encoding

Time is also saved when encoding the updated inventory in the Navision as it will be done automatically after ICS by the reader. An internal analysis has been made to assess the number of hours needed per day to perform this encoding operation:

-Logistic departure: 7 hours

-Logistic arrival: 5 hours

-Formwork departure: 7 hours

-Formwork arrival: 5 hours

As observed, it's taking 24 hours per day to manually encode the data. As the construction calendar is made of 220 days, it means that Bam Mat spends $24 * 220 = 5280\ hours/years$ to input the returned/leaving pieces in the database. This part of the process can be reduced of 59% because of the border reduction between bulk and individual equipment as showed in *section 5.3 Conclusion.*

$$5280 - 5280 * 0{,}41 = 3115\ hours/years$$

7.2.c Complaints

It's taking the complaint manager half of his time to handle them. This represents a total of 880 hours/year as an employee works 40h/week (220 days). However, as stated in *Section 3.5.b External Issues*, the number of complaints for wrong invoice is 14% of the

total complaints in 2017. This means that, it took him 123,2 hours in 2017. This amount will potentially be reduced as Bam Mat will make fewer errors and the construction site will tend to thrust them more.

7.2.d Dispatch

The order planners will also save some time as they always need to confront Navision inventory with the physical one. The system will make the database more accurate (*see next section*) which means less phone calls and time spent on finding and counting warehouse inventory to fulfill the demand. It has been estimated based on his schedule that he can spare at least 3 hours per week thanks to the new system.

$$3 * \frac{220}{5} = 132\ hours/years$$

7.3 Reliability

This section analyzes the advantages of the identification system on a reliability aspect.

7.3.a Database

The biggest impact worth mentioning is the one in the database Navision. As stated in paragraph *2.5.a Internal Problems*, a lot of issues are resulting in wrong information in their system:

-Identification errors

-Encoding errors

-Counting errors

-Timing errors

These are turning their database obsolete as it's difficult to extract accurate data. As an example, an extension of one month was needed on the project with PWC (*see section 2.7 Future 2021*). A part of this extension can be explained because of the accuracy issue of information.

All the above-mentioned errors can be avoided or at least diminished with an identification and tracking system.

Finally, as mentioned in *section 2.1 introduction of the company*, some pieces are rented to an external supplier if Bam doesn't have enough of them in the warehouse. The identification system would allow to identify and separate these pieces from the external rented one resulting in better relations with their partners.

It's impossible to quantify the benefits on the reliability aspect but they are real as saw with PWC example where Bam Mat could have saved time and money with accurate information. Being able to rely more on their own database is important for the further development of the company.

7.3.b Equipment

The reliability of Bam Mat equipment will also be improved as an important part of them will receive a unique identification number (59%, see *section 5.3 Conclusion*). This means that their tracking will be facilitated resulting in more security. In fact, the company will be able to know when the part has been bought, how many times it has been used and repair, … This increase in security is a major point for the construction sites which are dangerous environment.

7.4 Environnement

This system will remove a major part of the printed paper. Now, everything is done manually and this results in an impressive amount of printed paper (for every order and return process).

This is a good point for the company which can be incorporated into their CSR vision but this has to be trade off with all the energy consumption of the RFID readers and WIFI installation.

7.5 Digitalization

The digitalization of the company is a required step to achieve their vision "*We will be the preferred multidisciplinary partner adding value to our customers delivering service and equipment"* (Bam Mat 2017).

Bam Mat has to remain competitive and embrace the new technologies available on the market. Starting to track their assets is a step towards the completion of this digitalization. As stated in the first Chapter, the competitive environment in Belgium is fierce hence investment in innovation and development is more than needed to survive.

Chapter 8: Market analysis

In this chapter, the different providers on the Belgian market are presented and a potential collaboration is analyzed in case of a GO decision. Also, the different prices offered are summarized in order to be able to calculate the total cost of the project needed for the CBA in the next chapter.

8.1 Market Research

The main players on the Belgian market have been identified thanks to previous attendance at several fairs and analysis with PWC or other people of contact. *Figure 8.1* shows the different companies contacted and the available technology they are offering. An overview of them and their technologies is assessed in the next section (*annex 8* shows a summary table of these pros and cons).

	RFID Passif	GPS
Emixis	+/-	✓
Phi Data	✓	✓
SUIVO	✓	✓
Traxxeo	✓	✓

Figure 8.1: Available technologies per enterprise – Source: Author of the paper

8.2 Market overview

8.2.a Emixis

Emixis is a company specialized in the assets, fleet and workforce management. The enterprise is composed of 30 peoples and have more than 20 years of experience in the above-mentioned domains.

Two main solutions are offered: Active RFID and GPS technologies. From these, a lot of other applications were derived such as fuel tracking, anti-theft system, driver check-in, eco-driving, …

The platform they are using is Securysat. It allows to easily retrieve information about the location of a vehicle in real time and is also available on IOS and Android for free. This is a useful access to the needed information at any time or place.

Their priced offered for the GPS solution are the following:

-299€/device for the civil engineering equipment.

-345€/device for the vans and trucks.

-389€/device for the vehicles without batteries.

Emixis never worked with the same kind of companies as Bam Mat (construction renting) and doesn't have a lot of knowledge about their equipment specification. In fact, they are more specialized in the fleet management and tracking enterprise such as Bpost.

At the moment, this company is developing a passive RFID technology as there is a growing need from the market but they can't yet put a price on it. This is an important point regarding the integration but is more dangerous on the expertise side.

8.2.b Phi Data

Phi Data is specialized in the field of ICT (information and communication technologies). Their core activity is to help and support the enterprise to digitalize their process in various sectors such as healthcare, transport, logistics, retail, administration, ... This is achieved through their IoT solution and automatized identification (Phi Data, 2016).

The company is made of 50 employees (with six people accountable for the software integration) and has 35 years of experience in the domain of ICT. Their partners are carefully chosen so that they have a strong and healthy structure and are reliable. Phi Data has already implemented RFID/GPS solutions on more than 2000 clients and are still taking care of the maintenance and follow up of several projects.

Their strongest point is their expertise in construction as they implemented 90.000 passive RFID tags at Engie Fabricom who has similar equipment as Bam Mat. However, one weak point of this project was the software integration which necessitated some adjustment to be embedded in their ERP (SAP).

The price they are offering are the following:

-Passive RFID tags: 1,85€ - 5€

-RFID gun and industrial PDA (personal digit assistant): 3500€

-RFID label: 0,1€ - 0,15€

-Label printer: 2000€ - 4500€

-GPS devices: 150€ - 350€

-Training and documentation: 7600€

-Software utilization fees: 7€/month/GPS device

8.2.c SUIVO

SUIVO

SUIVO (35 employees) is a company specialized in the fleet management and software integration which was created in 2009 by the group Geosquare (135 employees). Geosquare is part of the group Cronos which is a main player in the ICT market and is made of more than 5000 workers.

They are offering about the same technology features as Emixis regarding their tracking devices (fuel tracker, eco-driving, …) and are producing them in Europe (less than 0,01% of defects). This enterprise also proposed an RFID solution in collaboration with *Aptus* (member of the Cronos group).

SUIVO can integrate these two solutions into their platform which has been built to be as open as possible. This platform can then be embedded into Bam Mat's ERP with a synchronization of the data in real time. Moreover, it allows to perform various analyses, sets control alarm to monitor some aspect of the assets and is subject to frequent updates.

Their priced offered for their GPS devices and software are the following:

-GPS devices: 281€ - 341 € (82€ installation costs included).

-Software utilization fees: 6,5€/month/GPS device which includes training, maintenance and documentation.

Also, as explained in *section 2.7 Future 2021*, Bam Mat is looking to replace its old ERP. SUIVO has already collaborated with Ifacto which is a provider of the Navision rental (considered possibility for their new ERP). This would facilitate the integration as both companies are used to work together.

Aptus

As explained above, Aptus is the chosen partner of SUIVO for the passive RFID implementation. This company is made of 12 employees and has 4 years of know-how in the domain. Aptus is lacking some expertise as they never implemented their solution in such a large scale (100.000+ tags). However, the price offered is on average the same as the market:

-RFID tags: 1,25€ - 5€.

-Annual fees: 0,25€ - 1€/tag.

-RFID guns and industrial PDA: 2000€ - 4700€.

8.2.d Traxxeo

Traxxeo is a company (15 people) specialized in the assets management of the construction sector. They have acquired a certain expertise in this domain and are currently offering GPS and RFID solutions.

Bam Mat is currently using their GPS devices for the tracking of the vehicle but are reaching the end of the contract period. Therefore, both companies are already used to work together and Bam Mat is already familiar with their platform.

Traxxeo understands well the activities of Bam Mat and are constantly keeping an eye on the new emerging technologies. They know exactly what solution is available and which one will best fit Bam Mat. Also, their operation director was in charge of the RFID implementation at Engie Fabricom. This means that a significant part of the tag analysis can be avoided.

However, Traxxeo has limited resources in terms of manpower. Bam Mat knows from their past collaboration with them that it can take some time before having the solutions to one problem. This lack of reactivity is a major concern as the implementation that will take place is on a large scale.

8.3 Selection

In the case of a positive analysis for the project implementation SUIVO would be the preferred partner for Bam Mat. In fact, their software expertise is a main concern for Bam Mat and they have enough resources in term of manpower to assure the follow-up of the project. However, a stronger partner than Aptus needs to be found for the passive RFID technology such as Phi Data.

