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Sustainable **U**rban **C**onsolidation **C**entr**ES** for con**S**truction

Process Mapping and management tools for construction logistics / D3.2

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Contents

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

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Executive summary

SUCCESS has chosen to target the construction industry as major impacting sector on city logistics which has un-exploited potentials of improvement of the efficiency of goods, waste and service trips in EU cities, by answering the challenges pinpointed by the European Commission and in particular by improving urban freight understanding and by introducing more resource-efficient, more environmental-friendly, safer and seamless supply chain innovations.

The deliverable ***D3.2 Process mapping and management tools for construction logistics*** is part of WP3 of the project, which provides the tools and methodologies needed to design innovative solutions for construction logistics in urban areas. We present the work done in *Task 3.2*. In this work we firstly study the *Process Management*, its methods and techniques. We thus focus on two of those techniques: the *Process Mapping* (PM) and the *Value Stream Mapping* (VSM).

We have studied these two techniques and have defined for the first time its application to the construction industry. This is particularly true for the VSM, that is a method typical of the lean manufacturing, thus we proposed a methodology and analysed its application to the construction industry.

To apply the Process Mapping technique to construction industry, we have identified and defined a common list of processes to map and have proposed a methodology and guidelines to support the pilot coordinators and harmonise the results between pilots. To apply the Value Stream Mapping technique to construction industry, we have also proposed a methodology and guidelines to support the pilot coordinators and harmonise results between pilots.

After that, we report the description of the maps provided to us by the coordinators of the four construction sites. We propose a detailed analysis for each of the map so to detect the main problems and the best practices.

We report the main conclusion and proposal of improvement.

We include the set of all the maps collected by the four pilot sites in the Annex.

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1 Process Management Tools

Due to markets' variability and the constant opening of new horizons, organizations must be able to adapt quickly and to forecast changes. In order to be constantly updated and to compete, they must be quick and precise. To help companies to do so, some management methodologies for companies have been developed: between these, one of the most efficient is the so called **Business Process Management (BPM)** methodology.

This chapter introduces the basic concept of this methodology, including the mapping tools - the **Process Mapping** and the **Value Stream Mapping** - which play a relevant role within the BPM and the Process Management tools.

To allow a better understanding of the following topics, we introduce some preliminary notions on Business Process Management.

1.1 What a process is

The European Association of Business Process Management (EABPM) defines a process as "a set of pre-defined activities which can be made by people or machines, to reach an objective". Processes are started by specific events (inputs) and end-up with specific results (outputs), which can represent the end of a process, or the beginning of another one. Processes are made by correlated activities that share a common goal. These activities of a process are a sequence of elementary operations such that a further breakdown would not be significant in the organization analysis.

Processes can be classified into:

- Strategic Processes: through which organizations compete on the market and try to overcome competitors;
- Operative Processes: that produce the companies' products and services;
- Support Processes: which add efficiency and effectiveness to Operative Processes.

1.2 Business Process Management (BPM)

The Business Process Management methodology aims to the management and improvement of the entire process life-cycle. It allows the organization to be in line with clients' and internal users' demands and requirements through the innovation, the flexibility and the integrated use of technology; in other words, the BPM is the set of all the necessary activities to define, optimise, monitor and integrate business processes, in order to create a complete process that makes companies' business more efficient and effective.

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In practice, the implementation of this methodology may lead to a reduction of time or costs of a process, or to a decrease of errors and a greater use of resources.

The Business Process Management is a strategy that integrates notions of Business Process Re-engineering (BPR) with those of Business Process Improvements (BPI). The BPR allows obtaining a substantial performance improvement through the re-design of business processes. Instead, the BPI allows maintaining this improvement and increasing it through the adjustment of processes with the external environment.

1.2.1 The BPM life-cycle

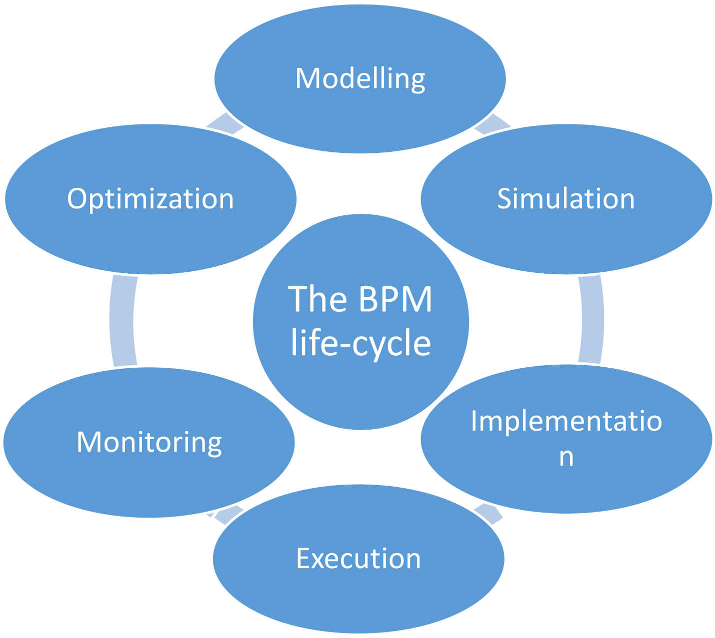

Figure 1 The BPM life-cycle

The BPM life-cycle is made of six main phases, introduced by a preliminary phase; they follow one another and each phase is the input for the subsequent one:

- Modelling
- Simulation
- Implementation
- Execution
- Monitoring
- Optimization

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1.2.1.1 *The preliminary phase*

The preliminary phase allows managers to obtain a general overlook of the current situation of the organisation and to focus on those points where the Business Process Management methodology will be applied. It is made of three main parts:

Information gathering: in order to have a clearer and more complete understanding of rules and processes, contacting all involved units and gathering the highest possible amount of information through surveys and interviews is needed.

Determination of the most important processes: not all processes have the same value within the organization; it is fundamental to identify which processes are the most critical and which are those that create the highest value for the company, so that they will be the first to be analysed.

Goal definition: having a clear idea of the objectives to be reached makes it easier for a company to define where to intervene and decide which processes are the most relevant for the company strategy.

1.2.1.2 *The Life-cycle Steps*

Modelling: the objectives of this phase are to document and to design the process, using models and techniques of process mapping. Furthermore, business goals (or Key Goal Indicators – KGI) and performance measures (Key Performance Indicators – KPI) must be stated.

Simulation: it consists in the simulation of all types and variations of the process taken in consideration. Performance indicators allow evaluating which process is the most efficient for the company.

Implementation: it translates into operative procedures every step of the model.

Execution: at this point, the process is ready to become operational. The company proceeds in making it operational.

Monitoring: it consists in following step by step the process functioning, controlling and monitoring its performance indicators and any possible issue.

Optimization: this is the final phase where process improvement areas are identified, by evaluating results of the previous point.

1.2.1.3 *BPM objectives*

As stated before, Business Process Management is a philosophy for companies' management aiming at improving their performance. However, to validate its

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effectiveness, it is necessary to understand which progress improvements are to be expected by a correct use of BPM.

The correct implementation of this methodology has the goal to increase company's process performances under three key aspects: effectiveness, transparency and agility.

1.2.1.3.1 Process effectiveness

The BPM aims at maximising a process' effectiveness by determining its optimal level for the current situation, making the process able to work in the most functional way and by activating controls on in-process activities. These improvements are possible thanks to the implementation of a set of activities (reported below) aiming at strengthening company's processes.

- Real-time monitoring: the BPM provides the visibility of the underway processes' status and extracts the key parameters to evaluate the company effectiveness. This allows judging performances and re-design processes so that value increases.
- "*What-if*" analysis: the BPM allows simulating processes' performances before their implementation. It allows testing the effectiveness of alternative scenarios, before choosing the optimal one.
- Automation: through the BPM it is possible to automate many processes that before were managed manually. For those processes which still need manual handling, the BPM coordinates the work flow, notifying workers the information they need to perform their tasks.
- Control and decision-making process: managers have direct access to process performance data and they have the control of rules and policies that steer on it. Furthermore, users of the organisation participate in the initial definition of the process and to its changing, so that it is constantly optimized.

1.2.1.3.2 Process transparency

It worth's keeping in mind one of the main principles of BPM: "what has to be modelled is what has to be implemented". In facts, with BPM, the model does not concern the project only, but also it is the actual engine of the process. Translation phases and all other phases with difficult document interpretation are meant to be deleted. In conventional development environments, more tools have to be used and different models for each phase of the model development cycle have to be created: multiple interpretations and inconsistencies follow. Instead, the BPM avoids these problems, as it provides a complete look of the environment.

It is important that processes are not seen as "black boxes", invisible to those who do not directly belong to them. For this reason, they need to have great visibility within a company, to communicate and interact as better as possible.

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Mainly, this occurs thanks to two factors: the monitoring and the analysis of meta-data.

- Monitoring and analysis: the BPM allows seeing processes while they are implemented, in order to determine how commercial transactions that affect them influence business key parameters. Moreover, it provides tools to react, answer, and manage forthcoming risks or opportunities. The BPM offers information which helps discovering causes of problems, by providing a feedback on how a process can be improved.
- Meta-data: processes are a complex set of models, rules, data, logic and much more. The structured gathering of information that describes these parts is named meta-data. The BPM uses meta-data to keep everything aligned. An architecture made of re-usable components implies many parts are in movement. Having different people controlling and modifying different components may represent a challenge for keeping a clear vision of all these parts and how they interact. Meta-data allow saving the description of all these pieces and their relation in a central "storage".

1.2.1.3.3 Process agility

The correct implementation of the BPM allows both changing and optimisation of existing processes and the development of new ones. To let these changes happen with agility, the Business Process Management provides two tools:

- Communication and cooperation: the greatest barrier to change is communication. The BPM breaks this barrier by increasing direct lines of communication and cooperation among all process participants. Also, it allows enlarging the company's boundaries, cooperating effectively with clients, partners and providers.
- Fast development: the BPM allows perceiving change while it happens, understanding its impact and developing a complete vision on how the company should intervene.

*At this stage of the project, we analyse only the 1st step: "Modelling" and we use the Mapping tools (**Process Mapping** and **Value Stream Mapping**).*

1.3 Process mapping

Process Mapping (PM) is the phase of Business Process Management that identifies maps, and models company processes, through a rigorous methodology and procedure. Mapping of business processes has as main objective the company business representation, in order to support the implementation of an organisation system based on procedures and best practices that identify clearly the activities' inter-functional responsibilities.

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A process map is a visual help to depict company processes. It shows how inputs, outputs and activities are linked. Process Mapping requires considering the process by highlighting main steps for the production of outputs, who executes these steps and where issues arise systematically. The goal of a process map is to help managers understanding better the organisation and increasing performances.

1.3.1 What is process mapping for?

Process mapping main function is to provide an overview of the company, useful for company managers, providers, clients, and/or other external collaborators. Another goal is to provide the basis to proceed, in a second phase, with the detailed study of processes and the identification of critical points.

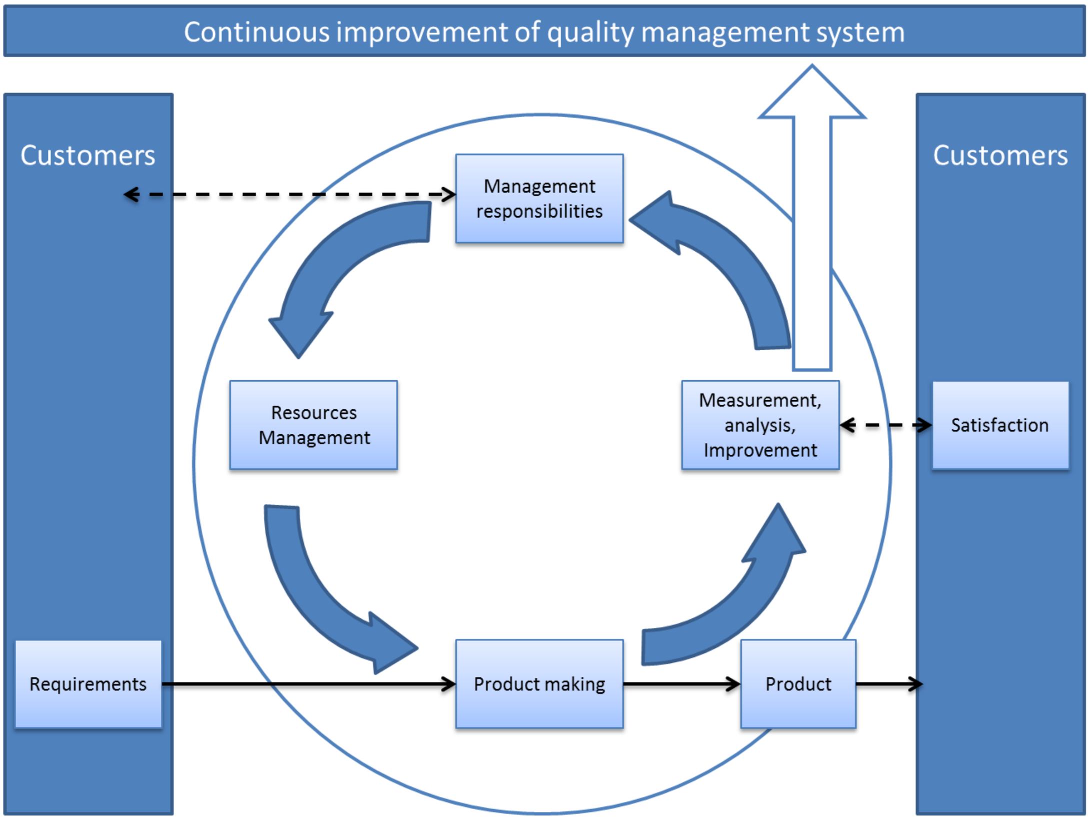

Figure 2 Continuous quality improvement

Having a complete view of processes allows assigning responsibilities and managing roles easily. It may lead to a revision of the company organigram and a decrease of hierarchical levels, so that processes are thinner and more efficient. Thanks to process mapping it is possible to extract a scheme of both paper and electronic documentation. Matching documents directly to a defined process, a link arises so that their management gets easier and they get faster to be retrieved. Finally, process mapping allows showing intuitively

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where different performance KPIs are located, what they measure and suggests where to add new KPIs.

Formalisation of company processes is the starting point for many certifications such as for the ISO 9001. This regulation proposes in facts a scheme for process mapping which is very similar to the one we have described. In this case the process map is needed to identify relevant processes for quality, which will be then formalized.

1.3.2 Process Mapping phases

Three main phases may be identified for a correct process mapping:

- **Macro-process Map**: first, a general scheme of the entire organisation, which included synthetically all company activities, has to be drawn.
- **Critical points identification**: using the general process map, it is possible to identify which processes are more important to be study into details.
- **Sub-processes and procedures description**: for each macro-process, a description of activities, responsibilities, support systems and sub-processes is done.

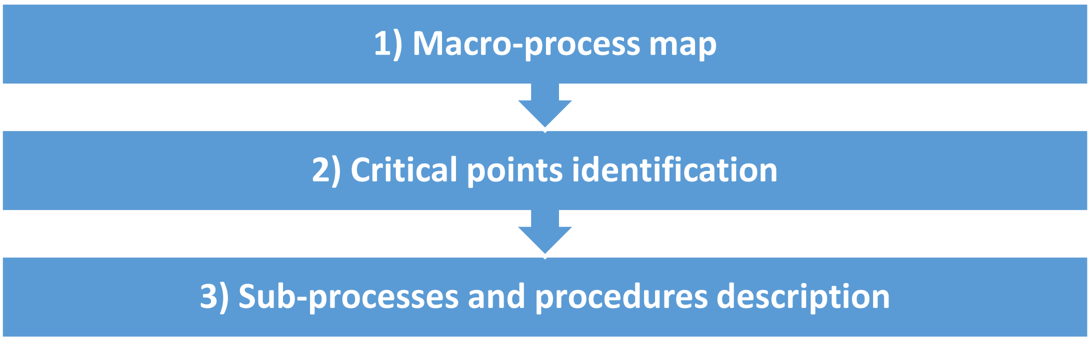

Figure 3 Process mapping main phases

It is worthy to recall that Process Mapping is a tool that managers use to have a complete understanding of a company. Clarity and usability must be favoured to formal correctness. Maps and their processes have to be easy and fast to understand and to trace. Often, formality is enemy of practicality.

Each phase mentioned above will be detailed in order to highlight key points.

1.3.3 Macro-process mapping

To develop a universal model, fitting each company type – from producers of material goods to service providers – it is possible to distinguish three types of processes:

- Management processes: all processes through which the management manages and monitors the work done within the company

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- Key processes: processes through which the company generates the added value that the client is wishing to pay. They can be divided into 3 categories:
    - Innovation processes: gathering activities aimed at generating new products or services.
    - Takeover – management of clients' relations: gathering activities aimed at having new clients and keeping/improving relations with existing ones.
    - Product creation/ service provision: gathering activities aimed at actually creating the product or that allow providing the service.
- Resource management processes: gathering processes that make necessary structures and resources available for the entire organisation. These resources can be human, financial, material and technological.

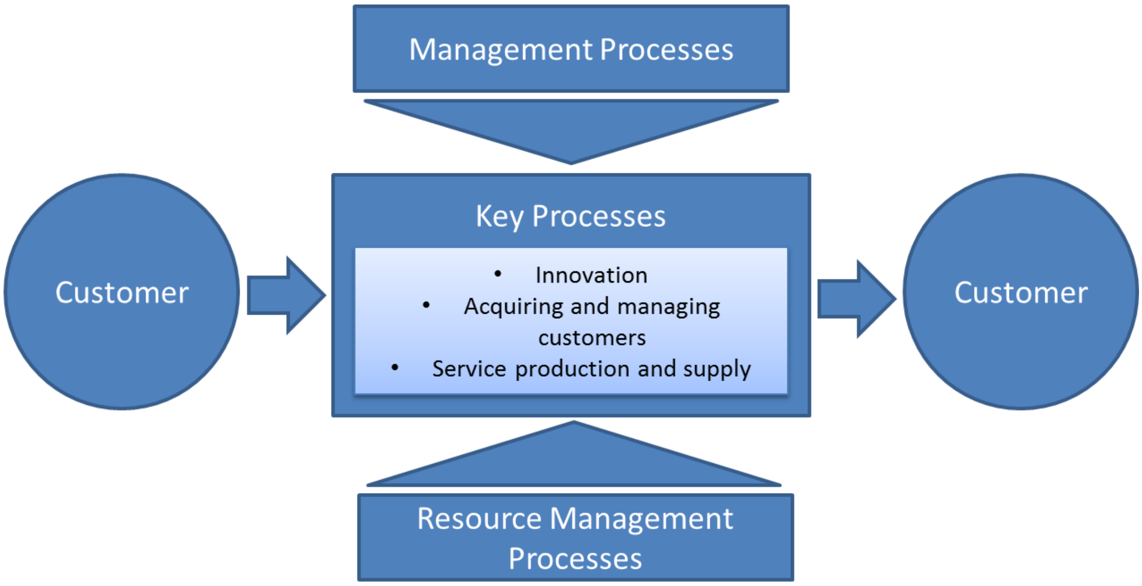

Figure 4 Macro-process Mapping

From the above mentioned scheme, two key aspects have to be noticed:

- The client is present from the beginning to the end of processes. It happens because he provides process' inputs, by communicating to the organisation his needs and requests, and he buys process' outputs, namely end products and services.
- It is never mentioned who executes each process. The goal of this map is to report what has to be done, not who does it.

1.3.4 Critical Points Identification

Starting from the general map, company macro-processes can be identified. Through these, it is possible to extract sub-processes, which, in turn, are made of several activities. The level of detail to describe a process is a business choice.

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However, it has to be kept in mind that having a very detailed description may lead to opposite results, thus nullifying the methodology effectiveness. Usually, three levels may be distinguished in a normal business activity: Macro-processes, Processes, single activities.

Formalizing all processes may be useless and inconvenient. Most important processes have to be identified. To do that, we propose the following list of key processes:

- Processes with relevant security aspects;
- Processes which need standardisation and present confusion and inefficiencies;
- Processes having significant impact on strategical company objectives;
- Processes implying great economic movements;
- Processes implying no client satisfaction;
- Processes that must be executed by law, following defined procedures.

1.3.5 Sub-processes and procedures description

The description phase of single processes and procedures allows going into details of the description and of the evaluation of company processes. It has to be recalled that a process always has the goal of producing an output, which will be purchased by the client. The client provides the inputs which starts the process. Thus, the gathering of activities which, in turn, start the process.

Several mapping processes methodologies exist; in the following sections, we provide some.

1.3.5.1 Flow chart

It is probably the most known and used tool. It makes use of few basic symbols (reported in Figure 5), linked by arrows indicating the direction of the process. The most common flow chart shape is the vertical one, where, on the left, there is the flow and, on the right, activities' information.

In favour of this methodology is the fact that it allows mapping several alternatives thanks to decision points, its general knowledge and its widespread use in the IT sector.

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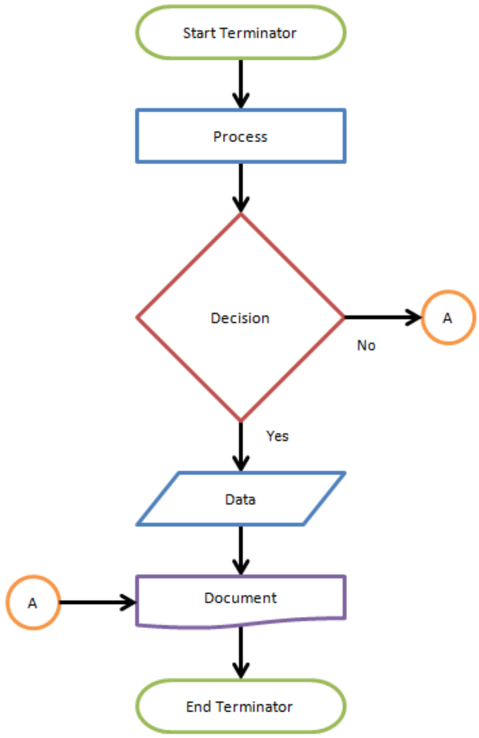

Figure 5 Example of a Flow chart (breezetree.com)

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Against it, a complex process description may be difficult due to the lack of detailed rules for representing different levels of abstraction. Furthermore, flowcharts highlight operations turning inputs into outputs. Then, inputs and outputs are often confused with arrows linking the operations, while they should be represented with specific symbols.

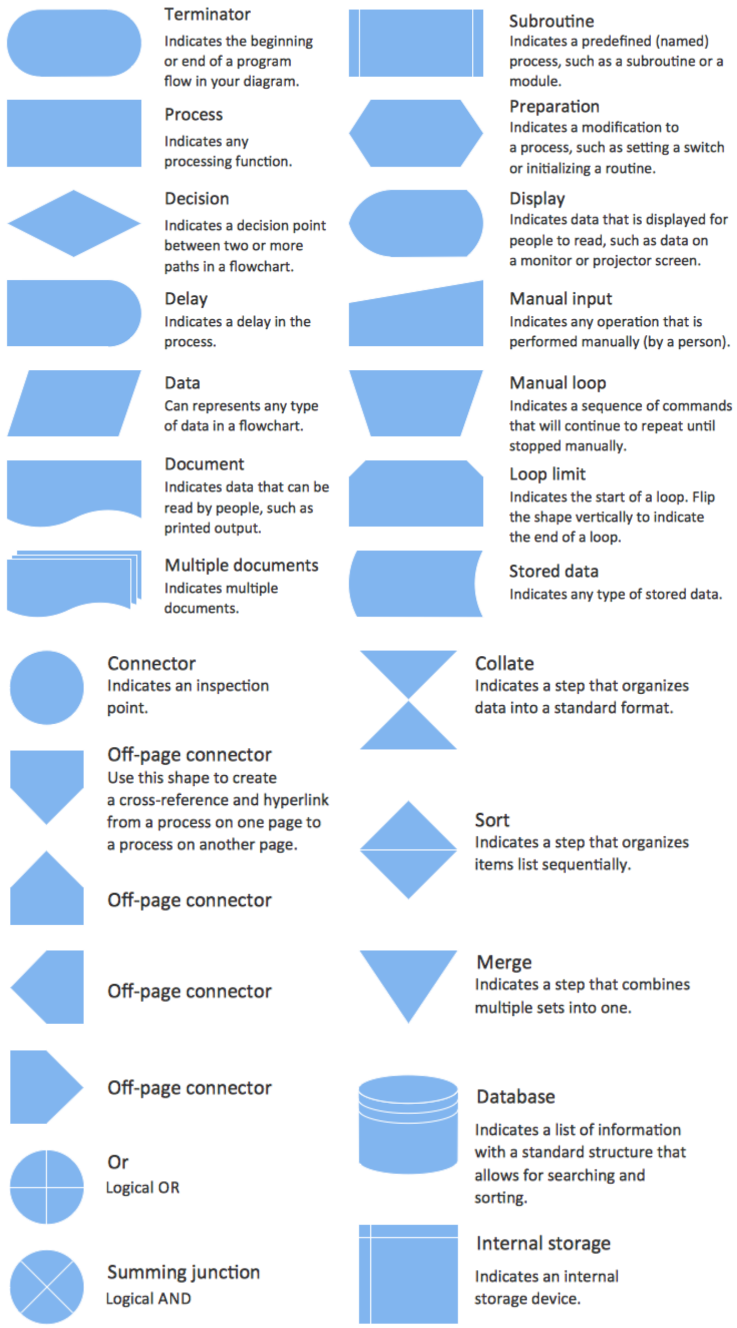

Figure 6 Flow chart common symbols (conceptdraw.com)

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1.3.5.2 *Inter-functional flow charts*

It is an evolution of the conventional flow chart described above. In this chase the chart is made of three areas representing responsible and who takes part to the process. Single activities are put in the area of actors who implement them. It allows understanding the working flows through involved functional units. Another strength of this method is that actors' interactions and critical points are immediately visible. Many companies are using this tool, given its great practicality. Two common issues are represented by the fact that there is not a unique and clear way to either depict activities performed by more actors, or to specify working tools linked to activities.

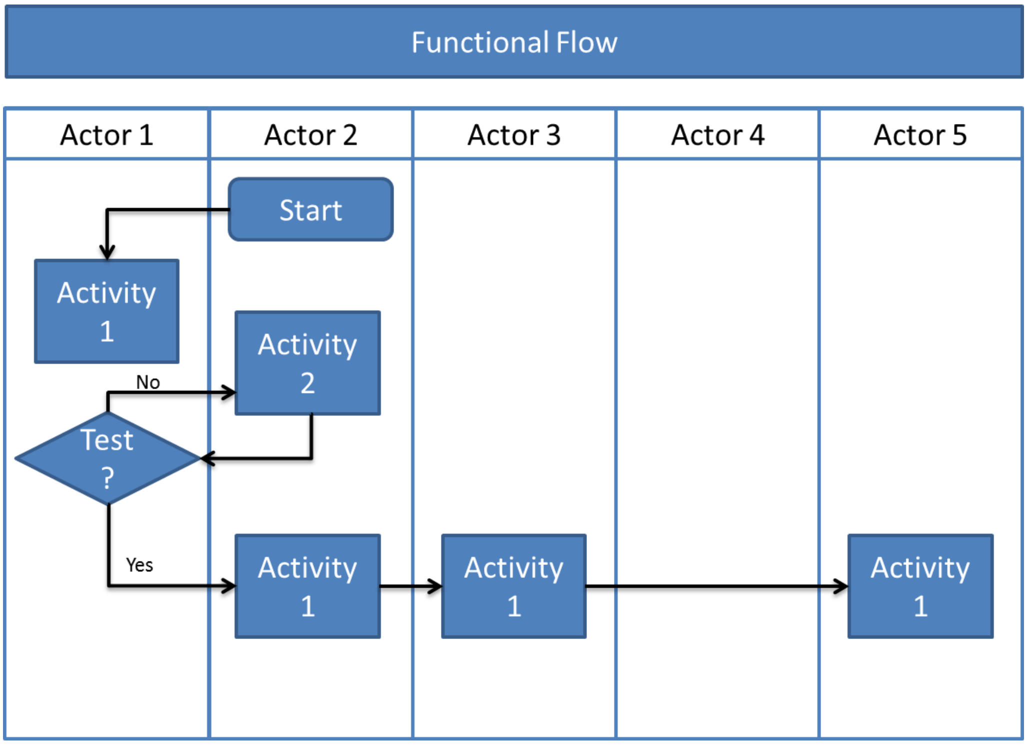

Figure 7 Example of an Inter-functional Flow-chart

1.3.5.3 *Standard BPMN (Business Process Modelling Notation)*

It is the standard notation to describe business processes, suggested by the Business Process Management Initiative (BPMI). This tool fits particularly well to sector operators. The **Business Process Modelling Notation** (BPMN) take concepts of the inter-functional flow chart, adding many symbols and making it more fit to business process mapping.

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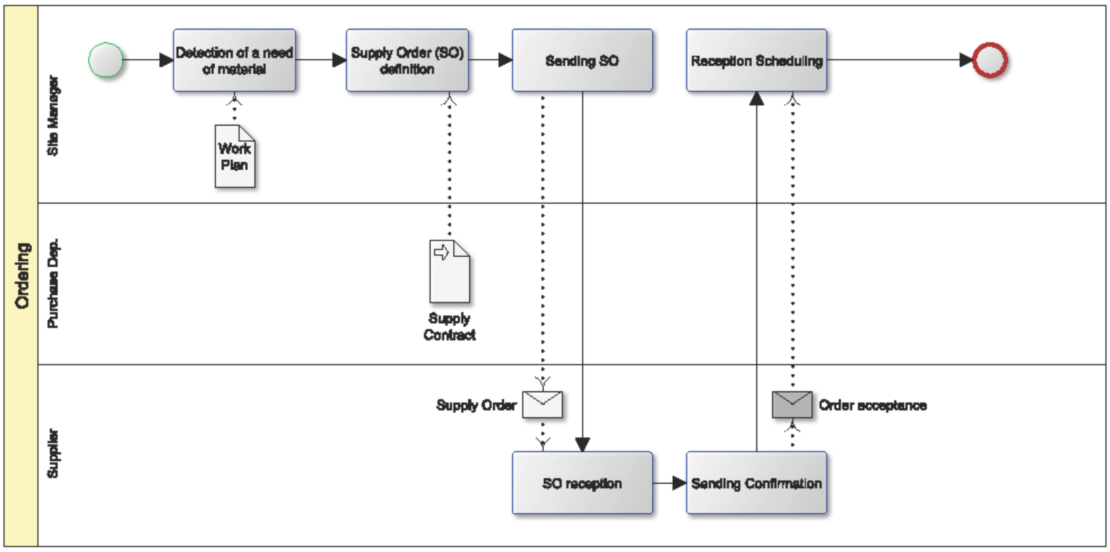

Figure 8 Example of a BPMN Process Mapping

1.3.5.4 Block diagram

In the Block diagram the activities are reported within a rectangular icon. Inputs are represented by an arrow entering the activity from the left, outputs by an arrow exiting the activity from the right. An arrow from the top specifies constraints and conditions, while the last arrow, from the bottom, represents the activity's responsibility. The creation of the process map occurs linking in chain all activities, so that each output becomes the input for the following activity.

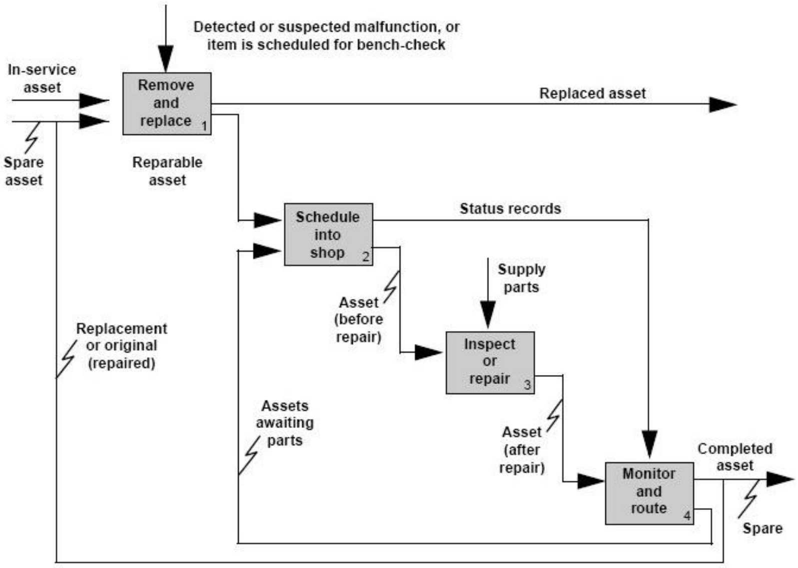

Figure 9 Example of a Block diagram

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1.4 Value Stream Mapping (VSM)

Value Stream Mapping is a methodology having the goal of graphically reporting the material flow, starting from the provider until the finished product, and the information flow. It is part of the *Lean Manufacturing*, a management approach developed in the Japanese industry, grounding its roots in the Toyota production philosophy.

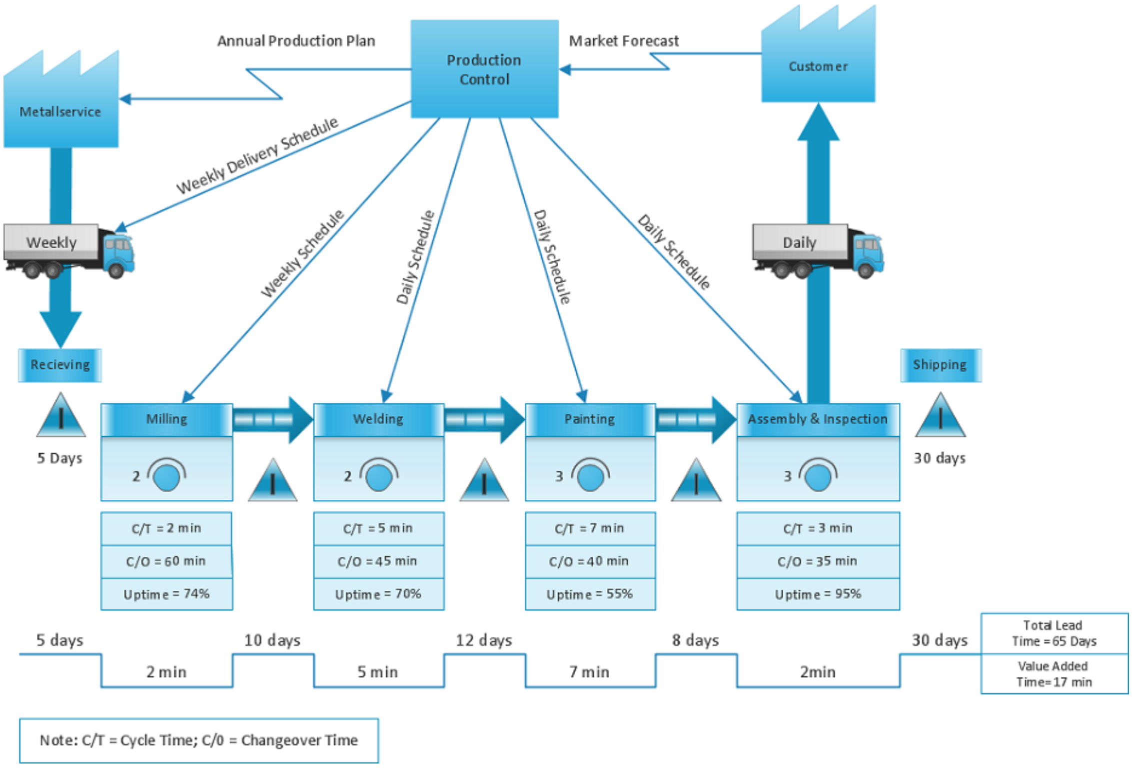

Figure 10 Example of the VSM (thechangeassociates.com)

1.4.1 Value Stream Mapping in 5 steps

Mike Rother and John Shook, in their book "Learning to See", define Value Stream Mapping as a graphical tool aiming to see and understand the material and information flow and how a product covers the value chain. The product manufacturing path, from the provider up to the client, is covered and a graphical representation of each process in the material and information flow is depicted. The value stream is the set of all required activities (both value-adding and non-value-adding) to lead a product from raw materials up to the consumer (productive flow) or from the idea to the launch (project flow). In other words, Value Stream Mapping is a graphical representation through standard symbols of two flows (information and material) generated by the process implementation, with the goal of obtaining a clear and readable map on how flows occur and which consumption of generated resources are present to develop a product or a service.

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Moreover, Mike Rother and John Shook describe the five steps that compose the mapping process. These phases are stated below.

1.4.1.1 Decision of the object to be mapped

Considering a single product is not useful for the good outcome of the methodology, unless the company does not deal with a very limited range of goods. Especially for those companies which produce a wide range of products, it is fundamental to identify the family of products for which mapping has to be done. A family is a group of products that go through similar manufacturing processes and that require the same type of equipment. To proceed with this grouping, a resources/products matrix, which shows clearly which goods require the same type of equipment in the production life-cycle, may be used.

1.4.1.2 Definition of responsibilities

Once it has been stated what has to be mapped, who will be in charge and which tool will be used has to be defined. The Value Stream Manager is the person in charge of understanding, managing and monitoring the value stream of a family of products. Also, he is in charge of creating the team that makes the mapping. The team is committed to the information gathering, to be done through interviews and measurements of strategic indicators. The manager has constant relations with the direction and communicates immediately any type of relevant issue.

1.4.1.3 Current-State Map design

The second step consists in the definition and representation of the current status. The team has to report a scheme that re-creates exactly the value stream of a family of products, from suppliers up to customers, passing through all the involved processes, at the current moment. Normally, the map is divided in three parts: at the top there is the information flow, in the middle the flow of material and in the bottom a temporal line. This graphical structure allows all components of the value stream to be clearer.

The information flow starts from the customer and arrives to the supplier, while the material flow goes in the opposite direction, from the supplier to the consumer.

With respect to the material flow, there is a perpendicular information flow which is used to communicate and monitor different processes. Information exchanges may occur through e-tools, manually and verbally.

VSM uses a set of standard icons to describe flows, even though, depending on the tool that has been used, there may be different symbols.

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To be performed properly, the current status mapping has to occur following some steps:

- Customers' requests: Mapping starts by customers and it follows through the manufacturing flow. The amount of requested end-product and the frequency of the request must be known.
- Productive phases and material flow: Main productive phases can now be reported. For each process, all the information gathered in the preliminary phase have to be added: the number of operators, the working times, the inventory, etc.
- Material flow: Going back through the flow there are suppliers. In this phase, products requested by the organization, their delivery frequency, the methodology to parcel them, have to be reported.
- Information Flow: Once material flow is mapped, the information flow has to be described. Both the methods information reach processes and how they go from customers to the company and from the company to suppliers have to be reported.
- Time line: The last phase requires reporting in the bottom of the map a time line that shows the duration of each process, highlighting working and waiting times.

1.4.1.4 Future State Map creation

Mapping of the Future State begins from the analysis of the Current State Map, where each imperfection on the value stream is spotted. To do so, the analysis of some parameters should be performed, such as:

- Time to set-up
- Inventory availability
- Machinery reliability
- Takt Time e Pitch

When the analysis phase is over, the process is re-designed and a second map is produced, where issues of the first map are deleted. The main goal is to have a fluid and equilibrated flow, able to front final customers' requests rapidly and efficiently, without disadvantages for the company production and turnover.

1.4.1.5 Future State Map achievement

The last phase consists in the practical implementation of the Future State Map. The goal is to modify the material and information flow in strategic points, in order to align manufacturing processes with business requirements. Once this is done, the analysis and mapping process through VSM can re-start to obtain

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greater results. The previous Map of Future State is now the Current State Map, on which further analysis and improvements can be done.

1.4.2 Pros and Cons of Value Stream Mapping

Value Stream Mapping is a very powerful tool that may lead to different advantages for the company; some of these are reported below:

- It allows, visualizing, at the same time, both small steps and the entire production flow. It is possible to pinpoint waste and their effect on the entire production chain, allowing a more agile identification of intervention priorities.
- It allows catching in a complete a detailed fashion links between the material and the information flow: it is a precious operation in order to identify possible improvements in the manufacturing itself, but also on the IT which controls it and that is often perceived as something independent and with limited influence on production flow results.
- It creates the basis for a long term project, made of further steps: as we have seen, *kaizen* is a continuous improvement process, made of small steps and constant adaptation of the conditions influencing production.

This methodology has also some limits; as reported by Zahir Abbas, N. Khaswala and Shahrukh A. Irani, VSM:

- Is not able to map more products with different material flow ;
- It does not report delays due to transports, movements and lines ;
- It does not report features and issues due to the machinery layout ;
- It fits low-ranging and continuous flows manufacturing systems. It finds poor applicability for non-manufacturing companies ;
- It does not show problems due to bad design and management of internal warehouses ;
- It does not allow managing rules to receive contemporary orders, capacity limits and delays due to lines ;
- It does not present the possibility to create multi-level graphics needed to map more complex chains. ;

In the following we will apply the VSM to the construction site processes trying to overcome the listed disadvantages: To do so we introduced our own flexible method to use VSM, as it is explained in the corresponding section below.

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2 Methods adapted to construction industry

In this chapter we propose two methods adapted to construction industry to map the **As-Is situation** of the four pilot sites: Luxembourg, Paris, Valencia, and Verona. In particular, we show how we decided to perform the two mapping techniques that we described in the previous chapter, the *Process Mapping* and the *Value Stream Mapping*. The main focus of the Process Mapping was on the logistics processes related to the construction site, but also other processes have been studied; while, thanks to the Value Stream Mapping we could map the lifecycle of some materials and components and the related information flow.

We describe, hereby, the methodology we provided to the pilot sites coordinators in order to provide the requested maps.

2.1 The Process Mapping

The Process Mapping has been defined previously as the phase of the Business Process Management keen in identifying, mapping and modelling the processes by using a rigorous method, in order to help managers to better and deeply understand the business processes with the aim of better understanding the organization, of improving the processes and/or to produce best practices.

With this aim, we follow a set of steps that we described in the previous chapter: we firstly defined and selected the 4 macro-processes: Distribution Network Processes, Construction Site Processes, Reverse Logistics Processes, and Support Processes. We then defined the critical processes, or the main processes that we intended to analyse. We subsequently detected the possible inputs, outputs, and main activities of the defined processes. Lastly, we provided a methodology to rigorously map the defined processes explaining how to use the process mapping tool.

The first part of the mapping methodology provided to the partners is represented by the definition of a set of questions for each process to be used for interviewing the actors of processes. The second part is represented by the explication of usage of a freeware to be used for mapping the processes, and the third one is the clear explanation of all the symbols typical of process mapping.

By providing the processes and its explanation, the questions for interviews, and the mapping technique explanation and tool, we expected the pilot site coordinators to map all of the processes occurring in the related pilot site (not necessarily all the defined processes) and to provide us the obtained maps.

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2.1.1 Main Processes Definition

To map the As-Is situation, it is crucial to collect information concerning the processes involved in the macro-processes: the construction site, the distribution network, and in the reverse logistic, and the support processes. In particular, we intended to map the As-Is situation of the processes regarding the logistics activities. The main objective has been the study of these processes in order to detect the activities that can be improved and optimized and those that do not bring an added value to the entire construction logistic process. In particular, we have been driven by the KPIs detected in D2.2 (KPIs and methodologies for construction logistics) an focused on the possible improvements and goals definition to link the As-Is analysis with Task 4.1 (Target Improvements Setting)

The first thing we performed is the definition of the main processes that can occur in a construction site. By a collaboration among the partners we concluded that not only logistics process, but also some other processes could be detected and analysed in order to provide input for the other tasks of WP3, such as Task3.1 (ICT collaboration tools for the Supply Chain Integration) and Task 3.3 (Business Model Development and Analysis).

Table 1 Table representing the main processes occurring in a construction site.

Distribution Network Processes	Construction Site Processes	Reverse Logistics Processes
1) Sourcing	4) Material Reception and Expedition	8) Waste Management
2) Ordering	5) Inventory and Storage Management	9) Return Management
3) Delivery	6) Material Handling and Equipment Management	
	7) Housekeeping	
Support Processes		
10) Planning and scheduling Resources		
11) Complaint Management		
12) Entrance and exit management		

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2.1.1.1 *Business Processes Description*

We describe hereby a set of processes that resulted important to analyse in the three phases in which we decided to study the supply chain (the distribution network, the construction site, and the reverse logistics) and a set of support processes.

To furnish with a better interpretation of the detected processes, we report, for each of them:

- the purpose;
- the inputs;
- the outputs;
- and the most common activities required to perform the process.

The following specification resulted very important to clarify what each process really is and to ease the mapping phase by suggesting the possible events and activities typical of the detected processes. All the activities are thus only a suggestion and will not be mapped if they are not present in one or all the pilot sites of the project.

In the following, we report only the Process 1: Sourcing, as an example. An interested reader can find the detailed description of all the processes we produced in Annex A.

2.1.2 Process 1: Sourcing

Process 1: Sourcing	
Purpose	The purpose of the *Process Sourcing* is to select suppliers for acquiring materials and services that are needed in the construction site.
Inputs	– Need of materials and equipment to accomplish the construction project – Need of waste collection for disposal
Activities	– Specify the requirements: enables to identify the needs and define the requirements – Explore market: enables the identification of materials and/or suppliers qualified and capable to deliver the requested material, equipment or service – Call for tenders: enables to ask request for bids/proposal/quotation – Select the bid/proposal/quotation: enables the selection of

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	the supplier and reference of materials best suited to the requirements of the contractor – Contractualization: enables to negotiate and define the type of contract that best suits the supply
Outputs	– Set of suppliers – Contracts

2.1.3 Process Mapping: How to perform it

Each pilot site coordinator contributed by detecting the main activities, the sub-activities and the events of each process occurring in the related pilot site starting from the process description and also by making use of a set of questions that we provided to them and that we report in the following. Some pilot site does not perform all the processes, thus, for some pilot sites we do not report the missing processes.

The Partners were required to map the 12 defined Processes as they take place in the relative construction site by making use of the

- **The Processes definitions and descriptions**

And by making use of the tools described in the following:

- **The Questions for interviews,**
- **The BPMN notation,**
- **The BPMN modeller.**

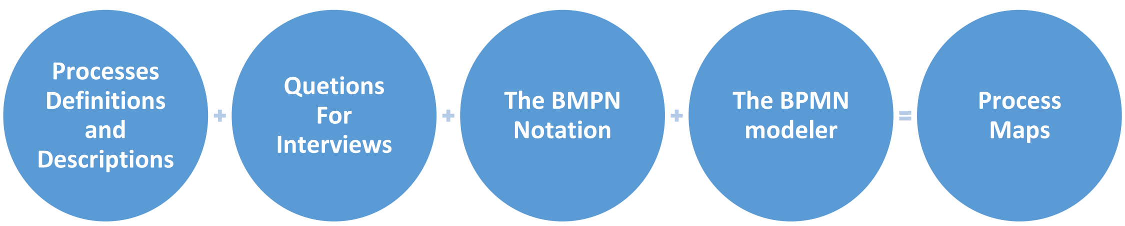

Figure 11 The Process Mapping main steps

2.1.3.1 Interviews

In this section we provide the not exhaustive set of questions that we provided to the pilot coordinators in order to help them to perform the business process mapping. We list the questions by process. To obtain information on for this Task and for others, we also asked the pilots coordinators to take care, during the interviews, to identify:

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- The non-added value activities,
- The organizational problems and possible solutions,
- The possible optimization problems,
- The used ICT tools and technologies,
- The activities where an ICT tool could be needed.

And to ask the following points:

- Who does things,
- Which documents are used/needed in any of the activities,
- If something can be improved or avoided.

We motivated the interviewers to:

- Be curious
- Observe
- Listen
- Be Empathetic
- Use an ethnographic spirit
- Have in mind what you need (the process mapping, the value stream mapping, the ICT tools, the optimization problems)

In the following we report the set of questions we provided to partners for Process 1 (Sourcing) and we invite the interested reader to refer to Annex B for the remaining processes.

Questions for Process 1: Sourcing

1. *How do you define the materials to be used in the construction site and their requirements?*
2. *How do you define the equipment to be used in the construction site?*
3. *How do you define the services needed?*
4. *Who is in charge of it? Who does it?*
5. *How do you explore the market?*
6. *Do you select from a list of suppliers?*
7. *Do you create a list of suppliers?*
8. *Who does it?*
9. *How do you call for tenders? Which procedures are used (RFQ, RFP, RFI…) are used?*
10. *Who does it?*
11. *How do you select the bids/proposals?*
12. *Who does it?*
13. *How do you negotiate?*
14. *How do you define the type of contracts?*
15. *Who does it?*
16. *What kind of contracts do you use?*

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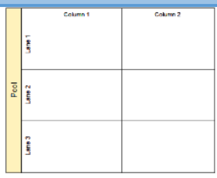
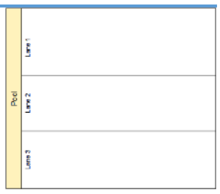
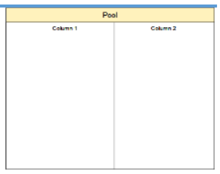
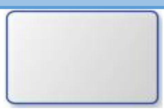
17. *Which improvements could ease your job?*
18. *Etc.*

2.1.3.2 The BPMN Notation

In the following we report the most common symbols for BMPN that are also those present in the BPMN library of yED Graph Editor. Table 2 reports, for each element, its name, its graphical representations, and a short description. We report the entire BMPN notation hereby because it is very important to deeply understand how Process Mapping has to be performed. In addition we provided to partners some examples.

Table 2 BPMN Notation

Element	Notation	Description
Swimlanes		
Pool (Lanes and Columns)		A Pool represents a Process. Graphically, it is a container for partitioning a Process and Participants. A Pool can be divided vertically, in Columns or/and horizontally in Lanes. Columns and Lanes are sub-partitions within a Pool and extend the entire length of the Pool. Lanes and Columns explain who is responsible for executing which tasks; they can represent things as internal roles, systems, internal departments, etc.
Pool (Empty)		
Pool (Lanes)		
Pool (Columns)		
Activities		
Task Activity		A Task Activity represents a work that the company performs in a Process.

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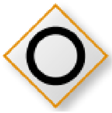
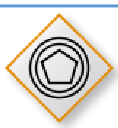
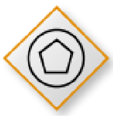
Task Activity (Open)		Sub-process Activity represent a Process that is included within another Process. By clicking on + the Process within the Activity is shown in an expanded view.
Sub-process Activity		
Transaction Activity		A Transaction is a Sub-process that is supported by a special protocol that insures that all parties involved have complete agreement that the activity should be completed or cancelled
Gateways		
Exclusive Gateway (Plain)		An exclusive gateway evaluates the state of the business process and—based on the condition—breaks the flow into one of the two or more mutually exclusive paths. Exclusive can be shown with or without the "X" marker. (XOR)
Exclusive Gateway		
Inclusive Gateway		An inclusive gateway breaks the process flow into one or more flows but allows for one or more output paths to continue a flow. (OR)
Parallel Gateway		Parallel gateways are used to represent two concurrent tasks in a business flow. (AND)
Complex Gateway		Complex gateways are only used for the most complex flows in the business process. They need more descriptive text.
Event–based Gateway		An event-based gateway is similar to an exclusive gateway because both involve one path in the flow. In the case of an event-based gateway, however, you are evaluating which event has occurred, not which condition is being met.
Exclusive Event–based Gateway		
Parallel Event–based Gateway		As the name suggest, this gateway is similar to a parallel gateway. It allows for multiple processes to happen at the same time, but unlike the parallel gateway, the processes are event dependent.

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Events		
Plain Start Event		An Event that indicates where a particular Process starts. The Start Event starts the flow of the Process and does not have any incoming Sequence Flow, but can have a Trigger.
Plain Intermediate Event		Intermediate Events are events that occur between a Start and an End Events. They affect the flow of the Process, but they don't start or terminate it.
Plain End Event		An Event that indicates where a path in the process ends. In terms of Sequence Flows, the End Event ends the flow of the Process, and thus, will not have any outgoing Sequence Flows.
Message Event		Identifies that an event may start from a message
Timer Event		Identifies an event that starts after a time frame.
Escalation Event		The Escalation-Event is a variant of the conventional Error Event but an Escalation does not necessarily imply an Error. An escalation event indicates that there is a condition that requires the process flow to be diverted to another role. If an escalation happens, the next higher level of responsibility shall be involved.
Conditional Event		Identifies something happening only if a certain rule or condition is true.
Link Event		Used to link a sequence flow (allowing a sequence flow to be broken and made invisible)
Error Event		Identifies an event that starts from an error that has occurred.
Cancel Event		Identifies that the process is cancelled.

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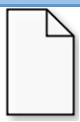
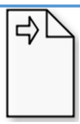
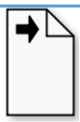
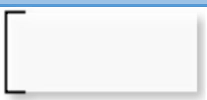
Compensation Event		Identifies that tasks that was executed in the Process, have to be cancelled later under certain circumstances.
Signal Event		Signals are similar to messages. The essential difference between a signal and a message is that the latter is always addressed to a specific recipient; in contrast, a signal is more generic, like a newspaper or a commercial.
Multiple Event		Identifies that an event may be caused by multiple triggers and it occurs as soon as even only one of its contained events occur.
Parallel Event		Identifies that an event may be caused by multiple triggers and it doesn't occur until all of its contained events occur.
Terminate Event		Identifies that the Process is terminated.
Data Objects		
Data Object		Data Object represents either data placed to the process, data resulting from the process, data that needs to be collected, or data that needs to be stored. Data Object can represent a singular object or a collection of object.
Data Object (Input)		Data inputs represent those data requirements of the business process.
Data Object (Output)		If a process generates data, a data output represents the information produced as a result.
Data Store		Data store is a place where the process can read or write data, such as a database or filing cabinet, and which persists beyond the lifetime of the process instance.
Artefacts		
Annotation		Annotations allow the modeller to describe additional flow parts of the modelling notation.

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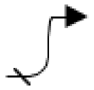
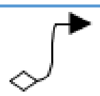
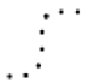
Group		A Group is a grouping of graphical elements that are within the same Category. This type of grouping does not affect the Sequence Flows within the Group.
Messages		
Reply Message		A message represents the content of a communication between two participants, and is passed along a message flow. An initiating message (Request Message) is coloured white, and a non-initiating message (Reply Message) is coloured grey.
Request Message		
Conversation		A conversation is a hexagon symbol in a conversation diagram that links two participants and regroups a set of message exchanges that share the same correlation.
Flows		
Sequence Flow		A directional connector between elements in a Process, Collaboration, or Choreography. A Sequence Flows represents the sequence of Flow Objects in a Process or Choreography.
Default Flow		For Data-Based Exclusive Gateways or Inclusive Gateways, one type of flow is the Default condition flow. This flow will be used only if all the other outgoing conditional flow is not true at runtime.
Conditional Flow		A Sequence Flow can have a condition Expression that are evaluated at runtime to determine whether or not the Sequence Flow will be used (i.e., will a token travel down the Sequence Flow). If the conditional flow is outgoing from an Activity, then the Sequence Flow will have a mini-diamond at the beginning of the connector. If the conditional flow is outgoing from a Gateway, then the line will not have a mini-diamond.
Association		An association represents relationships between artefacts (Data Object, Data Store,

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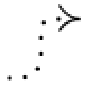
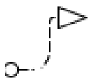
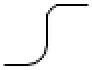
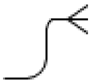
Directed Association		Annotation) and flow objects.
Bi-directed Association		
Message Flow		A Connecting Object that shows the flow of messages between two Participants.
Conversation Link		Conversation Links are used to connect Conversation to and from Participants
Forked Conversation Link		

2.1.3.3 BPMN modeller

In order to perform the process mapping we suggested (but we did not made it compulsory) the partners to make use of the freeware *yEd Graph Editor*, that can be downloaded for free at http://www.yworks.com/products/yed. It is an easy to use graph editor that includes the most common symbols of the Business Process Modeling Notation (BPMN), which are the ones that we used.

To help the partners we described all the steps needed to download the freeware, which we report in Annex C.

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2.2 The Value Stream Mapping

The Value Stream Mapping (VSM) is a lean-management method for analysing the current state of the value chain and designing an improved future state of it. VSM can be applied to nearly any value chain. The VSM considers the series of events (both value added and non-value added) that take a product or service from its beginning state (from the suppliers, its raw material state, or from the idea) to the customer, describing and highlighting both the materials and information flow. Indeed, this method was firstly used at Toyota, where it is known as "material and information flow mapping".

The VSM enables to see at a glance where the delays are in the process, any restraints and excessive inventory. The current state value chain map is the first step in working towards the ideal state.

2.2.1 VSM and Constructions

The VSM is a technique that has been developed for the production world, and in particular for the lean production. The VSM has been used, since its development, almost exclusively in manufacturing companies. The automatization and standardization of manufacturing processes make them a perfect object for VSM. The use of VSM in the world of construction is new, to our knowledge. Constructions represent a particular production process that is typically non-lean. Indeed, in the construction sites each task can be accomplished a very small amount of times and sometimes just once, and cannot be considered as continuous production. Moreover, many factors can make the production process more and more stochastic, indeed, the majority of the operations are made by human workforce, and weather and congestion can increase uncertainty of the production process in construction sites.

Nevertheless, we believe that VSM is of great help to highlight problems and best practices, to provide a snapshot of the As-Is situation of the four pilot sites, and to provide suggestions for improvements.

Thus, we needed to be flexible when applying the VSM to the construction sites. In the following we report some points that have been adapted in order to apply the VSM method to construction sites:

- The customer can be hidden. The final customer of a construction site is the contracting authority, but the customer in the VSM we mapped can be seen as the construction company itself / the main contractor (when building one component), or the dump site (receiving dumping material).
- The process of construction that take place in a construction site is made of activities that are various and diverse, if not unique. This means that it can be impossible to compute cycle times and takt time. If needed, a

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parametrical time can be computed with respect of the amount of material used.

- Frequencies or inventories are very hard to detect for building actions that take place only once. We avoided considering things that could not be computed.

2.2.2 The VSM Method: How to perform it

The VSM method normally follows four steps:

1. Planning and preparation.
2. Create a current state value stream map.
3. Create a future state value stream map.
4. Create an Action Plan to work towards the Ideal state

In the following we report the methodology we suggested to the partners in order to perform the first two steps of the VSM, that are the ones needed to define the As-Is situation. We also suggest a Freeware and a set of common symbols to perform the Value Stream Maps.

2.2.2.1 *Planning and preparation*

2.2.2.1.1 Identify the target product family or service to map

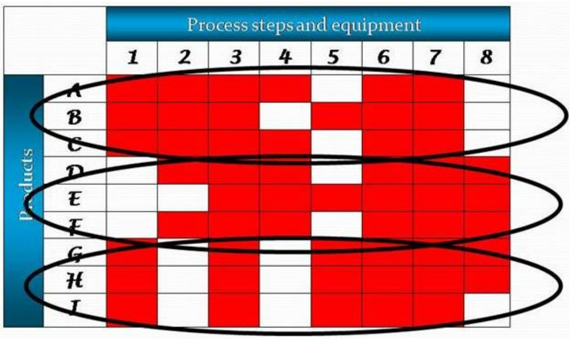

Figure 12 A product family analysis matrix (leanmanufacturingtools.org)

In order to identify the object of the VSM, we need to select a service, a product, or a family of products that we are interested in mapping. In a company that produces many products or delivers many services, we can decide to map the product with highest production volume or with highest value, or we can consider a strategic option and be driven by the product or service we expect to do more business in the future, moreover we can decide to be guided by the customers.

In case the company in which we intend to draw a VSM produces a large set of products, we can use a Pareto analysis based on volume, value or on a combination of them to select only the most relevant products of the company. Afterwards, we might conduct a product family analysis, by making

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use of a product family analysis matrix (see Figure 12). It the matrix we report all the products, their process steps, and the equipment that are used, and thus we can group the most similar products or family or products that share similar lifecycle, processes, and equipment use.

In the construction logistics case, the selection of materials is left to the team dedicated to the VSM. We requested selecting at least 3 materials (or set of materials) representative of the pilot site. If considering material is hard or not very representative, also to map the value stream of an entire component, and not just a material (e.g., the construction of the floor, etc.), was allowed. Of course, the selection of materials has been influenced by the construction phase in which each pilot site was during the data and information collection.

2.2.2.1.2 Create a flow, define the problem, set the goals and objectives, select the team

The current state value stream map is a team effort that is conducted by those people who are involved in the process, at the actual process.

The goal is to detect any organizational problem present in the current value chain. In the SUCCESS construction logistics each pilot site coordinator is in charge of forming the mapping team.

2.2.2.1.3 Discuss the flow with the management team

The pilot site coordinator is in charge of communicating with the construction company operators to allow a day-by-day discussion about the flow to analyse with all the involved actors.

2.2.3 Create a current state value stream map

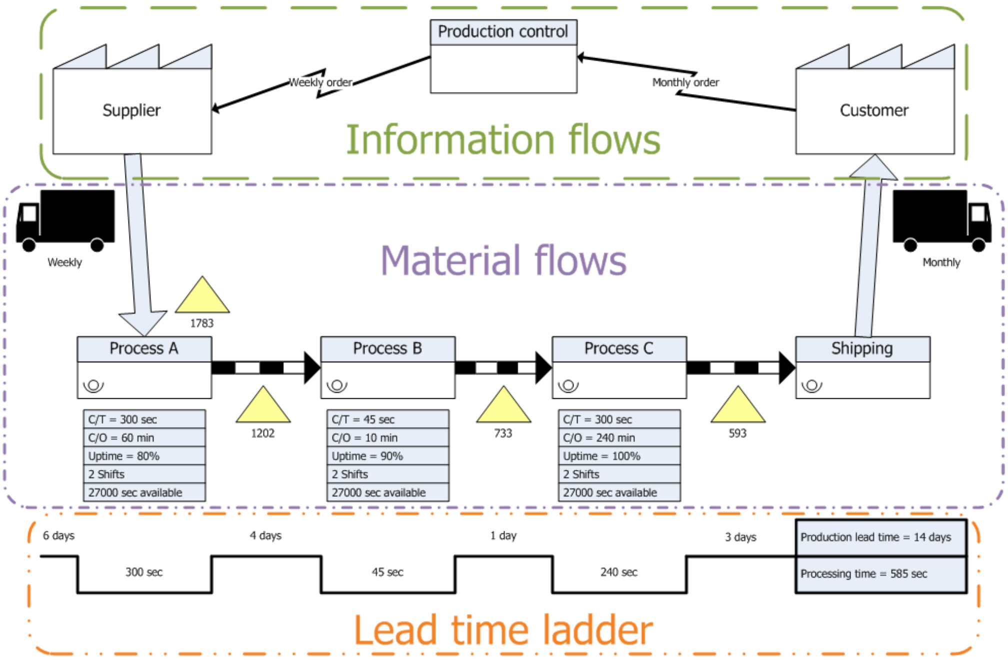

Figure 13 An example of VSM indicating the Information flow, the Material Flow, and the Time Line (Wikipedia.org)

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A VSM is normally divided into three parts, as we can see in Figure 13: (i) the material flows, (ii) the information flows, and (iii) the time line. In the following we will define how to draw each of the three components.

A current state VSM should be drawn while on the field, and should show the current steps, delays, and information flows required to deliver the target product or service. To do so we will use the standard symbols for representing supply chain entities.

The key to creating an excellent current state VSM is to document what we actually see with our own eyes. We are not interested in how the process is supposed to work, or was designed to work. Instead, we are interested in how the process is performing today.

2.2.3.1 *Value Stream Mapping Symbols*

To map the value stream there are really only a few icons we will always use

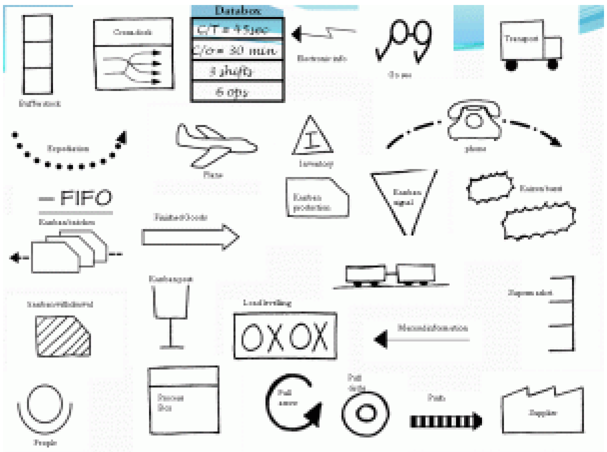

Figure 14 Some of the symbols for use in VSM (leanmanufacturingtools.org)

Figure 14 shows some of the commonly used VSM symbols. We will furnish a set of useful symbols and their explanation, in the following, together with the Freeware we suggest to use, in order to provide a common set of value stream maps.

We will be drawing the value stream map using software, but we recommend to always drawing the map on paper first.

2.2.3.2 *Add the Material Flows*

2.2.3.2.1 Bound the Process

We need to decide the limits of our map, most value stream maps are conducted from supplier to customer within an organization and these should be the first boxes placed on our VSM to bound the process. It is possible to map

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the entire supply chain, in this case the start and end points for our process map would be the raw materials and the final consumer, instead of putting boxes for process steps thereafter however we would use companies.

A good bound in construction logistics should be represented by the providers, on one side, that is where the supply chain starts. On the other side the situation is less clear. The customer of our process is, most of the time, the construction itself, and thus for some materials the construction site will represent both the production phase and the customer. In some other cases the end of the supply chain can be represented by a dump site, in case we are considering the waste life cycle, or by the supplier, in case we are considering the material return.

2.2.3.2.1.1 Supplier and Customer icons

We should draw the supplier by using the correct icon, as in Figure 15

Figure 15 Supplier Icon

The customer icon is similar to the supplier one, but in our case the customer is also the construction site, so we leave a space to include the production control inside the customer icon. See Figure 16 and Figure 17.

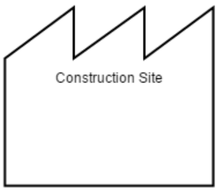

Figure 16 Customer Icon: the construction site is also the customer in our case

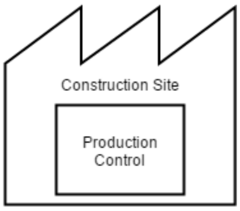

Figure 17 The production control box is included in the construction site icon

2.2.3.2.2 Shipping icons

Now we can connect the production process (that we haven't drawn yet) with shipping symbols.

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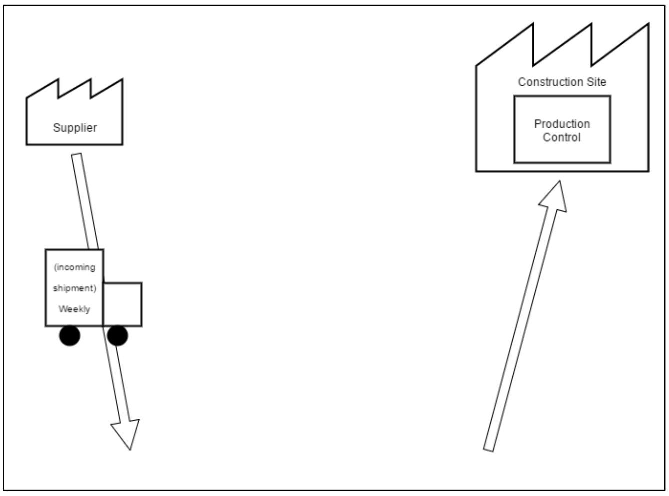

Figure 18 Shipping from the supplier and to the customer

We have a real shipment between the supplier icon to the production process and thus we include both the shipment arrow and the shipping truck, while for customer we don't have a real shipment, because we do not move from the construction site, thus we just report the shipment arrow.

In the example we use a shipping truck, but also plain, trains, and boats can be used. It is important to insert inside the shipping truck icon the period of shipment, weekly in the example in Figure 18.

2.2.3.2.2.1 Supplier box /details

Under the supplier icon we can insert the supplier box that can include the following information:

- the material arriving from them,
- the frequency of delivery,
- the typical batch,
- the type of packaging,
- the delivery time,
- etc.

In the information is limited you can insert it into the Supplier icon.

Figure 19 Supplier icon with some information

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2.2.3.2.3 Customer box / details

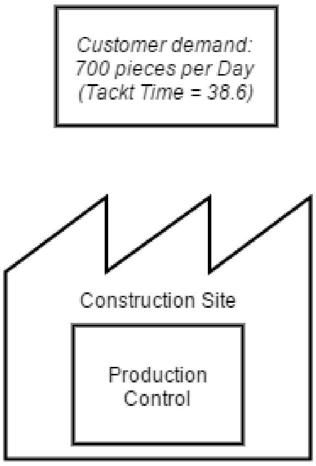

Figure 20 Example of customer and customer box

In the top right hand side of the paper we draw the little saw topped box representing our customer. We also note their monthly and/or daily demand along with the takt time.

2.2.3.2.4 Add the Process steps

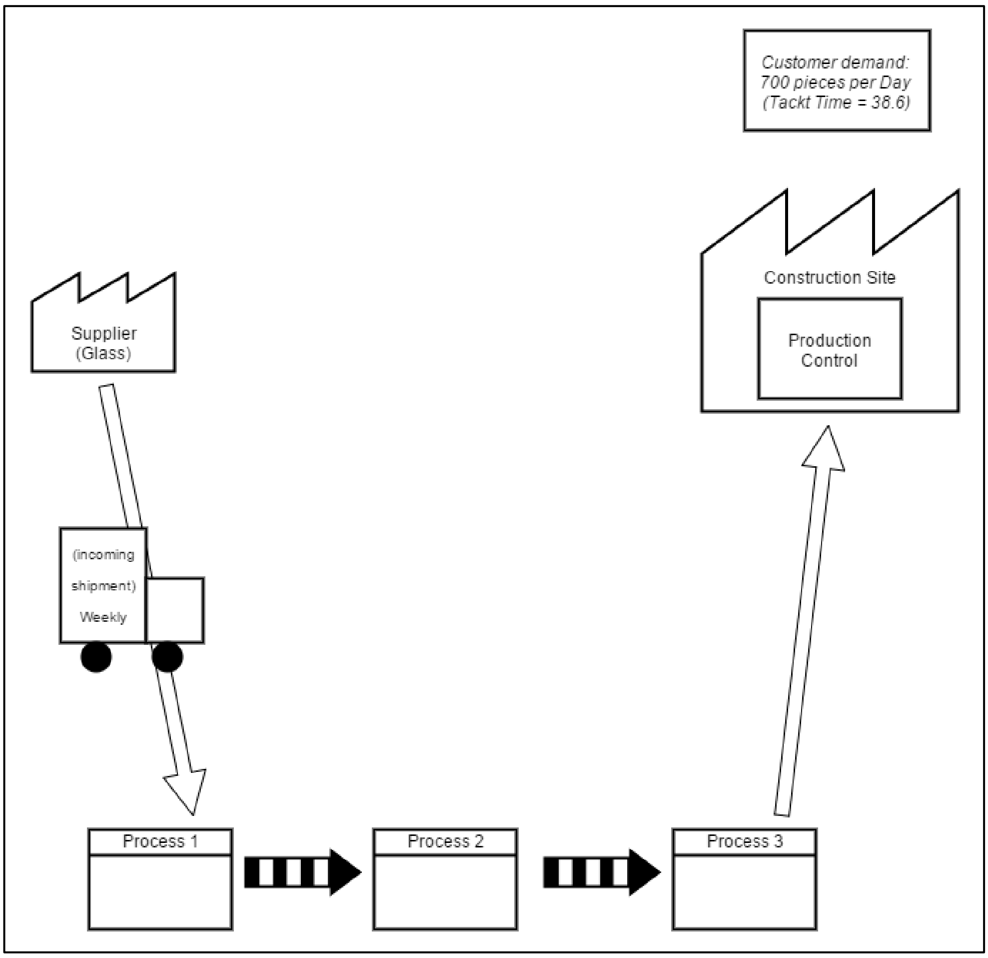

Figure 21 VSM with process bounds and process steps

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At this point, the bounds of the VSM should be defined and we should include the process steps in the map. This can be done by starting from the supplier, following the process up to the customer (the construction site, in our case). This can also be done starting from the customer up to the supplier.

The process steps are all the activities that are performed on a product, these are normally located in one place and have an inventory entrance point and an inventory exit point. More operations can be summarized into one process step. It is not our intent to separate each operation into a specific task, this kind of detail can be analysed thanks to other techniques such as Process Mapping.

We should walk the process front to back in order to understand the general flow. At the end of this part we should know which are the "production" phases.

These phases are included in process icon, as in Figure 22:

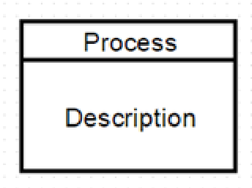

Figure 22 Process icon

Typical processes that are relevant for the SUCCESS process are the material handling and internal transportation. For some of the material handling processes that can be studied in detail, we can depict it as a particular process, by using the forklift icon. Please relate to the example in the following Figure 23.

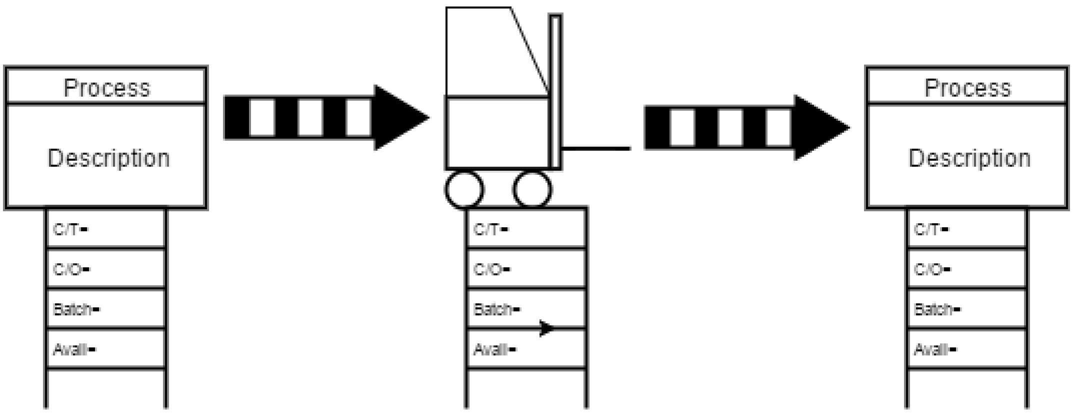

Figure 23 The Material Handling Process: how to represent it

The processes are normally separated by the push arrows:

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Figure 24 Push arrow icon

But in case the material is pulled, thus we can use the Material pull icon:

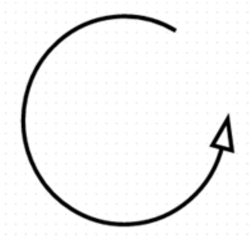

Figure 25 Material Pull icon

2.2.3.2.5 Collect and Add Process Data

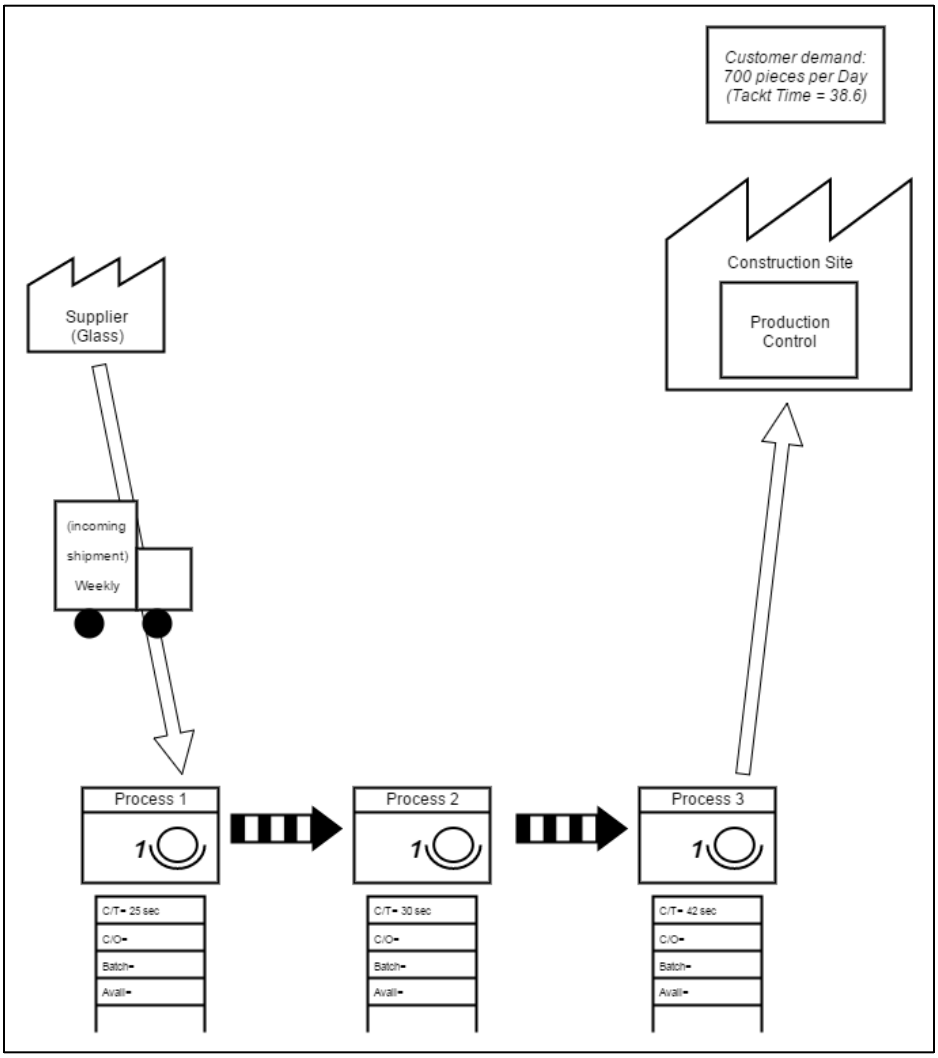

Figure 26 Example of processes with data boxes, cycle time, and operator information

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This part of the VSM is where we need to collect data regarding the performance of each step of the process; typical types of date to collect are:

- Cycle time (time taken to make one product)
- Change over time (from last good piece to next) (setup time)
- Up-time (on-demand machine utilization)
- Number of operators on each process
- Shifts worked (how many? How long?)
- Net available working time (without brakes)
- Scrap rate (Percentage of failed assemblies or material that cannot be repaired or restored, and is therefore condemned and discarded)
- Pack size / pallet sizes
- Batch Size
- Where are the quality controls? Percentage of good and flawed products. Do we have backflows for flawed products? Where?
- Etc.

We must now select the relevant measures for our process and record actual data at the workplace. We should try to avoid "historical" measures where possible, and get our own current information.

We invite the partners to include in the VSM at least the number of operators of each process and the cycle time.

The data must be recorded in the "data boxes" on our Value Stream Map:

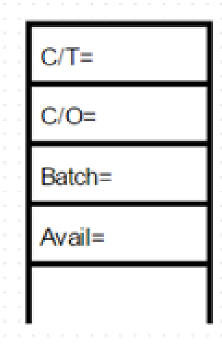

Figure 27 Example of data boxes

2.2.3.2.6 Add the Inventory/Wait Times

In lean production, seven type of waste can be identified: transport, inventory, motion, waiting, over-processing, overproduction, defects. Among these, inventory and overproduction are two of the most relevant and happen when problems exist in the production process. When defining the inventory and waiting times to insert into a VSM, we should also consider if the location of inventory is out of ordinary and detect why.

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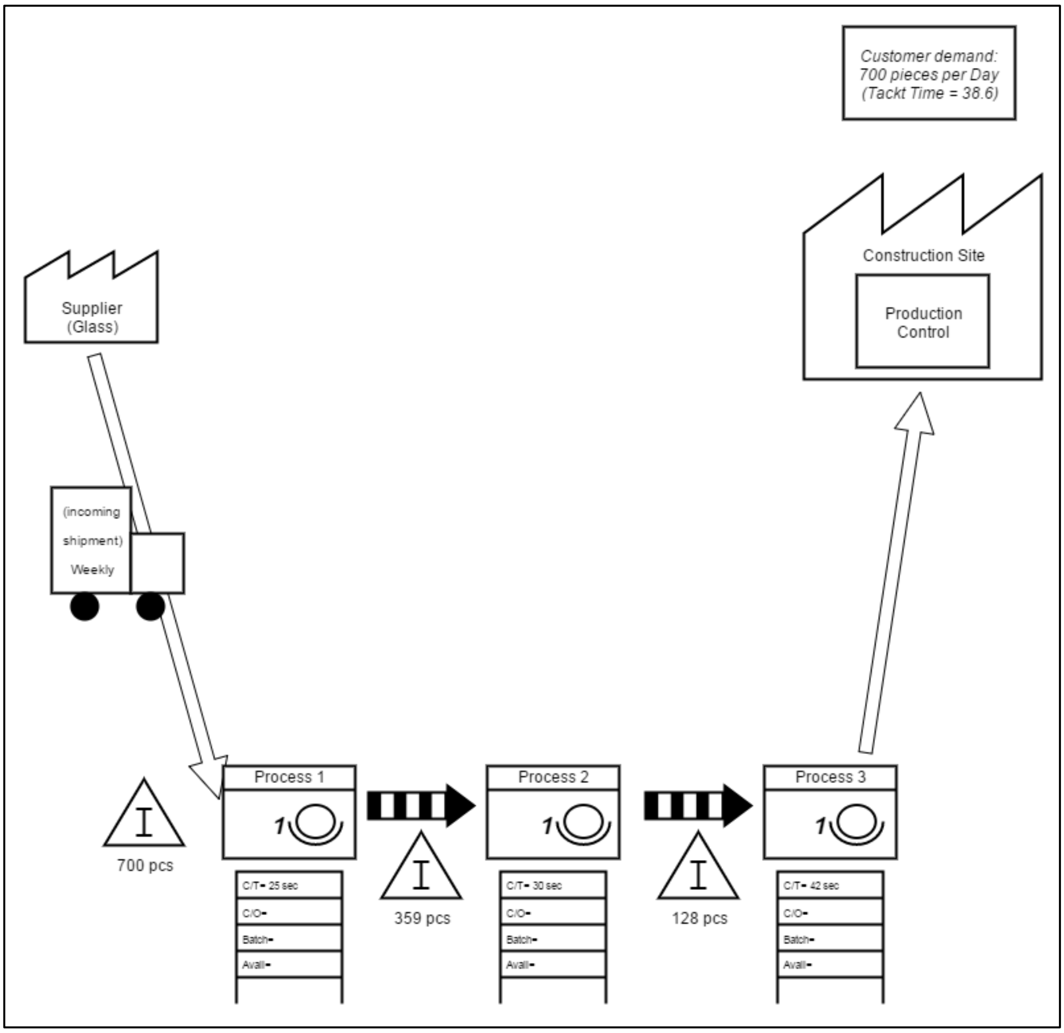

Figure 28 VSM with Inventory icons and inventory data

Once we have inserted all the process and data boxes in the map, we can add inventory and/or waiting times. The corresponding icon is represented by little triangles, sometimes they can have an “I” in the middle. To note the inventory level on the map, we can count the number of pieces between one process and the subsequent.