Chapter 9: Profitability

In this chapter, the profitability of the project is assessed. A sensitivity analysis will be performed with Two scenarios (best case and worth case). In fact, "CBA reports are only as good as the sensitivity analysis surrounding them; if a report does not include some allowance for uncertainty, then its recommendation can become very fragile for the decision maker" (Williams, 2008, p69-70).

These two scenarios are based on the different budget given by the providers. The exact cost of the project should lie within these two scenarios.

9.1 Cost

9.1.a Variable cost

Figure 9.1 shows the total and yearly variable cost of the best-case scenario while *figure 9.2* represents the worst one.

TOTAL COST BEST CASE SCENARIO								
	Qty	Revised Qty	Price	Asset cost	Installation cost	Total cost	Lifetime	Yearly cost
RFID tag	119.565	114.782	2,50	286.956	269.356	556.312	6	92.719
RFID label	109.167	104.800	0,10	10.480	122.966	133.446	3	44.482
Autonomous GPS	226	226	250	56.500	18.532	75.032	5	15.006
Alimented GPS	440	440	200	88.000	36.080	124.080	8	15.510
Devices	10	10	2.000	20.000	-	20.000	5	4.000
Software fee	656	656	78	51.168	-	51.168	1	51.168
Total	230.064	220.915	2.453	461.936	446.934	960.038	28	222.885

Figure 9.1: Best-case scenario – Source: Author of the paper

TOTAL COST WORST CASE SCENARIO								
	Qty	Revised Qty	Price	Asset cost	Installation cost	Total cost	Lifetime	Yearly cost
RFID tag	119.565	117.174	3,50	410.108	549.935	960.043	5	192.009
RFID label	109.167	106.984	0,15	16.048	188.291	204.339	2	102.169
Autonomous GPS	226	226	250	56.500	18.532	75.032	5	15.006
Alimented GPS	440	440	200	88.000	36.080	124.080	5	24.816
Devices	10	10	3.000	30.000	-	30.000	4	7.500
Software fee	656	656	84	55.104	-	55.104	1	55.104
Total	230.064	225.489	3.454	600.655	792.838	1.448.598	22	396.604

Figure 9.2: Worst-case scenario – Source: Author of the paper

The quantities are the one established in *section 5.1 categorization of the equipment* and have been retrieved from the database. However, as explained in *section 3.5 Identification problems and impact*, this database is subject to significant identification errors and omission about the declassification of several products. That's why the quantities were revised (96% of the total equipment for the BC and 98% for the WC) to have a scenario that better fit reality.
This hasn't been done for the GPS categories as those vehicles are heavy one and Bam Mat assure a more precise follow up of them leading to no errors in the database.

Once the quantity revised, two different prices have been established for the WC and BC scenario based on the estimated budget range given by the different providers (*see section 8.2 Market overview*). These prices have allowed to calculate the total cost of the implemented assets.

Regarding the RFID installation cost, the yearly price of a worker was the first data needed. Bam Mat's workers cost the enterprise 40€/hour and the construction calendar is made of 220 working days. This represents a yearly cost of $40 * 220 * 8 = 70.400$€ as a working day is composed of 8 hours.
Then, based on the RFID implementation at Engie Fabricom, it has been estimated that a man installs between 15.000 (WC) and 30.000 (BC) tags per year while they can reach 40.000(WC) to 60.000(BC) units for the RFID labels. This allowed Bam Mat to calculate the total installation cost:

$$Installation\ cost = \ yearly\ cost\ per\ worker * Number\ of\ workers\ needed$$

Where: $Number\ of\ workers\ needed = \frac{Qty\ revised}{Number\ of\ tags\ installed\ per\ year\ per\ worker}$

Regarding the GPS installation cost, the price on the market was used: 82€/device.

Finally, in order to have a yearly cost, the lifetime of the different components was estimated. As the passive RFID tags have an "infinite lifetime" the average lifetime of the equipment has been taken which is 5-6 years. This has been shortened for the label (2-3

years) as those are less resistant to harsh environment and will therefore need to be replaced before the end of the product lifecycle.

The GPS device lifetime is well known by the market and is estimated to be between 5 and 8 years maximum. However, for the autonomous one that mainly correspond to the electric group, an average of 5 years was taken as this is the maximum lifetime of this type of equipment.

Adding the yearly software subscription fee to the yearly cost of the assets and installations, a total yearly cost between *222.885€* and *396.604€* has been assessed.

9.1.b Initiation cost

Before starting to install the different tags on the equipment, Bam Mat needs to know which tags fits best which pieces. This analysis has to be done with, on the one hand, an RFID of the selected provider and who knows well the technology and on the other hand, an experiment worker of Bam Mat.

It has been estimated (based on *annex 7*) that there will be about 350SKU for whom the company needs to find a suitable RFID solution and that it should take about 150 hours of work to find a solution for all of them. This means that it will cost Bam Mat $150 * 40 = 6.000$€ to which has to be added the cost of the external consultant (around 20.000€).

9.2 Revenue

The quantifiable part of the revenue is analyzed in this section. *Figure 9.3* shows the total revenue of the project.

REVENUE					
	hours/day	hours/year	Hourly rate	Complaint reduction	Yearly revenue
ICS	0,80	176,08	40	-	7.043
Encoding	14	3.115	40	-	124.600
Dispatch	0,6	132	70		9.240
Complaint	0,56	123	70	3.855	12.479
Contract Traxxeo	-	-	-	-	60.000
Total	16	3.546	220	3.855	213.362

Figure 9.3: Total revenue – Source: Author of the paper

9.2.a ICS

In section *7.2.a Identification counting and sorting*, the gain of time per year is analyzed thanks to the new system during the ICS operation (176,08 hours/year). This means that Bam Mat will save annually 7.043€ as a worker costs 40€/hour (under ICS in *figure 9.3*).

9.2.b Encoding

As explained in *section 7.2.b Encoding*, it's taking time for the employees to encode the data of the returned/departed equipment in the database (3.115 hours/year). This process will be totally automatized meaning that Bam Mat will earn:

$$40 * 3115 = 124.600€/\text{year}$$

9.2.c Dispatch and Complaints

A part of the time allocated to handle the different complaint related to the identification errors will be eliminated. In *section 7.2.c Complaints*, it has been demonstrated that the time needed per year is about 123 hours/years. Knowing that the complaint manager is paid 70€/hours it means that Bam Mat will save:

$$123 * 70 = 8.610€/\text{year}$$

Adding to this, the money that the company has to pay back to the different clients for wrong invoices will be spared as Bam Mat will not incur errors anymore: 3.855€ (*see section 7.2.c Complaints*). This means that the complaints department will cost in total 12.479€ less per year.

Also, the dispatch manager is saving $132 * 70 = 9.240€/year$ (*section 7.2.d Dispatch*).

9.2.d Others

Finally, the deletion of the current contract with Traxxeo regarding the GPS utilization has to be taken into account (as Bam Mat won't pay twice for the GPS devices). This represents an annual saving of $60.000€/\text{years}$.

9.3 Profitability

As observed in *figure 9.4*, the project isn't profitable with a loss between 9.523€ and 183.242€ per year for respectively the best and worth case scenario. This needs to be compensated by an increase of 0,03% - 0,89% in the turnover in order for the project to reach breakeven (Bam Mat's turnover was 20.000.000€ in 2017, *see section 2.1 Introduction of the company*). The average between the best and worst case shows a required increase in turnover of 0,46% which should be closer to the reality.

ROI analysis			
	BC	WC	Average
Revenue	213.362	213.362	213.362
- Total cost	222.885	396.604	309.745
Profit	- 9.523	- 183.242	- 96.383
Turnover	20.000.000	20.000.000	20.000.000
Increase in turnover	20.009.523	20.183.242	20.096.383
% Increase	0,05%	0,91%	0,48%

Figure 9.4: Return on investment – Source: Author of the paper

On the side of the non-quantifiable data, a lot of advantages have to be mentioned.

9.3.a Reduction of the border between bulk and individual equipment

In results to the project, Bam Mat will have a unique identification number on 59% of their material compare to only 5% before (*see section 5.3 Conclusion*). This is a colossal information regarding the accuracy of information and data management. It means that Bam Mat will be able to perform various analysis on their equipment such as automatically calculating the turnover rate, the utilization rate, the return of investment of each part, … This will allow them to easily identify which pieces are profitable or not and if which pieces are over/under used in order to adapt the next order.

9.3.b Differentiation

As explained in Chapter 2, the competitive environment of Bam Mat is mature and it's therefore difficult to gain some market share. Bam Mat must catch these new identification and tracking opportunities if they want to remain competitive and not be outpaced by their

competitors in the long term. Thanks to this project, they will be able to improve the quality of their services and be more efficient regarding their cost structure.

9.3.c Others

Finally, potential gain about the *efficiency* of the workers, the *reliability* to the customer, the *accuracy* of the database, the environmental aspect, the facilitation of the order planner's job, the increase in equipment *security* and the creation of a *competitive advantage* with the digitalization of the company can be observed (see *chapter 5: Benefits analysis of an identification system).*

Because of all these important non-quantifiable reasons, Bam Mat is convinced that this project will be profitable for them. The increase in efficiency, reliability and accuracy should attract more customers (a market feasibility study can certify it) and therefore increase the utilization rate of the equipment (and the turnover). This increase will not necessarily be translated into costs as they don't have to buy more equipment.

0,91% gain in market share is totally reachable seeing the significant competitive advantage that the company will face as they will be one of the first construction renting company in Belgium to implement such project.