It could be interesting to convert the inventory data into days’ supply. This can be done dividing the number of pieces in inventory by the daily demand used to compute takt time. Let us consider that our daily demand is 120 pieces and we count 360 pieces of inventory in between two contiguous processes, we will have as a result 3 days’ supply (360/120) in between the two processes.

In our case, the inventory is related to the storage of materials inside the construction site. Thus we will have both a transportation and an inventory symbol between the supplier and the first process. On the other hand, we may or may not have inventory between the other processes.

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2.2.3.3 *Add Information Flows*

The representation of Information flows into the map produces the main difference between the VSM and the other mapping tools. In the information flow are indicated the communications and the communication means between the company and the suppliers, between the company and the customers (not in our case), and the communication of requirements to the processes.

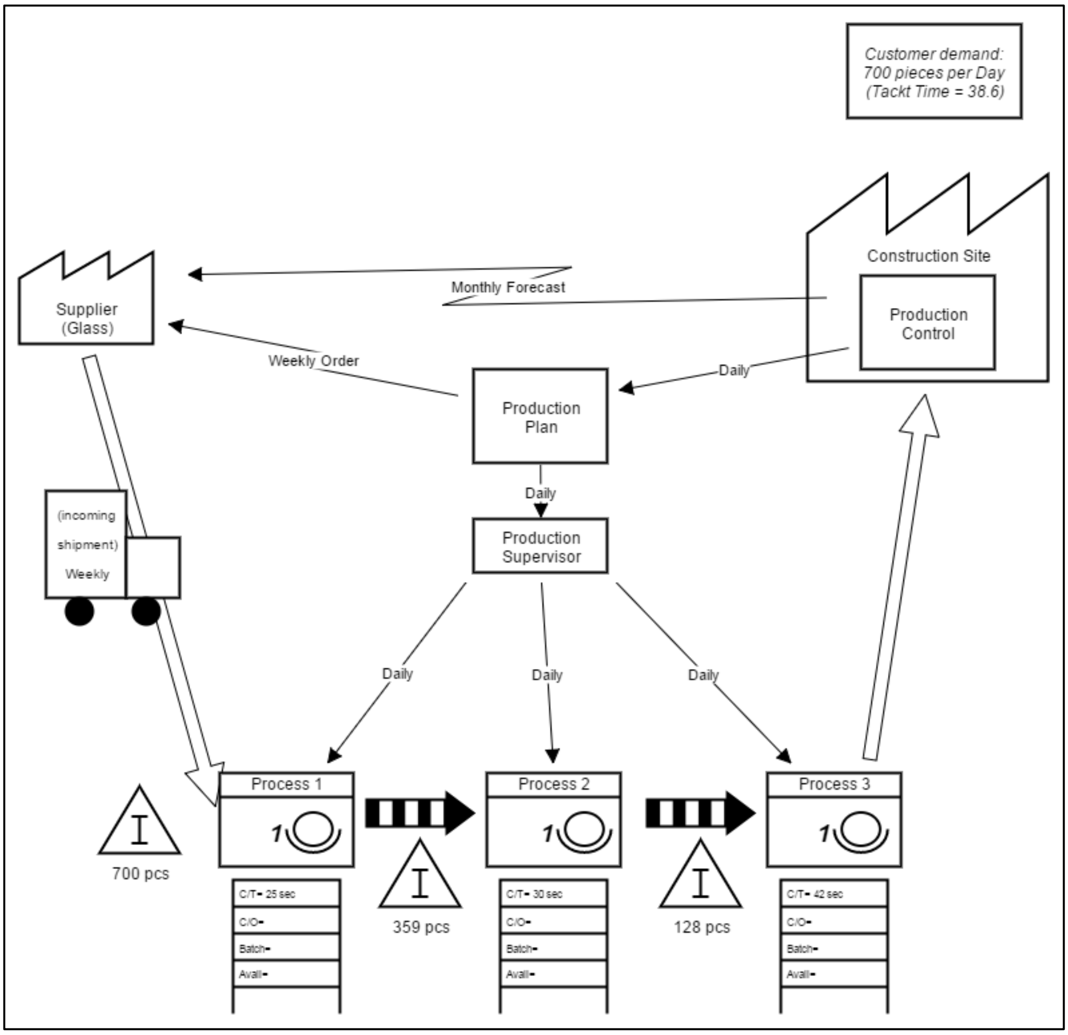

Figure 29 The VSM with the Information Flows

During this step we also draw in our production control box and/or define the production control, plan and schedule. For many production companies VSM, the production control box will include the letters "MRP" in it. In most mass production systems we typically see several manual information (straight) lines coming out of the MRP box aimed straight at each process step box.

In our case, we do not have an MRP production schedules. The production schedule is given by the site manager. If we have not done it yet, we can include in the VSM is the Production Control Icon. We also need to include all

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the other components of the production hierarchy, such as the Production Plan Icon, and the Production Supervisor Icon, etc.

Figure 30 Production Control Icon

2.2.3.3.1 Information flow between Production Control and Customer / Suppliers

We need to include how the customers order products, the frequency and the method used to order, and how we translate that back to our suppliers. To do so we can draw wiggle arrows to represent the electronic information flow.

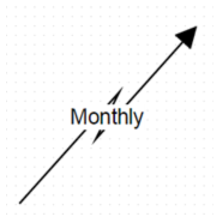

Figure 31 Wiggle Arrow for electronic communication

On these arrows we can report the frequency of the orders and the frequency of the forecasts, if given. In our case the information between customer and production control is not reported because these actors merged into the same one.

In this part of the VSM we should answer to the following questions:

- What kind of forecast and orders we have between production control and supplier/customers?
- Which function has the information?
- How much time is required to process the information?

2.2.3.3.2 Information flow between Production Control and the Production Processes

The next information flow we need to include into the VSM is the one between the Production Control to the many processes of the production. This information flow is normally "manual" (made without the use of electronical instruments) and the typical arrow used to represent the manual flow is a straight line.

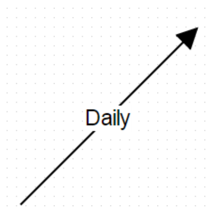

Figure 32 Straight Arrow for manual communication

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On these lines we can also include the type of frequency of the schedule (daily, weekly, etc.).

We should be able to answer to the following questions:

- What kind of scheduling is used?
- What kind of production instruction is given?
- How is the production hierarchy organized?
- How is the frequency of scheduling?

2.2.3.4 Add the Time Line

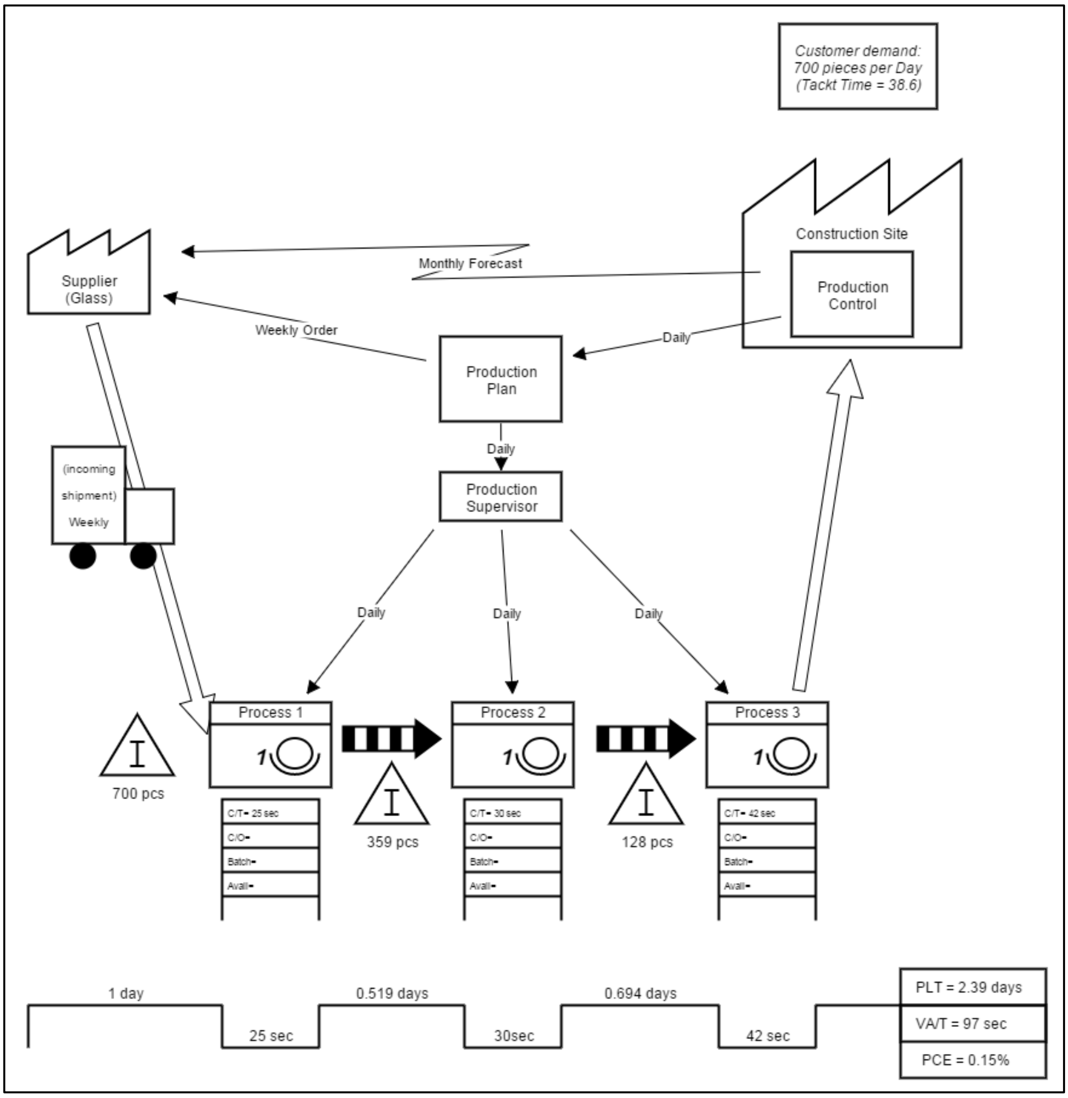

Figure 33 A time line in a complete current state VSM

At this point, the time line can be added to the VSM. The time line is a saw tooth looking line that highlights the value added cycle time (that is the one included into the data boxes) and separate it from the non-value added time. The time line can quickly provide information on the total process times and lead times for inventory in the entire production process.

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The cycle time needed to produce one product can be placed in the lower portion of the time line. By summing up all these value-added cycle times (VA/T) we obtain the total process time that is reported in the timeline box.

In the upper portion of the time line we include the inventory time corresponding to each inventory between two processes. By summing up the inventory times we can compute the non-value added time. We note into the timeline box the production lead time (PLT), that is the summation between the non-added time and the value added cycle time (VA/T).

A common thing, at this point, is that lead times are of several days, while process times are of seconds to minutes: this shows the amount of waste is present in the system.

In the example in Figure 33, the total value add cycle time (VA/T) sums to 97 seconds and the total non-value add "inventory" time sums to 2.39 days. We call the summation of the two times the Production Lead Time (PLT). In this example we can consider the PLC equal to the non-value add "inventory" time, being 97 seconds irrelevant with respect to 2.39 days. Sometimes the PLC can be represented only by the non-added value time.

In order to calculate the Process Cycle Efficiency (PCE) we divide the value-add time by the PLT, and multiply for 100. When we do this we get a PCE of 0.15%. (We recall that, in our example, 1 day is made of 7.5 hours, 8 hours per shift minus the 30 minutes break).

The computation of all the important values typical of the timeline of the VSM is provided in the next subsection.

We have completed current state value stream map.

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2.2.3.4.1 Timeline calculations

After adding data to process and inventory icons, we will need to add to the value stream map a timeline. The timeline shows the impact of cycle time and inventory on our process.

2.2.3.4.2 Inventory time

Inventory time values for inventory shapes appear on the peaks of the timeline.

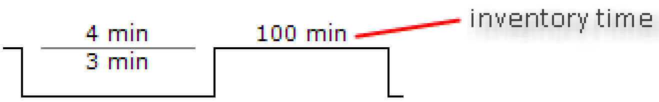

Figure 34 Location of the inventory time in the timeline

Table 3 Type of inventory and calculation of inventory time

Type of inventory	Calculation
Process step inventory	Inventory time = (inventory × CT) / (# of operators × A × B × uptime %) When: CT = the highest value from the process icon to the right of the inventory icon A = First pass yield, or 1 – scrap rate %, whichever value is lower B = Machine availability %, or operator availability %, whichever value is lower
Finished goods inventory	Inventory time = (inventory × takt time) / (# of operators × A × B × uptime %) When: A = First pass yield, or 1 – scrap rate %, whichever value is lower B = Machine availability %, or operator availability %, whichever value is lower

2.2.3.4.3 Cycle time (CT or C/T)

Cycle time values for process shapes appear in the troughs of the timeline. The timeline displays cycle time at the top of the trough and value added cycle time at the bottom of the trough.

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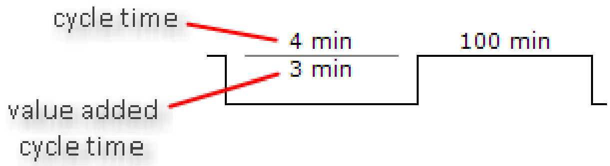
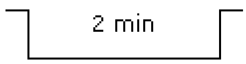
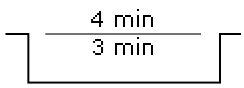


Figure 35 Location of the cycle time in the timeline

Cycle time (CT) = value added cycle time (VA CT) + non-value added cycle time (NVA CT)

Table 4 Compute and display the cycle time and non-value added time in the timeline

Scenario	Example of user-entered values	Timeline display
If CT = VA CT (NVACT = 0)	CT = 2 min VA CT = 2 min	VA CT appears in the trough 
If NVA CT > 0	CT = 4 min VA CT = 3 min NVA CT = 1 min	CT (top); VA CT (bottom) 

2.2.3.4.4 Timeline summary box calculations

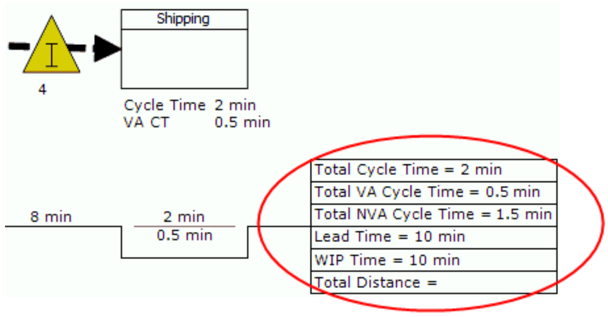


Figure 36 An example of a timeline summary box

A value stream map keeps a running total of the timeline data in the timeline summary box. In the following we report the main information that is normally included into a Time summary box and the way to compute them.

2.2.3.4.5 Total Cycle Time

The sum of the cycle time values for the process icons.

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2.2.3.4.6 Total VA Cycle Time (VA/T)

The sum of the value added cycle time values for the process icons.

2.2.3.4.7 Total NVA Cycle Time

The sum of the non-value added cycle time values, either entered or calculated, for the process icons (not from the inventory)

2.2.3.4.8 Lead Time/Process Lead time (PLT)

The sum of the inventory time values for the inventory icons, plus the sum of the cycle time values for the process icons.

2.2.3.4.9 WIP Time

The sum of the inventory time values for the inventory icons, excluding raw materials inventory and finished goods inventory, plus the sum of the cycle time values for the process icons.

2.2.3.4.10 Process Cycle Efficiency (PCE)

The division of the Total VA Cycle Time by the PLT.

2.2.3.4.11 Customer demand and takt time calculations

The computation of the takt time is based on the customer demand and facility data. If a customer demand is not available, we can use a constant customer demand, let's say **a** to produce parametric information.

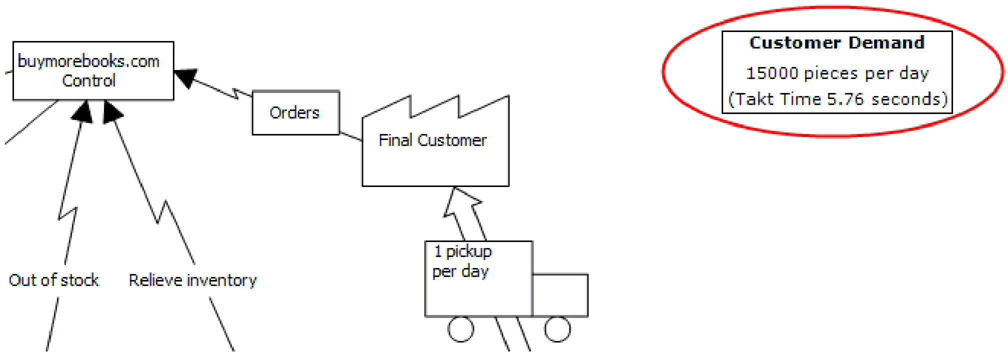

Figure 37 Customer demand and takt time on the VSM

Customer demand and takt time appear in the upper right corner of the value stream map.

2.2.3.4.11.1 Customer Demand

The number of product units or service units that a customer requires in a certain period of time. It can also be a parametric value, if it is not known: let's say **a** pieces a day, or a week, etc.

2.2.3.4.11.2 Calculate Takt Time

We provide an example on how we should calculate the takt time in the following:

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- We have a daily demand of **700 pieces**.
- Hours per shift: 8
- Break minutes per shift: 30
- Shifts per day: 1
- Days per week: 5

➔ (8 – 1/2) h/shift * 1 shift/day * 1day/700 pieces * 3600 s/h = 39 s/piece

The takt time is 39 seconds per piece. In other words, we need to produce a product every 39 seconds in order to satisfy customer demand.

If we did not have the information on the number of pieces a day required, we could have used the parameter **a:**

(8-1/2) h/shift *1 shift/day *1day/ **a** pieces * 3600s/h = 2700/ **a** s/piece.

2.2.4 VSM: the Freeware and used Icons

As we did for the process mapping, we decided to use a Freeware to allow all the partners to be able to address the VSM. Among the few number of free software for the VSM, we picked one that combines simplicity, completeness, and a good quality of graphical representation.

We decided to use https://www.draw.io/.

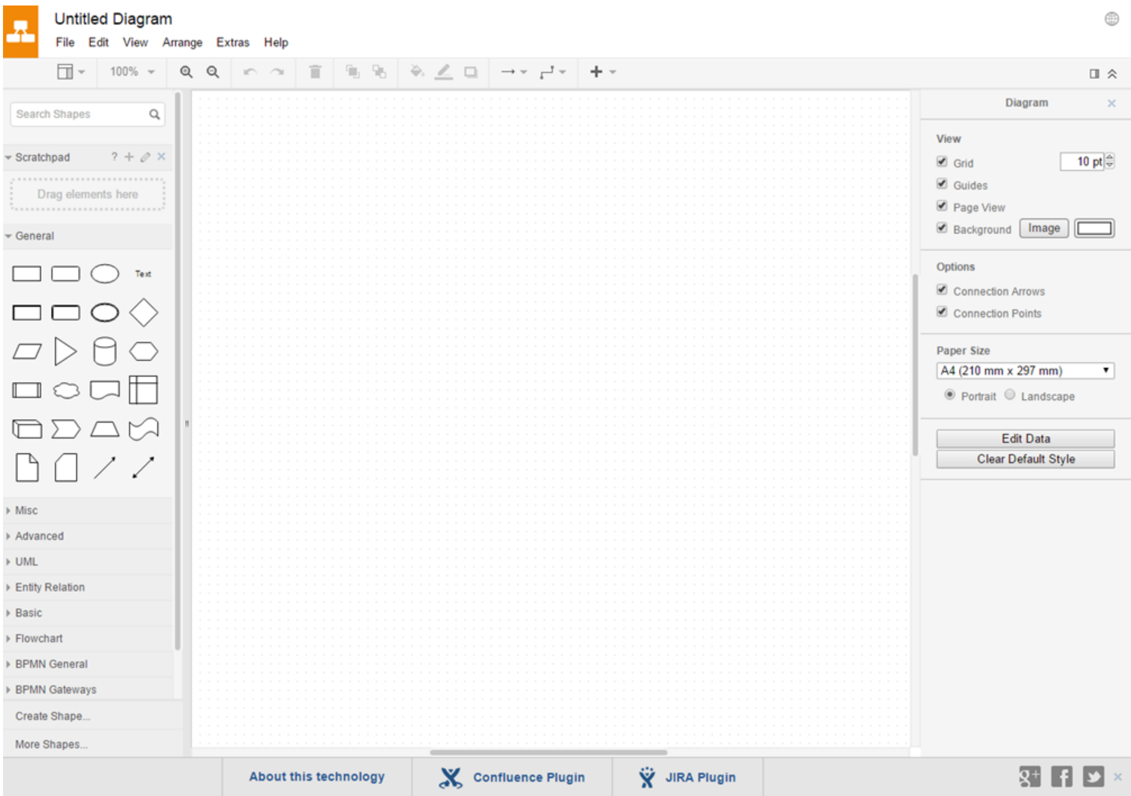

Figure 38 Starting page of the freeware for VSM

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This freeware provides instruments form many kinds of graphs and mapping, thus, to show the VSM icons, we have to perform the following steps.

a) Write "Value stream mapping" in the "Search Shapes" space.

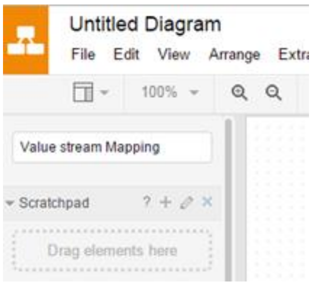

Figure 39 Searching the VSM symbols

b) Now we have some of the Icons needed for VSM. To have all of them click twice on "More Results"

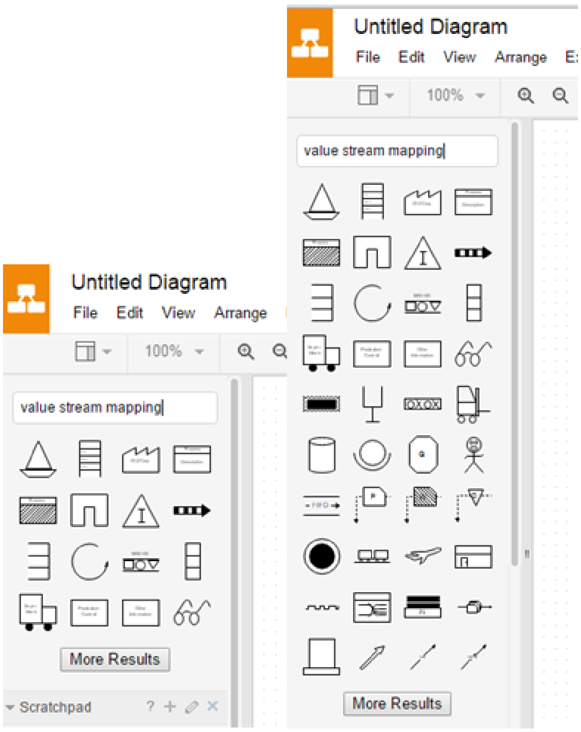

Figure 40 The VSM symbols

2.2.4.1 *Icons description*

The interested reader can find the used Icon with a deep explanation in Annex D.

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3 The Process Maps and the process analysis

3.1 Maps and analyses of the key processes

In the previous chapter we defined the main processes that we decided to study in the construction sites and the procedure detected to perform the process mapping. In this chapter we perform an analysis of the process maps received by the coordinators of the four pilot sites (Luxembourg, Paris, Valencia, and Verona). The four pilot coordinators provided the maps of the processes defined by using the suggested methodology, the BMPN notation, and the suggested freeware or equivalents.

Not all the partners have provided the maps for all the detected processes, indeed in some of the pilot sites some processes are not performed or do not have a typical and common way to be performed.

Once we received the process maps we could study how each process is performed in each pilot site. We could also compare the several methodologies adopted in the pilot sites and try to understand if some process or part of it could be used as benchmark for the others; if some suggestion could be provided in order to improve entire or part of the processes; if the efficiency could be improved; if some good practices could be applied to all pilot sites. The four pilot sites, representing different building and projects being built, being located in different environments and countries, and being supervised by different companies, could represent various manners of performing the same process in urban areas.

All the collected maps are available in the Annex E.

In order to better comprehend the process maps, we detected as necessary to provide a set of actors that play a key role in the processes. We introduce some of them in the following:

- *Main Contractor:* the main contractor is the company responsible for the entire construction site, to which to work has been commissioned. The main contractor is responsible of the deadlines and of the research and contractualization of subcontractors.
- *Subcontractors*: the subcontractors are companies hired by the main contractor in order to accomplish specific tasks or part of the main construction project. The subcontractor is contracted and paid by the main contractor.
- *Site Manager:* the site manager is in charge of the organization, managements and run the building site. The Site Manager keeps a close relationship with all the departments, coordinates and follows the execution of the contract and supervises the use and application of the safety plans.

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- *Foreman:* the foreman coordinates the workforce in the construction site. It can be a high level worker, an architect, or an engineer.
- *Supplier:* suppliers are the companies that provide the required goods, materials, and equipment.

In the following we report each of the defined processes, for each of them we provide a description, including the main actors, the main activities, and underling the good practices and possible areas of improvements, if detected.

3.1.1 Process 1: Sourcing

Main actors: Designers, Site Manager, Purchase department, Suppliers.

The starting event of the Sourcing process is always the general project, from which are derived the bill of quantities, the purchase sheet, and other documents whose aim is to specify the materials that must be bought from the suppliers, their specification, their quantities, and the moments in which are expected to be delivered to the construction site.

Once these documents are made available, the site manager, the purchase department and who is responsible for it, can define the budget and the contract to propose to the possible suppliers. At this point a purchase sheet is provided to a list of suppliers (that can be defined by making a call for tenders or by selecting among suppliers for with which the main contractor has already cooperated with or suppliers of the area of the construction site).

The suppliers prepare their offers and send them to the purchase department of the main contractor that compares them and choses the most appropriate.

At this point an economical and technical negotiation starts with the set of selected suppliers. The selection of supplier is made, with respect to prize and technical issues, and the contract is defined and signed.

Sourcing is a very important process in terms of keeping costs low, and this is why it is a very standardized process.

The process is extremely linear if not for the negotiation part that inevitably requires several loops to be competed between the main contractor and the suppliers. The use of internet leads to an extremely fast and accurate information flow.

As we said, the Sourcing process is particularly standardized in all of the construction sites, and, because of this we can report the same big scheme used by all the main contractors, that is divided in the following phases:

- Definition of material requirement;
- Identification of potential suppliers;
- Negotiation;
- Choose of suppliers;

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- Signature of the contract.

As we have already said, the Sourcing process is highly standardized; however we could find some good practices in some of the maps of the partners that can be useful also if applied to the other construction sites:

- Call for tenders;
- Use of web systems to store supplier data and compare the past offers, prices, materials, etc.
- Use of web system to compare the supplier's offers.

3.1.2 Process 2: Ordering

Main actors: Site Manager, Purchase Department, Administration, Suppliers.

The material order can be due to the need of material in the construction site because the reorder quantity is reached or it can be planned by following the work plan of the construction site.

In Luxembourg, the orders that are above a certain amount of euros need a validation of the site manager before to be set, while for the other cases the reorder is more directly forwarded to the suppliers.

For some materials, such as concrete, the order cannot be set with much advance because it cannot be stored and its use depend on the weather conditions, thus the communication with the supplier must be continuous in order to agree on delivery times and schedules, as it is shown by the map proposed by the Paris site.

Another thing to take into account is the case that the amount of reorder material lays outside the stipulated contract. In such a case contract integration is needed. This case is highlighted in the map proposed by the Verona pilot site.

Once the supplier receives the order, the material can be prepared and delivered, with the invoice, respecting the agreed times.

After the arrival of the ordered material, the foremen and the administrator will take care of controlling the correctness of the documentation and of the materials delivered. In case those are not correct, a Complaints Management Process is started. In case the material corresponds to the required one, and the invoice is as expected, the payment is submitted by the administration of the main contractor to the supplier.

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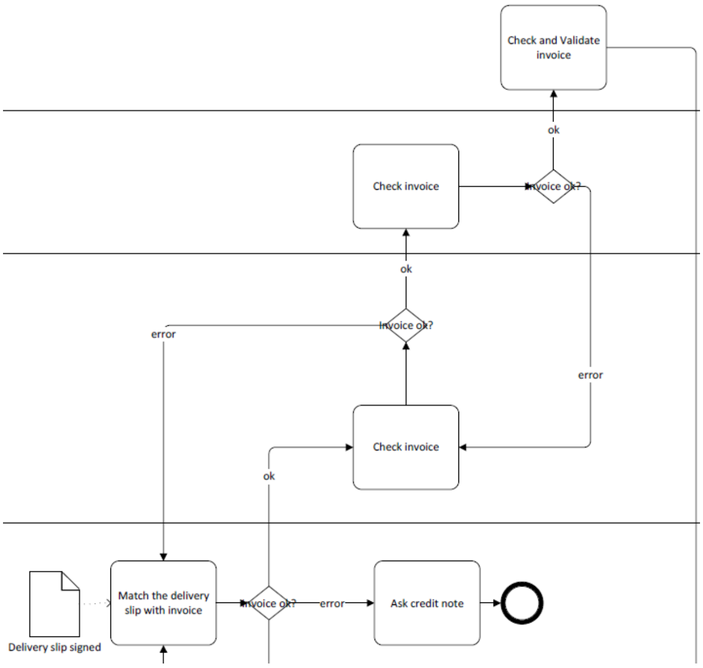

Figure 41 Highlight of the Luxembourg pilot site Order map

As one can see in the reported highlight of the map provided by the Luxembourg site, the system used to control and accept the invoice is less simple than in the other sites. In this site the documents should be analysed by three different actors, and only when the invoice is considered right by all of them the payment is submitted. On one hand this method can simplify the work of the higher level in the hierarchy, because if the invoice is considered not correct at lower level, then a feedback loop is performed. On the other hand this process can be considered too bureaucratized and long. A suggestion could be to set only two actors, instead of three, in charge of checking the invoice, in order to have a good trade-off between safety check and time savings.

3.1.3 Process 3: Delivery

Main actors: Main Contractor, Subcontractor, Haulier, Supplier.

The Delivery process starts from the order arriving at the supplier that prepares the order to be transported and give it to the haulier that transports the ordered material to the construction site. The supply can be checked on arrival and then unloaded. In case of early or late delivery the haulier can communicate it directly to the construction site so they can react to this inconvenience, if possible.

The map provided by the Paris site is related to the concrete delivery, being concrete the only material directly managed by the main contractor. The concrete delivery process in Paris corresponds to a very short term order. Indeed, the concrete delivery is a separated process due to the reactivity that

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requires. In this case the construction site is informed of the arrival and prepares the logistic team to receive the material.

In the Luxembourg pilot site they react in a different way in case the material unloading requires the use of a crane or other equipment. This is why in Luxembourg they make use of a weekly program for the deliveries that need the use of shared equipment.

Once the material is on site, the Material Reception and Expedition Process, the Entrance and Exit Management Process, and the Unloading Process can be activated.

The good practices that can be detected thanks to the provided maps are:

- Check of material on arrival for early reject;
- Early preparation for material reception and unloading;
- Reactivity to late or early arrival on site;
- Weekly schedule for shared unloading equipment.

It is also very important to avoid congestion on site and delays, and this is why it can be important to have a weekly schedule for deliveries that also accounts the deliveries of the main contractor and the subcontractors. And that considers as well the unloading times to avoid congestion on site and on the unloading areas. Another point could be to assign a different priority to different materials or hauliers in order to know how to quickly react in case of late and early arrival with respect to plans and consequent presence on site of many vehicles and thus to the related congestion.

3.1.4 Process 4: Material Reception and Expedition

Main Actors: Foreman, Subcontractor, Supplier, Crane operator, Forklift operator, Quality Department, Logistic Team.

The Material Reception and Expedition Process has been depicted and mapped in very different ways by the four pilot sites. This is why in the following we describe it in separately.

3.1.4.1 Valencia and Paris

In the Paris and Valencia pilot sites they perform a material quality check in entrance. When the haulier arrives at the construction site it is performed a visual quality check on material, a check of the delivery note and the other documentation, such as quality certification, is required. If needed, a sampling on site is performed by the quality department. If the conformity of the material is verified then the Unloading Process can start, otherwise it is activated the Return Management Process.

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3.1.4.2 Verona

In the Verona Pilot site the process is different in case of concrete or other materials. The concrete must be directly used, because it cannot be stored, while the other materials can be brought to the storage areas. In case the loading or unloading of material requires the use of crane or forklifts, than it is notified to the foreman that defines the use of handling equipment.

3.1.4.3 Luxembourg

Reception. At the arrival of the truck at the construction site, at first it is checked if the delivery regards the main contractor or one of the subcontractors. Afterwards, it is performed a check on the delivery slip, if this is ok the next step is to check if the arrival was scheduled in the weekly schedule, if not they evaluate the materials and if the unloading equipment (crane) can be available for unloading. If so, the unloading is performed. Otherwise, they refuse the materials and scheduled in another moment. If the delivery was scheduled, a check on the material and on the document is performed, the delivery slip is signed and the payment of material can start.

Expedition. When the truck arrives at the construction site, firstly the material to be loaded is checked, and the need of handling equipment is evaluated. In case those are not needed, the loading is performed and the material can leave the construction site. If the use of equipment is needed, the availability must be checked on weekly schedule. If there is no availability the pickup must be rescheduled.

To avoid the vehicles to wait long times before being unloaded or loaded, or in the worst case scenario, to leave the construction site, it is crucial to check at the same time arrivals and departures that need the same critical handling equipment at the construction site.

The loading and unloading phase is one of the most important in the construction site, from the logistic point of view. These operations require handling equipments (such as forklifts and cranes) that is also used for other operations related to construction, making their management extremely complex. The maps furnished by Verona and Luxembourg are those that better represent and highlight this point and the problems related to the handling equipment use.

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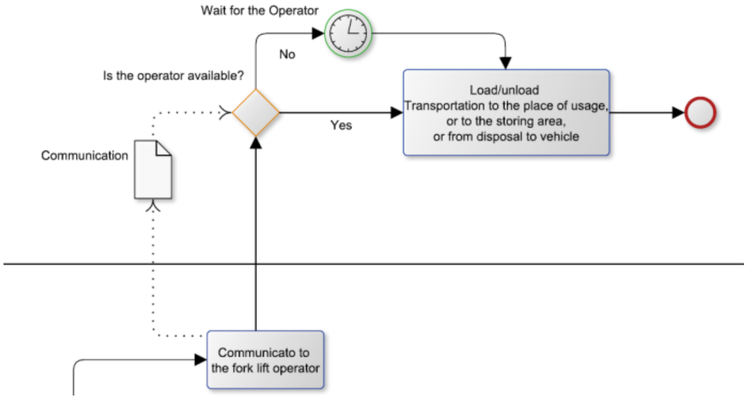

Figure 42 Highlight of forklift operator availability request for loading/unloading in Verona pilot site

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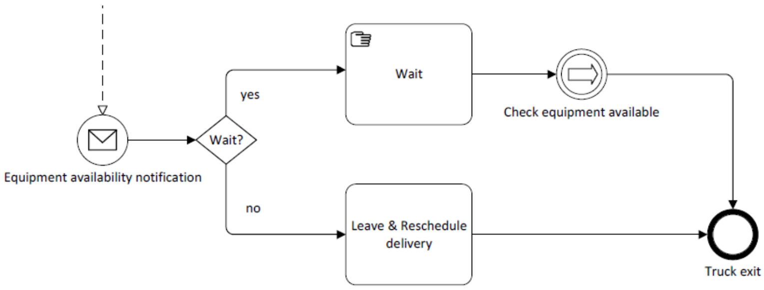

Figure 43 Highlight of the equipment availability request for loading/unloading in Luxembourg pilot site

The Luxembourg site map reports the use of a weekly schedule for the use of the crane. This is a good practice that should be formally implemented also in the other construction sites.

In particular, we can highlight these points:

- Some of the sites (Valencia, Paris, and Luxembourg) report many checks on different levels (type, quality, quantity of materials, documentation, etc.) performed by many actors. The practice of performing checks in entrance and exit is very good, but the multiple checks and the large number of people involved could require too much workforce. The simplification of this process could be important, while keeping the same level of check quality.
- In some pilot sites (Paris and Luxembourg), the scheduling of handling equipment (especially cranes) is performed, and this should be implemented in all sites. It is important to consider together the delivery schedule, the pickup schedule, the use of the handling equipment for movements inside the construction site, and the use of equipment for construction, that should be prioritized.

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- Make sure that suppliers, subcontractors, and hauliers book their arrival and departure times, and thus the handling equipment, for the operations they need is crucial. Also to make sure they respect the schedule is extremely important.

3.1.5 Process 5: Inventory and Storage Management

Main Actors: Foreman, subcontractor, Main contractor, supplier, designers, crane/forklift operators.

Considering the Storage Management, it is possible to identify two approaches for defining the storage areas: the use of a medium time storage area and the use of a short time storage area definition.

In the first case, as in Verona and Valencia, the designers and the foreman locate the storage areas in the designing phase; and/but the construction project can be modified to allow the storage area to be located when needed.

In the second case, as in Luxembourg, the subcontractors detect the storage area and require to the main contractor the location for the next week by following the work plan. This can also be due to the fact that the construction site keeps changing quickly.

In Paris, they establish the storage location at the design phase of the project and they allow the supplier to book the storage areas. If necessary, storage areas are updated (moved, deleted) according to the progress of construction work.

In Luxembourg, they separate the type of storage with respect to the value, the importance, or the size of the material to be stored. In case of large size materials or equipment, the main contractor provides a dedicated area upon request. For fragile, costly, and dangerous materials, the main contractor provides a safe and closed area still upon request.

In most of the sites, the foreman has the due of checking the storage areas, evaluating the state of materials if they are damaged, broken, stolen, etc. or if some materials need to be reordered. The foreman and the operators check stock level and storages and provide feedbacks.

For this Process, good practices detected are:

- The possible modification of the design to allow a better use of the storage areas if this can improve the operation and works;
- The possibility of booking the space on storage areas;
- A regular check on material, stock level, safety issues, and equipments;
- A regular check on the obstructions and problems on the storage areas;
- The use of safety and closed areas for dangerous and costly materials;

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- The possibility of defining new storage area with respect to the subcontractors need and the work plan.

3.1.6 Process 6: Material Handling and Equipment Management

Main actors: Foreman, Crane operator, Fork lift operator, Workers.

This process starts when there is a need of handling some materials. In all the construction sites is needed to detect which handling equipment is required. If the workers can move material without equipment they do it, otherwise the availability of the needed equipment is evaluated. The critical equipments are usually the cranes, that are in small number (if not unique) and are needed for many operations (for the production and the logistics).

The use of equipment should be planned in detail in order to avoid waste of time and resources. Many times the planning is made with large approximation and it is made by verbal communication. This can lead to many requests of handling materials at the same time, bad organization, delays on the operations, congestion, etc. This is why the management and scheduling of the shared equipment, especially the cranes, is crucial for a lean management of the construction site.

It is important to highlight the planning document that is shown in the Paris process map used to check the crane availability. This type of document or software can be very important for planning the main material handling inside the construction site, and should be used in other construction sites.

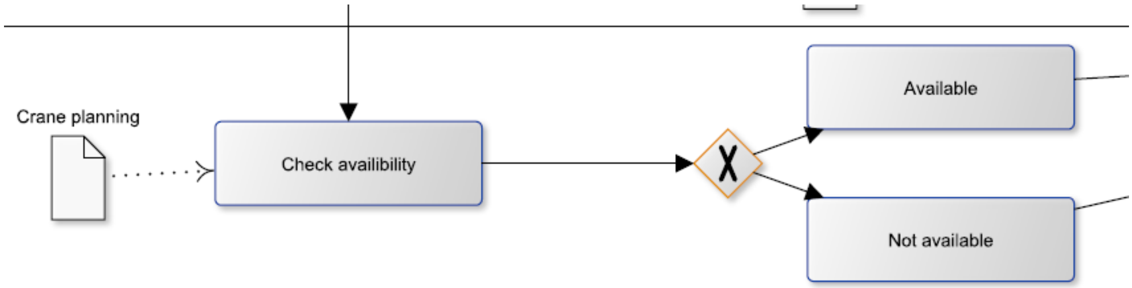

Figure 44 Highlight of the material handling map of the Paris construction site

3.1.7 Process 7: Housekeeping

Main Actors: Foreman, Subcontractor, Staff

Regarding the Housekeeping process, inside the construction sites the main law is that: who produces waste and obstructing problems is responsible for them. Thus, who is in charge of construction tasks must take care of the related waste and cleaning. This can be done by the main contractor or by the subcontractors.

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Concerning housekeeping, there are two kinds of cleaning and housekeeping: the one performed following a routine, performed after a certain amount of time, and one to be performed after a certain construction task. The foreman is in charge of supervising if the housekeeping is performed and the obstruction material is removed from the construction site. If the subcontractor in charge of housekeeping does not perform their duty, a complaint process is open and it can be the case that a dedicated subcontractor is contracted to perform housekeeping. An invoice will thus be sent to the subcontractor that did not made its job. In Paris this can create problems between subcontractors and the main contractor: the law "who produces waste and obstructing problem is responsible for them" is not accepted by all subcontractors. Indeed, they can declare that it is another subcontractor who created the problem.

Cleaning and tidiness in the construction site are of extreme importance to avoid obstruction in the working and storage areas, and for making a good use of the constrained areas of the pilot sites. They should be performed once a day in order to avoid accidents and material damages. However, in the case of Valencia, due to the high availability of space on the construction site, the process is not as critical as for the other construction sites, and thus there is no standardised housekeeping process for this site.

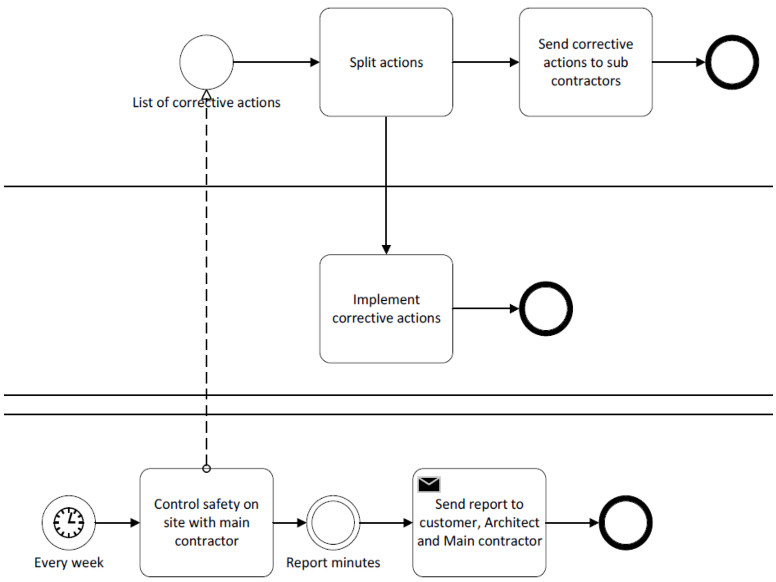

Figure 45 Highlight of the Housekeeping process Map of Luxembourg pilot site

As you can see from the maps provided by Luxembourg and Verona, the methodology for housekeeping is very similar in different sites.

In the Luxembourg map they also report the safety check on the pilot site: it is important to highlight that safety is tightly related to tidiness and cleanness of

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the construction site. The safety coordinator is in charge of monitoring weekly the site and reports to the main contractor the corrective actions to perform. This reports to the linked subcontractors and ask them to implement corrective actions. This can be seen as a good practice to import in other sites.

In Paris construction site, a software on a tablet is used to report a safety risk or a cleaning issue: this software permit to take a picture, send a report to sub-contractor concerned and asking him to solve this problem. This can be seen as a best practice.

3.1.8 Process 8: Waste Management

Main actors: main contractor, Subcontractor, Haulier.

The Waste Management process concerns many types of materials, indeed, a big number of waste types can be produced in the construction sites. The first distinction between types of waste concerns the fact that some waste can be recycled, while some other cannot be recycled. In the Paris site, for example, there are four types of waste: wood, iron, rubble, and other waste. In the Valencian pilot, there are five different containers: paper and cardboard, plastics, concrete, wood, and debris.

In order to dispose the most common materials, waste bins for different materials are located next to where the operations take place. When the bins are full, the bins are emptied into big containers, located in a dedicated area in the construction site. The big containers can be used for disposal by the main contractor or by the subcontractors that normally have their own containers. The less common waste disposal is normally entrusted to who produced it. The foreman normally checks the fulfilment levels of the containers every certain amount of time and, when it is necessary, the foreman is in charge of requiring the disposal of the containers by collecting them and carries them into a dumpsite. This can be done directly by the interested subcontractor that produced the waste or by a company contracted to carry waste to dumpsites. At this point, the entrance and exit management process and the loading process are activated.

One remark on the Paris construction site waste management process: they schedule the pickup and report all the documentation into a database and provide a monthly report to obtain the HQE certification, a standard French certification for sustainable construction.

Another important thing to highlight it is the preliminary phase that is performed in Verona pilot site to check if waste is suitable for reuse. This is done in order to reduce waste inside the construction site and not to dispose good material that can be reused in following operations.

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3.1.9 Process 9: Return Management

Main Actors: Site manager, Supplier, haulier, main contractor, subcontractor.

The material to be returned can be listed in:

- Materials that do not respect the required and agreed specifications;
- Material damaged during transportation;
- Exceeding materials after use.

When the first two cases happen it is normally created the non-conformity form and the problem encountered is reported to the supplier in order to contract the return of the material. In case we can notice the problem on time (when still on the vehicle) we can refuse to unload material gaining time in the return procedure. This is why a check on material quality before unloading is important.

When the material exceeds the needed quantity after the end of some tasks in the construction site, the material can be temporarily stored and then returned to the supplier, if the supplier agrees. Otherwise the material is considered as waste.

In both cases the supplier is in charge of the material collection that should be planned in advance.

A good practice is the one used in Luxembourg and Verona: where, before returning the material, they check if the material can be reused in other work or in other construction sites of the same company.

In the case of Valencia, the Return Management is a process incorporated in the so-called quality management system. Each case is analysed individually and the causes that led to the return are established. This process minimizes the repetition of returns for similar causes.

A very interesting map is the one provided by the Paris pilot, in which they report the use of a logistic software. To each one of the suppliers is given a login access. They can thus use the software for planning material collection at least 48 hours in advance. In the request they can define the time of arrival, the loading area, and the necessary handling equipment. The logistic team is in charge of checking the availability of the times and areas required by the supplier and accept or decline the request.

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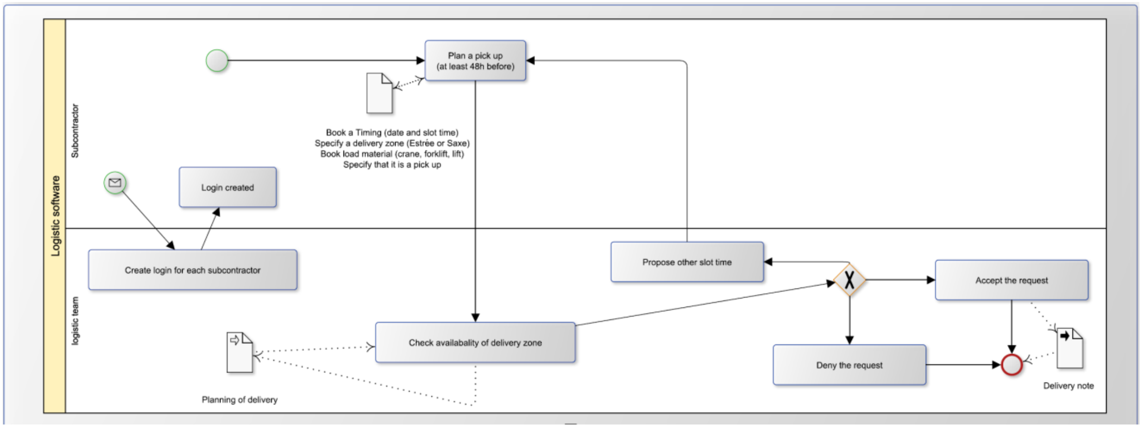

Figure 46 Highlight of the logistic software used in the Paris pilot site

This software makes the material return management and planning very efficient and the use of similar tools should be considered in other construction sites. For example, in the Luxembourg pilot site the materials to be returned are stored at the site entrance with no planning, and this can be a problem for the site congestion. In Verona as real scheduling is not performed and should while it could improve organization and productivity.

3.1.10 Process 10: Planning and scheduling Resources

Main actors: Foreman, Site manager

The Planning and scheduling of the resources derives directly from the work plan. Normally the Site manager, the foreman and the other responsibles in the hierarchy are responsible of checking the effective state of the construction site and of the works, and are responsible of planning the activities to be performed in each week, taking care of the resources, that are

- the material needs,
- the equipment needs,
- the workforce needs.

The result of the planning and scheduling can be very different from reality thanks to the high level of uncertainty typical of the construction sites. Hence, it is very important to monitor everything and to be reactive in changing the plans and schedules, if needed. The Foreman and the Site manager have, at different levels, the duty of taking care of planning, scheduling and solve these problems.

In Valencia, the project management board checks the plans weekly. In Luxembourg, the foreman takes care of the plan which is then verified at higher level before being applied. Probably, the most sophisticated but highly efficient way of organizing is the one used by the Paris pilot site, especially considering the logistic activities and the use of limited resources.

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In the provided maps the planning of the common and limited resources was not explicated perfectly, even if it has a key role in construction sites from the logistic and the operative point of view. It requires a very high level of communication and cooperation between the stakeholders (crane operator, lift operators, etc.) and providing plan and schedules and tools to perform them can improve all the operations.

As said before, the method used by the Paris pilot site seems to be the most fitting with our expectations. They use data from the logistic software and data from the logistic board to manage the urgent requests. Thanks to these inputs they can provide a daily plan of logistics activities from which can be derived very crucial documents, such as the crane plan, the forklift plan, and the daily plan of deliveries. It is clear that the use of these types of data and documents can lead to a very efficient way of managing constrained resources and should be exported to other construction sites.

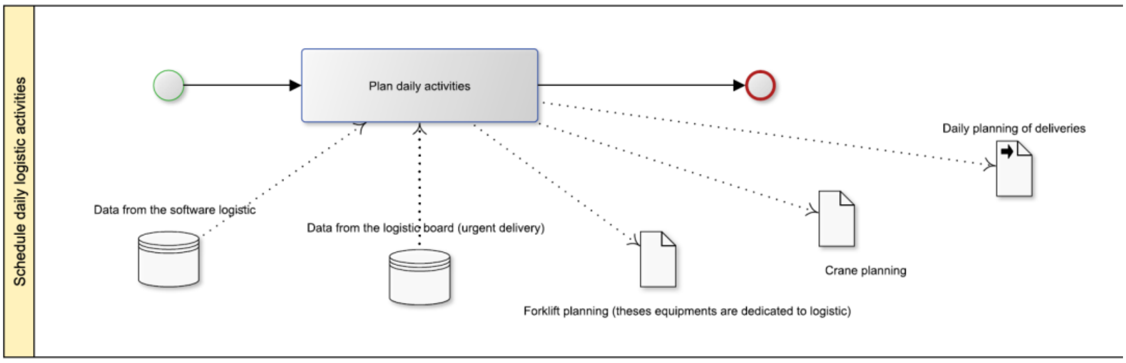

Figure 47 Highlight of the Daily schedule of logistic activities in Paris pilot site

3.1.11 Process 11: Complaint Management

Main Actors: Foreman, Main Contractor, Subcontractors, Suppliers.

We can highlight to main occurrences that can happen in the construction site that lead to a Complaint Management process:

- Delivery of non-conform material
- Mistakes and problems during the operations and construction works

In both cases it's the foreman that must take care of these issues.

The Verona pilot site map is the most detailed and considers both cases. When material non-complying with required specifications is delivered, they check if the material can be used even if differs from the ordered one or if it can be reused, before starting a return management process. In case the material can be used it is produced an Approval Sheet that certifies the conformity of the material. Otherwise, the error is communicated to the supplier that must take care of the collection of the non-complying material and of a novel delivery.

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If a subcontractor complains about a problem in the construction works, then the first thing to do is to identify the actors responsible for it. After that the main contractor can charge the subcontractor for the rework and the additional incurred costs.

Complaint management typically begins because of other processes, as it also possible to note in the maps. It is normally started only for problems of a certain entity that cannot be solved in an easier way, but need a dedicated procedure. In the Luxembourg map are reported also the easiest ways to take care of complaints management.

3.1.12 Process 12: Entrance and exit management

Main actors: Main contractor, subcontractor, hauler, workers, porter.

All the construction sites under study have doorkeepers on the entrance and exit of the construction site that in some cases can be the same point.

In the Paris map, it is reported the procedure for creation of the badge needed for entrance and exit used by the workers, by the subcontractors, and by the suppliers and visitors. These badges can last 6 months for the workers and 1 day for the suppliers.

The trucks should notify their arrival at the construction site to the main contractor or to the subcontractor, depending who are related to. This could be done before the arrival or on site, depending on the construction site. At the entrance many checks are performed, on the identification documents, on the truck plug number, on the delivery note, on the transported materials, etc. If all the documents and parameters are correct, then the truck can enter the site and start the loading and/or unloading operations.

The main issues at this point are when several vehicles arrive on site because of delays, bad or missing planning. It is thus important that this is correctly managed and a good way could be to define priority levels in order to answer quickly and efficiently to these problems.

As detailed in the Verona's map, a fast communication of the truck arrival made by the supplier or hauliers allow a correct anticipation on the possible congestion on site, in entrance and exit. And this can lead to a good management of the entrance and exit of many vehicles at the same time.

In the Luxembourg map it is shown how some problems and inefficiencies can arise in the choice of the unloading area that can be avoided with a previous planning.

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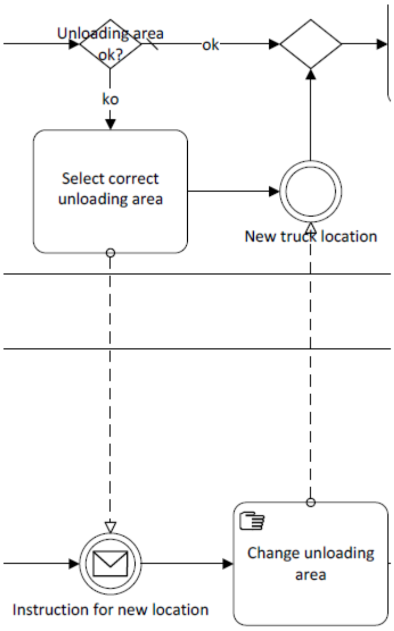

Figure 48 Highlight of the unloading area selection in the Luxembourg map

3.2 Conclusions on Processes

The aim of the process mapping and the study of the map requested to and provided by the pilot sites was to determine the As-Is situation, to give a precise and detailed description of the main processes as they are performed at the moment, and detect good practices to be exported and practices that could by improved. The aim was not to evaluate and criticize how companies work. Indeed, all the proposed processes have been refined during the years by the construction companies, thanks to their experience on field. On the other hand, after the analysis we performed, we can observe methods that have been better improved in some companies with respect to others. Moreover, some organizational and logistics problem are present in many of the processes studied. This is why we propose here some possible ways to solve those problems.

3.2.1 Main problems

By analysing the main processes that have been mapped, we could identify some weaknesses. We list them below.

3.2.1.1 Lack of communication and planning tools and methods

Very often the foreman, the site manager, and other stakeholders of the hierarchy are aware of the information needed for a perfect management of the construction site, but they normally prefer the oral communication with respect to the written one. This clearly leads to a lack of information and miscommunication. The stakeholders also prefer to communicate on voice and

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phone with respect to software, tools, and other manners of communicating and planning operations.

3.2.1.2 Lack of congestion planning

A non-accurate congestion planning in entrance and exit on site can lead to queues and delays in the construction process, to the bad use of the storage areas and of the limited shared equipment, and to highly congested construction sites, that can also bring up safety issues. This is true especially in particular phases, let think of the earth excavation or the concrete installation, where big trucks in the first case and concrete mixers in the second case arrive in a continuous flow that should be coordinated with the other deliveries.

3.2.1.3 Lack of scheduling for pickups and deliveries

There is a lack of scheduling for pickups and deliveries of vehicles on site and for the use of shared and critical equipment such as cranes and forklifts. The arrivals and departures should be scheduled also making use of booking tools and optimization tools.

3.2.1.4 Lack of scheduling for storage areas

The use of loading, unloading, and storage areas is also very critical because of the limited space and because they normally depend on the use of shared equipment. These problems could be avoided by using a system for booking and then optimally scheduling these activities.

3.2.1.5 Lack of scheduling for shared equipment

The lack of scheduling for shared equipment causes delays in the production. In the studied maps it is easy to encounter the flow section as reported in Figure 49, where queue might be formed because the handling equipment is not available.

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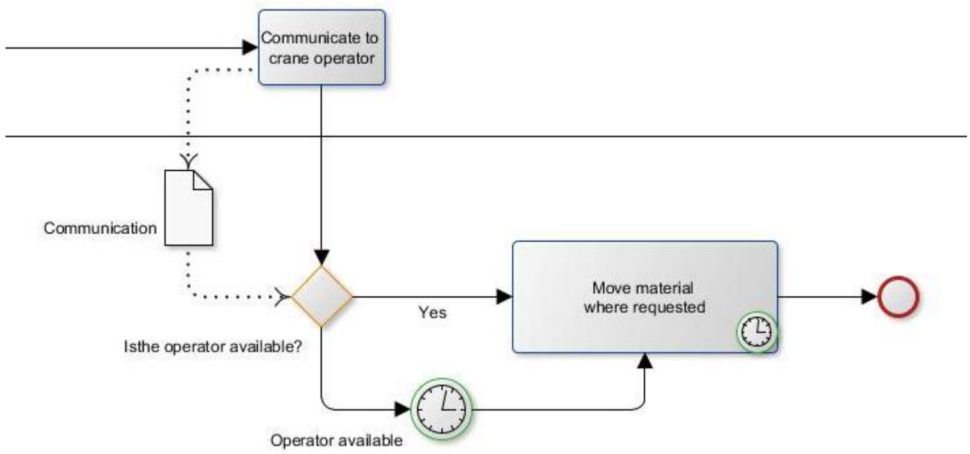

Figure 49 Example of the possible delays when using cranes

3.2.2 Possible solutions

In order to avoid the creation of these problems and to tackle their causes, in addition to the use of a CCC, we propose two tools that can be helpful to improve the results and decrease the delays and organizational problems.

3.2.2.1 Weekly plan of arrival and departures and Booking operations

We believe that it could be useful to improve the delivery plans already existing by integrating a set of other information. For each arrival and departure, the provider must indicate:

- Date and time of planned arrival
- Type of material
- Quantity of material (weight volume, etc.)
- Information on the hauler, truck, to ease the creation of badge or entrance on site
- If the loading / unloading requires the forklift or crane
- If the loading / unloading requires one or more workers from the site: forklift operators and crane operators
- Estimated time of loading / unloading

We also think that it can be useful that the suppliers submit to the construction site a delivery request in booking their arrivals on logistic software while the staff on the construction site reviews the request and decides to accept or refuse them. It is very important that all the stakeholders are aware of this and that the construction site differentiate between usual or exceptional practice.

The construction site can add to the document:

- If samples and tests on materials are needed

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- The level of priority of material (in case of congestion)
- Type and size of vehicle (that can influence specific conditions for its entrance and stay on the construction site)
- Indication of indoor / outdoor storage is required
- Indication of risk or danger material: to create dedicated storage areas

3.2.2.2 *Weekly schedule for shared equipment*

In some construction sites, such as the one in Paris and the one in Luxembourg, the documentation needed for the planning and the scheduling of the crane is already a reality. This is not the case in the other sites.

The idea is to provide a tool that helps the logistic team to schedule the use of the crane. And, if this works well, it can be considered as a tool which might also be applied for the scheduling of other critical equipment (forklift, platforms, etc.)

The logistic team will check all the booking requests for arrival and departure, for loading and unloading and thus book the use of the equipment and the foreman or the crane operator can define if they are allowed to use the crane or if it is needed for construction or movement of internal material or for the construction operations.

A plan will provide quick response, avoid delay as much as possible and give an idea of the change of inserting urgent activities.

3.2.2.3 *Weekly schedule of the storage areas and storage area booking*

A similar system could include the possibility of booking and scheduling the storage areas, the needed space in the storage areas, and the operation in the storage areas, also taking into account the needed equipment.

3.2.2.4 *The use of CCC*

The ultimate solution would be to externalize most of these problems by using a construction consolidation centre. This can improve the economic performance, the organization, and decrease the nuisances and environmental constraints (such as pollution, noise, accidents, derange, etc.).

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4 The Value Stream Maps and its analysis

4.1 Maps and analysis of materials and components

In previous chapter, we propose a method to apply Value Stream Mapping, a technique coming from lean manufacturing, to construction industry.

Each pilot coordinator applied the proposed methodology on their respective sites to produce 14 value stream maps presented in Table 5 The selected materials or components. Depending on the construction phase of each site and nature of construction, the pilot coordinators selected at least three materials or construction components. Indeed, each site is different with respect to the others, and each pilot site is in a different construction phase, thus different materials are used at the moment. We let the coordinators to select the material also because the material selection is part of the VSM method.

Because the Verona VSMs have been the first to be produced, we could think that this created a bias on the partners. However, this bias improved the meaningfulness of the following analysis, letting us to compare similar materials value streams in different construction sites.

Table 5 The selected materials or components

Luxembourg	Paris	Verona	Valencia
	Plasterboard	Plasterboard and Tiles	
Doors	Doors	Doors	
Windows	Windows	Windows	
		Reinforcement Iron Bars	Iron Bars
Prefabricated Balconies			
Plaster wall			
			Pipelines
			Concrete

Even if all the pilot coordinators interpreted the VSM method in a different way, with respect to the others, we will report, in the following, the maps grouped by materials and not by pilot site, in order to be able to perform comparison and derive some conclusions.

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4.1.1 Plasterboard (and tiles)

In the first analysis we consider plasterboard and tiles. We consider them together because they are described in the same VSM for the Verona pilot site, due to the fact that they follow the same pattern. We firstly provide a short description of the materials to help the reader's understanding.

Plasterboard is a panel made of gypsum plaster pressed between two thick sheets of paper. It is used to make interior walls and ceilings (Wikipedia.org).

Figure 50 Plasterboard panels (sidtelfers.co.uk)

Ceramic tiles are tiles used to cover floors.

Figure 51 Ceramic tiles (wikipedia.org)

4.1.1.1 Paris

VSM of plasterboard in the Paris pilot site shows that the construction site informs weekly the supplier about the material request. The supplier delivers 3 trucks per

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week. The time for each activity is presented on Figure 52 and it decomposed as follows:

- the material reception and the handling to storage areas take 1 hour;
- the storage is 3 days long;
- the transportation to the point of use takes 2 minutes with one person;
- and the installation of one piece takes 20 minutes with 2 people.

The information flow is straightforward, the reception, handling, and installation are fast, and when the material is transported to point of use, it is directly installed without additional waiting time, as we can see from the pull icon in the VSM (see Annex F). However, the storage time seems to be very long, as one can see form the graph in the following. In the graph in Figure 52 and in the following graphs, the orange line represents the average among the times required by the activities to be completed. This line gives an idea of which activity is more time expensive. In this case the storage time is very high and we can state that the site could benefit from the introduction of a CCC by providing plasterboard just when needed.

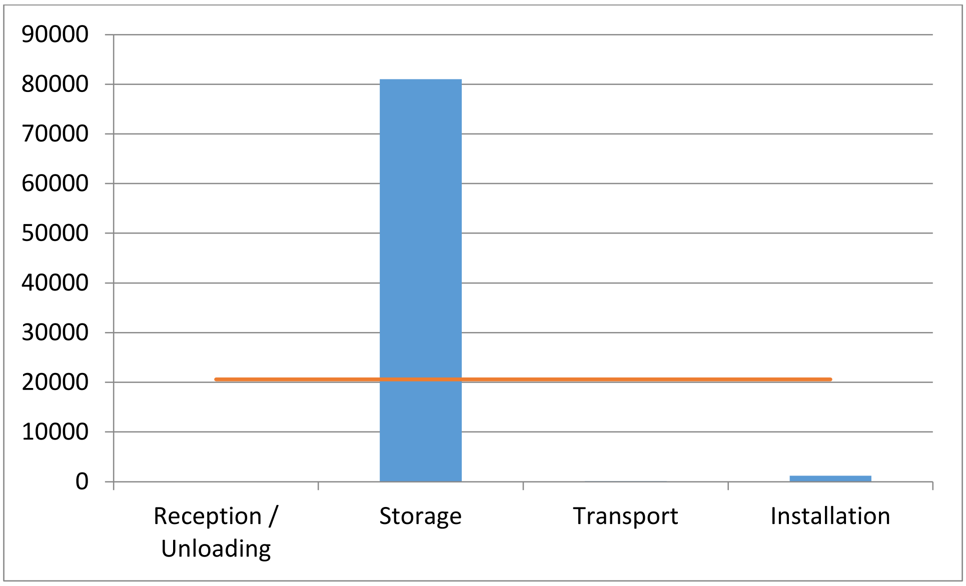

Figure 52 Time for activities for plasterboard, Paris (time expressed in seconds)

4.1.1.2 Verona

In this Verona's VSM (see the Annex F), two materials that follow the same path are considered: plasterboard and tiles. They follow the same path: they are bought, delivered, unloaded, handled, and installed.

The construction site sent once a global order and then sent delivery request to the supplier on a weekly or monthly basis, with respect to the need of material on the construction site.

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The time for each activity is presented on Figure 53 and it decomposed as follows:

- the total amount of plasterboard (350 panels) is received and unloaded in 2 hours with the use of forklift and crane;
- then it is stored for 1 day
- and moved to the point of use where the installation of each panel takes about 20 minutes.

The reported times are in line with the Paris installing time: as one can see form Figure 53the storage time is the most relevant. Also in this VSM the pull arrow is used between the handling and the installation of material that means that the material does not wait on the point of use.

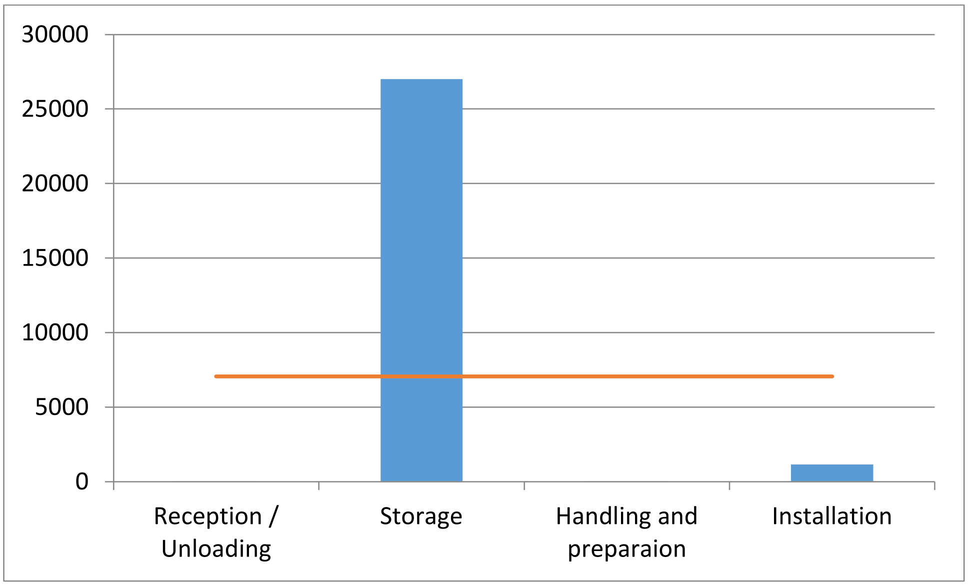

Figure 53 Time for activities for plasterboard, Verona (time expressed in seconds)

In parallel, the tiles VSM is provided. The activities are the same as for plasterboard, however, for tiles the waiting time is even more incident on the entire stream. Thus, also for Verona, the instruction of a CCC could be very important to avoid this very long waiting times on the construction site, that fulfil unreasonably the highly constrained storage areas.

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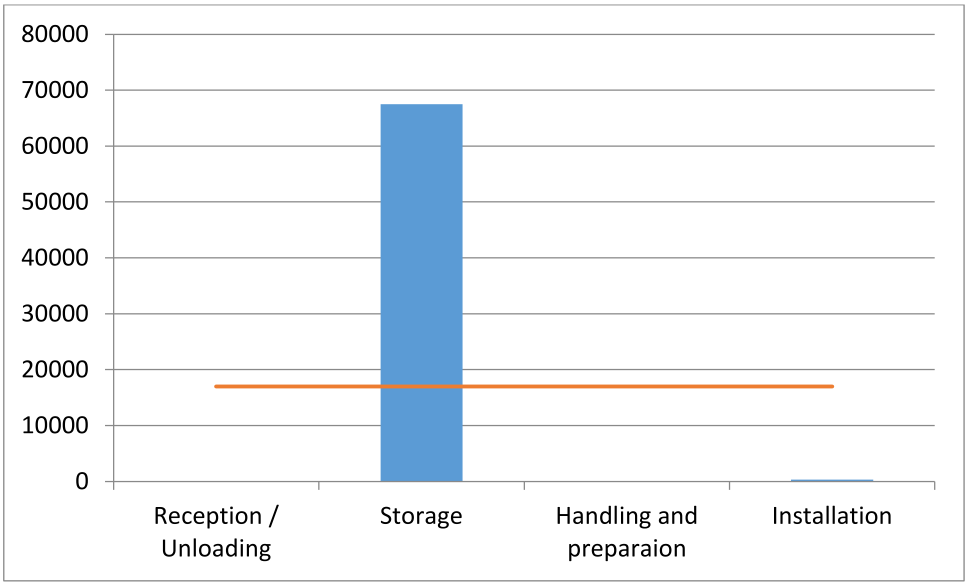

Figure 54 Time for activities for tiles, Verona (time expressed in seconds)

4.1.1.3 Comparison on plasterboard

We now provide a brief comparison between the Verona's and Paris' plasterboard VSMs. They are very similar and show the same activities from reception to installation. One difference is represented by the supplied quantities: in Paris they receive 3 vehicles with 1000 panels a week, while in Verona they receive one vehicle loaded with 350 panels per week. This can be due to different panel size; however the large amount of supply provided in Paris causes a larger amount of storage time, and thus non-added value time, and this affects the storage areas occupied. The storage time is of 3 days in Paris and of 1 day in Verona, that imply 22.5 h and 7.5 h of non-added value time, respectively.

Another difference is represented by the workforce used in the two pilot sites. In Paris they make use of 4/5 workers: 1/2 for reception and unloading, 1 for handling, 2 for installation. In Verona 6 workers are needed: 2 for reception and unloading, 1 for handling, and 3 for installation. It looks clear and it can be point of discussion the fact that in Paris they need one worker less to install pasteboard in the same amount of time. Moreover, the handling and preparation time is different: 120 seconds in Paris, compared to less than 11 seconds in Verona. This could be due to the different distances between the storage areas to the point of use.

In Figure 55, one can see the differences of Process lead times, Value added times, and the percentage efficiency. The efficiency is low in both sites but in Verona is higher due to a smaller lead time.

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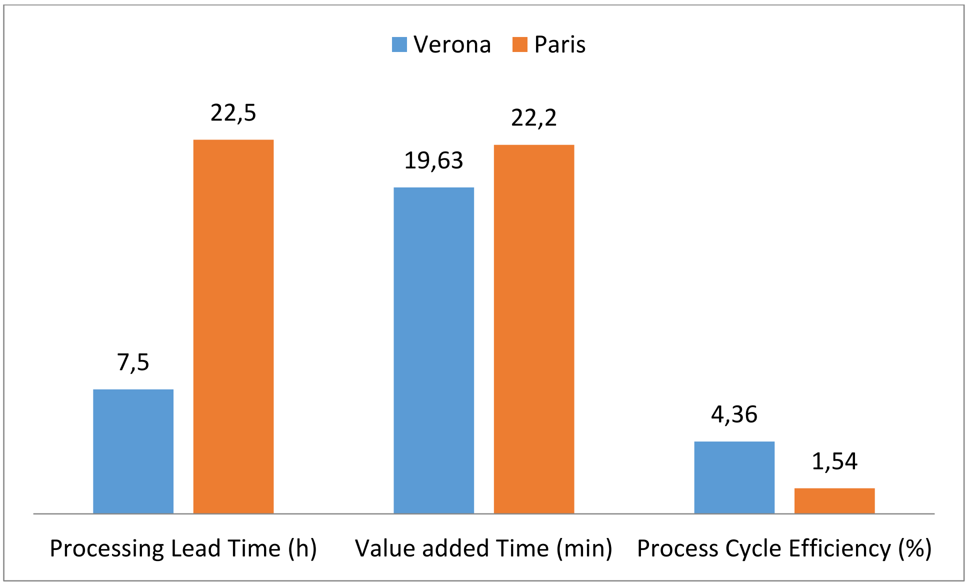

Figure 55 Comparison between Paris' and Verona's plasterboard VSMs.

4.1.2 Doors

On second instance we consider the internal doors.

Figure 56 Internal Doors (roverplastik.it)

4.1.2.1 Luxembourg

In the Doors VSM provided by Luxembourg (see Annex F), it is reported that each week the material needs are specified to the supplier, that then carries the doors on a car with trailer to the construction site.

- On the construction site they need 6 people for unloading, reception, and handling for 1 hour, in total. In this case the number of needed people seems high. This does not seems necessary, being this time the

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shorter in the all stream, as one can see on the graph in Figure 57. Maybe less people could be used for this activity, being the average time around 50 minutes.

- Afterwards, 2 people take 10 minutes to prepare each of the doors;
- and 40 minutes to install them;
- 4 people need 150 minutes for the finishing.

No waiting times or inventory are reported, which means that the process is very straightforward. Probably, to decrease waiting times they had to increase the number of workers needed, as it is possible to see from the high number of workers involved.

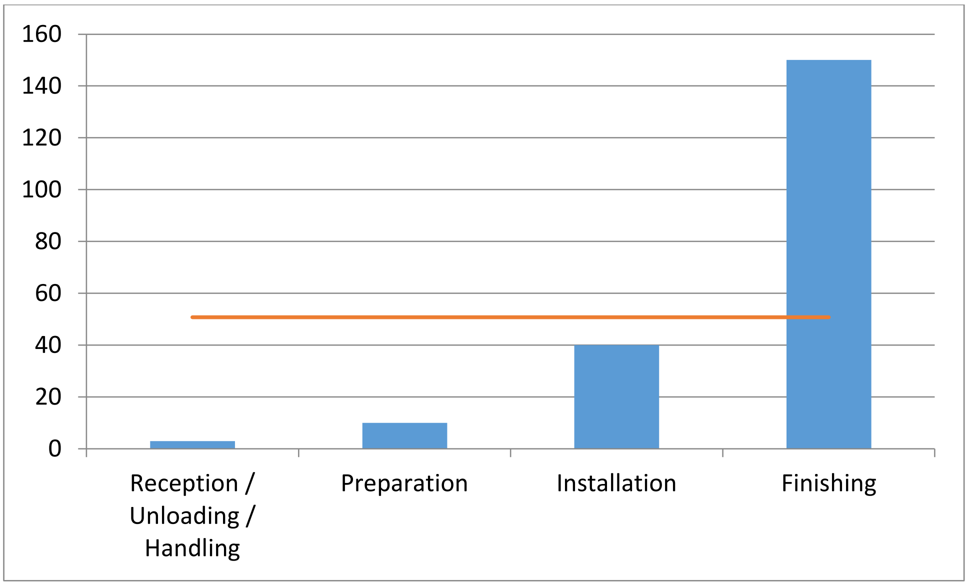

Figure 57 Time for activities for doors, Luxembourg (time expressed in minutes)

4.1.2.2 Paris

In Paris, after the main order, from the construction site they send weekly the door needs to the supplier. The door supplier produces the doors and carries them to the construction site once a week. In the VSM (to be found in the Annex F) one can see that:

- handling, assembly, and installation need a reasonable number of dedicated workers and time.
- The installation pulls the transportation of the material to the point of use.
- The non-value added activity can be identified by the 5 days that the doors need to wait before being installed, as one can see on the following graph in Figure 58. This waiting time means a good portion of space in the storage are that is occupied for 5 days in the construction site. This can justify the introduction of a CCC in order to externalize this waiting time and to let the material arrive on time without a use of excessive space on site.

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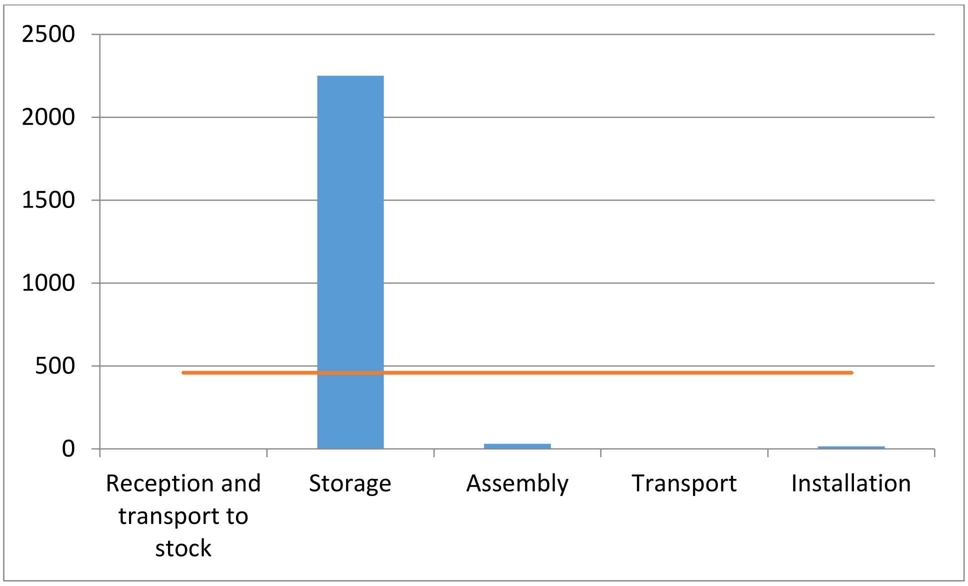

Figure 58 Time for activities for doors, Paris (time expressed in minutes)

4.1.2.3 Verona

The Verona doors VSM (see Annex F) is the most sophisticated VSM regarding doors, because it considers approximately the entire supply chain, with the information and the material flow from all the suppliers to the installation.

- The main contractor provides weekly or monthly the material requests to suppliers, with respect of the moment of construction.
- Thus the supplier contacts its wood and HPL suppliers.
- After the arrival of these materials at the supplier site, those must be cut and assembled with the other accessories.
- Afterwards, the doors and the jambs are packed and sent to the construction site. One can see from the following graphs in Figure 59, Figure 60, and Figure 61, that the waiting and storing times are often very high compared to the working times.
- The reception, the unloading, and the handling times are low and reasonable, so is the installation time.
- The main non-added value time is the time material need to wait before being installed that is 2.5 days. This material could be stored in a CCC before use to decrease waiting time on site, the use of limited storage areas, and the possibility of damage.

In three points of the VSM there is a pull arrow that shows that in in some parts of the process the flow is straightforward.