Chapter 10: Scalable learning

As a recall, the main purposes of the project are to convert as muck bulk equipment as possible in individual and to facilitate their handling through automatization. This way, a lot of errors can be avoided (*see chapter 7 Benefits analysis of an identification system*) as Bam Mat knows exactly which pieces they are handling. These errors are the same for the other material renting companies.
The identified solution can therefore be applied in several companies.

10.1 Shareholders

On the side of their shareholders, Bam Mat Ndls (part of BAM group) can directly benefit from these researches. They also haven't implemented any solution yet and could benefit from the knowledge of Bam Mat Belgium on this domain.
The other material service companies of the group could be interested as well such as Bam Mat the UK, Bam Mat CH, Bam Mat the, …

Also, their main suppliers (Wolftech, Adria, Van Der Speck) are also dealing with construction equipment.
Introducing an automated identification and tracking system in these companies could benefit Bam Mat as they would become more reliable and efficient. In fact, knowing directly and accurately what is in their stock will accelerate the entire shipping process. In the long run, it will increase Bam Mat's customer satisfaction.

10.2 Belgium

As stated in *section 2.1 Introduction of the company*, there are a lot of different construction equipment renting enterprise. All of them meet each other's every 4 months to discuss the further development of the market, the innovation in the sector and the problems they are dealing with.

They have been recently discussing about this need for identification. At the moment, none of these companies have an efficient identification and tracking solutions for their

equipment. They all have huge amount of bulk equipment that can't precisely be tracked. It's during these meetings that a lot of interest was showed for Bam Mat's research on this problem and some of the enterprise offered to collaborate with them on analyzing the best RFID tag solution for the different parts and sharing the cost of it. In fact, they all have the same equipment to some extent.

Bam Mat can set the Belgian industry standards on this domain.

10.3 International

More widely, this project could be applied to any construction equipment renting company that faces identification issues as they are composed of the same type of pieces.

Conclusion

The construction environment is an information-intensive industry. Every day, a lot of information is exchanged between the different stakeholders and is an important part of the business (Mohtat, 2016). With the era of digitalization, new challenges and opportunities have emerged to facilitate this flow of information and can lead to a significant competitive advantage.

The purpose of this paper was to analyze the profitability and feasibility of an identification and tracking system inside a construction rental company. In fact, a lot of equipment doesn't have a unique identification number and is therefore difficult to track. The main concerns were:

-To study the available technologies and their features

-To find among these technologies, the one(s) that would best fit the large variety of equipment inside the company.

-To assess the economic and technical feasibility of the project.

It results that implementing one solution is not possible due to the wide panel of material but a mix of RFID and would already significantly increase the amount of individual equipment of 54%. This will allow for an easier exchange of information between Bam Mat and the construction sites.

Figures showed that the project isn't profitable and an increase of about 0,48% of the turnover is needed. However, a lot of non-quantifiable data has to be taken into account:

-The increase of the individual equipment will allow to assess for each piece if it's profitable or not and if the company needs to invest more in one category or remover another one from its catalog.

-The abovementioned increase will also improve the equipment security as the enterprise will know since how long they are using it and how many times they have been rented/repaired. This improve in security is a main concern for the construction site.

-The system will allow Bam Mat to differentiate from his main rivals, improve the quality of service and reduce the internal cost structure. This will lead to a sustainable competitive advantage and increase the market share.

-The database reliability and the reactivity of the company will be improved thanks to an easier tracking. This is needed to keep an important customer satisfaction and make sure that they will work with Bam Mat on other projects.

In conclusion, despite the fact that the profitability analysis didn't show outstanding results, Bam Mat is convinced thanks to the established research (technical and economic) that this system would be profitable for the company and lead to an increase of more than 0,48% of the turnover.

Further thinking for the company would be first to study the possible evolution of the market thanks to the market feasibility study. Then, an analysis the management and legal feasibility presented in *Chapter 1: Introduction* would be interesting in order to have a better control on the project.

Bibliography

-Adan, A., & Valero, E. (2016). Integration of RFID with other technologies in construction. *Measurement, 94*, 614–620. doi: 10.1016/j.measurement.2016.08.037

-Ahmad, M., Wanglin, Y. (2016). Long-range wireless sensor networks for geo-location tracking: Design and evaluation. *18th International Electronics Symposium (IES)*, 76-80. doi: 10.1109/ELECSYM.2016.7860979

-BAM international. (n.d.) *Royal BAM NBN acquires HBG*. Retrieved January 30, 2018 from https://www.baminternational.com/en/news/royal-bam-nbm-acquires-hbg

-*Bam Mat Présentation*. (2017). Unpublished document.

-Bauer, L., Henkel, J., Samie, F. (2016). IoT Technologies for Embedded Computing: A survey. *International Conference on hardware/Software Codesign and System Synthesis (CODES+ISSS)*. doi: 10.1145/2968456.2974004

-Bilchev, G., & D'Roza, T. (2003). An overview of location-based services. *BT Technology journal, 21* (1), 20–27. doi: 10.1023/A:1022491825047

-Caldas, C., Goodrum, P., Haas, C., Nasir, H., Razavi, S., & Young, C. (2010). An implementation model for automated construction materials tracking and locating. *Canadian Journal of Civil Engineering, 37* (4), 588–599. doi: 10.1139/L09-178

-Central Expenditure Evaluation Unit CEEU (2012). *Guide to economic appraisal: Carrying out a costs benefits analysis*. Retrieved June 06, 2018 from https://publicspendingcode.per.gov.ie/wp-content/uploads/2012/08/D03-Guide-to-economic-appraisal-CBA-16-July.pdf

- Christananda, Y. Simanjuntak, M. (2017). The feasibility study framework of mixed used construction project in Bitung, North Sulawasi, Indonesia. *Imperial journal of interdisciplinary research (IJIR), 3* (4), 2188-2194.

-Confédération Construction. (n.d.). *CMK 1993*. Retrieved February 01, 2018 from https://www.confederatiebouw.be/fr-be/eshop/eshop/cmk1993.aspx

-Dursch, A., Shih, D., & Yen, D. (2004). Bluetooth technology: an exploratory study of the analysis and implementation frameworks. *Computer standards & interfaces, 26,* 263–277. doi: 10.1016/j.csi.2003.12.005

-El-Misalami, T., & Jaselskis, E. (2003). Implementing Radio frequency identification in the construction process. *Journal of Construction Engineering and Management, 129* (6), 680–688. doi: 10.1061/(ASCE)0733-9364(2003)129:6(680)

-Galère. (n.d.). *65 ans d'histoire et de savoir-faire*. Retrieved January 30, 2018 from https://www.galere.be/entreprise/histoire/

-Harjunkonsky, I., Isaksson, A., & Sand, G. (in press). The impact of digitalization on the future of control and operations. *Computers and Chemical engineering*. doi: 10.1016/j.compchemeng.2017.10.037

-Hugues, C. (2015). *Bluetooth low energy for use with MEM Sensors* (Master's Thesis). Arizona State University, Tempe.

-International Federation of Automatic Control. (2015). An overview on RFID technology Instruction and Application. *IFAC-PapersOnline, 48* (3), 382–387. doi: 10.1016/j.ifacol.2015.06.111

-Juels, A. (2006). RFID Security and Privacy A research survey. *IEEE Journal on Selected Areas in Communications, 24* (2), 381–394. doi: 10.1109/JSAC.2005.861395

-Kantner, C., Langer, J., & Madlmayr, G. (2008). NFC devices: Security and Privacy. *Third international Conference on Availability, Reliability and security ARES*. doi: 10.1109/ARES.2008.105

-Kasim, N. (2015). Intelligent materials tracking system for construction projects management. *ITB Journal, 47* (2), 218–230. doi: 10.5614/j.eng.technol.sci.2015.47.2.11

-Ku, C., Theiss, & A., Yen, D. (2005) Global Positioning systems: an analysis of application, current development and future implementation. *Computer standards and interfaces, 27*, 89–100. doi: 10.1016/j.csi.2004.06.003

-Landt, J. (2005). The history of RFID. *IEEE Potentials*, *24* (4), 8–11. doi: 10.1109/MP.2005.1549751

-McNeff, J. (2002). The global positioning system. *IEEE Transactions on Microwave Theory and Techniques, 50* (3), 645-652.

-Mohtat, A. (2016). *Construction Material tracking inventory control system using smart Bluetooth/NFC tracking devices* (Masther's Thesis). Illinois Institute of Technology, Chicago.

-Phi Data. (2016). *À propos de Phi Data*. Retrieved March 21, 2018 from http://www.phidata.be/fr/phi_data/

-PWC & Bam Mat. (2017). *2.B Order preparation – Small equipment*. unpublished document.

-PWC & Bam Mat. (2017). *4,1 Material return – BU Formwork*. unpublished document.

-Krotov, V. (2017). The internet of things and new business opportunities. *Business Horizon*, 60 (6), 831-841. doi: 10.1016/j.bushor.2017.07.009

-Roberts, C.M. (2006) Radio Frequency Identification (RFID). *Computers & Security, 25* (1), 18-26. doi: 10.1016/j.cose.2005.12.003

-*Safety rules*. (2017). Unpublished document.

-Sardroud J. (2012). Influence of RFID technology on automated management of construction materials and components*. Scientia Iranica, 19* (3), 381–392. doi: 10.1016/j.scient.2012.02.023

-Srivannaboon, S. (2006). Linking project management with business strategy. *Paper presented at PMI® Global Congress 2006*—North America, Seattle, WA. Newtown Square, PA: Project Management Institute.

-Tan, J., Wang, M., & Xie, J. (2017). A Novel Method to Evaluate the RFID System Reliability. *Procedia Engineering, 174*, 465–469. doi: 10.1016/j.proeng.2017.01.167

-William, B. (2008). Cost-benefit analysis. *Economic & Labour Market review, 2* (12), 67-70.