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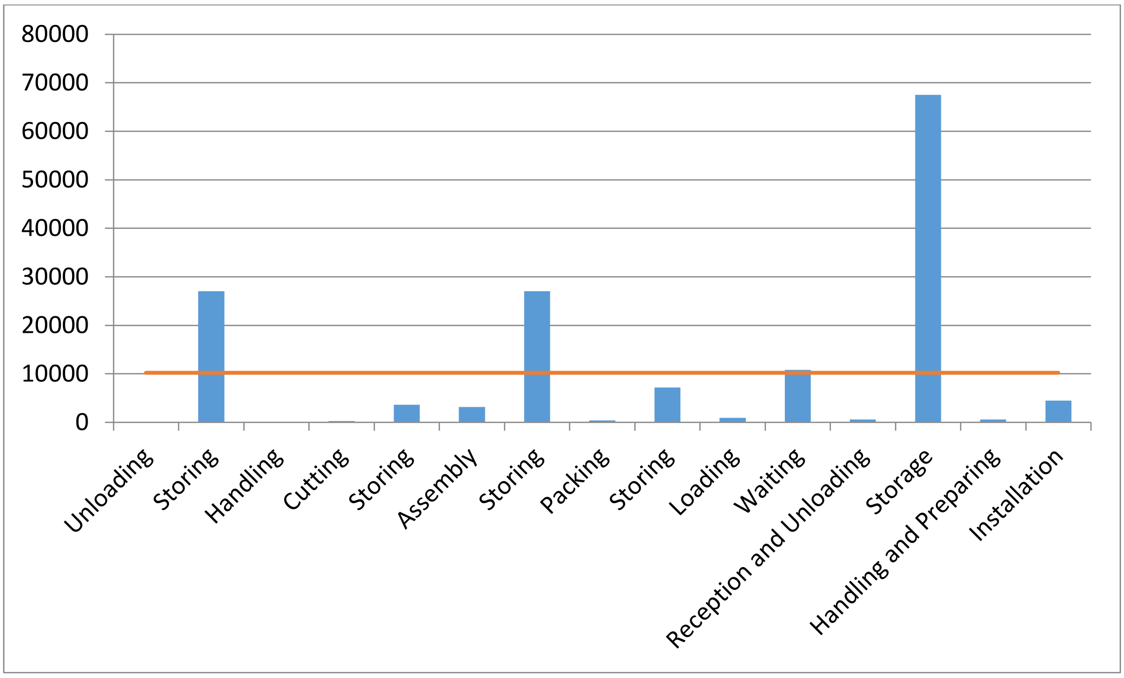

Figure 59 Time for activities for doors, Verona (time expressed in seconds)

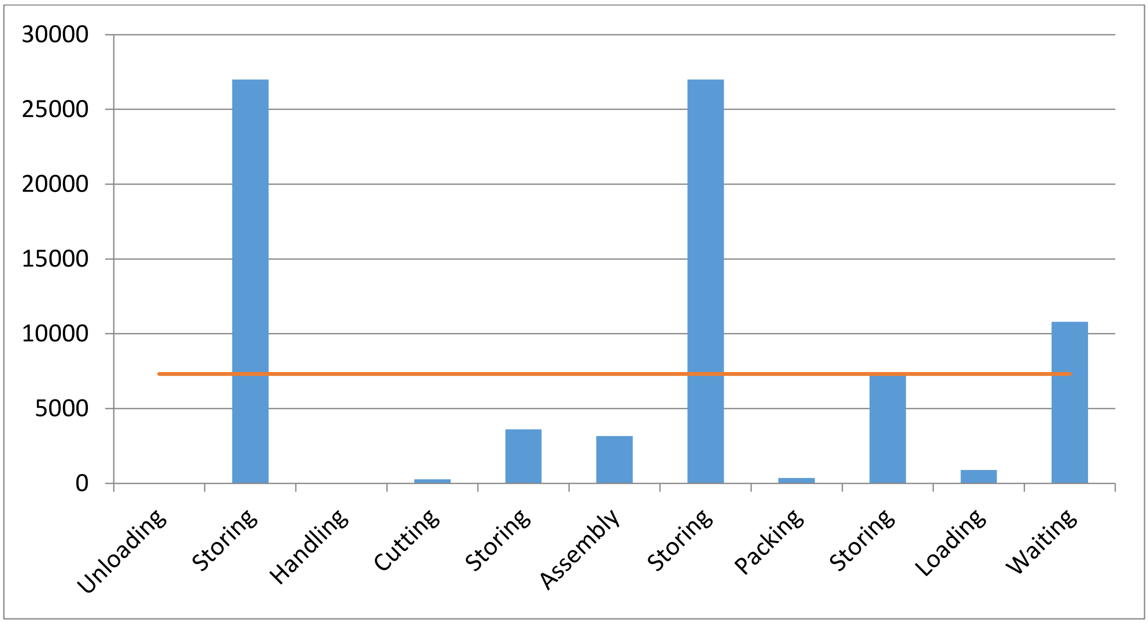

Figure 60 Time for activities for doors before the construction site, Verona (time expressed in seconds)

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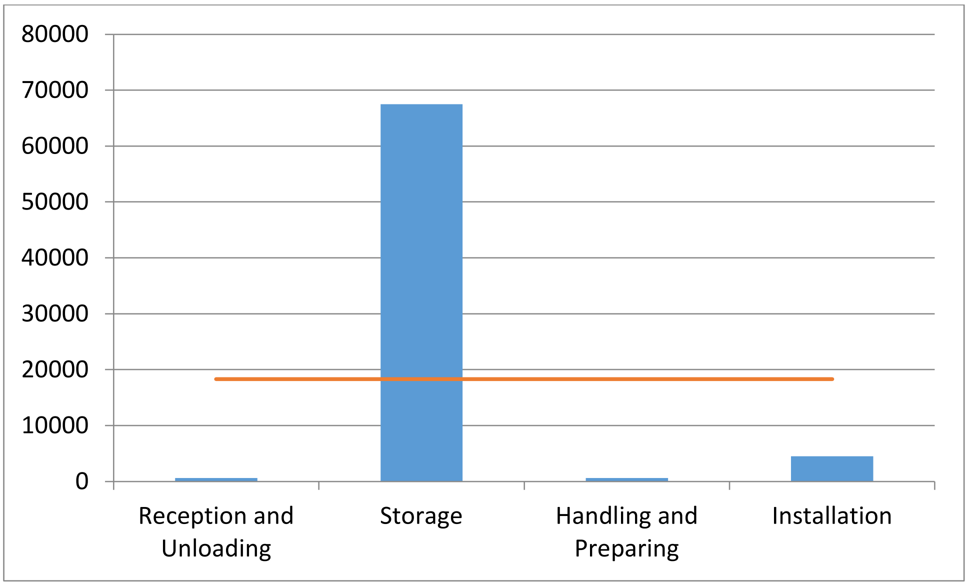

Figure 61 Time for activities for doors inside the construction site, Verona (time expressed in seconds)

4.1.2.4 Comparison on doors

The three pilot sites that analysed doors provided three similar VSMs for the activities performed inside the construction site.

In Figure 62 and Figure 63 we analysed only what happens inside the construction site and we tried to homogenise the activities with respect to the three pilot sites.

We can observe that the Process Lead Time is very relevant for Verona -2.5 days- and even more for Paris -5 days-, while it is not present in the VSM provided by Luxembourg. This means that the door value stream in Luxembourg is the most efficient with respect to the other construction sites, followed by Verona. On the other side, the number of workers needed in Luxembourg is larger than in the other sites: 6 people for reception, unloading, and handling, 2 people for preparation, 2 for installation, and 4 for finishing. In Paris 2 workers are needed for assembly, 1 for handling, and 2 for installing material in a shorter time with respect to Luxembourg and Verona. In Paris they take 15 minutes and 2 workers for the installation of a door, compared to 4/6 people and 190 minutes in Luxembourg, and 75 minutes and 2 people in Verona. It should be analysed in detail if this is due to the efficiency / non-efficiency of the workers, or to other reasons, such as different types of doors.

In Paris they need more time for preparation but the same amount of workers with respect to the other pilots sites, while in Verona the same behaviour is produced by the reception and unloading activity: these points should be investigated.

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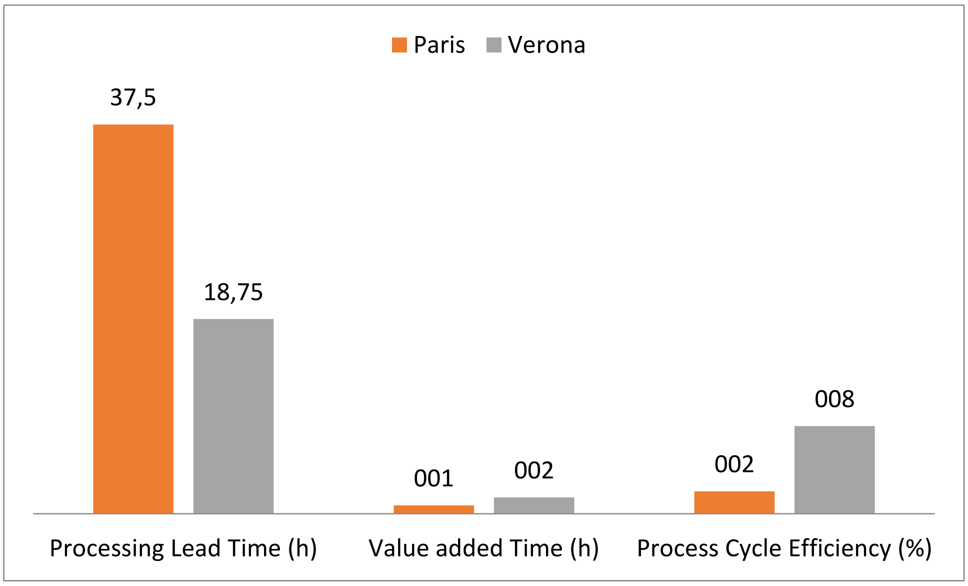

Figure 62 Comparison between Luxembourg's, Paris', and Verona's door VSMs.

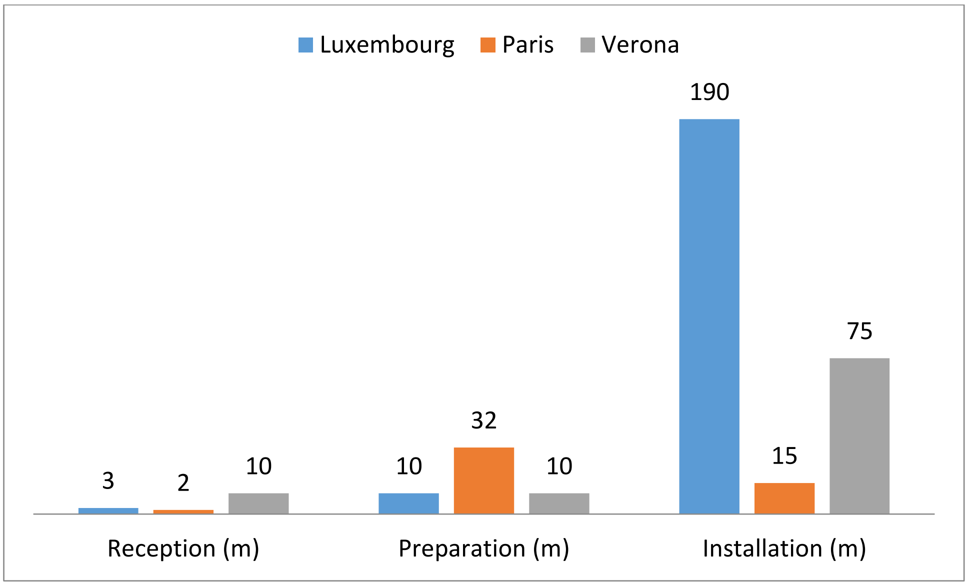

Figure 63 Comparison on doors VSMs with respect to activities

4.1.3 Windows

By using the word widows we represent both normal windows (see Figure 64) and window façades (see Figure 65).

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Figure 64 Windows (ferroealluminio.com)

Figure 65 Example of Window Façade (pixabay.com)

4.1.3.1 Luxembourg

In this VSM presented by Luxembourg about windows (see Annex F), the construction site orders to the supplier and every 6-8 weeks they adjust the site needs following the work plan. The material request is specified weekly to the supplier. When the windows arrive to the construction site:

- they take 6 minutes to receive and unload each of them;
- they take 10 minutes for handling and prepare each of them,
- and 90 minutes to install each window.

The non-value-added times are not present and the number of workers involved is reasonable.

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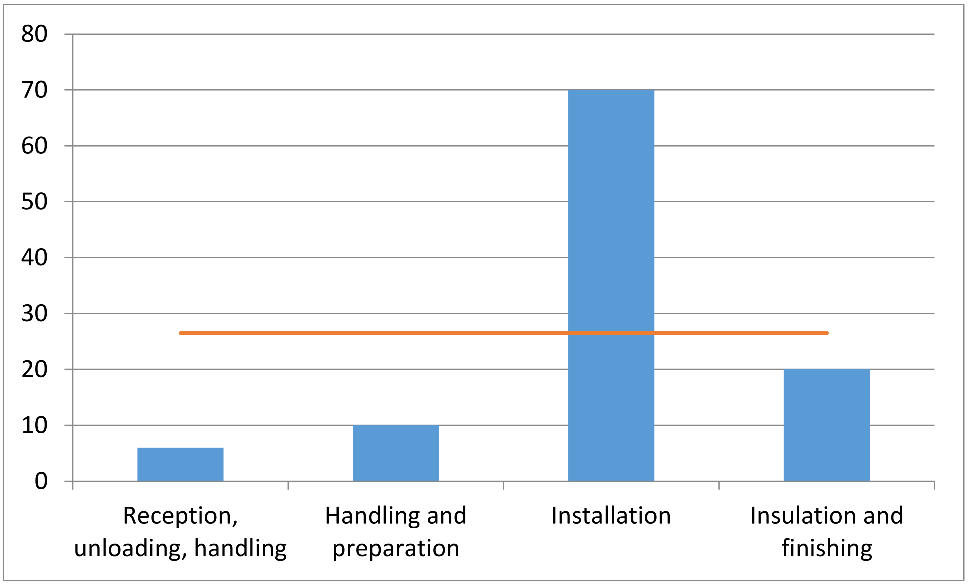

Figure 66 Time for activities for windows, Luxembourg (time expressed in minutes)

The installation is the most expensive activity in terms of time, in this case. An increment in terms of workers could improve the takt time of this process.

4.1.3.2 Paris

In the Paris windows VSM (see Annex F) it is described the entire supply chain including the two kinds of glass supply and the chassis manufacturing; however a description of times before the entrance on the construction side is not shown. Reception, unloading, and internal handling and transportation respect the typical times, while the internal storage takes a long period of 5 days (see Figure 67).

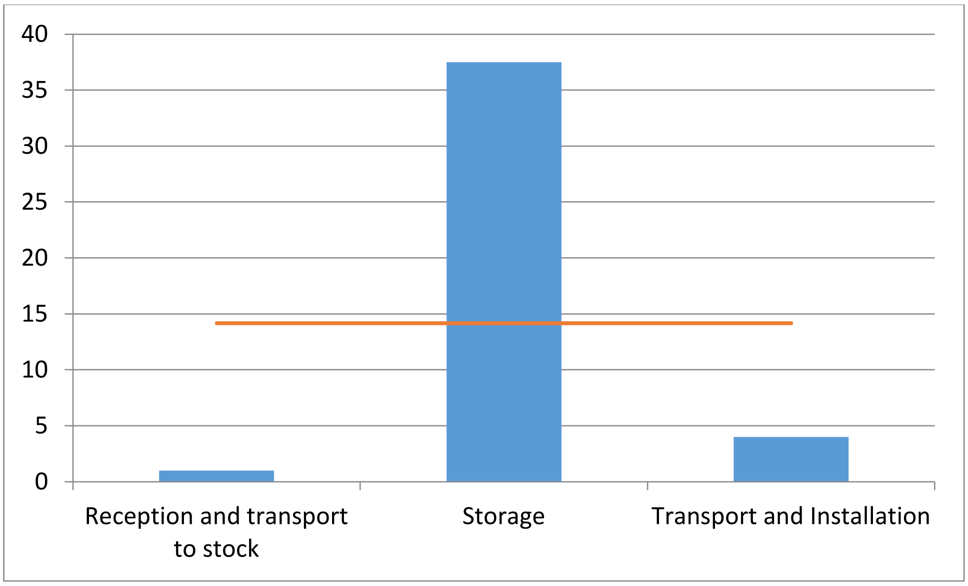

Figure 67 Time for activities for windows, Paris (time expressed in hours)

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The long period wasted in storage could justify, also in this case, the introduction of a CCC for allowing the arrival of material on the construction site when needed.

4.1.3.3 Verona

In the VSM provided by Verona pilot site regarding windows, they also consider the entire supply chain and in a more specific way (see Annex F).

As in other maps, the information flow is very active and continuous and this could suggest the use of a communication and collaboration tool.

The presented VSM is quite straightforward from the beginning to the delivery of windows on the construction site. The very long waiting time is the one before the installation: 2.5 days. The waiting and storage time are very high also in the previous part of the supply chain: a more lean production should be attempted in both cases. Also this VSM could suggest the use of CCCs to store material outside the construction site and make it available only when needed.

A good coordination is needed to make sure the glass arrive when the windows arrive on site, also this could be improved by collaboration tools and by considering the introduction of a CCC. This is also suggested by the high waiting times on site.

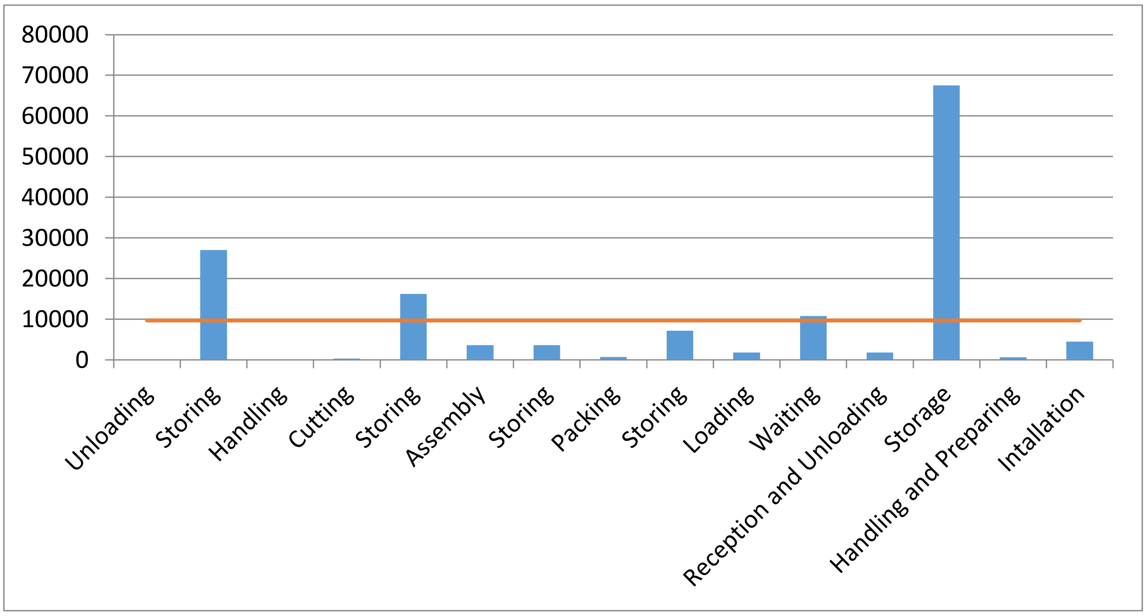

Figure 68 Time for activities for windows before the construction site, Verona (time expressed in seconds)

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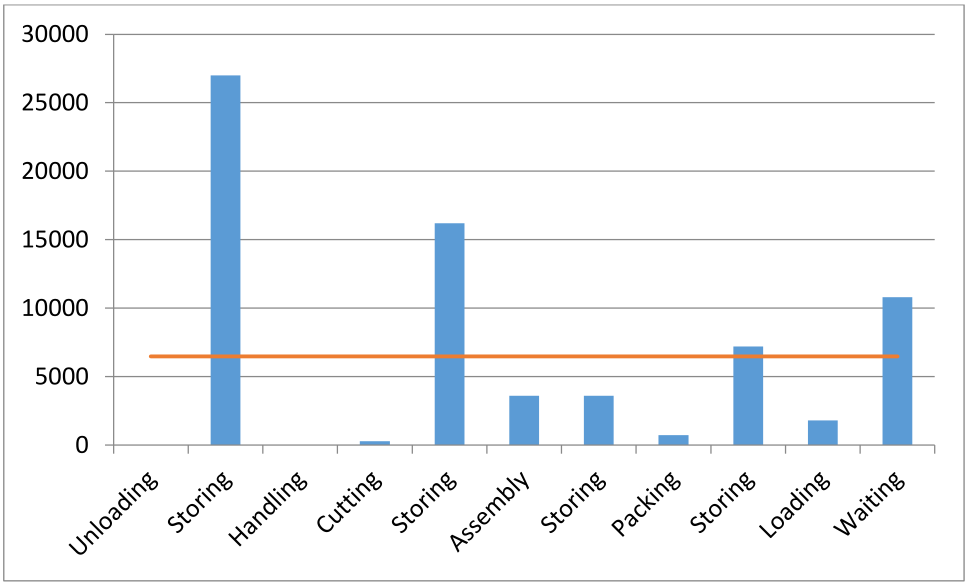

Figure 69 Time for activities for windows before the construction site, Verona (time expressed in seconds)

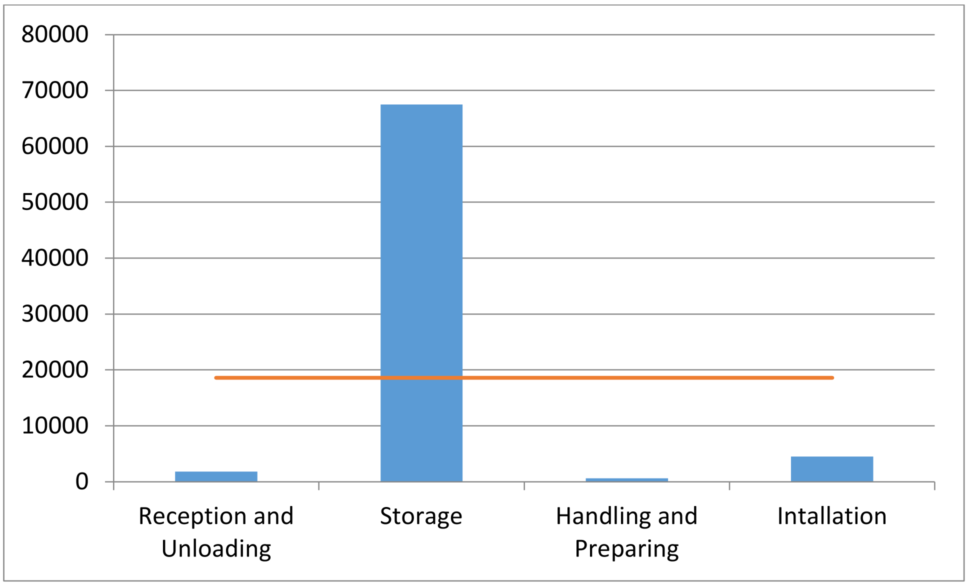

Figure 70 Time for activities for windows inside the construction site, Verona (time expressed in seconds)

4.1.3.4 Comparison on windows

By analysing the three VSMs regarding windows provided by Luxembourg, Paris, and Verona, and in particular considering what happens inside the construction site, the first thing one can notice is that Luxembourg and Verona provided the data with respect to one window, while Paris provided data with respect to the entire set of windows supplied. On the other side we can still provide some comparison: first of all, the value added time of Luxembourg and

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Verona is, respectively, 106 and 101 minutes, very similar as very similar are the times for all the other activities. We can imagine that the 5 hours of Paris divided by the number of windows shows a similar result. In Luxembourg non-added value activities are not present, while in Verona the waiting time in storage area is of 2.5 days, and in Paris of 5 days.

One more comment can be provided on the number of workers needed on each pilot site. In Luxembourg they need 2 workers for each process, while in Paris they need 3 people. This could be reason of a more detailed analysis. In Verona, 2 people are needed for reception and unloading, 1 for handling and 2 couples for installing windows. Of course this number can be heavily influenced with respect to the type of window and façade.

4.1.4 Iron bars

The iron bars are used to produce reinforced concrete.

Figure 71 Example of Iron bars (celsauk.com)

4.1.4.1 Valencia

In the VSM about iron bars provided by Valencia, they provide the supplier with the forecast based on the project and send a weekly order with the reinforcement design. Afterwards:

- a 12 tons truck arrives at the construction site where it is unloaded by 2 people in 30 seconds per bar;
- the material is storage for 6 hours,
- and later on, 2 iron workers work on each bar for less than 7 minutes.

Also in this VSM the waiting time is very long with respect to the other operations. This is due to the fact that the delivery is represented by a full load truck and only two workers are involved in the iron works.

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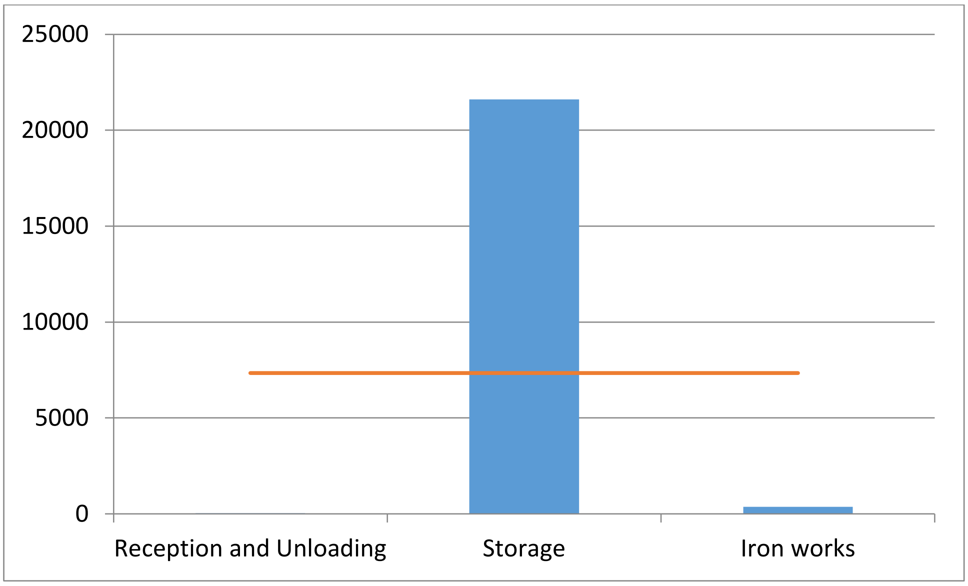

Figure 72 Time for activities for iron bars, Valencia (time expressed in seconds)

4.1.4.2 Verona

The VSM regarding iron bars provided by Verona (see Annex F) is slightly more complicated; indeed, they also map the production of cages for pillars.

The supplier receives the 2 month forecast and the material request together with the structure tables weekly. The supplier provides the shaped iron bars with their location tags.

- Twice a week a full loaded truck arrives at the construction site where it is unloaded.
- Then the material waits 1 week before being used by the iron workers that build the cages for the pillars or / and to bend the bars.
- After that, the material is stored for 1 day before being carried to the exact point of use.
- The installation takes 5 people, more than in the Valencia pilot site.

The waiting and storage time are very relevant when it comes to consider the lead time. The most relevant is the time in which the bars are stored on the construction site before being used. The reason of such a time could be the arrival of a fully load truck. This could motivate the use of a CCC to free some space on the site.

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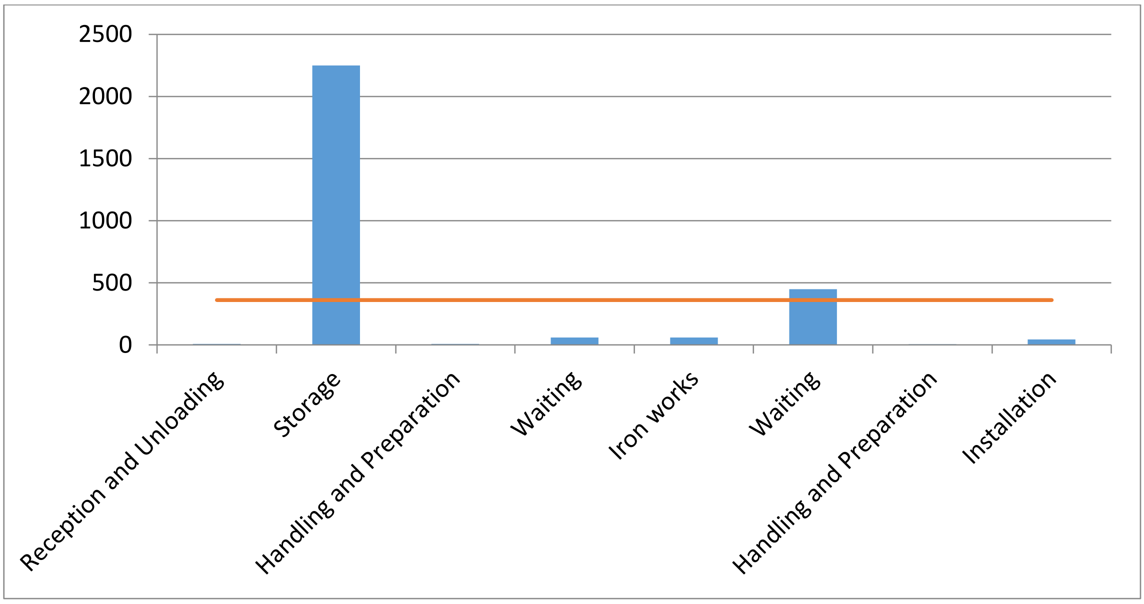

Figure 73 Time for activities for iron bars, Verona (time expressed in minutes)

This map shows that not only the material could be stored in a CCC and carried to the site only when needed, but also some intermediate work, as the one of the iron workers, could be produce outside the site, for example in a dedicated area at the CCC. This would let free some areas at the construction site that is already highly constrained.

4.1.4.3 Comparison on iron bars

A good comparison between the Verona and the Valencia VSM on iron bars is not possible because the maps are very different. In Verona, for instance, they also consider the production of cages for pillars that occurs in the construction site, thus the VSM gets split in two parallel paths that re-join at some point. A similar thing is not done or represented by the Valencia VSM. Moreover, the Verona VSM considers the stream for a certain amount of bars needed for 50 m^2 of ceiling, while in Valencia they consider a 120 bars batch. However, we can still detect that the amount of time spent by the bars in storage areas in the Verona's site is much higher than the one in Valencia: 1 week compared to 6 hours. One more thing we can comment on is the number of workers needed in the two pilot sites: in Verona the number of workers involved is much higher. In Valencia, 2 workers unload the vehicle and 2 iron workers work the material on its point of use; in Verona, 2 workers download the vehicle, then some part of the material is prepared by 1 person and worked by 2 iron workers, then the material is handle with the crane and installed by 5 workers.

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4.1.5 Prefabricated Balconies

Figure 74 Example of prefabricated balconies (halfen.com)

4.1.5.1 Luxembourg

In the VSM on prefabricated balconies reported by Luxembourg (see the Annex F), the site manager orders 2 weeks before the site needs and defines the delivery process 1 day before the prefabricated arrival. After the unloading of the prefabricated,

- the struts arrive at the construction site on a weekly order base
- and they are installed in 1.5 hours.
- Then, the balcony is moved by 4 people and by crane to its location.
- Afterwards, the sealing is performed and the balcony needs to wait 28 days to get dried. In the VSM the drying process is represented as a leading time, thus a non-value added activity, even if it is part of the process, and we will consider it as an added value activity.
- After this time, the struts are withdrawn and the balcony secured.

No waiting times are added, thus from the VSM it seems that the process is straightforward. It is clear that the average time to install a prefabricated balcony is driven by the time needed by the element to dry, thus not much can be done to improve the process.

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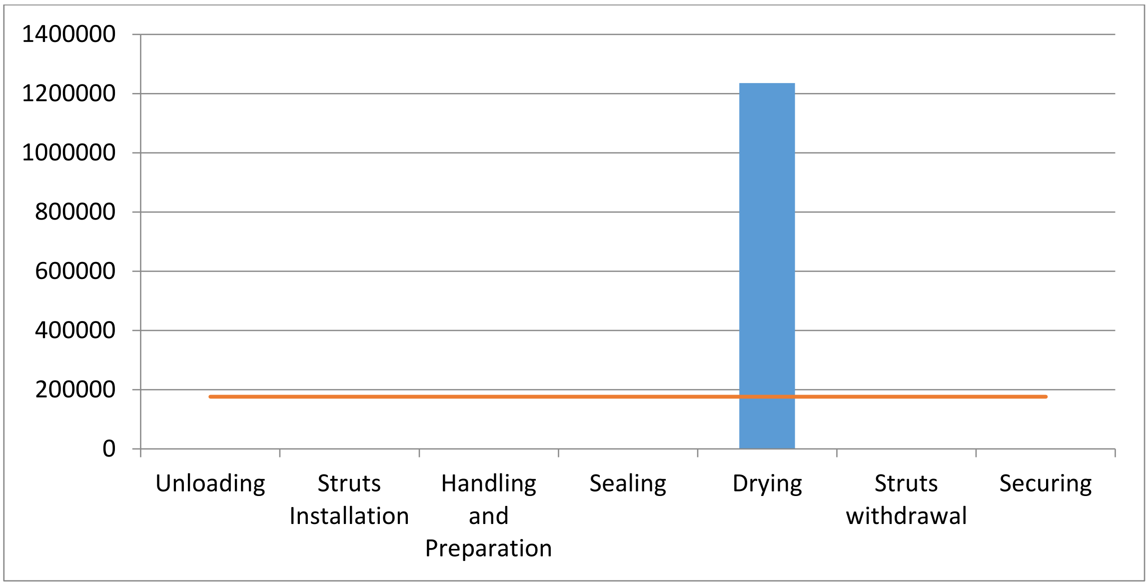

Figure 75 Time for activities for prefabricated balconies, Luxembourg (time expressed in minutes)

4.1.6 Plaster wall

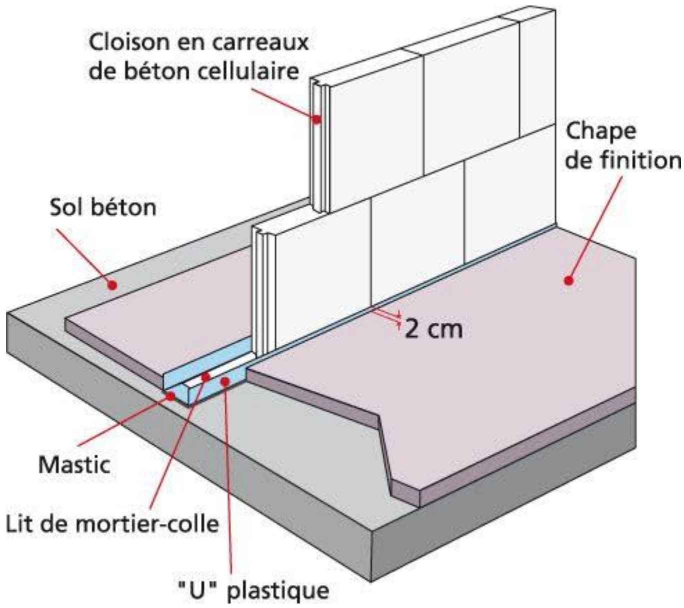

Figure 76 Example of plaster wall blocks to be set on a ribbon

4.1.6.1 Luxembourg

The Luxembourg pilot site is the only one that describes and maps the plaster wall (see Annex F). In the VSM we can see that the order is done once and each week they provide the supplier with the necessary modification or explanation following the project. The supplier, one week in advance, communicates the requests to its supplier.

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- The materials for plaster wall, such as plaster wall tiles, glue, coating, are unloaded by 3 people,
- These materials are set on the storage area, where they wait for 5 days before being used.
- Then the plotting is performed in one day,
- and the ribbons are installed.
- After that, the other processes are performed, such as shaping, cutting, jointing, etc. in 1 day.
- At this point, 1 day is needed for drying.
- After that, one worker performs 20 minutes coating and 20 minutes cleaning.
- We finally have a high PCE = 70.22%

As we can see, the only very long time, if we do not consider the drying, that cannot be avoided, is the time the materials waits in the storage area before being used. This could be a good reason to justify the use of a CCC.

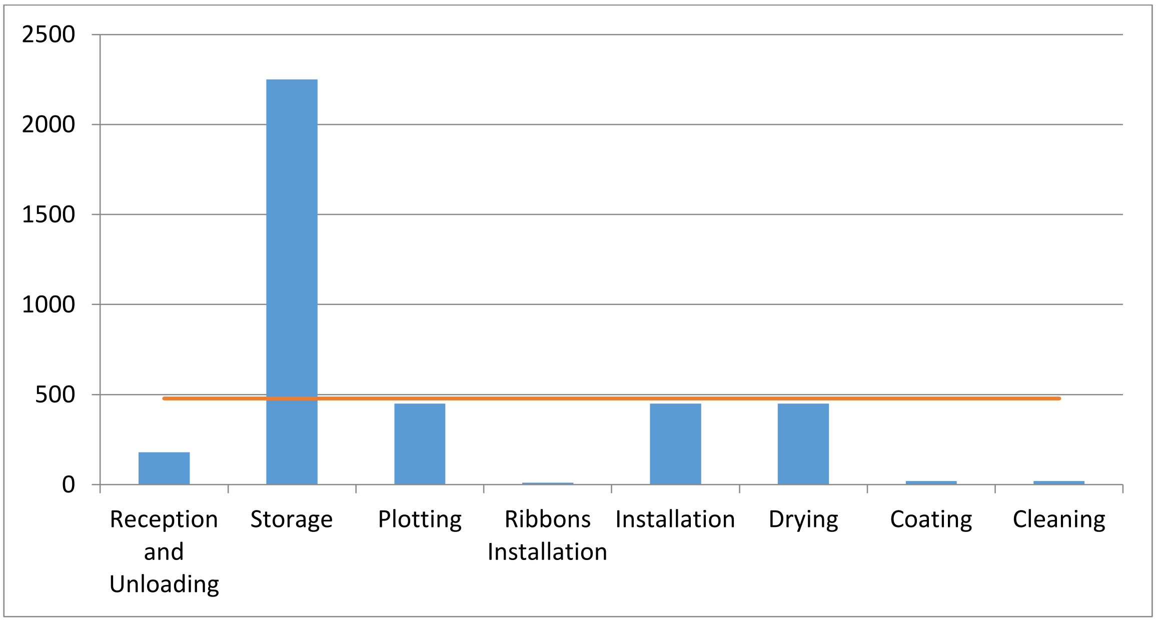

Figure 77 Time for activities for plaster wall tiles, Luxembourg (time expressed in minutes)

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4.1.7 Pipelines

Figure 78 Example of Pipelines (wikipedia.org)

4.1.7.1 Valencia

The Valencia Pilot site also performed a VSM regarding the pipelines (see Annex F). For this material, the suppliers are given with the project forecast and a weekly order.

- The supplier provides a full load truck of pipelines that are received and transported to the storage areas where they stay for 15 days.
- After the storage, the pipelines are moved to the point of installation and installed by 4 people in 20 minutes per piece.

The PCE is very low, being equal to 0.30%. The waiting time before installation is particularly long and this storage could be done in a CCC.

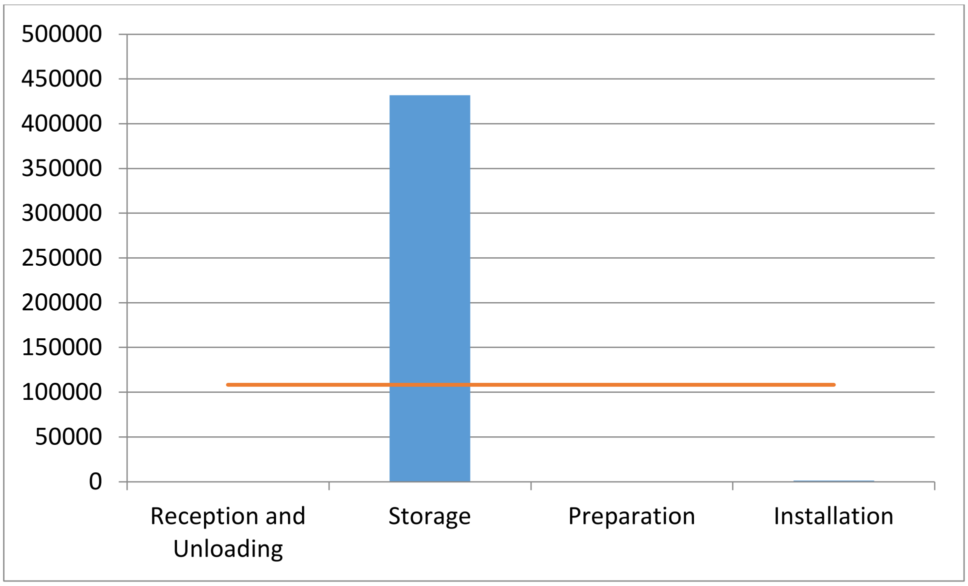

Figure 79 Time for activities for pipelines, Valencia (time expressed in seconds)

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4.1.8 Concrete

Figure 80 Concrete (wikipedia.org)

4.1.8.1 Valencia

In the VSM regarding concrete that the Valencia Pilot site provided (see Annex F), the concrete supplier is aware of the forecast based on the project. This could support the theses of installing collaboration and communication ICT tools between the stakeholders.