Annex

Annex 1: Table of content of the CMK 93 cost scale.

TABLE DE MATIERES

INTRODUCTION DU CMK 93

1. CONTENU ET EMPLOI 9
2. CLASSEMENT ET NUMEROTATION (codes clés) 9
3. CARACTERISTIQUES TECHNIQUES ET SPECIFICATIONS 10
4. DEFINITION DE DUREE POUR L'UTILISATION ET L'EVALUATION DU MATERIEL 10
5. VALEUR MOYENNE DE REMPLACEMENT ET INDICE DES PRIX A LA CONSTRUCTION INDUSTRIELLE 11
6. AMORTISSEMENTS CALCULES ET INTERETS 12
7. REPARATIONS ET COUTS DE REPARATION 12
8. COUTS DE MISE A DISPOSITION DU MATERIEL 14
9. COUTS GLOBAL DU MATERIEL EN LOCATION 15
10. VALEUR RESIDUELLE DU MATERIEL DE GENIE CIVIL 15
11. CLASSIFICATION, INTERPOLATION ET EVALUATION DU MATERIEL 16
12. REGLEMENT GENERAL SUR LES INSTALLATIONS ELECTRIQUES (R.G.I.E.) 17
13. CHOIX PARMIS LES UNITES LEGALES UTILISES DANS LA TECHNIQUE 18

1. MATERIEL DE MALAXAGE ET DE BETONNAGE

11 MALAXEURS A BETON ET CENTRALES A BETON POUR CHANTIERS 21
12 BALANCES, INSTALLATIONS DE DOSAGE ET D'ALIMENTATION POUR AGREGATS ET LIANTS 46
13 SILOS, TOURS DE DOSAGE, SILOS DE TRANSBORDEMENT 55
15 APPAREILS DE DOSAGE ET DE CONCASSAGE 61
16 APPAREILS DE CLASSIFICATION, D'EGOUTTAGE ET DE LAVAGE; CONSTRUCTIONS METALLIQUES POUR INSTALLATIONS DE PREPARATION DES MATERIAUX 70
17 INSTALLATIONS POUR LA PREPARATION DES MATERIAUX 85
18 VIBRATEURS EXTERNES, VIBRATEURS INTERNES, GENERATRICES ELECTRIQUES HAUTE FREQUENCE 87

2. ENGINS DE LEVAGE ET DE TRANSPORT

21 GRUES ET EQUIPEMENTS 97
22 TREUILS MANUELS POUR CABLE, TREUILS DE LEVAGE, SCRAPERS, PALANS ELECTRIQUES 169
23 MONTES-CHARGES, ELEVATEURS A GODETS ET TRANSPORTEURS A COURROIE 190
25 INSTALLATIONS POUR LE TRANSPORT, DISTRIBUTION DU BETON ET CIMENT 214
26 VERINS HYDRAULIQUES ET POMPES, PETITS APPAREILS DE LEVAGE 244
27 CHARIOTS ELECTRIQUES ET DIESEL ET ELEVATEURS A FOURCHES 273

28 MATERIELS SUR RAILS 286

29 VEHICULES A MOTEUR, REMORQUES ET TRACTEURS 295

3. MATERIEL DE TERRASSEMENT, DE BATTAGE ET DE COMPACTAGE

31 EXCAVATRICES 349

32 BENNES PRENEUSES, BACS DE DRAGLINE, POIRE DE DEMOLITION 405

33 ENGINS DE NIVELLEMENT, BULLDOZERS, CHARGEUSES, NIVELEUSES, SCRAPERS 410

34 ENGINS DE BATTAGE 421

35 ENGINS PILONNANTS ET VIBRATEURS POUR COMPACTAGE 440

36 ROULEAUX-COMPACTEURS 447

4. INSTALLATIONS DE FORAGE DE PUITS, INSTALLATIONS DE FORAGE DANS LE SOL ET DANS LES ROCHES

41 INSTALLATIONS DE FORAGE, MACHINES POUR LE FORAGE DES ROCHES, FOREUSES MOBILES 457

42 TUBES DE FORAGE, INSTALLATIONS D'EXTRACTION, EQUIPEMENTS POUR PAROIS MOULEES 480

43 FLEURETS, TIGES DE FORAGES ET ACCESSOIRES 491

44 CHEVALETS DE FORAGE 509

46 POMPES CENTRIFUGES 510

47 POMPES A PISTONS, INSTALLATION D'ALIMENTATION EN EAU DOMESTIQUE, POMPES A VIDE 518

48 CONDUITES, VANNES ET RESERVOIRS A EAU 525

5. MATERIEL DE CONSTRUCTION ROUTIERE ET FERROVIAIRE

51 EQUIPEMENTS POUR LA PRODUCTION OU LA PREPARATION DE MELANGES HYDROCARBONES 537

52 MACHINES POUR LA POSE DE REVETEMENTS HYDROCARBONES 554

53 MACHINES POUR LA CONFECTION DE CHAUSSEE EN ASPHALTE COULE 565

54-55 ENGINS POUR LA CONSTRUCTION DE REVETEMENTS EN BETON 570

56 EQUIPEMENTS POUR LA STABILISATION DES SOLS, EQUIPEMENTS DIVERS POUR TRAVAUX ROUTIERS 584

57 MATERIELS DE CONSTRUCTION DE VOIES FERREES 594

6. MATERIEL PNEUMATIQUE POUR CONSTRUCTION DE TUNNELS ET FONCAGE

61 COMPRESSEURS 617

62 RESERVOIRS SAS, ACCESSOIRES POUR CIRCUIT D'AIR COMPRIME ET DISPOSITIFS DE REGULATION 629

63 OUTILS PNEUMATIQUES 647

64 EQUIPEMENTS DE CREUSEMENT DE TUNNELS 654

65 EQUIPEMENTS DE POUSSAGE ET DE FONCAGE DE TUBES 670
66 BOUCLIERS DE CREUSEMENT 676

7. MATERIEL DE CONVERSION ET DE DISTRIBUTION D'ENERGIE

71 CHAUDIERES A VAPEUR, CHAUFFES-EAU ET CLIMATISEURS 677
72 MOTEURS A COMBUSTION INTERNE 682
73 GROUPES ELECTROGENES 683
74 MOTEURS ELECTRIQUES TRIPHASES 689
75 APPAREILLAGES DE COMMANDE 692
76 TRANSFORMATEURS, CHARGEURS DE BATTERIE, CONDENSATEURS 696
77 ARMOIRES DE DISTRIBUTION ELECTRIQUE 704

MATERIEL DE DRAGAGE ET AUTRE MATERIEL FLOTTANT - TECHNIQUES D'AMELIORATION DE L'ENVIRONNEMENT

81 MATERIELS DE DRAGAGE ET AUTRES MATERIELS FLOTTANT 713
82 DRAGUES SUCEUSES REFOULEUSES, CONDUITES DE REFOULEMENT, DISPOSITIFS FLOTTANTS DE DECHARGEMENT 716
83 REMORQUEURS, BATEAUX ET PROPULSIONS AUXILIAIRES 729
84 CHALANDS, PONTONS, TREUILS 733
85 TECHNIQUES D'AMELIORATION DE L'ENVIRONNEMENT 741

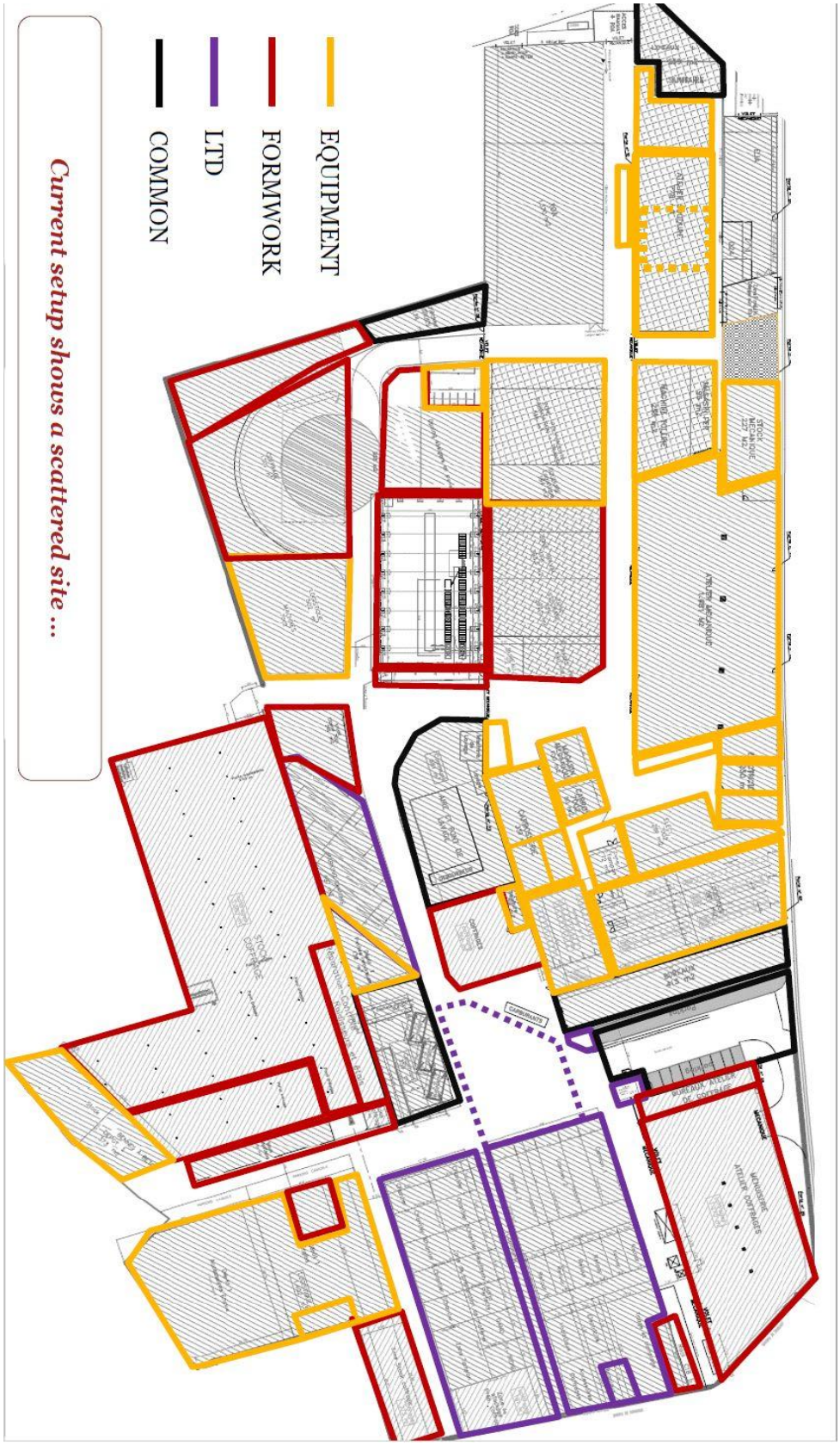
9. MACHINES DIVERSES, EQUIPEMENTS DE CHANTIER

91 MATERIELS D'ATELIER MECANIQUE 745
92 MACHINES POUR LE TRAVAIL DU BOIS 784
94 BARAQUES, HANGARS EN PANNEAUX ONDULES, ROULOTTES, CONTAINERS 800
95 INSTRUMENTS DE MESURE, DE LABORATOIRE ET D'ESSAI 819
96 ECHAFAUDAGES, HALLS DE PROTECTION (INTEMPERIES), COFFRAGES, ETAIS 841
97 MACHINES DE BUREAU, EQUIPEMENTS DE BUREAU, APPAREILS DE COMMUNICATION 863
98 APPAREILS ET ENGINS DIVERS, PNEUS 884

INDEX ALPHABETIQUE DES MOTS-CLES 917

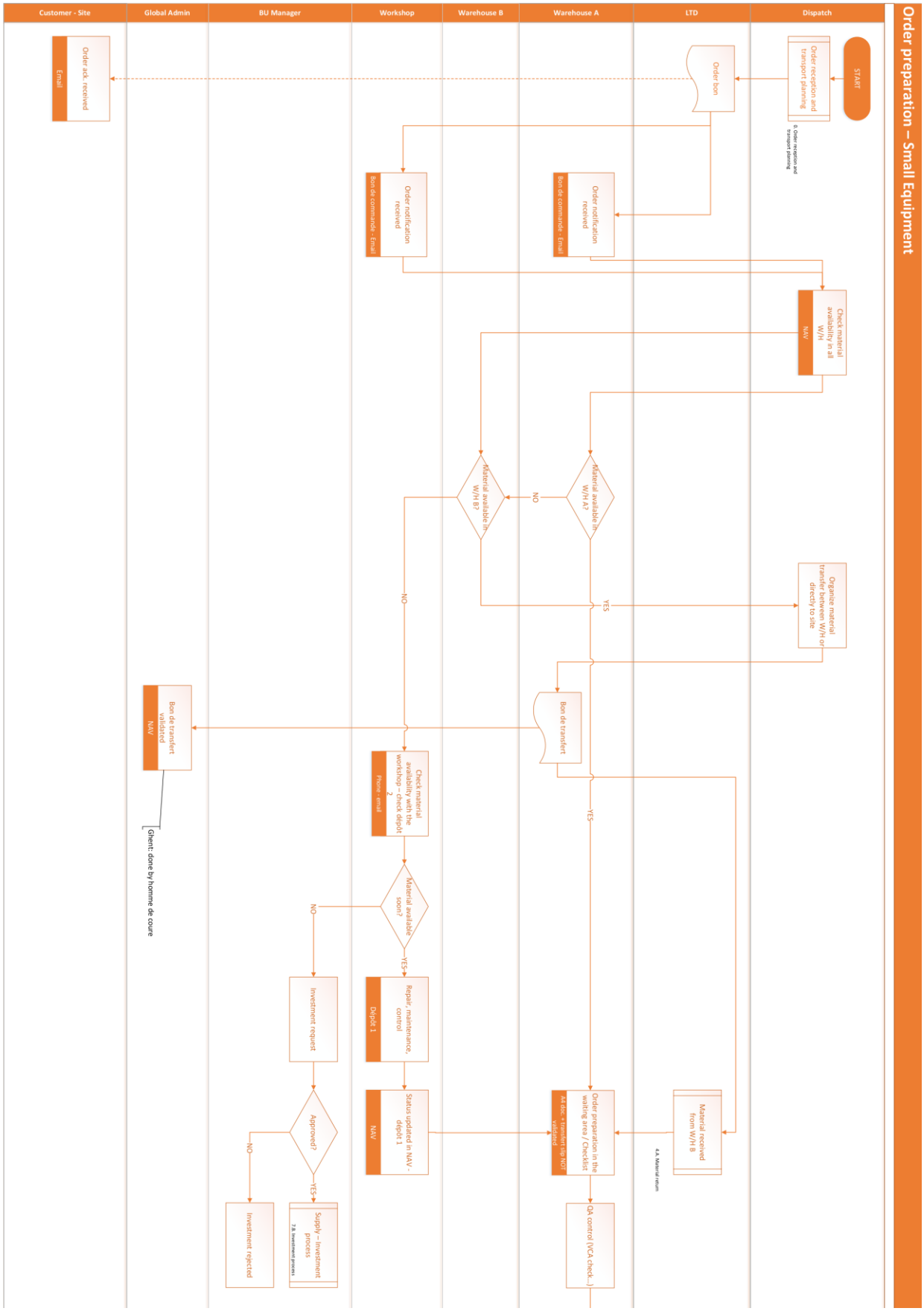
Source : Confédération Construction : *CMK 1993*

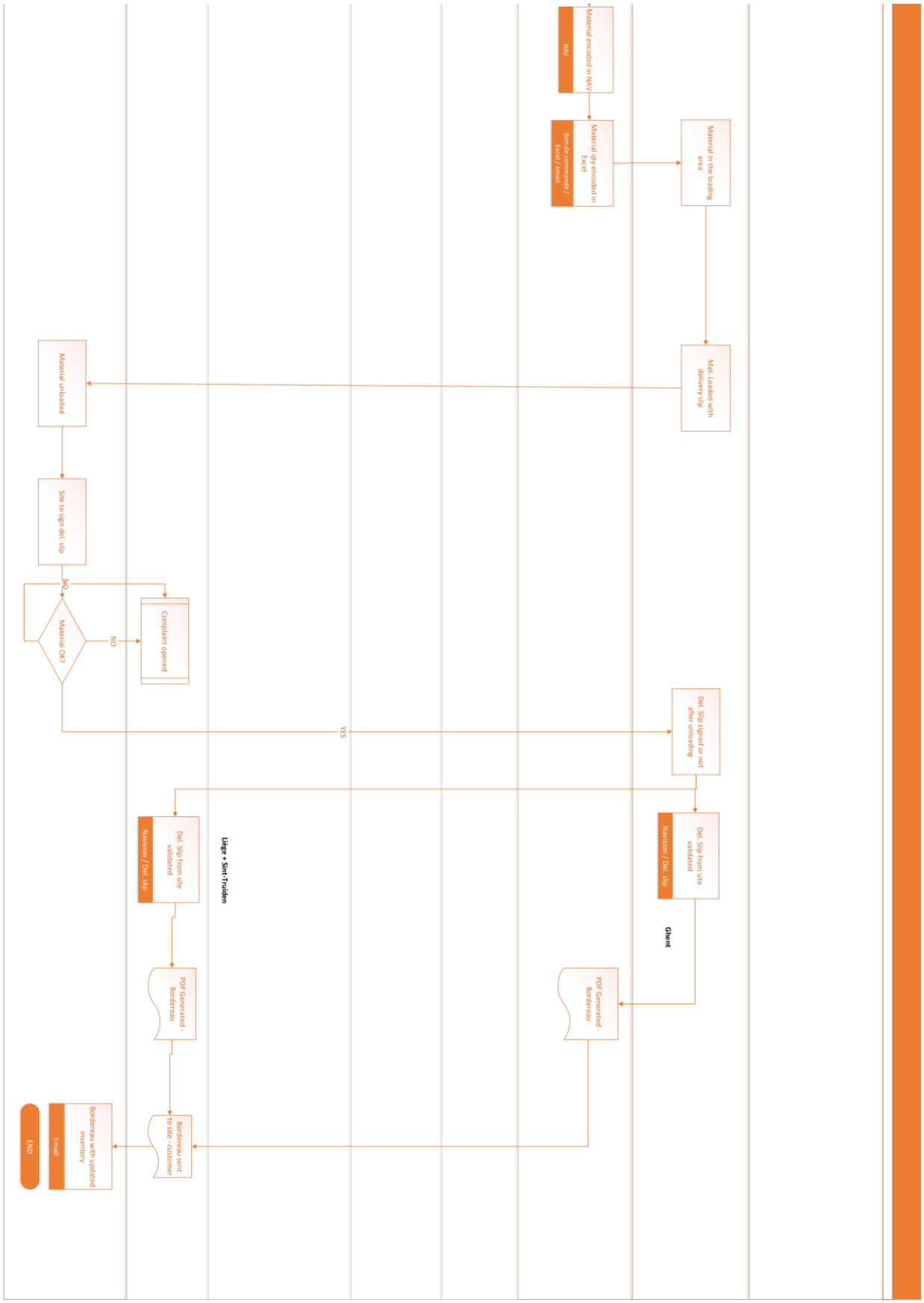
Annex 2: Structure of Liège site (31 900m^2)



Source: PWC & Bam Mat. (2017). Bam Mat-Detailed site design. Unpublished document.