- The supplier receives a weekly order and under request can send a large number of concrete mixers per day: 7 mixers.
- Before the mixers arrival, 5 workers perform preparation and excavation works.
- After the reception of the concrete mixers the concrete is installed by 3 people.

In this process, no waiting times are reported because of the fact that the concrete cannot wait in storage areas. Thus, the installation of a CCC is irrelevant for concrete.

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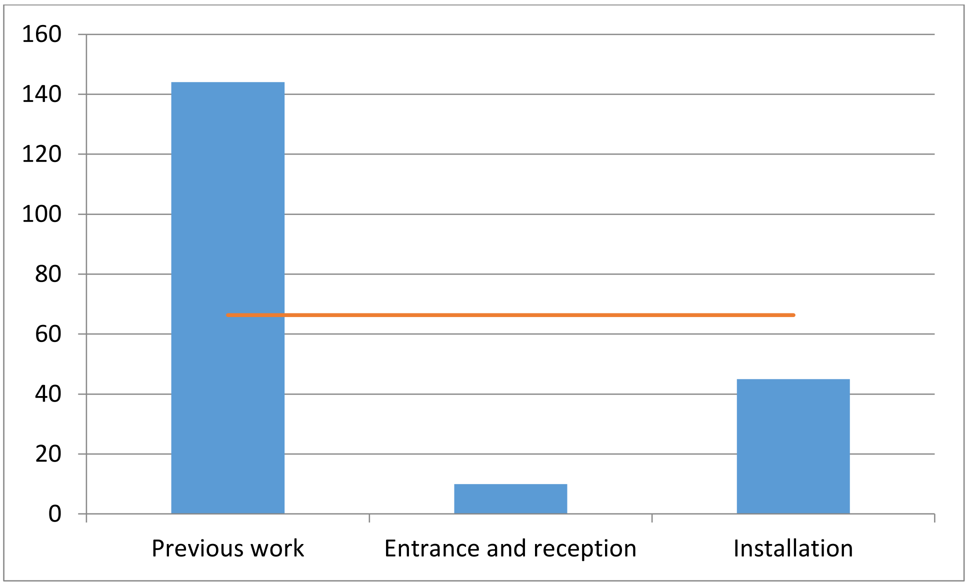

Figure 81 Time for activities for concrete, Valencia (time expressed in minutes)

4.2 Conclusions on VSM

By analysing the VSM reported by the pilot sites coordinators, we could see that the most relevant problem to make the processes leaner is the time that materials spend in storage areas before being used for construction. This time is particularly high especially right after the unloading activity.

We also notice that not all the vehicles are fully loaded when entering the construction site.

Another point we noticed is the continuous information flow, where also forecast and other kind of information and document are exchanged with the suppliers many times during the project. Thus the information process should be improved and enhanced.

Eventually, one thing that can be seen on the VSMs, even if it is not evident, is the many trips that are needed to carry material to the construction site and their routes that make the processes and the value stream long and weak.

In the following we propose some possible solutions to the listed problems.

4.2.1 Introduction of a CCC

The introduction of a CCC can decrease the waiting times of material on the construction site, decreasing the space used for and on the storage areas, decreasing congestion, making the work leaner because so materials can be provided exactly when needed. Using the CCC will also decrease the chances of material to be stolen or damaged on site and the use of wrong material or wrong installation of materials. The introduction of a CCC could also improve the traffic management in entrance and on site. Eventually, the introduction of

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a CCC can reduce nuisances and environmental constraints such as noise, congestion, pollution, etc.

In the Paris pilot site there is no specific tools or methodology to manage storage areas: no control on storage duration, no comparison with the construction plan. That is why sub-contractors stock for several days. Some sub-contractors are forced to stock on site because their suppliers do not want to stock material on their site. This can provide an example of how a CCC introduction accompanied with ICT collaboration tools can be of extreme relevance.

One more thing is that in many cases the trucks are fully loaded, but in other cases the load could be optimized by the introduction of a CCC.

4.2.2 Use of Collaboration ICT Tools

The information flow is continuous between the many stakeholders so as the exchange of forecasts and documents. Thus, a collaboration and communication ICT tool between the main contractor, the subcontractor, and the suppliers could be important and suggested.

Collaboration tools together with CCCs for making things arrive at the same time on the construction site could be very important, see, e.g., the synchronization shown for the arrival of windows and glasses at the same time.

4.2.3 Introduction of Optimisation tools and algorithms

To overcame the routing problems concerning the vehicles and the scheduling problems concerning the construction site: optimisation tools and algorithm can be defined and used by the main contractor and the other stakeholders.

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5 Conclusions

In this Deliverable we described the Process Management and its techniques. In particular we treated in detail two tools: the Process Mapping and the Value Stream Mapping.

5.1 Application of Lean Management tools to the Construction Industry

One first contribution is the use and the adaptation of the Process Mapping (PM) and the Value Stream Mapping (VSM) to the construction industry. We adapted these methods to the construction industry with support of ICT tools. After the application of these methods we can conclude that:

- the VSM is not easy to be applied to the construction industry because:
  - The stream of materials is not necessary linear, but many parallel activities can take place.
  - Moreover, it is not easy to detect a relevant object to study, due to many assembly activities and to the use of many materials in order to complete one part of the construction site. On same map batches and unique pieces can be considered making the comparison unclear.
  - The takt time is not possible to be computed except for very simple construction components.
  - Many peculiarities cannot be considered in the VSM: such as the different time to handle material due to the different location of storage areas and the different layout of the construction sites.

  More generally speaking, processes are not standard, so VSM is not the best tool to be used in construction industry even if some important conclusions could be drawn. These are reported in the following point.

- The PM resulted more relevant in the construction industry. Thanks to it we could detect many good practices and problems that led us to the following conclusions.

5.2 The main conclusions obtained thanks to Process Management methods

Mapping the logistics processes and some relevant materials in a similar manner on the four pilot sites enables to compare easily the sites. By doing so we have been able to compare how things are done in different environments, and to understand their main problems, weaknesses, and strengths. The main conclusions are listed in the following.

- Thanks to the analysis of the PMs of the four pilot sites we could detect the following current problems:

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- Lack of communication and planning tools and methods;
    - Lack of congestion planning;
    - Lack of scheduling for pickups and deliveries;
    - Lack of scheduling for storage areas;
    - Lack of scheduling for shared equipment.
- These points helped us to define some possible good practices or solutions, also supported by ICT collaboration tools:
    - Weekly plan of arrival and departures and Booking operations;
    - Weekly Schedule for shared equipment;
    - Weekly schedule of the storage areas and storage area booking;
    - The use of CCC.
- Thanks to the analyses of the VSMs of the four pilot sites we detected the following problems:
    - High storage times and large storage areas on site;
    - Low information flow and collaboration among the stakeholders;
    - Long trips for supply and pickups on non-fully charged vehicles.
- These detected problems helped us to determine the possible solution actions:
    - Introduction of CCCs;
    - Use of Collaboration ICT Tools;
    - Introduction and use of Optimisation tools and algorithms.

All these points are explained in details in Chapter 3 and Chapter 4.

5.3 Future steps

The above conclusions confirm interest in evaluating benefits of CCCs, ICT tools, and optimization algorithms. The use and introduction of these methods will potentially improve all the KPIs detected in Task 2.2.

The detected problems and solutions will help in defining the main goals of our action to be included in *Task 4.1 Target improvements setting*.

We will define a set of business models for the management of the CCCs. This will include the collaboration methods and techniques. (see *Task 3.3 Business Model Development and Analysis*).

We will define a way of deciding where to locate CCCs and how to deliver and collect materials from them. This will be done by studying and introducing mathematical model and optimization algorithms (see *Task 3.4 Optimisation Models, Algorithms, and Tool*).

The previously defined method will thus be used for the development of *Task 4.2 Solution Design* and *Task 4.3 Solution Test and Simulation*.

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Moreover, some of the best practices to be applied have already been collected in the present work and will furnish an input for *Work Package 6 Replicability and Take up*.

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7 Annex A: the Business Processes Description

7.1 Distribution Network Processes

7.1.1 Process 1: Sourcing

Process 1: Sourcing	
Purpose	The purpose of the *Process Sourcing* is to select suppliers for acquiring materials and services that are needed in the construction site.
Inputs	– Need of materials and equipment to accomplish the construction project – Need of waste collection for disposal
Activities	– Specify the requirements: enables to identify the needs and define the requirements – Explore market: enables the identification of materials and/or suppliers qualified and capable to deliver the requested material, equipment or service – Call for tenders: enables to ask request for bids/proposal/quotation – Select the bid/proposal/quotation: enables the selection of the supplier and reference of materials best suited to the requirements of the contractor – Contractualization: enables to negotiate and define the type of contract that best suits the supply
Outputs	– Set of suppliers – Contracts

7.1.2 Process 2: Ordering

Process 2: Ordering	
Purpose	The purpose of *Process Ordering* is to acquire the needed materials, equipment, and services.
Inputs	– Material, equipment, and service needs – Set of suppliers – Contracts

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	–	Possible complaints that need a return of material or a reorder
Activities	–	Place an order of material, equipment, or service request at a desired date
	–	Readjust order: enables to update the order if there was an error and if the order doesn't fit needs on the worksite
	–	Follow order status
	–	Prepare expedition: enables the delivery of the materials (see Process 3: Delivery)
	–	Validate invoice: enables to check the conformity of the invoice with the contract
	–	Submit payment: enables to execute payment to the supplier
	–	Match the delivery with the order after delivery
	–	
Outputs	–	Purchase order: the document which indicates types, quantities and agreed prices for materials, equipment, or services.
	–	Delivery note: the document which accompanies the delivery and list details about the materials delivered.
	–	Preparation of expedition

7.1.3 Process 3: Delivery

Process 3: Delivery		
Purpose	The purpose of *Process Delivery* is to transport the goods from suppliers to the construction site.	
Inputs	–	Purchase order
	–	Delivery note
	–	Preparation of expeditions
Activities	–	Schedule (agreed) the date and hour of delivery
	–	Load materials at the supplier
	–	Transfer in intermediate storage
	–	Transport from the supplier to the construction site

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		– Manage and communicate possible exceptions: late/early arrival (see Process 10: Planning and Scheduling Resources) – Complain: enables to address a complaint if there is an error (e.g. Price, quantity, reference) (see Process 11: Complaint management)
Outputs		– Materials (and trucks) arrival at the construction site – Possible complaints

7.2 Construction Site Processes

7.2.1 Process 4: Material Reception and Expedition

Process 4: Material Reception and Expedition	
Purpose	The purpose of *Process Material Reception and Expedition* is to manage at the arrival of the vehicle, its loading for delivering materials or unloading for collecting waste and returning materials, and the activities involving the trucks from the entrance to the exit of the construction site.
Inputs	– Loaded and empty trucks entering the construction site – Materials to be unloaded – Waste and return materials to be loaded
Activities	– Execute entrance procedures (see Process 12: Entrance and Exit Management) – Assignment of the loading/unloading zone to the driver – Unload material (this should be exploded for each of the unloading possibilities, crane, forklift, etc. And also for different materials, typical the example of concrete, where unloading is performed by directly using concrete from the truck). – Check conformity (quality, quantity, type) of materials – Manage the trucks and trucks congestion (optional). – Load return material or waste (again, this should be exploded for each methodology) – Verify conformance of the delivery note – Match the delivery with the order – Complain: enables to address a complaint if there is an error

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		(e.g. Price, quantity, reference) (see Process 11: Complaint Management)
	–	Sign the delivery note
	–	Execute exit procedures (see Process 12: Entrance and Exit Management)
Outputs	–	Loaded and empty trucks exiting the construction site
	–	Materials unloaded
	–	Waste and return materials loaded

7.2.2 Process 5: Inventory and Storage Management

Process 5: Inventory and Storage Management		
Purpose	The purpose of *Inventory process* is to specify the size and placement of stocked goods to avoid overstock or shortage. The purpose of *storage management process* is to provide an operational management of the storage, the assignment of the storage location for the materials.	
Inputs	–	Information regarding materials storage, orders, needs, and use
	–	The construction plan (Gantt chart, etc.)
	–	Material arrival and departure, etc.
Activities	–	Decide storage location in construction site
	–	Decide material location in storages
	–	Track materials on site (quantity, location, entrance and exit from storages)
	–	Confirm availability of materials
	–	Make an inventory to detect missing or damaged materials
	–	Establish replenishment/use replenishment techniques to anticipate use
	–	Track equipment on site
	–	Track returnable packaging on site
Outputs	–	Information regarding materials storage, orders, needs, and use

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7.2.3 Process 6: Material Handling and Equipment Management

Process 6: Material Handling and Equipment Management	
Purpose	The *Process Material Handling and Equipment Management* has the purpose of moving materials within the construction site by using the right equipment to guarantee the continuity of the activities.
Inputs	– Need of material handling derived from construction activities: from unloading to storage, from unloading to use, from storage to storage, from storage/collection/housekeeping to sorting, from sorting/storage to loading, etc. – Knowledge of all the material and equipment location and status – Status of construction activities
Activities	– Select adequate equipment – Select adequate materials for handling – Move equipment – Move material to the adequate location – Track materials and equipment (availability, location) – Ensure maintenance of equipment
Outputs	– Material and equipment ready where needed. – Knowledge of all the material and equipment location and status

7.2.4 Process 7: Housekeeping

Process 7: Housekeeping	
Purpose	The purpose of *Process Housekeeping* is to minimize the degradation and pollution of materials and maximize safety for workers in keeping the site clean and tidy.
Inputs	– Need of housekeeping and waste collection – Location of the housekeeping need
Activities	– Tidy the worksite (correct place of materials, equipment, containers)

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	– Sweep floors and collect waste – Remove waste (see Process 8: Waste Management) – Remove material to be returned (surplus and unused materials) (see Process 9: Return Management) – Secure material stored on sensitive areas (on roofs, open floors, excavations, trenches) – Secure dangerous materials (flammable and explosive) – Keep fire extinguisher station clear and accessible – Complain (see Process 11: Complaint Management)
Outputs	– Clean, safe, and tidy site – Waste collected – Material to be returned collected organized and complaints addressed

7.3 Reverse Logistics Processes

7.3.1 Process 8: Waste Management

Process 8: Waste Management	
Purpose	The *Process Waste Management* purpose is to collect construction waste, demolition debris, packaging waste, etc., recycle and sort material. Minimizing waste, maximizing reuse, recycling or reprocessing. Organize and sort waste following legislation. Organize the disposal of waste that has been collected and sorted.
Inputs	– Waste location, type, quantity, contracts with subcontractors and dumpsites, etc. – Material ready to be loaded and dumped – Information on containers and bins
Activities	– Sorting: enables the identification of waste and sorting of materials in the appropriate container. – Recycle/reuse – Collection: Containers and bins containing waste are collected. – Track waste on site (quantity, location, etc.)

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	–	Evaluate level of fulfilment of containers and bins
	–	Scheduling (agreed) on data and hour of collection at construction site
	–	Possible exceptions: late/early arrival of collector
	–	Communication of possible exceptions on late or early arrival
	–	Exception management (see Process 10: Planning and Scheduling Resources)
	–	Arrival to the construction site
	–	Loading (see Process 4: Material reception and expedition)
	–	Departure from construction site (see Process 12: Entrance and Exit Management)
	–	Possible intermediate storage
	–	Transport to dump site
	–	Arrival to the dump site.
Outputs	–	Information on the exiting material
	–	Material exit and disposal

7.3.2 Process 9: Returns Management

Process 9: Returns Management		
Purpose	The purpose of *Process Returns Management* is to organize and perform unused and unsuitable material exit and return to sub-contractor or supplier and give returnable packaging back to the supplier (e.g. Pallets)	
Inputs	–	Material to be returned location, type, quantity, complaints managements information, information from the sub-contractors and suppliers
	–	Packaging which need to be returned to the supplier
Activities	–	Schedule (agreed) a date and hour of collection at construction site
	–	Possible exceptions: late/early arrival
	–	Communication of possible exceptions on late or early arrival
	–	Exception management (see Process 10: Planning and Scheduling Resources)

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	–	Loading (see Loading and unloading) Departure from construction site (see Process 12: Entrance and Exit Management) Possible intermediate storage Transport from the construction site to sub-contractor.
Outputs	–	Return of unused and unsuitable materials.

7.3.3 Process 10: Planning and Scheduling Resources

Process 10: Planning and Scheduling Resources	
Purpose	The purpose of *Process Planning and Scheduling Resources* is to schedule and plan the activities and the needed resources such as workforce, equipments, and spaces. We recall that *planning* is the process of identifying all activities necessary to complete the project while *scheduling* is the process of determining the sequential order of activities, assigning planned duration and determining the start and finish dates of each activity. Planning is a prerequisite to scheduling because there is no way to determine the sequence of activities until they are not defined.
Inputs	– Material arrival and departure – Work activities (defined in plan such as Gantt chart) – Material handling needs – Information on storage areas (such as capacity, etc.)
Activities	– Plan and schedule workforce for arrival, unload, material handling, and load – Plan and schedule equipment for arrival, unload, material handling, and load – Plan and schedule spaces for arrival and unload, and load – Provide a plan for storages use (including a possible layout definition) – Plan and Assign the materials to the storage areas (on the basis of the place where material is needed, on the basis of capacity, etc.)

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	–	Plan and Assign the material to a specific place into the storage areas
Outputs	–	Plans, schedules and reservation for the main resources (workforce, equipment, spaces)

7.3.4 Process 11: Complaint Management

Process 11: Complaint Management		
Purpose	The purpose of *Process Complaint Management* is to address complaints, non-conformities, and resolve disputes.	
Inputs	–	Non-conformity issue
Activities	–	Express complaint: enables the complainant to provide all relevant information about the complaint (event date, complainant, issue, involved people or organisations, category, priority, etc.)
	–	Submit complaint: enables to address the complaint to the concerned organisation(s) via any mode of communication (email, telephone, in person, etc.). It can imply reorder or return management.
	–	Action: enables to solve the problem and do a follow-up of the situation
	–	Validate solution: enables to validate the effectiveness of solution proposed
Outputs	–	Solved complaints (could be for materials, reordering or returning materials).

7.3.5 Process 12: Entrance and Exit Management

Process 12: Entrance and Exit Management		
Purpose	The purpose of *Process Entrance and Exit Management* is to grant rights to authorized people and vehicles to the construction site while maintaining safety in and out the worksite and efficient operations on the worksite.	
Inputs	–	Arrival and exit of vehicles and people

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Activities	– Receive request (identity, period) – Verify request – Provide access rights (provide, remove, restrict) – Check access on site (temporization) – Monitor access rights – Check travel documents – Visual check in the truck for materials – Visual check for equipment – Track people and vehicles movements
Outputs	– Status on movement of vehicles, people, and material entering and exiting from site.

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8 Annex B: the Questions for Process Mapping

In the following we report the questions we provided to Partners to perform the **Process Mapping**. In particular we list here questions from Process 1 to 12.

8.1 Questions for Process 1: Sourcing

Questions for Process 1: Sourcing
1. *How do you define the materials to be used in the construction site and their requirements?* 2. *How do you define the equipment to be used in the construction site?* 3. *How do you define the services needed?* 4. *Who is in charge of it? Who does it?* 5. *How do you explore the market?* 6. *Do you select from a list of suppliers?* 7. *Do you create a list of suppliers?* 8. *Who does it?* 9. *How do you call for tenders? Which procedures are used (RFQ, RFP, RFI…) are used?* 10. *Who does it?* 11. *How do you select the bids/proposals?* 12. *Who does it?* 13. *How do you negotiate?* 14. *How do you define the type of contracts?* 15. *Who does it?* 16. *What kind of contracts do you use?* 17. *Which improvements could ease your job?* 18. *Etc.*

8.2 Questions for Process 2: Ordering

Questions for Process 2: Ordering
1. *How orders are placed?* 2. *Who is in charge of the order placement?* 3. *How often an order is placed with respect to a certain provider?* 4. *Which documents are involved?* 5. *Can you follow the order status? How?* 6. *Can you validate the invoice?* 7. *How do you submit the payment?* 8. *Which improvements could ease your job?* 9. *Etc.*

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8.3 Questions for Process 3: Delivery

Questions for Process 3: Delivery
1. *Do you agree the delivery date and hour? How? Who does it?* 2. *Are CCCs or other kind of depot used?* 3. *Do materials arrive directly from the production site?* 4. *Do you make use of couriers?* 5. *How do you manage late/early arrival at the construction site?* 6. *How do you manage nonconformity and complaints?* 7. *Do you perform check on materials? How?* 8. *Which improvements could ease your job?* 9. *Etc.*

8.4 Questions for Process 4: Material Reception and Expedition

Questions for Process 4: Material Reception and Expedition
1. *How is managed the arrival of the provider's trucks at the building site?* 2. *Are schedule agreed with the providers?* 3. *How many arrivals can be managed together?* 4. *Who is in charge of the arrival acceptance?* 5. *How many people are needed?* 6. *Is a particular technology used? For example, sensors, badges, infrared, etc.* 7. *Are some kinds of check on the arriving material performed? I.e. quality check, quantity check etc.* 8. *Is there specific place inside the building site for unloading? More than one?* 9. *How do you assign loading and unloading areas?* 10. *Do you load and unload different materials in different ways?* 11. *How long does it take, in average, to unload a truck?* 12. *How many people are needed/involved?* 13. *Who is in charge?* 14. *What kinds of equipment are needed? Crain, fork lift, etc.* 15. *Is it possible to unload more than one truck at a time?* 16. *Are some kinds of check on materials performed after unloading the trucks? I.e. quality check, quantity check etc.* 17. *How do you manage unused or unsuitable materials?* 18. *How is waste loaded?* 19. *Are different kinds of material mixed on the same vehicle when leaving the building site?*

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20. *What kinds of equipment are used for loading?*
21. *How many people are involved?*
22. *Who is in charge?*
23. *How much time is needed, in average, for loading?*
24. *How much space is available for truck loading?*
25. *Are the same space and equipment used for both loading and unloading?*
26. *How material (normally waste) departure is managed?*
27. *Is there a process to check who (trucks) and what is leaving the building site?*
28. *How many people are involved?*
29. *Who is in charge?*
30. *Are schedules used?*
31. *Are some documents needed?*
32. *How do you verify material conformance?*
33. *How do you manage the congestion on site?*
34. *How do manage exit process?*
35. *Which improvements could ease your job?*
36. *Etc.*

8.5 Questions for Process 5: Inventory and Storage Management

Questions for Process 5: Inventory and Storage Management
1. *How materials are stocked?* 2. *Are there one or more storage points?* 3. *Is it followed an order when stocking materials in storage points?* 4. *Are the storage points temporary or they last till the end of the works?* 5. *Is somebody in charge of the storage points and storage policy?* 6. *How do you decide where to locate storages in the construction site?* 7. *How do you truck materials on site? Who does it?* 8. *How do you check availability of materials on site?* 9. *Do you use replenishment techniques to anticipate use?* 10. *Do you make inventories to detect missing or damaged materials?* 11. *Are materials moved more times inside the same storage point? How is this done? Using which equipment?* 12. *Do you track equipment on site? How? Who does it?* 13. *Do you truck packaging on site (like pallets)? How? Who does it?* 14. *Which improvements could ease your job?* 15. *Etc.*

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8.6 Questions for Process 6: Material Handling and Equipment Management

Questions for Process 6: Material Handling and Equipment Management
1. *Are materials left where unloaded?* 2. *Are materials carried directly to the storage points?* 3. *What kinds of equipment are used to move materials from unloading position to storage points?* 4. *How long does it take?* 5. *How many people are needed?* 6. *Are the material movement and repositioning recorded somewhere? Paper note, file, just oral, etc.* 7. *How materials are moved in the construction site?* 8. *Which equipment is used to do it?* 9. *Who does it?* 10. *Who is in charge?* 11. *How many people are needed?* 12. *Are materials moved just when they are needed for construction?* 13. *Are materials moved from one storage point to other storage points?* 14. *How many times are materials moved?* 15. *Are there some materials that are moved more often than others?* 16. *Do you track materials and equipment before and after use? How? Who does it?* 17. *Do you ensure material equipment? How?* 18. *Which improvements could ease your job?* 19. *Etc.*

8.7 Questions for Process 7: Housekeeping

Questions for Process 7: Housekeeping
1. *Do you perform housekeeping?* 2. *Who does it?* 3. *Do you plan it?* 4. *When do you remove waste?* 5. *How do you remove waste or surplus material?* 6. *Where do you stock it?* 7. *Who does it?* 8. *How do you secure material and areas?* 9. *Which improvements could ease your job?* 10. *Etc.*

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8.8 Questions for Process 8: Waste Management

Questions for Process 8: Waste Management
1. *How do you manage waste?* 2. *Who is in charge of it?* 3. *How do you collect construction waste, demolition debris, and packaging waste?* 4. *Do you reuse waste?* 5. *Do you recycle and reprocess?* 6. *How do you sort waste?* 7. *Do you have dedicated waste storages in the construction site?* 8. *Is waste moved more than once inside the building site?* 9. *How waste is moved from one part to another of the building site?* 10. *Which equipment is used?* 11. *Do you make use of subcontractors for waste management?* 12. *Do you have containers and bins?* 13. *When do you perform disposal?* 14. *Who does the disposal?* 15. *Which improvements could ease your job?* 16. *Etc.*

8.9 Questions for Process 9: Return Management

Questions for Process 9: Return Management
1. *Do you return material?* 2. *How do you return unsuitable and exceeding materials?* 3. *Do you return pallets?* 4. *Who is in charge of it?* 5. *How do you arrange the return?* 6. *Where do you storage the materials to be returned?* 7. *Which improvements could ease your job?* 8. *Etc.*

8.10 Questions for Process 10: Planning and Scheduling Resources

Questions for Process 10: Planning and Scheduling Resources
1. *Do you plan resources such as workforce, equipment, and places in advance for entrance exit management?* 2. *And for loading and unloading?* 3. *And for material handling?*

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4. *If so, how do you do it?*
5. *Do you perform scheduling?*
6. *Do you have a plan for the use storage and for their layout?*
7. *Do you assign different materials to different storage areas? How?*
8. *Do you assign specific places into the storage areas to specific materials? How?*
9. *Which improvements could ease your job?*
10. *Etc.*

8.11 Questions for Process 11: Complaint Management

Questions for Process 11: Complaint Management

1. *How do you manage non-conformity issues?*
2. *How do you manage complaints?*
3. *How do you express and submit complaints?*
4. *What actions are performed?*
5. *How do you solve disputes?*
6. *Which improvements could ease your job?*
7. *Etc.*

8.12 Questions for Process 12: Entrance and Exit Management

Questions for Process 12: Entrance and Exit Management

1. *How do you manage the access to the construction site?*
2. *Which documents are required? Travel documents?*
3. *Do you need to have a request in advance?*
4. *Do you use badges?*
5. *Do you perform visual check for people?*
6. *And for materials?*
7. *Which improvements could ease your job?*
8. *Etc.*

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9 Annex C: How to download and Install yEd Graph Editor, and How to Use the BMPN on yEd Graph Editor

In this Annex we describe how to download and install the freeware we suggested the partners to use in order to perform the ***Process Mapping****, yEd Graph Editor. We also explain the use of the BPNM on the freeware.*

9.1 How to download and Install yEd Graph Editor

Step 1) Go to http://www.yworks.com/products/yed and select **Downloads**.

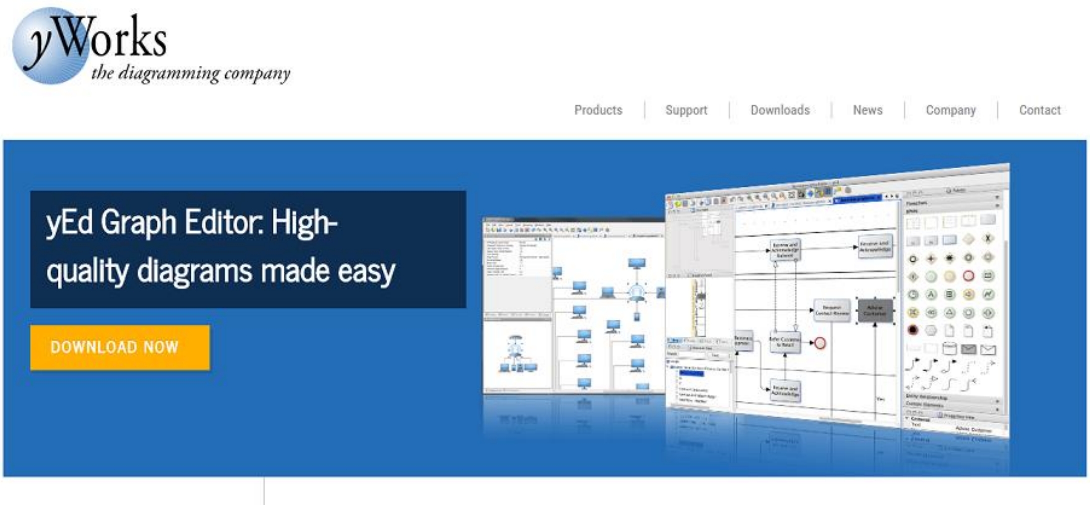

Figure 82 The yED Graph Editor main page

Step 2) In the drop-down menu select **yED.**

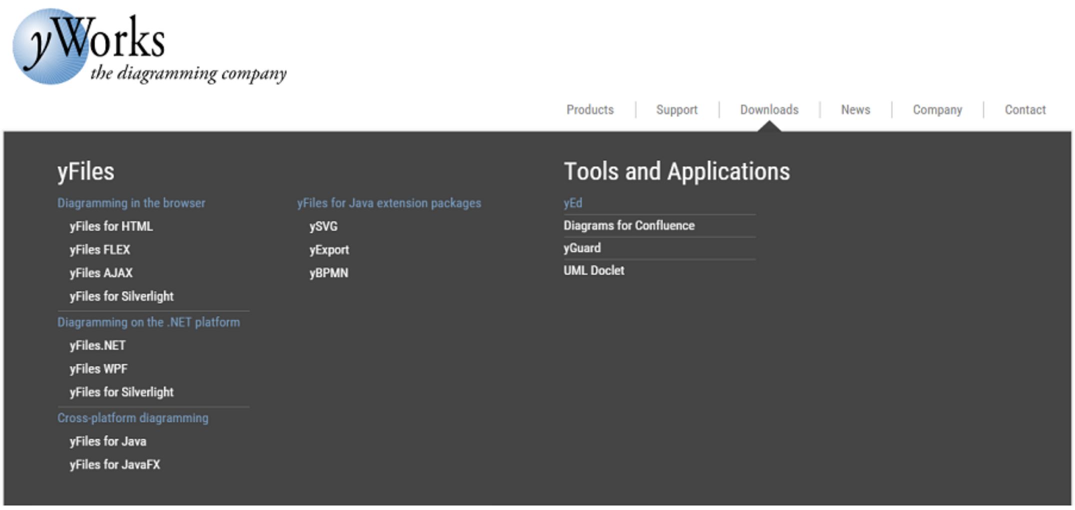

Figure 83 Selecting the right tool

Step 3) In Tools and Applications section, select the option for your operating system.

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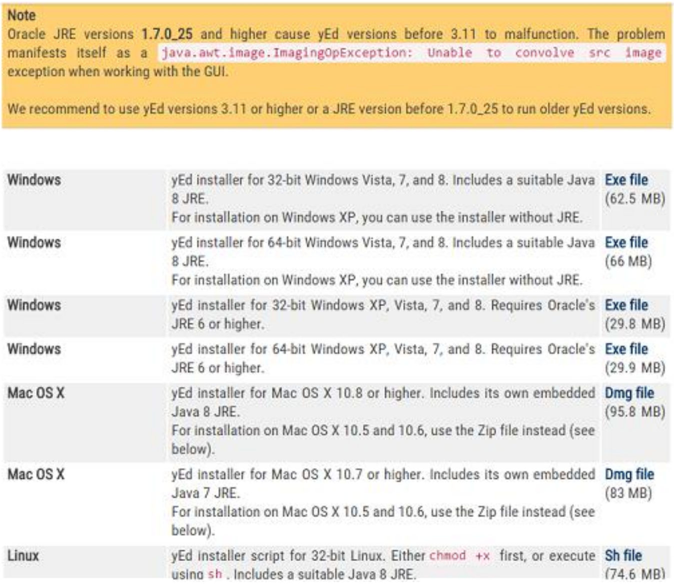
Note
Oracle JRE versions 1.7.0_25 and higher cause yEd versions before 3.11 to malfunction. The problem manifests itself as a `java.awt.image.ImagingOpException: Unable to convolve src image` exception when working with the GUI.

We recommend to use yEd versions 3.11 or higher or a JRE version before 1.7.0_25 to run older yEd versions.

Windows	yEd installer for 32-bit Windows Vista, 7, and 8. Includes a suitable Java 8 JRE. For installation on Windows XP, you can use the installer without JRE.	Exe file (62.5 MB)
Windows	yEd installer for 64-bit Windows Vista, 7, and 8. Includes a suitable Java 8 JRE. For installation on Windows XP, you can use the installer without JRE.	Exe file (66 MB)
Windows	yEd installer for 32-bit Windows XP, Vista, 7, and 8. Requires Oracle's JRE 6 or higher.	Exe file (29.8 MB)
Windows	yEd installer for 64-bit Windows XP, Vista, 7, and 8. Requires Oracle's JRE 6 or higher.	Exe file (29.9 MB)
Mac OS X	yEd installer for Mac OS X 10.8 or higher. Includes its own embedded Java 8 JRE. For installation on Mac OS X 10.5 and 10.6, use the Zip file instead (see below).	Dmg file (95.8 MB)
Mac OS X	yEd installer for Mac OS X 10.7 or higher. Includes its own embedded Java 7 JRE. For installation on Mac OS X 10.5 and 10.6, use the Zip file instead (see below).	Dmg file (83 MB)
Linux	yEd installer script for 32-bit Linux. Either `chmod +x` first, or execute using `sh`. Includes a suitable Java 8 JRE.	Sh file (74.6 MB)

Figure 84 Choosing the operating system

Step 4) The License Agreement appears; read the license, select "I accept the license terms" and click Download.

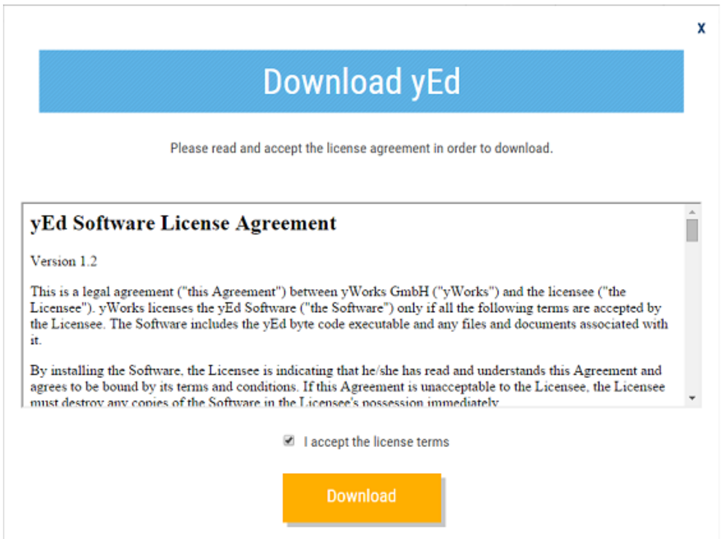

Figure 85 License agreement

Step 5) Download the installation file.
Step 6) Run the downloaded file to start the installation process.
Step 7) Follow the instructions on your screen.

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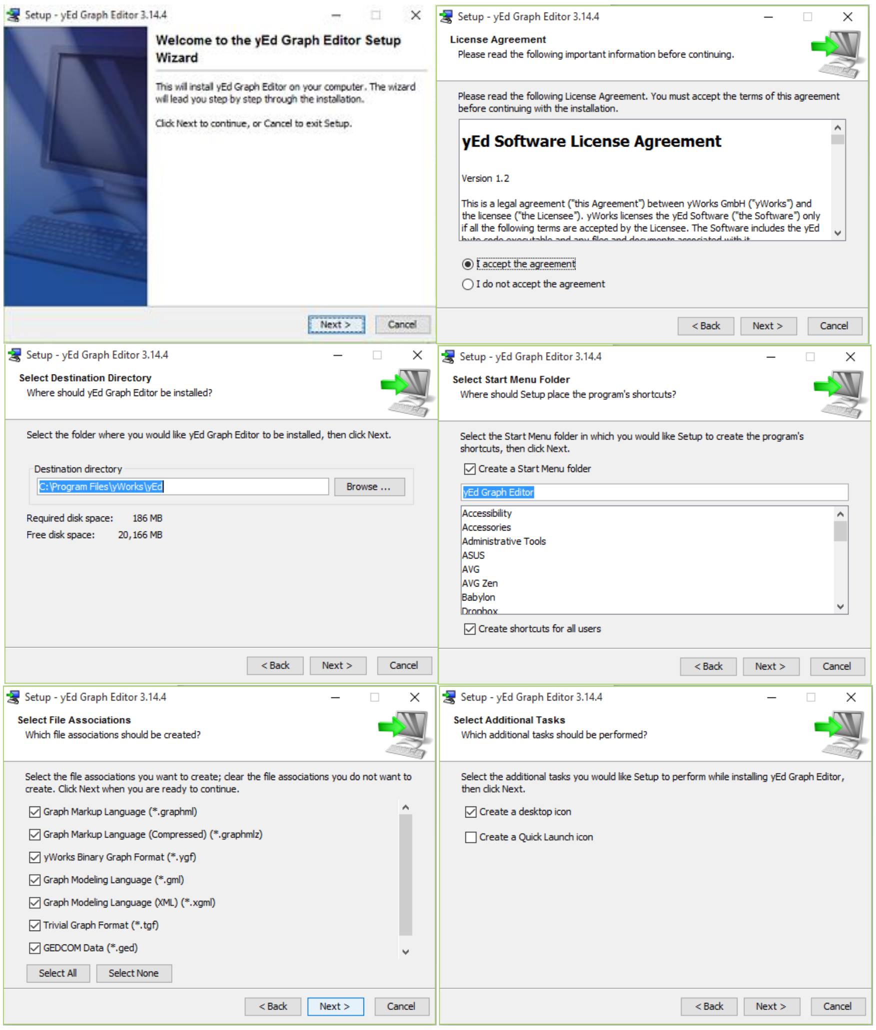

Figure 86 The following steps to install yED Graph Editor

Step 8) Click Finish to complete the installation.

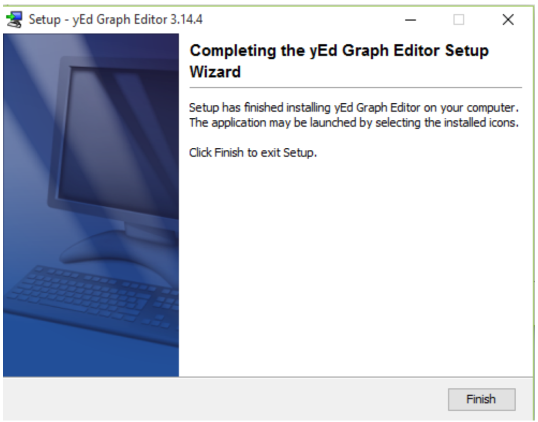

Figure 87 Finishing the installation of yED Graph Editor

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9.2 How to use the BPMN on yED Graph Editor

Create a new project

Step 1) Click on yED Graph Editor icon (in the following) and start the program.

Figure 88 The yED Graph Editor Icon

Step 2) Select new document

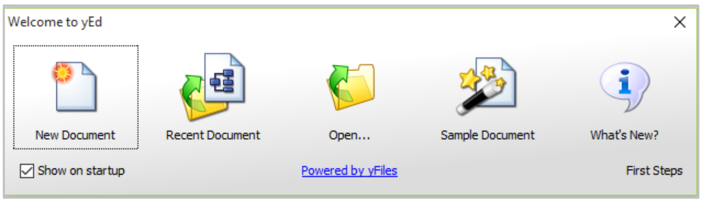

Figure 89 Selecting a new document

Step 3) Click on BPMN, in the top right section, to see all the BPMN Symbols.

Step 4) To add a symbol to diagram, select it in the top right section and drug it in the central area.

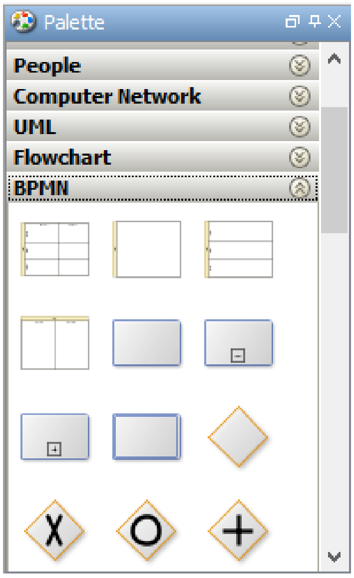

Figure 90 Selecting the BPMN symbols

Step 5) Once the symbol is added to the diagram, select it to modify its properties, in the bottom right section.