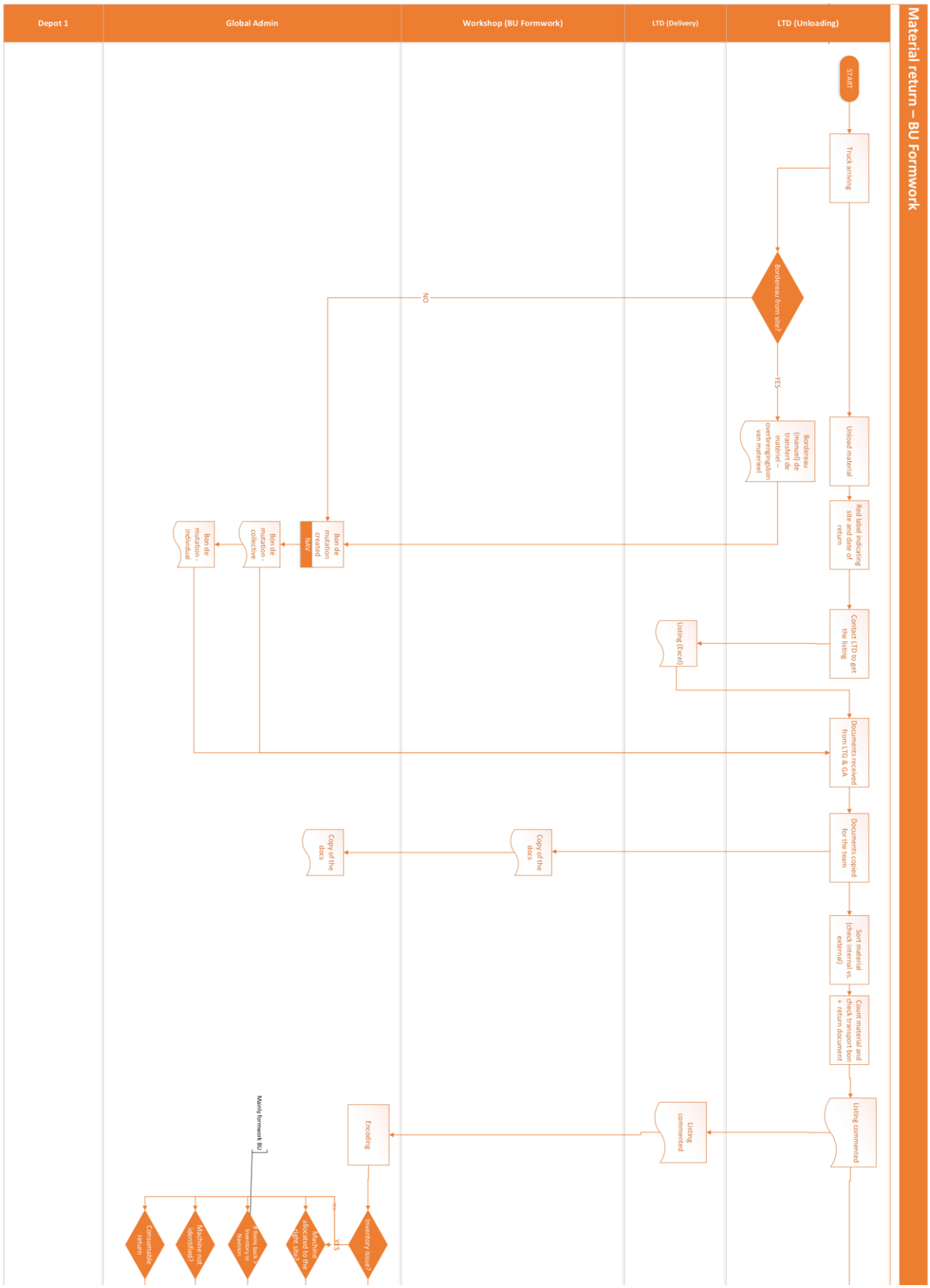
Annex 3: Order preparation process – Small equipment

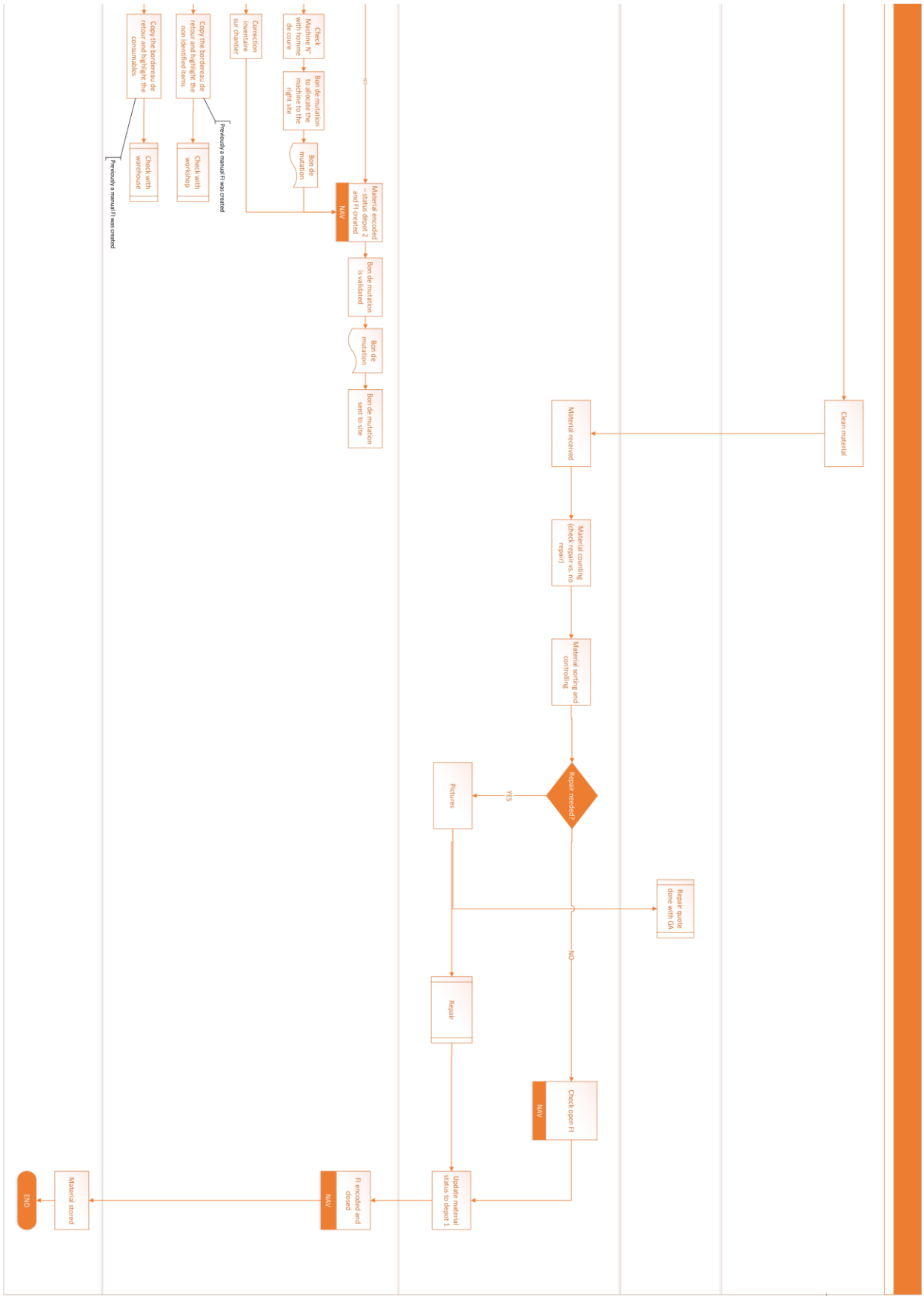




Source: PWC & Bam Mat. (2017). 2.B Order preparation – Small equipment. unpublished document.

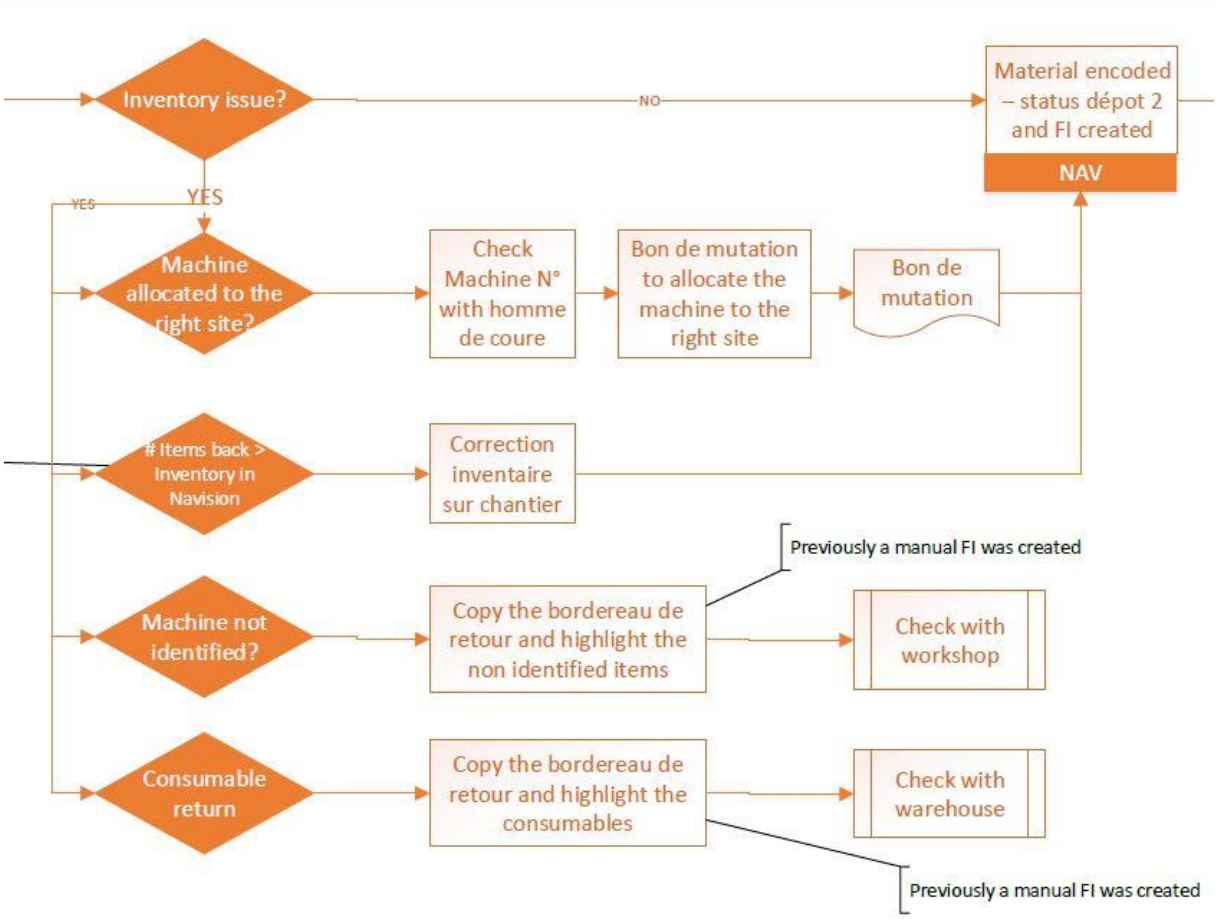
Annex 4: Material return process – BU Formwork





Source: PWC & Bam Mat. (2017). 4,1 Material return – BU Formwork. unpublished document.

Annex 5: Detailed inventory issues



Source: PWC & Bam Mat. (2017). 4,1 Material return – BU Formwork. unpublished document.

Annex 6: Detailed equipment classification

Type	Tag 1	Tag 2	Tag 3	Quantité
COL				412989
	Accessoires			16612
		Bloc		10513
		Extincteur		1097
		Mobilier		5002
	Clôture			8329
	Coffrage			279746
		Gros équipement		84920
			Console	6662
			Etai	32021
			Filière	4804
			Panneau	7775
			Poutre	402
			Raidisseur	24827
			Rail	3013
			Trépied	5416
		Moyen équipement		50873
			Barre d'ancrage	18686
			Connecteur étai	597
			Eclisse	16456
			Garde-corps	15134
		Petit équipement		143953
			Attache	1593
			Boulon	3995
			Broche	13573
			Cale	2065
			Clavette	2758
			Ecrou	29553
			Etrier	18049
			Manchon	686
			Pied	6637
			Pince	18115
			Plaque	13219
			Raccord	4153
			Sécurité	8518
			Tendeur	5314
			Tête	15725
	Echafaudage			65898
		Structure		49945
			Cadre	5503
			Croisillon	1990
			Croix	2062
			Diagonale	5689
			Garde-corps	4785
			Goujon	2636
			Horizontale	12404
			Passerelle	265
			Plancher	7114
			Plinthe	3734
			Tuyau	3660
			Limon	103
		Jointure		15953
			Raccord	4038
			Collier	11915
	(vide)			42404

IDV				**19706**
	Equipement			10058
		bac		498
			benne	97
			décombre	200
			mortier	192
			nettoyage	3
			rétention	6
		citerne		163
		électrique		2696
			aiguille vibrante	19
			cabine	307
			chargeur	19
			Coffret	862
			compresseur	59
			éclairage	1002
			fontaine eau	207
			pilonneuse	23
			plaque vibrante	75
			poutre vibrante	14
			transformateur	59
			ventilateur	16
		électroportatif		4537
			aérotherme	25
			aiguille vibrante	466
			appareil à cercler	125
			aspirateur	114
			bétonnière	10
			boulonneuse	200
			canon à chaleur	62
			carotteuse	25
			chalumeau	33
			climatiseur	19
			cloueuse	28
			compresseur	44
			Convertisseur	96
			décapeur	8
			defonceuse	7
			déshumidificateur	29
			foreuse	200
			fraiseuse	4
			malaxeur	76
			marteau	706
			mélangeur	4
			meuleuse	649
			perceuse	21
			pistolet	26
			pompe	346
			Ponceuse	64
			poste soudure	137
			riveteuse	6
			scie	344
			talkie walkie	346
			tronçonneuse	154
			visseuse	163

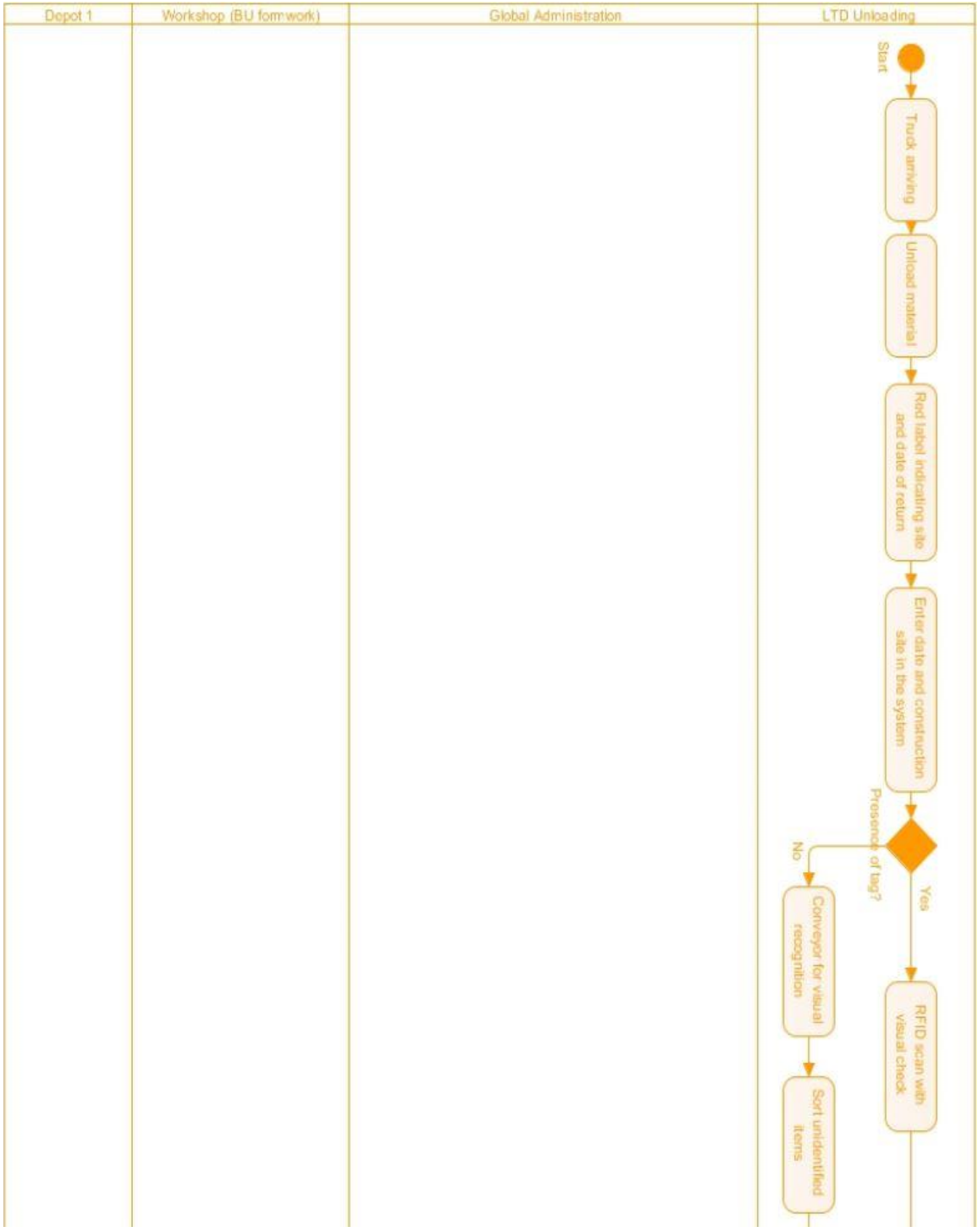
		outil		291
			aiguille vibrante	7
			coupe-dalle	5
			lave-bottes	7
			nettoyeur	62
			obturateur tuyau	18
			rampe distribution eau	16
			scie	176
		Sécurité		98
		topographie		534
			dynamomètre	3
			GPS	99
			Laser	247
			niveau	149
			télémètre	12
			Theodolite	24
		accessoire véhicule		1095
			bac	346
			brise béton	15
			crochet à boule	6
			fourche	21
			grappin	12
			grue	597
			pince	4
			plateau vibrant	6
			potence	2
			remorque	75
		Mât		146
	groupe électrogène			178
	Grue tour			38
	Installation chantier			1105
		container		1080
		roulotte		25
	Levage			6870
		anneau		287
		câble		101
		chaine		888
		chariot		65
		crochet		375
		échelle		751
		élingue		102
		harnais		1516
		manille		393
		œillet		63
		palan		131
		palonnier		49
		pince		221
			béton	2
			bordure	95
			chambre de visite	18
			palette	5
			palplanche	9
			pantographe	8
			poutrelle	13
			tôle	51
			tuyau	20
		porte fût		26
		sangle		1624
		Transpalette		95
		grappin		34
		cric à crémaillère		87