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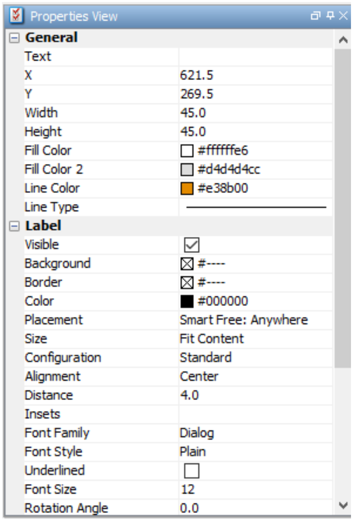

Figure 91 The properties view

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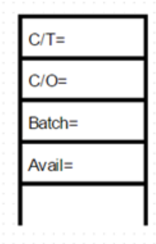
10 Annex D: The VSM Notation

In the following we report the main symbols used to perform the Value Stream Mapping, their name, and their description.

Icon	Name	Description
	Process Icons	
	Data Box	The data box goes under other icons that have significant information/data required for analysing and observing the system. a) Typical information placed in a Data Box underneath *Outside Resources (suppliers or customers)* icons is the frequency of shipping during any shift, material handling information, transfer batch size, demand quantity per period, etc. Sometimes this information is written directly into the Supplier or Customer boxes, or in a square box. b) Typical information in a Data Box underneath *Process* icons: • C/T (Cycle Time) - time (in seconds) that elapses between one part coming off the process to the next part coming off. The C/T is the time required to complete one manufacturing process in the value stream. • C/O (Changeover Time) - time to switch from producing one product on the process to another. C/O is the non-value added time required to convert a setup for one product line to a setup for another product line. • Uptime - percentage time that the machine is available for processing. • EPE - a measure of production rate/s; acronym stands for "Every

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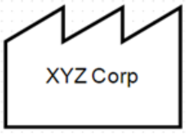
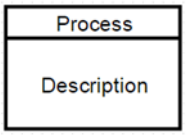
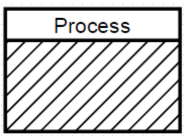
		Part Every___". • Number of product variations. • Available Capacity. • Scrap Rate - Percentage of failed assemblies or material that cannot be repaired or restored, and is therefore condemned and discarded. • Transfer Batch size - based on process batch size and material transfer rate. • Etc.…
	Outside sources (Customer/Supplier)	Customers, suppliers, and outside manufacturing processes that provide materials or services. This icon represents the Supplier when in the upper left, the usual starting point for material flow. The customer is represented when placed in the upper right, the usual end point for material flow.
	Dedicated Process	The dedicated process icon is a process, operation, machine or department, through which material flows. Typically, to avoid unwieldy mapping of every single processing step, it represents one department with a continuous, internal fixed flow path. In the case of assembly with several connected workstations, even if some WIP inventory accumulates between machines (or stations), the entire line would show as a single box. If there are separate operations, where one is disconnected from the next, inventory between them and batch transfers, then use multiple boxes.
	Shared Process	The shared process icon represents a process operation, department or work centre that other value stream families share. Estimate the number of operators

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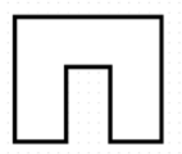
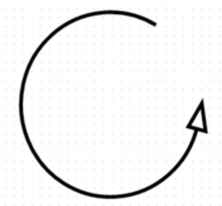
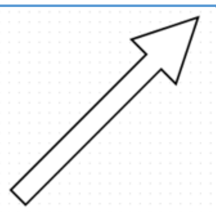
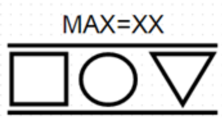
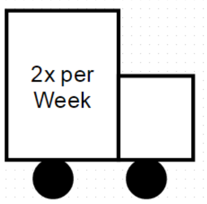
		required for the Value Stream being mapped, not the number of operators required for processing all products.
	Work cell	The work cell symbol indicates that multiple processes are integrated in a manufacturing work cell. Such cells usually process a limited family of similar products or a single product. Product moves from process step to process step in small batches or single pieces.
Material Flow Icons		
	Material pull/ Withdrawal	The point where a downstream process pulls from an upstream supermarket. Supermarkets connect to downstream processes with this "Pull" icon that indicates physical removal.
	Push arrow	This icon represents the "pushing" of material from one process to the next process. Push means that a process produces something regardless of the immediate needs of the downstream process.
	Shipments	This icon represents movement of raw materials from suppliers to the Receiving dock/s of the factory. Or, the movement of finished goods from the Shipping dock/s of the factory to the customers.
	FIFO Lane	First-In-First-Out inventory. This icon is used when processes are connected with a FIFO system that limits input. An accumulating roller conveyor is an example. Record the maximum possible inventory.
	Truck shipment	Shipments of materials or products by truck. The frequency can be indicated inside the icon. Shipments from suppliers or to customers using external transport.

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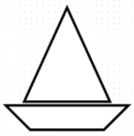
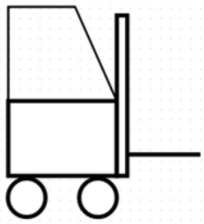
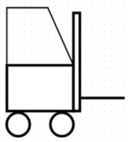
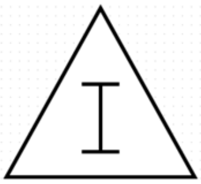
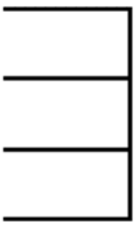
	Rail Shipment	Shipments of materials or products by train.
	Boat shipment	Shipments of materials or products by boat.
	Air fright	Shipments of materials or products by plain.
	Move by forklift	Movement of materials by using forklift. Because other symbols of internal movement are not given, we propose to use this icon by specifying the type of shipment. If we are using a crane:  Crane
	Inventory	
	Inventory	These icons show inventory between two processes waiting to be used. While mapping the current state, the amount of inventory can be approximated by a quick count, and that amount is noted beneath the triangle. If there is more than one inventory accumulation, use an icon for each. This icon also represents storage for raw materials and finished goods.
	Supermarket	A controlled inventory that supplies a downstream process without interruption. The open side should face the process that supplies the materials for the supermarket. This is an inventory 'supermarket" (*kanban* stock point). Like a supermarket, a small inventory is available and one or more downstream customers come to the supermarket to

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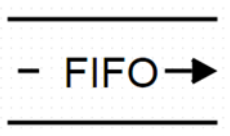
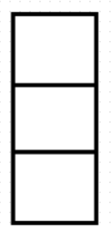
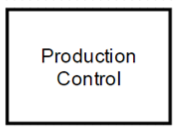
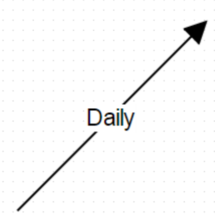
		pick out what they need. The upstream work centre then replenishes stocks as required. When continuous flow is impractical, and the upstream process must operate in batch mode, a supermarket reduces overproduction and limits total inventory.
	First-In-First-Out Sequence Flow	A type of inventory that promotes consistent, sequential workflow by requiring that the first piece to enter the inventory is also the first piece to enter the subsequent process step.
	Safety Stock	This icon represents a type of inventory that is used to protect against uncertainties in customer demand and in the supply chain. Also known as buffer stock. This icon represents an inventory "hedge" (or safety stock) against problems such as downtime, to protect the system against sudden fluctuations in customer orders or system failures. Notice that the icon is closed on all sides. It is intended as a temporary, not a permanent storage of stock; thus; there should be a clearly-stated management policy on when such inventory should be used.
	Information Flow	
	Production Control	This box represents a central production scheduling or control department, person or operation.
	Manual Information	The manual transfer of information, such as a printed production schedule. Inside the arrow we can include the frequency. A straight, thin arrow shows general flow of information from memos, reports, or conversation.

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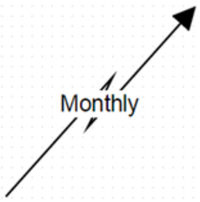
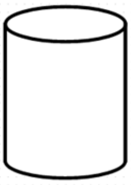
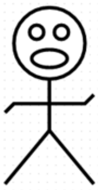
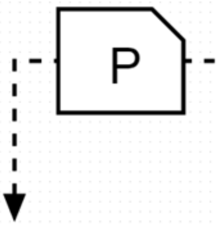
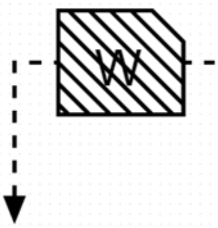
	Electronic Information	This wiggle arrow represents electronic flow such as electronic data interchange (EDI), the Internet, Intranets, LANs (local area network), WANs (wide area network). We may indicate the frequency of information/data interchange, the type of media used ex. fax, phone, etc. and the type of data exchanged.
	MRP/ERP	Scheduling using MRP/ERP or other centralized systems.
	Go See Scheduling	Gathering of information through visual means.
	Verbal Information	This icon represents verbal or personal information flow.
	Production Kanban	A signal to produce a certain amount of a part or service. This icon triggers production of a pre-defined number of parts. It signals a supplying process to provide parts to a downstream process.
	Withdrawal Kanban	A signal to acquire or transfer materials. This icon represents a card or device that instructs a material handler to transfer parts from a supermarket to the receiving process. The material handler (or operator) goes to the supermarket and withdraws the necessary items

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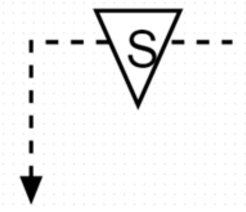
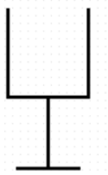
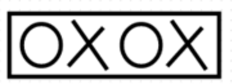
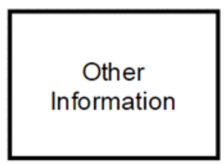
	Signal Kanban	A signal to produce a batch of parts from the supplying process. Use it when the supplying process requires changeovers. This icon is used whenever the on-hand inventory levels in the supermarket between two processes drops to a trigger or minimum point. When a Triangle Kanban arrives at a supplying process, it signals a changeover and production of a predetermined batch size of the part noted on the Kanban. It is also referred as "one-per-batch" *kanban*.
	Sequenced-Pull Ball	A signal to immediately produce a given quantity of a part or service. Use it in a pull system without supermarkets. This icon represents a pull system that gives instruction to subassembly processes to produce a predetermined type and quantity of product, typically one unit, without using a supermarket.
	Kanban Post	A *kanban* collection point. A location where *kanban* signals reside for pickup. Often used with two-card systems to exchange withdrawal and production *kanban*
	Load Levelling	A tool that levels the amount and mix of *kanbans* over a given time period to create a steady flow. This icon is a tool to batch *kanbans* in order to level the production volume and mix over a period of time
	General Icons	
	Information	Other useful or potentially useful information.

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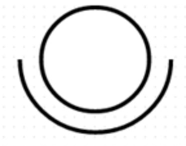
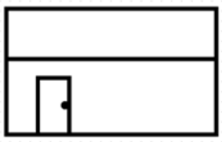
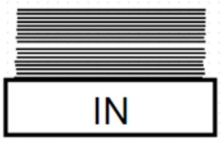
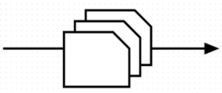
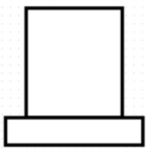
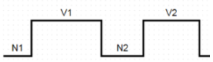
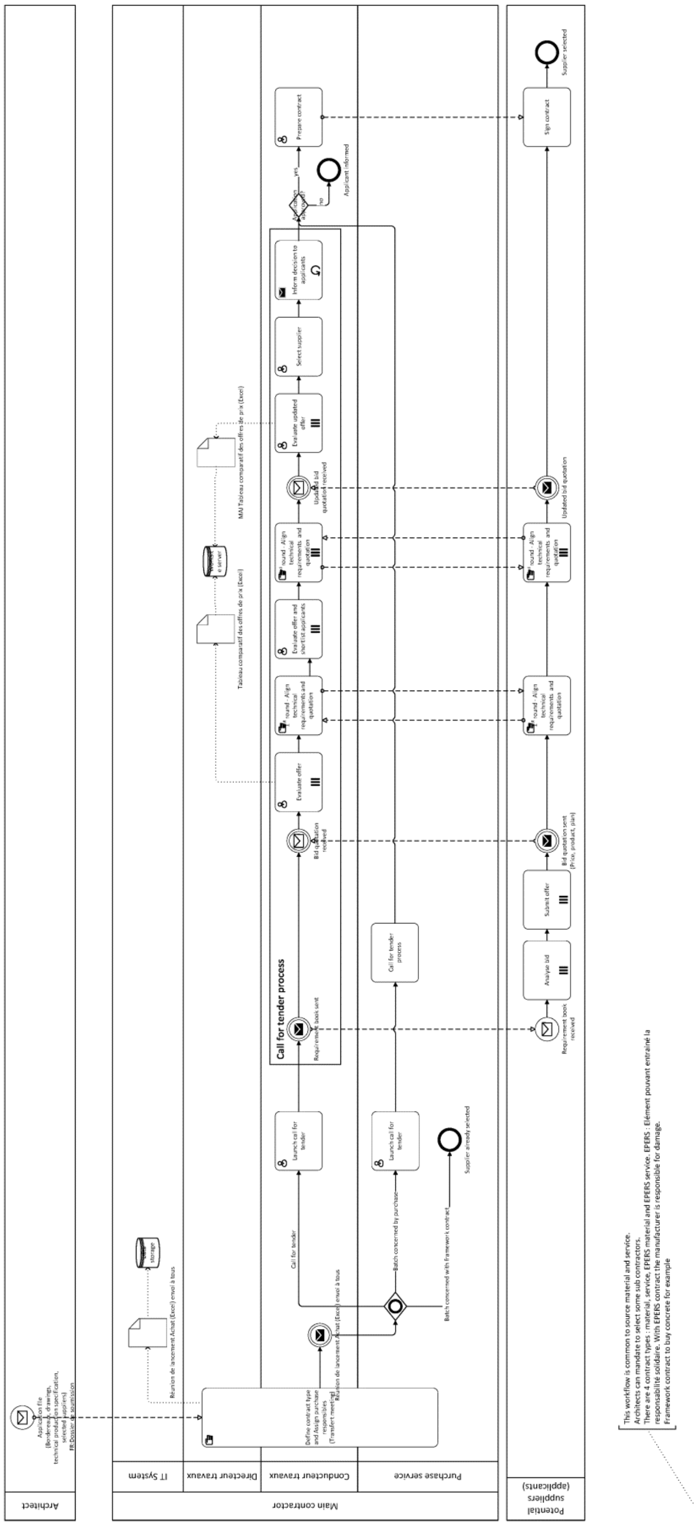
	Kaizen Burst	These icons are used to highlight improvement needs and plan kaizen workshops at specific processes that are critical to achieving the Future State Map of the value stream.
	Operator	This icon represents an operator. It shows the number of operators required to process the VSM family at a particular workstation.
	Extended Icons	
	Warehouse	The Warehouse icon can represent an internal or external warehouse. It may also be used in lieu of the Customer/Supplier icon.
	Cross-dock	In Cross-Docking inbound and outbound trucks are closely coordinated so that materials move directly from inbound trucks to outbound or, at least, with only a brief staging.
	Orders	This icon represents conventional sales orders or purchase orders.
	Batched Kanban	Kanban cards or signals sent or received in batches.
	Control Centre	Control Centre icon for centralized *kanban* control.
	Time Line Icon	
	Time Line	The timeline shows the impact of cycle time and inventory on the process. (In the program that we are using the time line icon is very static, thus we suggest creating a timeline by combining horizontal and vertical lines).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

11 Annex E: The Process Maps

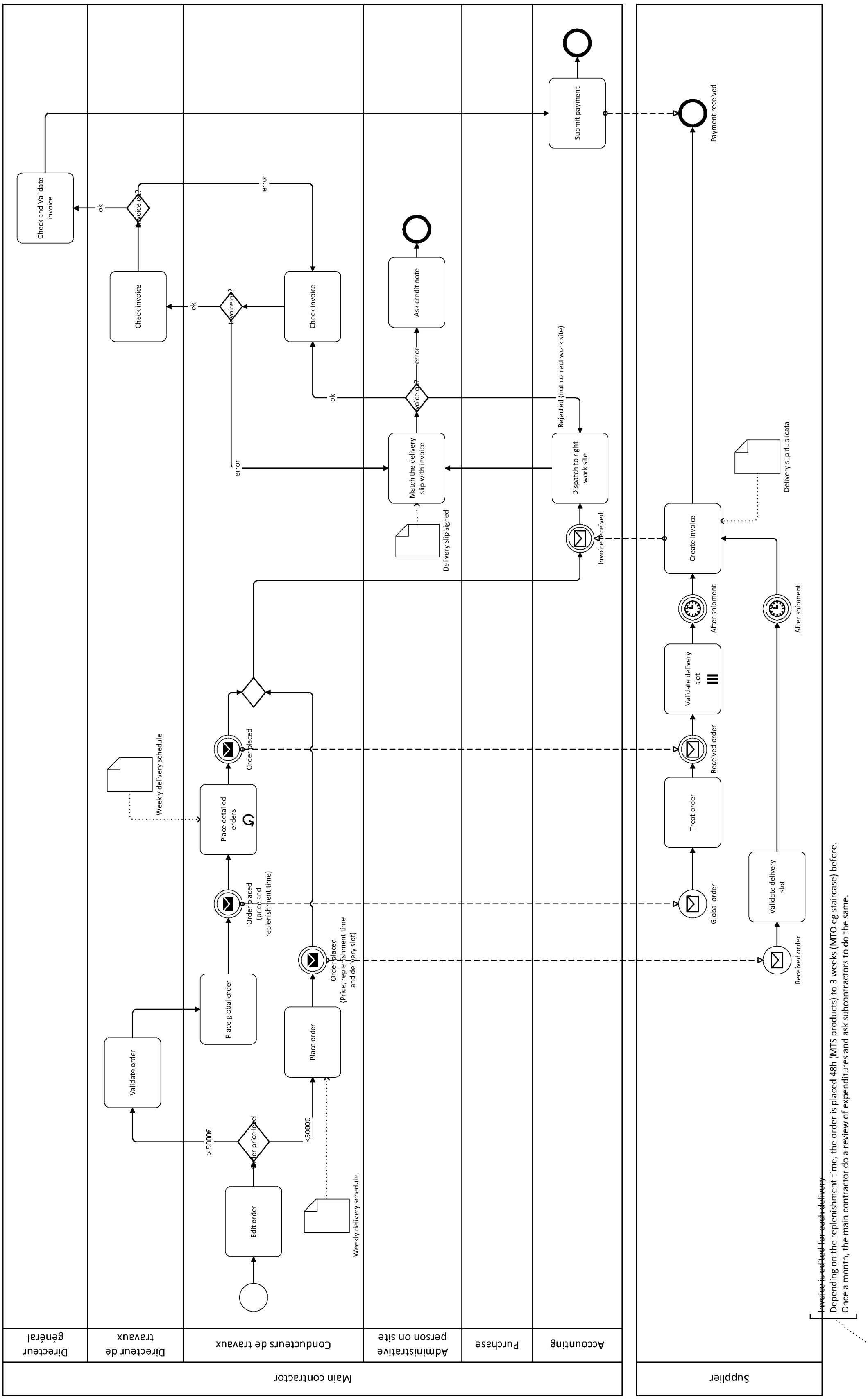
11.1 Process Maps: Luxembourg

11.1.1 Process 1: Sourcing



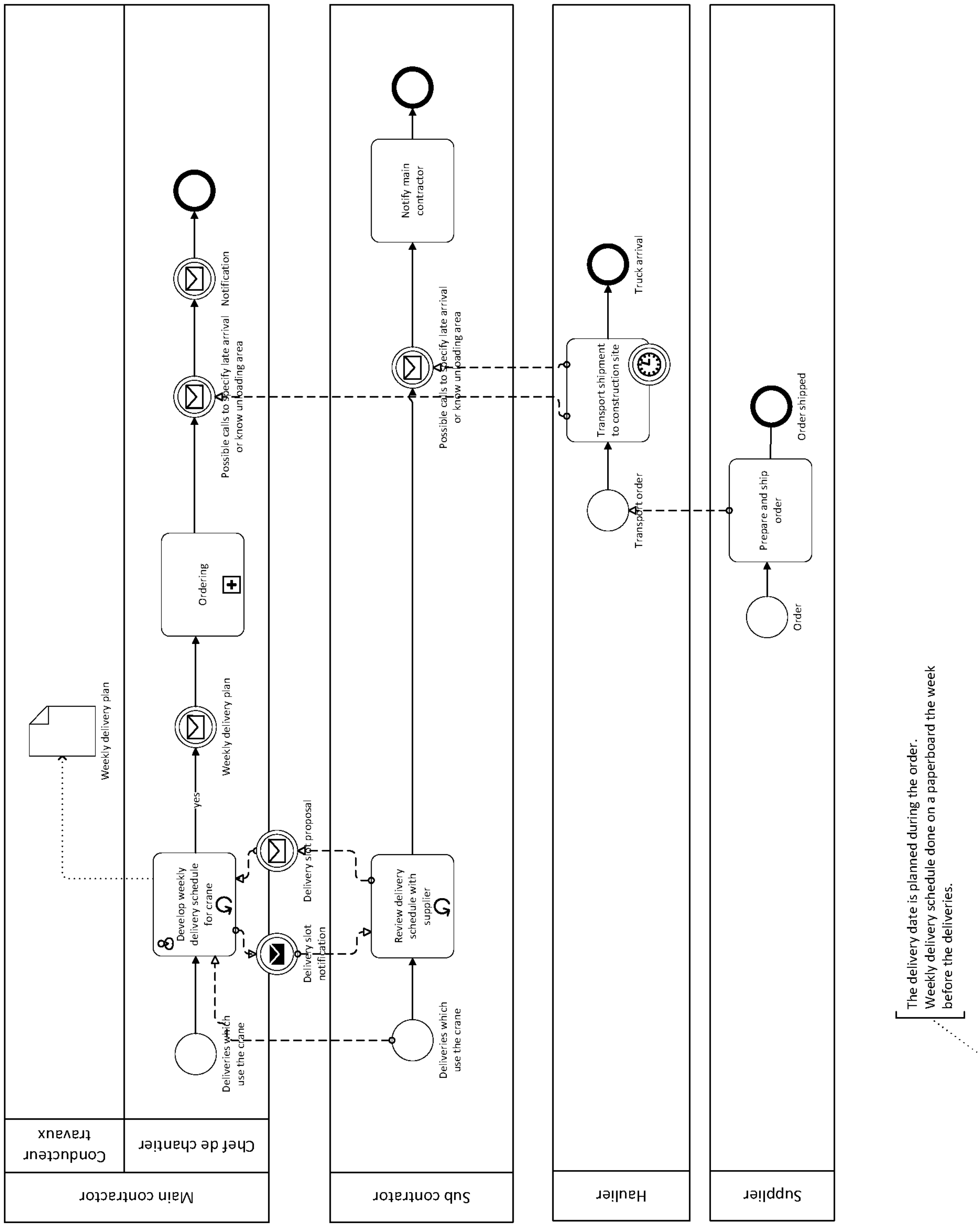
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

11.1.2 Process 2: Ordering



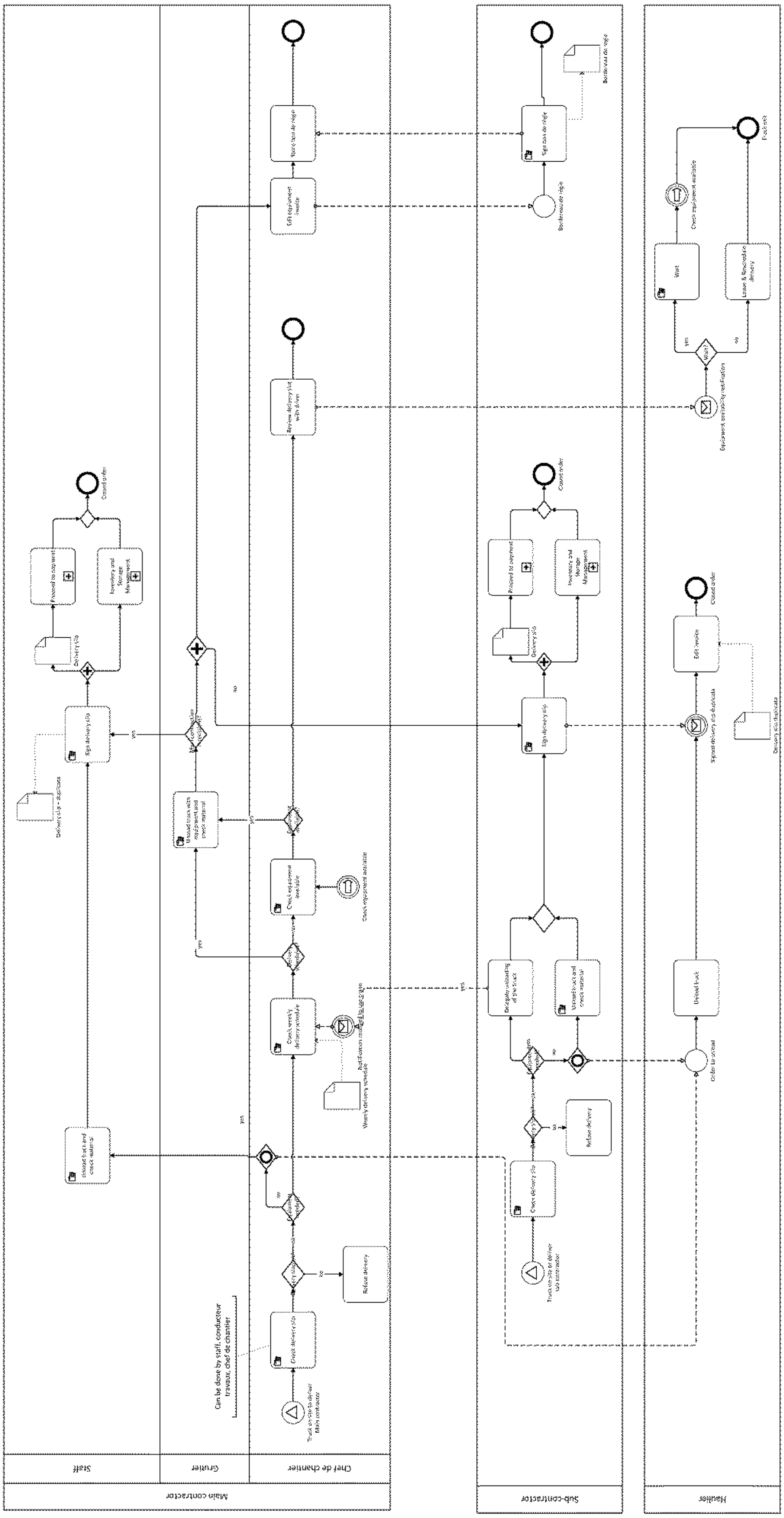
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

11.1.3 Process 3: Delivery



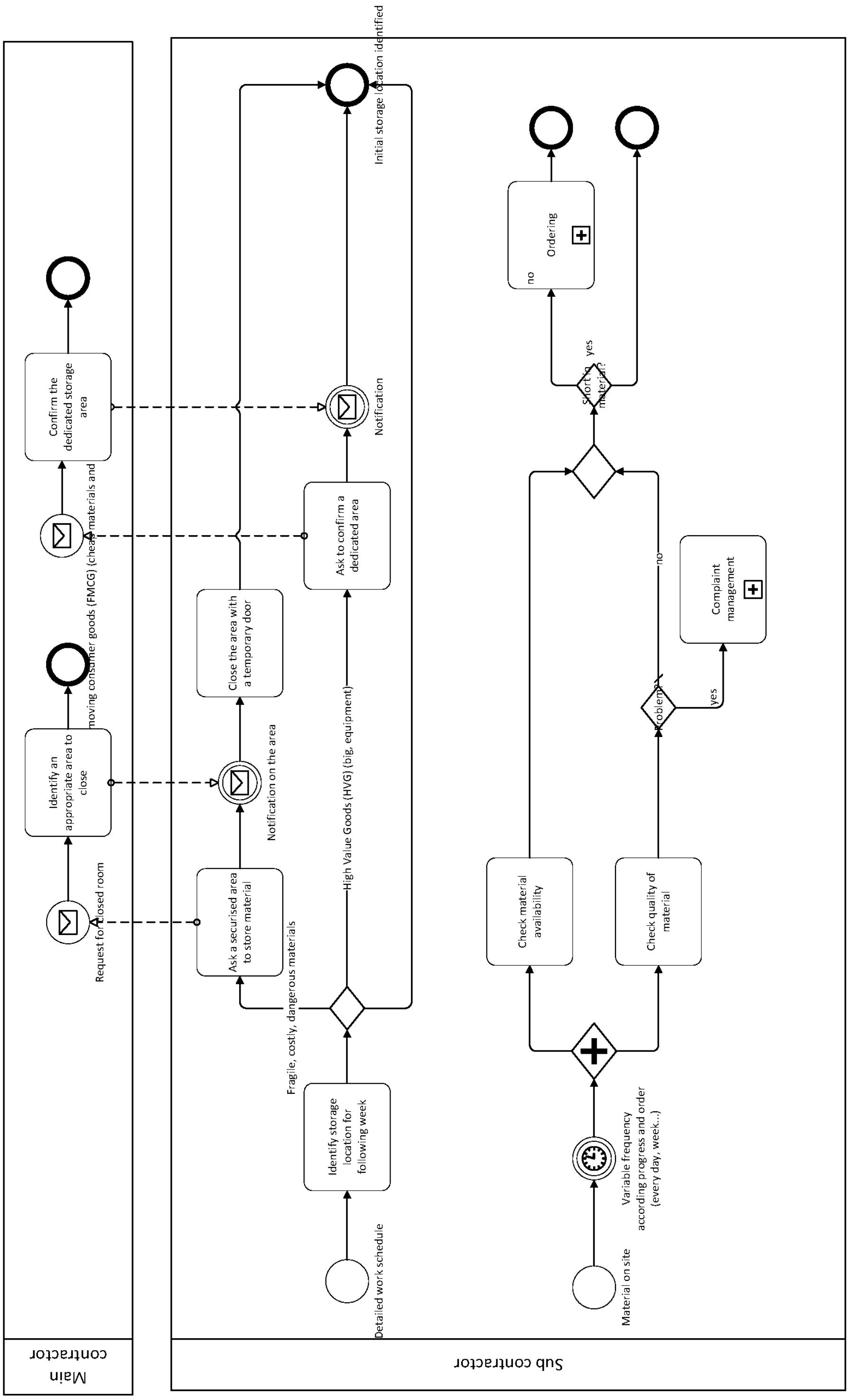
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

11.1.4 Process 4: Material Reception and Expedition



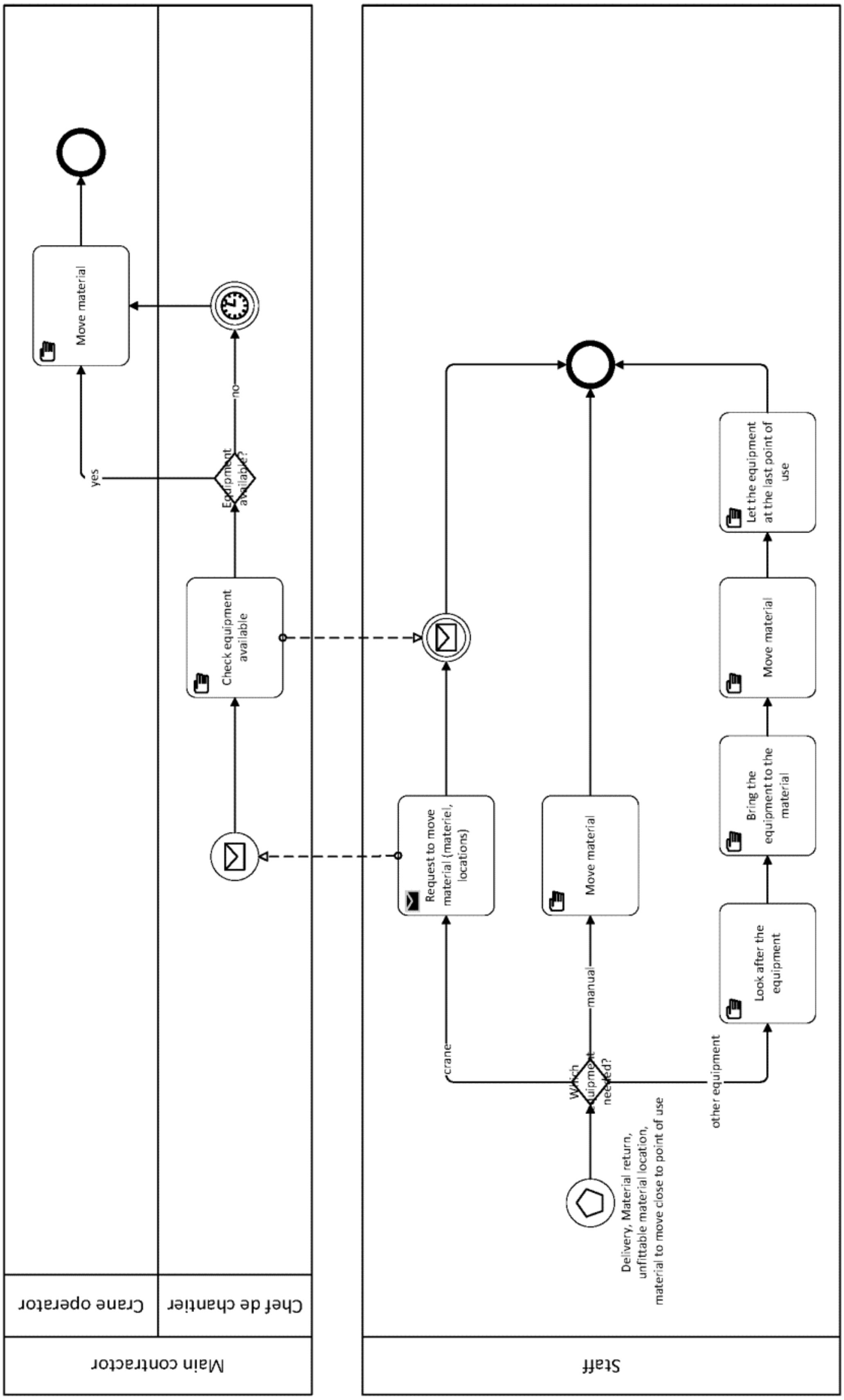
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

11.1.5 Process 5: Inventory and Storage Management



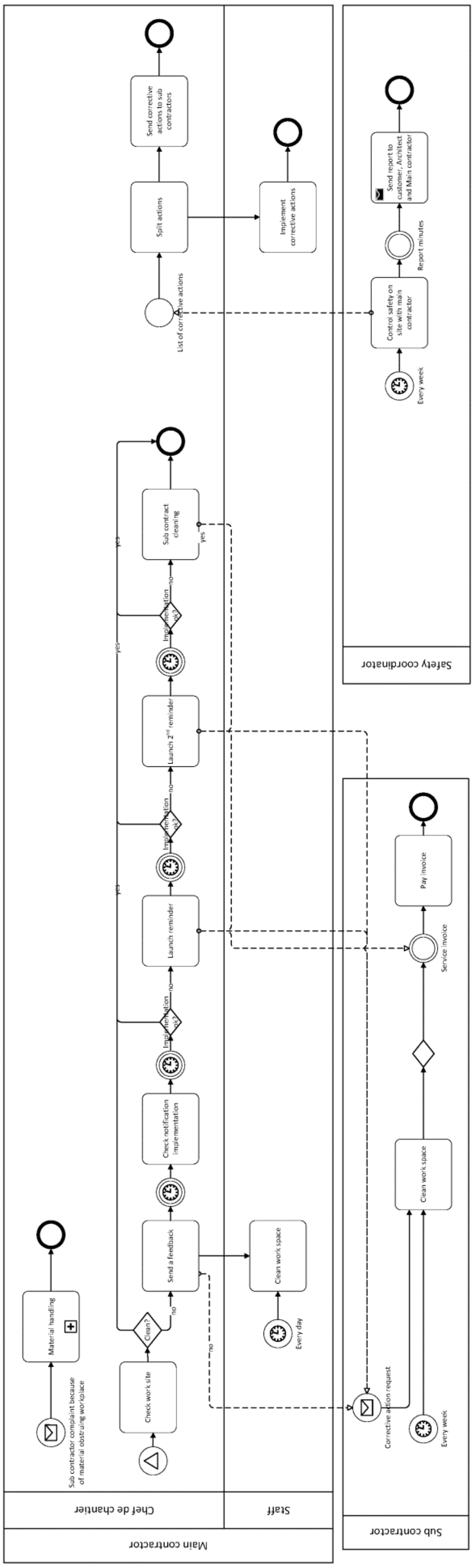
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

11.1.6 Process 6: Material Handling and Equipment Management



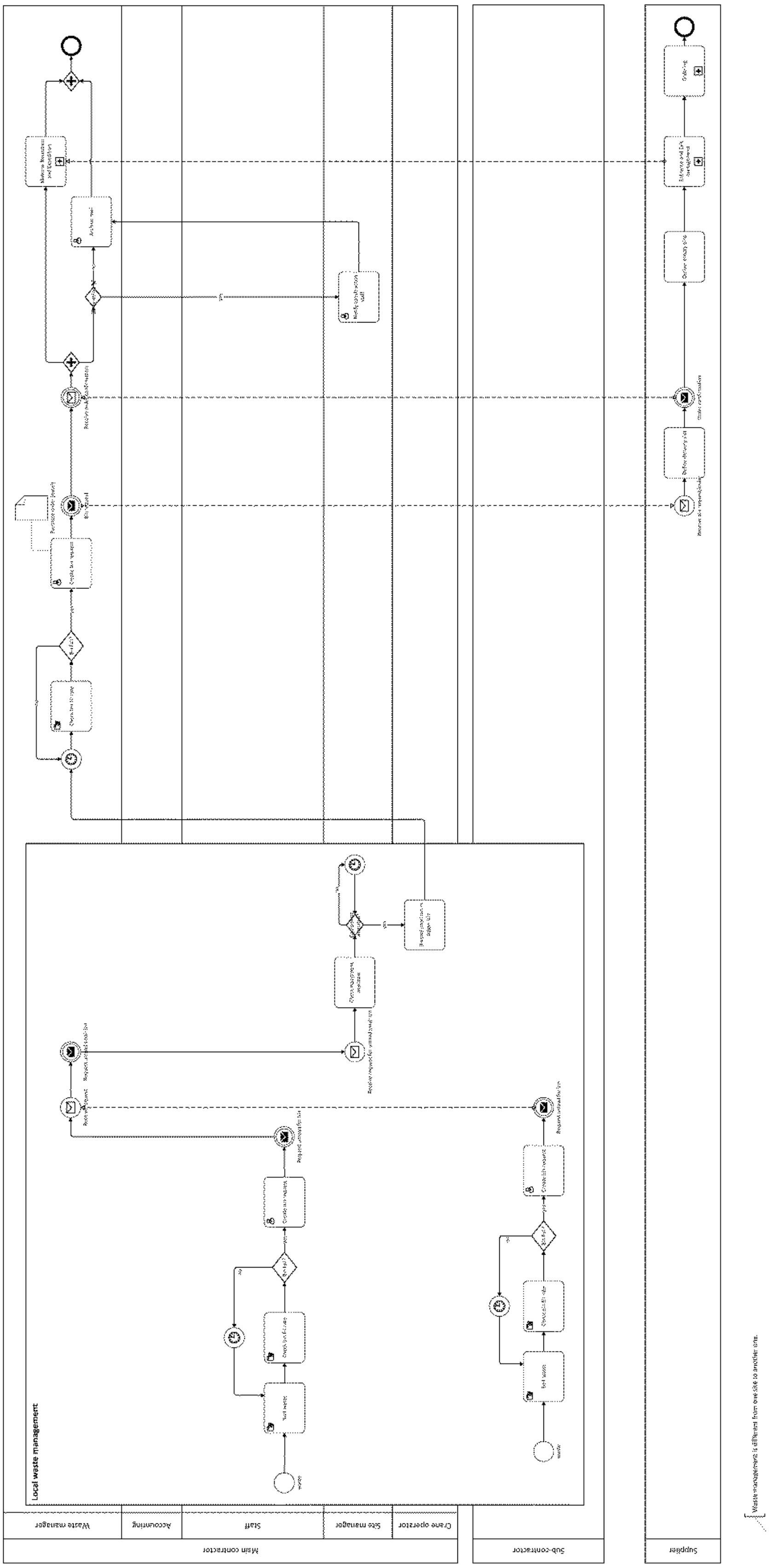
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