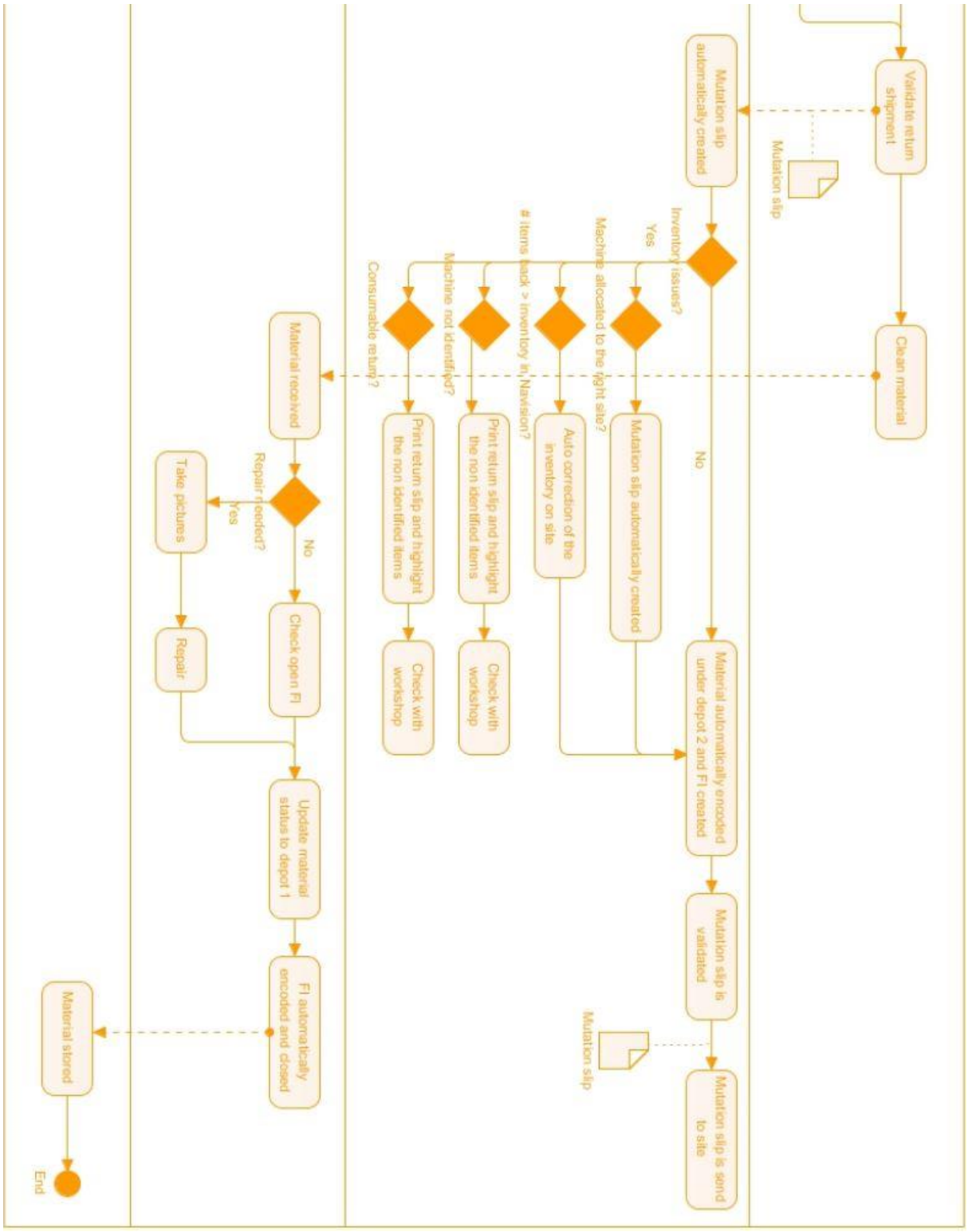
	Véhicule			440
		camion		34
		génie civil		184
			balayeuse	13
			bétonnière	11
			bulldozer	4
			chargeur sur pneus	15
			dumper	13
			élévateur bras téléscopique	25
			foreuse	4
			grue téléscopique	7
			pelle hydraulique	69
			rouleau	23
		voiture		141
		camionette		34
		Elévateur		47
	(vide)			1017

Data retrieved 01/03/2018 from the database

Source: Author of the paper

Annex 7: Materiel return process with an automated identification and tracking system





Source: Author of the paper

Annex 8: Detailed timing test

N°	Description	Tag 2	Quantité	Temps
9683121810	Caisse container 800x500	Bac	3	10
96609990	Panier pour etançons	Bac	2	5
96609988	bac de transport 100x80x50	Bac	1	5
9683121801	Panier pour etais 1200x800	bac	3	5
96831211801	Panier pour etais 1200x800	Bac	1	9
9683121807	Bac de stockage panneau lumineux	Bac	1	8
9630015075	Dywidag 15 - Barre d'ancrage 75	Barre d'ancrage	127	340
9618301104	Cadre de 125x75 série 5100	Cadre	1	12
9618301107	Cadre de travail 200x75 série 5100	Cadre	3	24
96381499001	Cornière galva pour console M/R	Console	38	312
96389534010	Console pignon 1,40 m	Console	6	57
96371488900	Rasto - Eclisse d'angle v 35/26	Eclisse	16	34
96371488910	Rasto - eclisse d'ajustement 55	Eclisse	54	208
96371489000	Rasto - Eclisse d'alignement 35	Eclisse	10	25
96112633257	AR alu volée escalier + palier (2mx2m57x0,64m)	Escalier	1	5
96121464633	Modex Alu esalier 250	Escalier	2	6
96600260	Etai galva 152/260 - 20 KN - Rouge	Etai	70	589
96602564381	Rasto bracon n°3	Etai	23	356
9618303706	Etai horizontal 245 série 5100/5200	Etai	7	221
9618303716	Etai diagonale 245 série 5100/5200	Etai	8	213
9635011245	Filière 2m45 SRZ 100 Peri	Filière	18	123
9635011245	Filière 2m45 SRZ 100 Peri	Filière	12	856
96112638257	AR garde corps de volée (2mx2m57)	Garde-corps	3	10
9618302910	Elément garde-corps 75x106 série 5100	Garde-corps	3	69
	Takko - angle intérieur 120x30x30	Panneau	9	65
96361120090	Takko panneau 120x90	Panneau	4	56
96361120045	Takko panneau 120x45	Panneau	1	12
96361150075	Rasto Panneau 150x75	Panneau	12	156
96361120060	Takko - panneau 120x60	Panneau	2	27
96361270075	Rasto - panneau 270x75	Panneau	12	140
	Rasto - angle intérieur 150x30x30	Panneau	8	123
96361270030	Rasto - panneau 270 x 30	Panneau	10	139
96361120075	Takko - panneau 120x75	Panneau	13	121
96361120060	Takko - panneau 120x60	Panneau	28	72
96361120075	Takko - panneau 120 x 75	Panneau	4	13
96121427973	Modex - Plancher acier 250/32	Plancher	2	7
96301464600	Paque écrou 130	Plaque écrou	202	1310
9618305571	Set de plinthe en alu 245/75 série 5100	Plinthe	1	12
96603601385	TPK - raccord rapide	Raccord	1	5
96450020290	H2O - Raidisseur 2m9	Raidisseur	143	1490
96450020330	H2O - Raidisseur 3m3	Raidisseur	32	316
96450020750	H2O - Raidisseur 7m5	Raidisseur	16	343
96450020180	H2O - Raidisseur 1m80	Raidisseur	32	154
96450020360	H2O - Raidisseur 3m60	Raidisseur	18	72
9618305611	Stabilisateur triang 200 série 5100	Stabilisateur	2	10
9618305611	Stabilisateur triang 200 série 5100	Stabilisateur	4	37
96370566667	Manto - support ext. D'ancrage MR	Support ancrage	44	324
96603417565	Tête étai en fourche 8/20	Tête	50	134
96603587377	Trépier universel Hunnebeck	Trépied	3	15
96603587377	Trépier universel Hunnebeck	Trépied	31	116
96371488900	Rasto-Eclisse d'angle v35/26	Eclisse	10	120
96371488910	Rasto - Eclise d'ajustement 55	Eclisse	21	236
96360330120	Manto- Panneau 330x120	Panneau	16	752
96360330240	Manto- Panneau 330x240	Panneau	8	456
Total			**1152**	**10335**

Source: Author of the paper

Place des Doyens, 1 bte L2.01.01, 1348 Louvain-la-Neuve, Belgique www.uclouvain.be/lsm