11.1.7 Process 7: Housekeeping



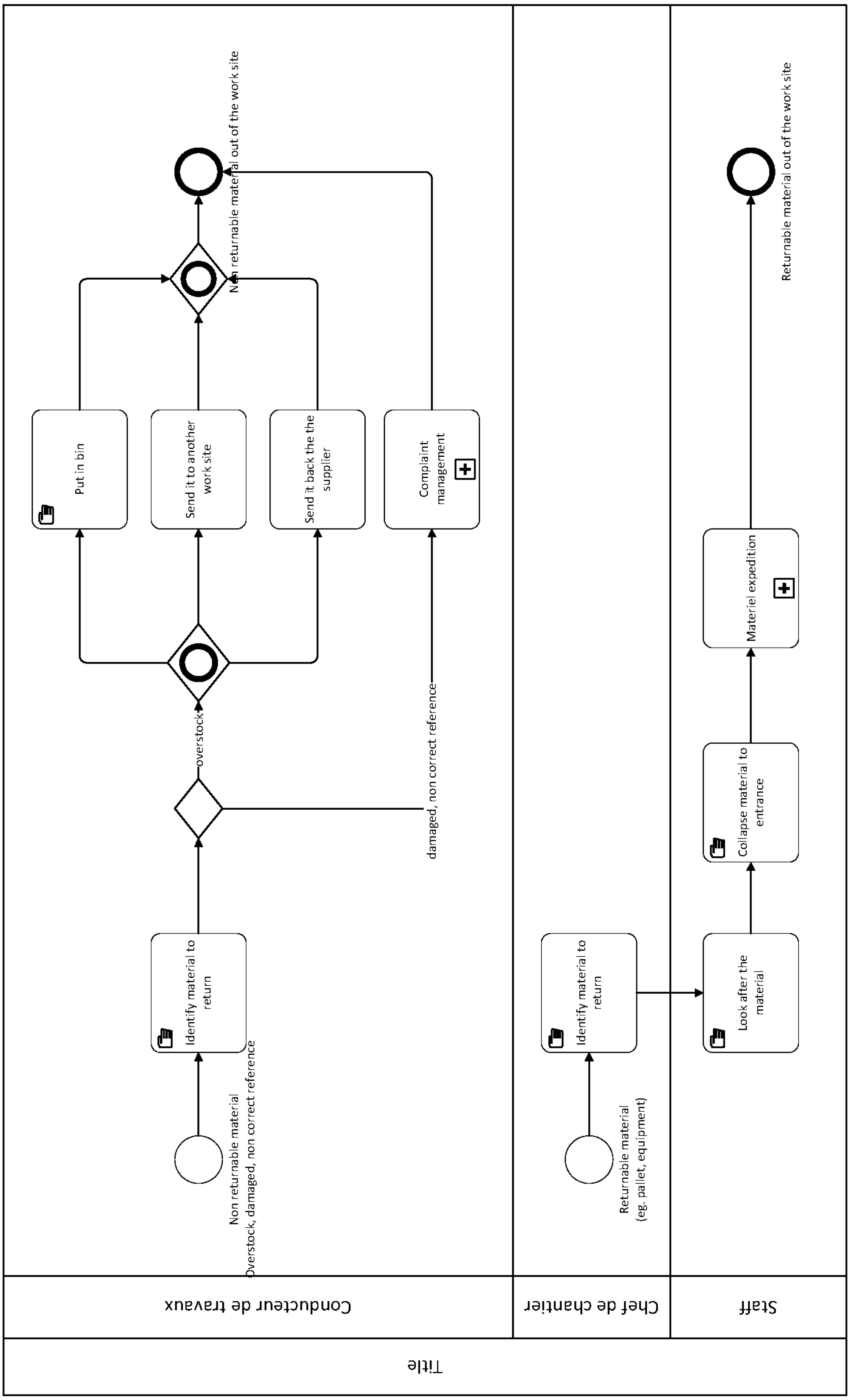
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

11.1.8 Process 8: Waste Management



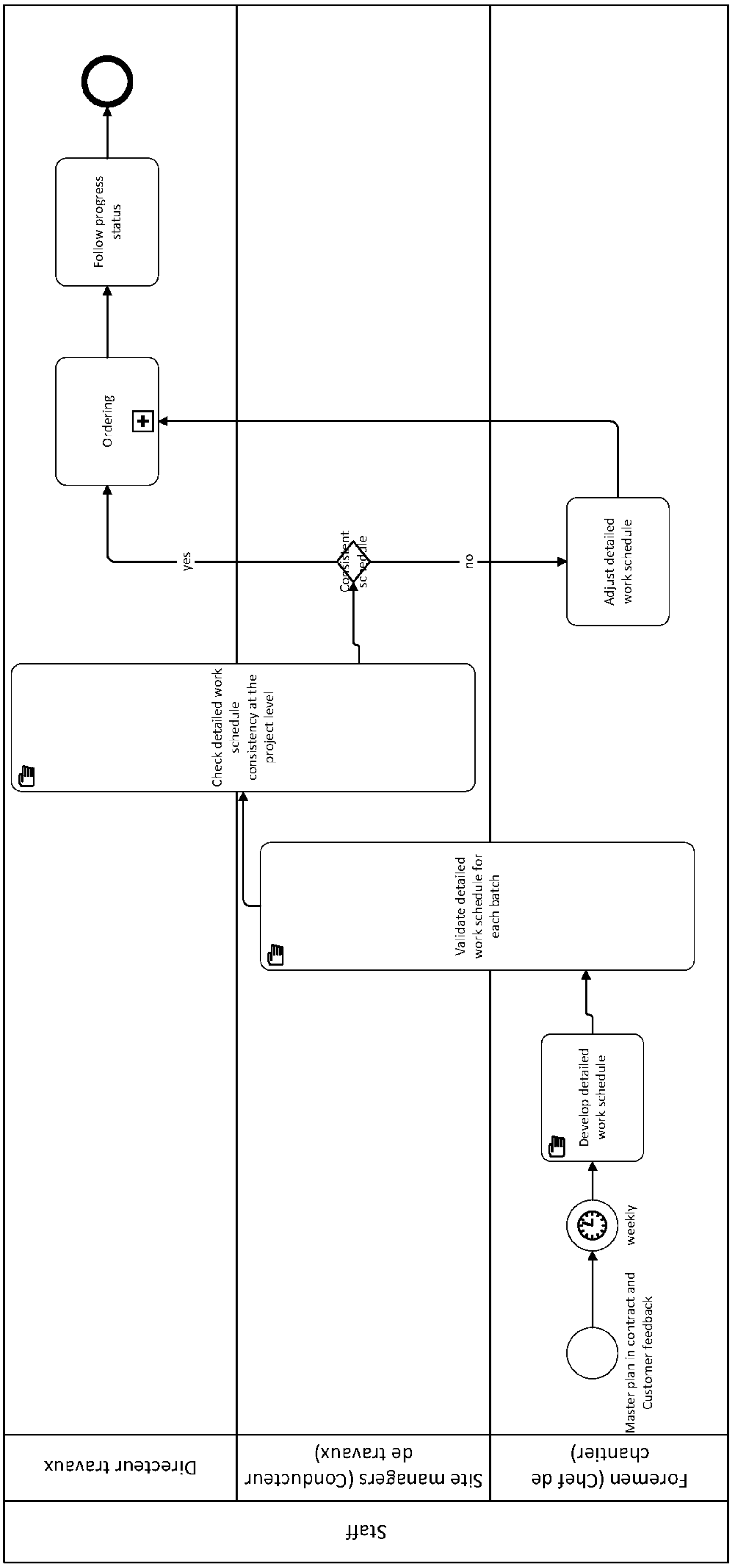
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

11.1.9 Process 9: Return Management



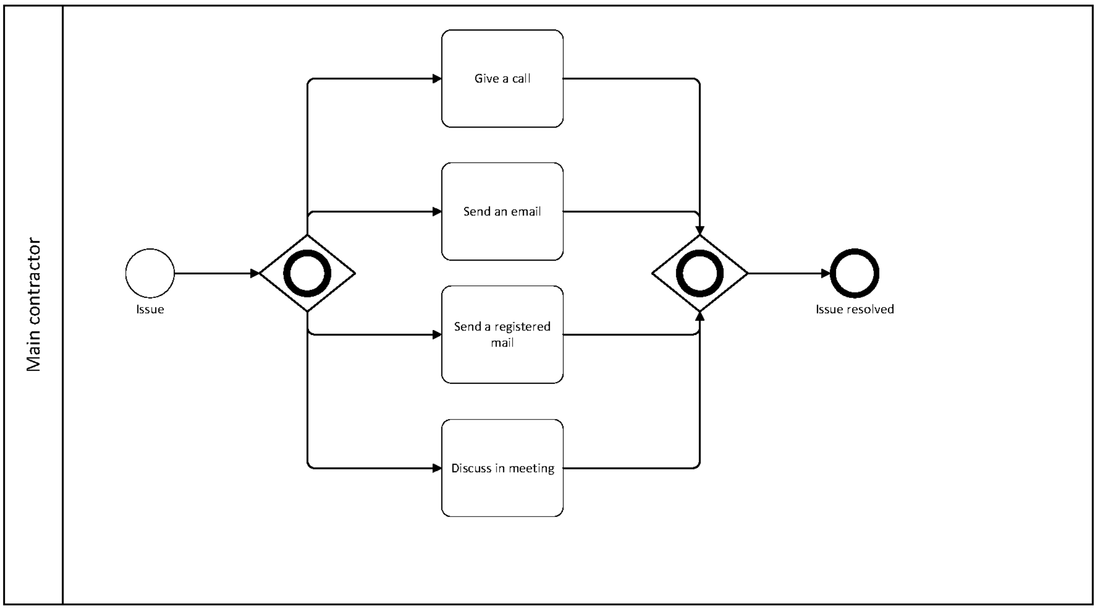
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

11.1.10 Process 10: Planning and Scheduling Resources



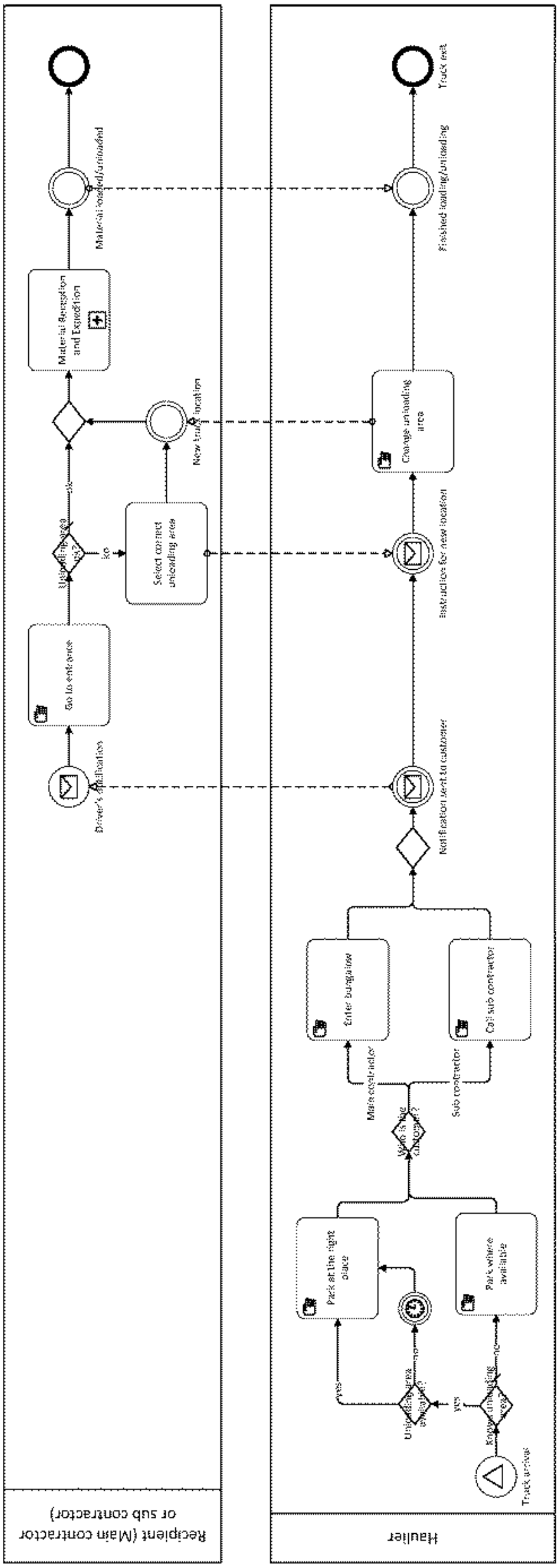
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

11.1.11 Process 11: Complaint Management



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

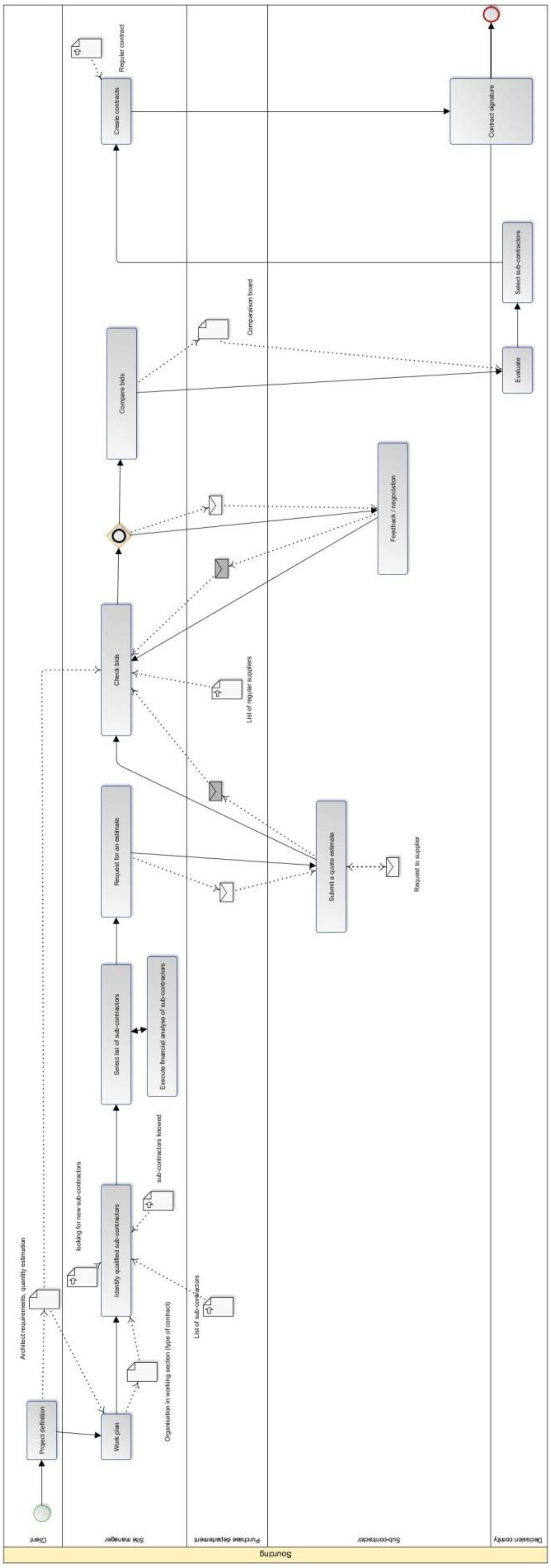
11.1.12 Process 12: Entrance and Exit Management



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

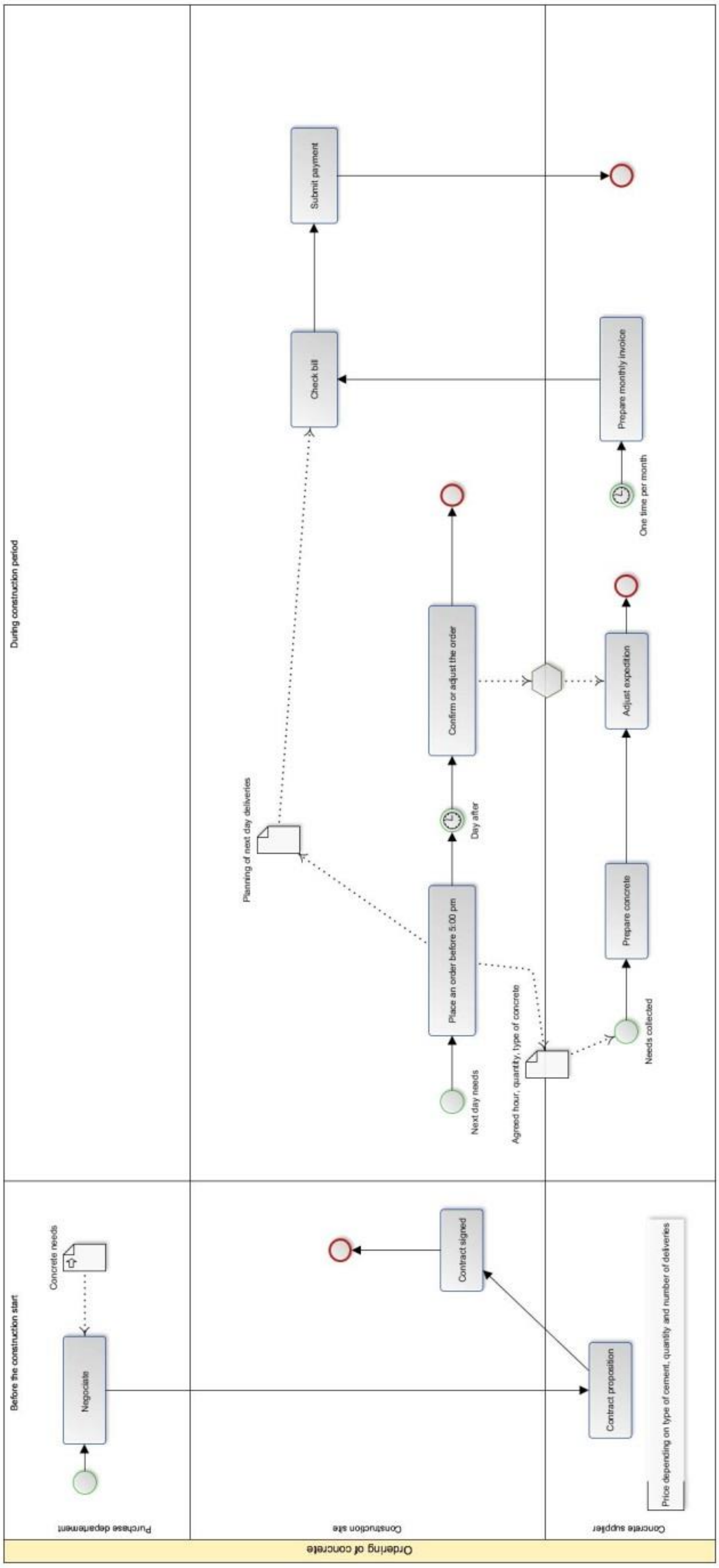
11.2 Process Maps: Paris

11.2.1 Process 1: Sourcing



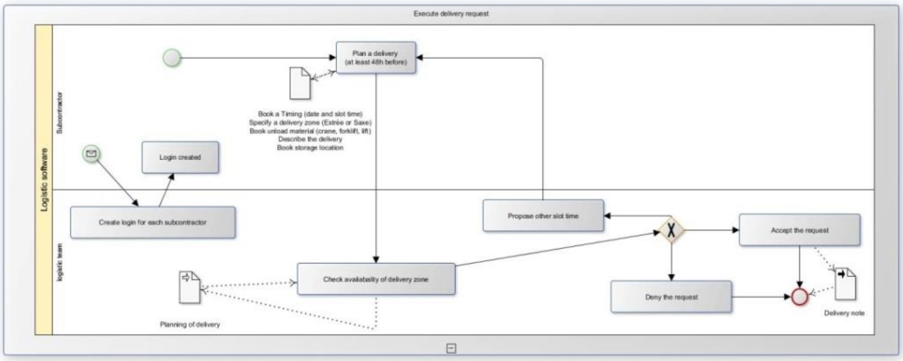
This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No. 633338.

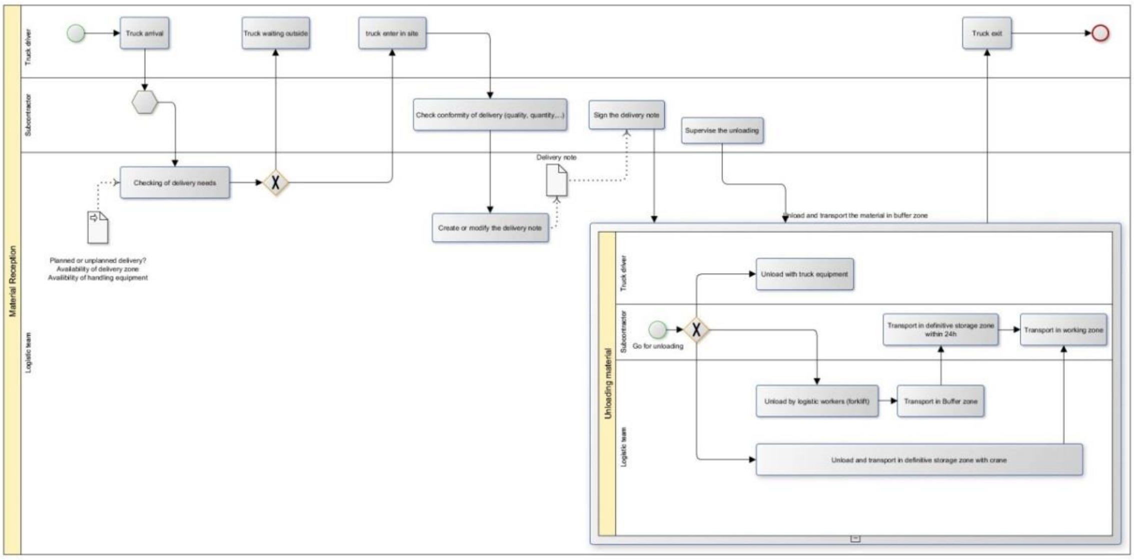
11.2.2 Process 2: Ordering

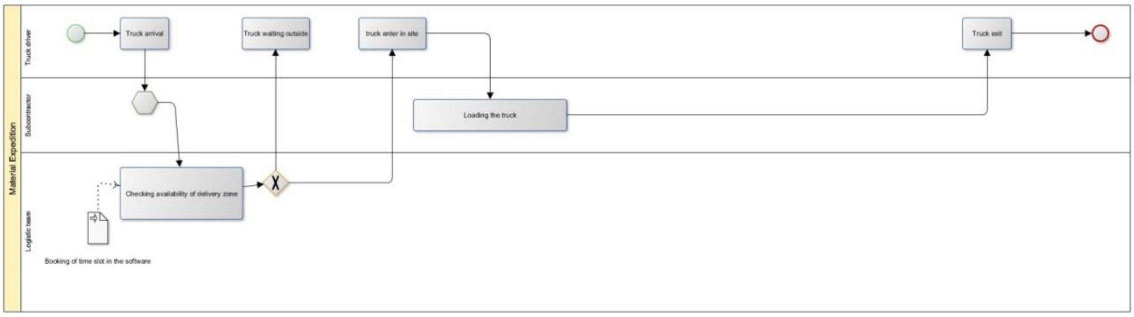


This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

11.2.3 Process 3: Delivery

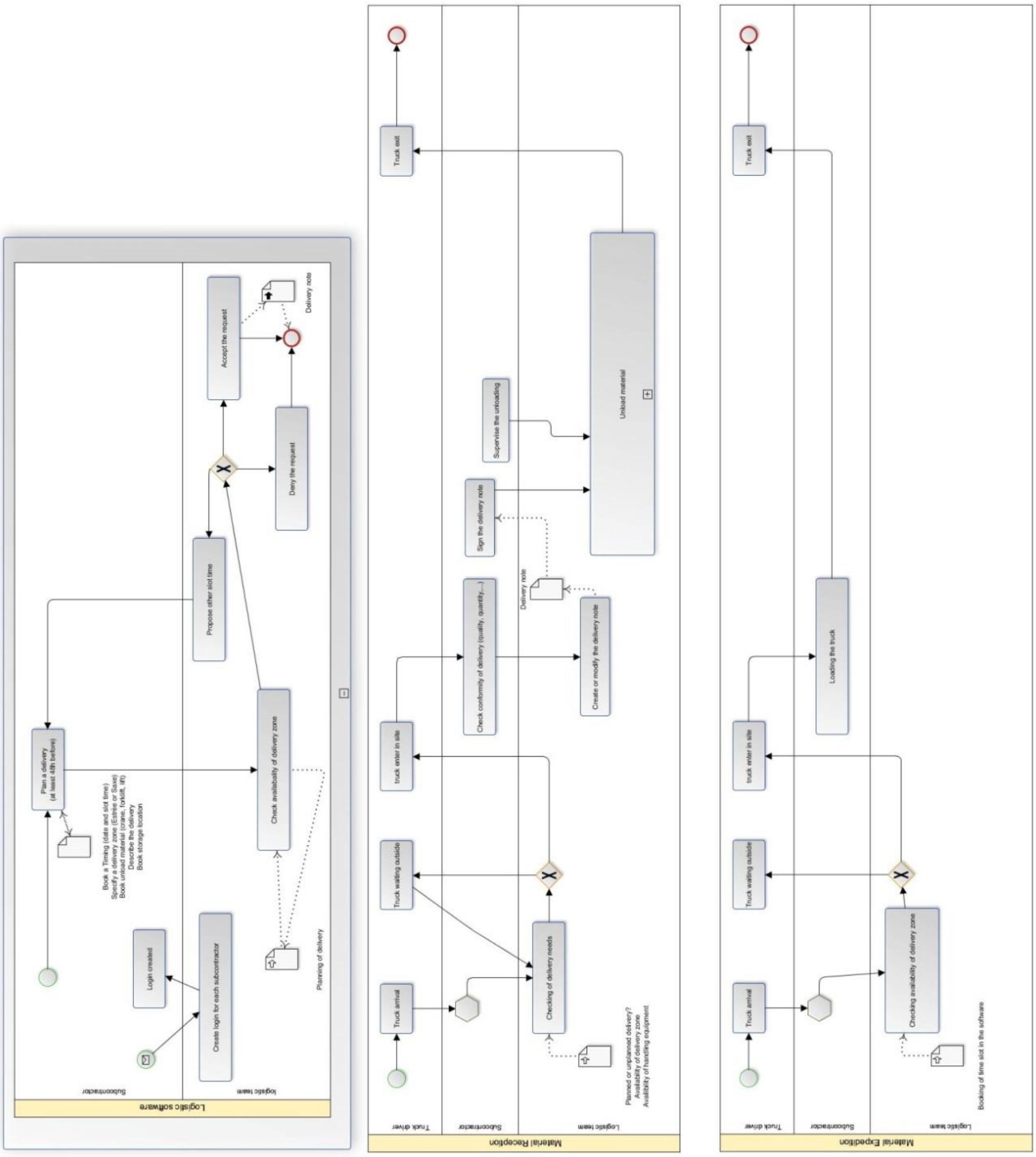






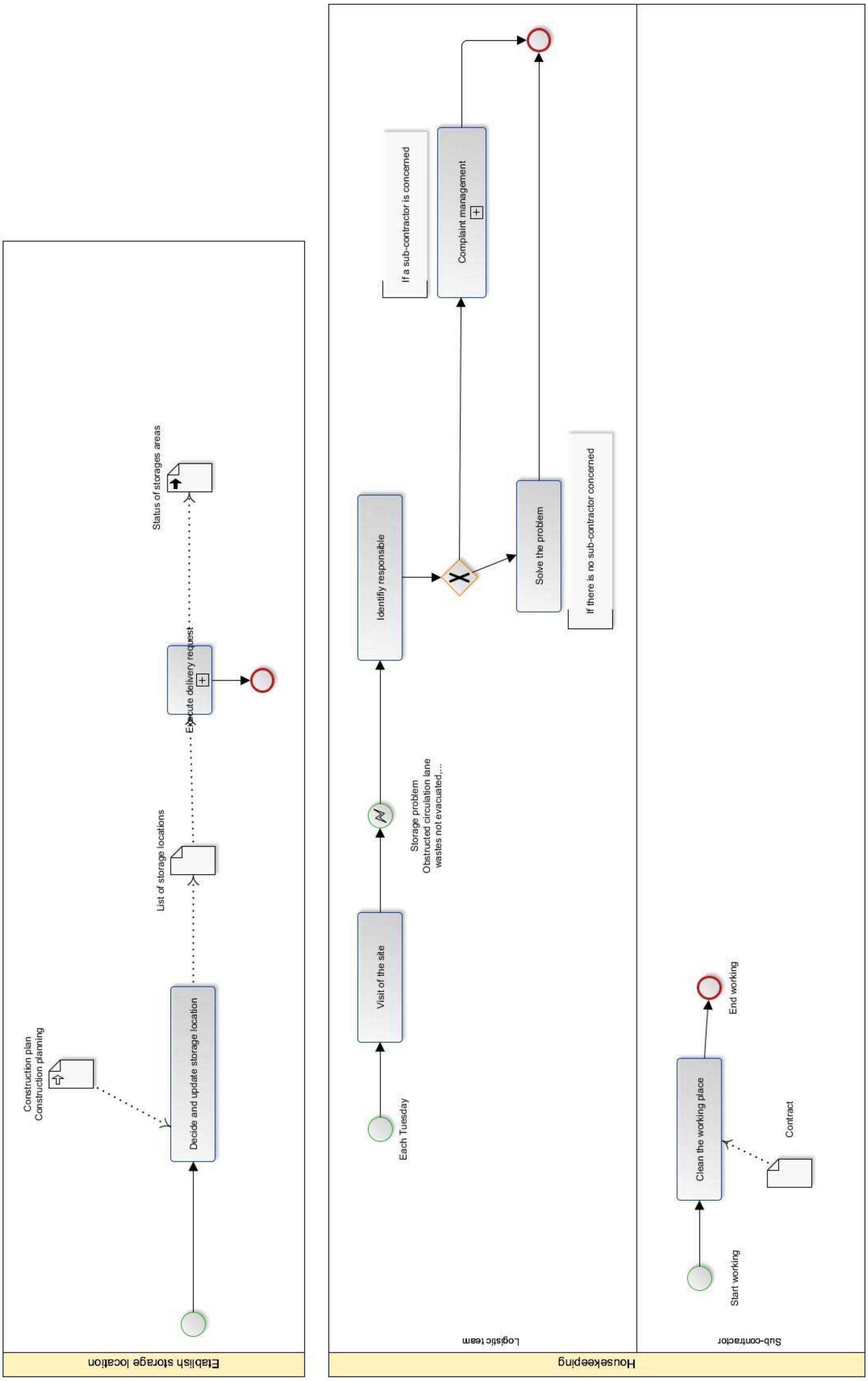
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

11.2.4 Process 4: Material Reception and Expedition



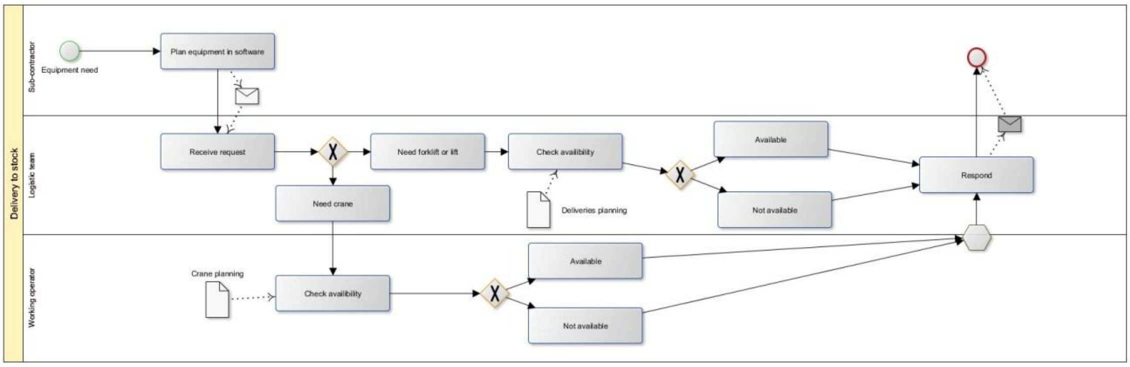
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

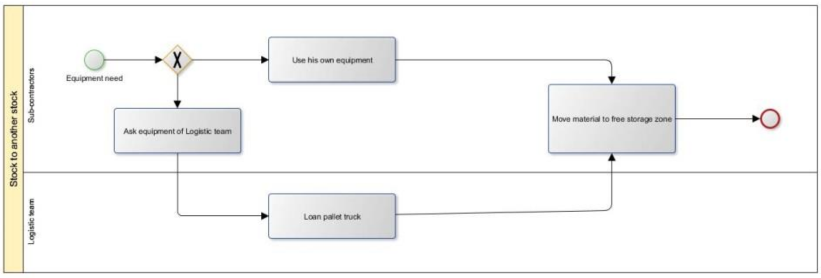
11.2.5 Process 5 and Process 7

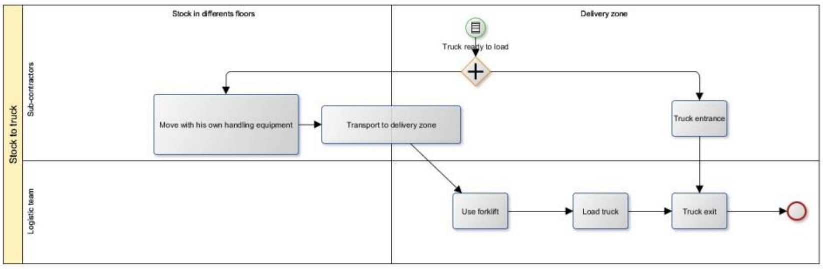


This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

11.2.6 Process 6: Material Handling and Equipment Management

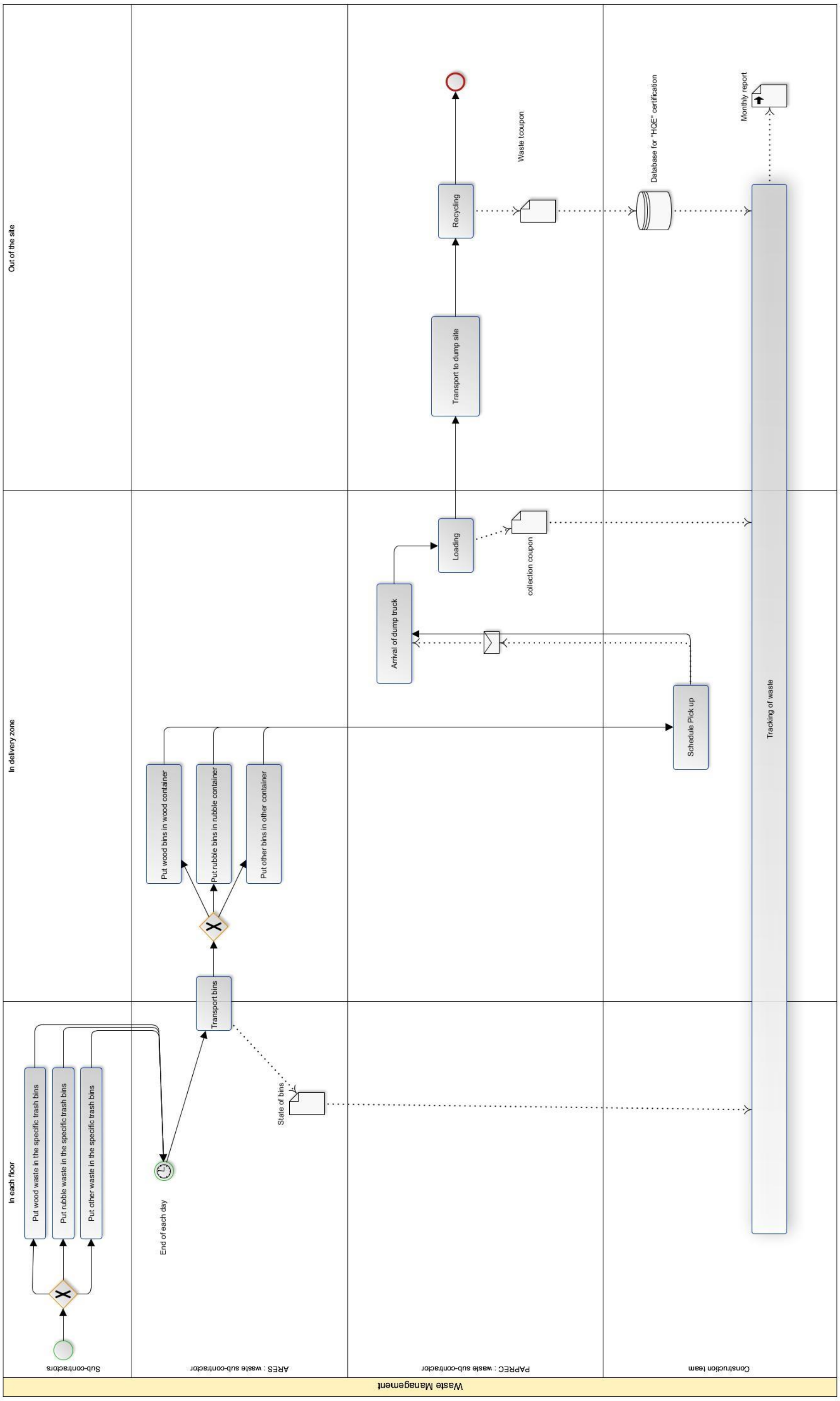






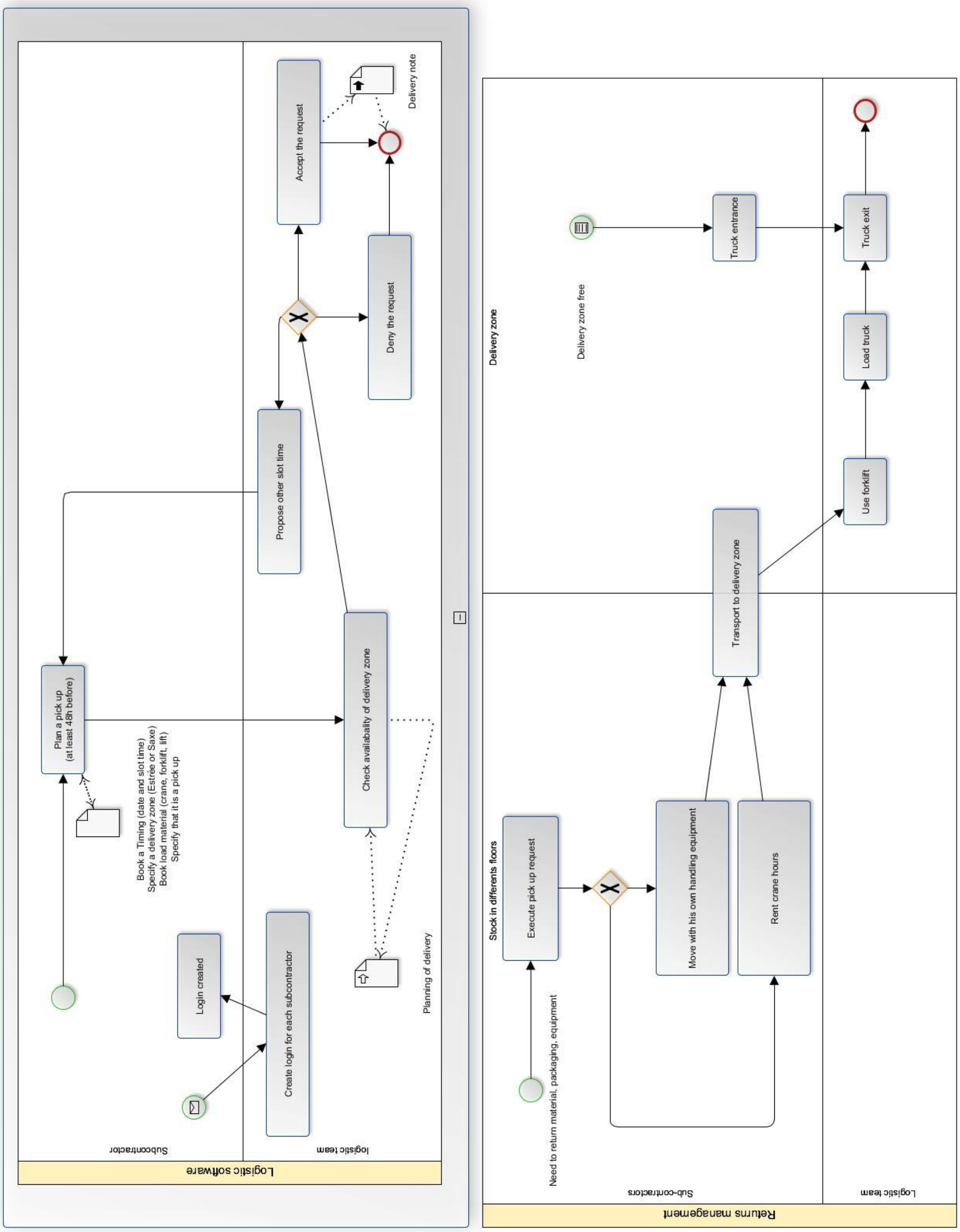
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

11.2.7 Process 8: Waste Management



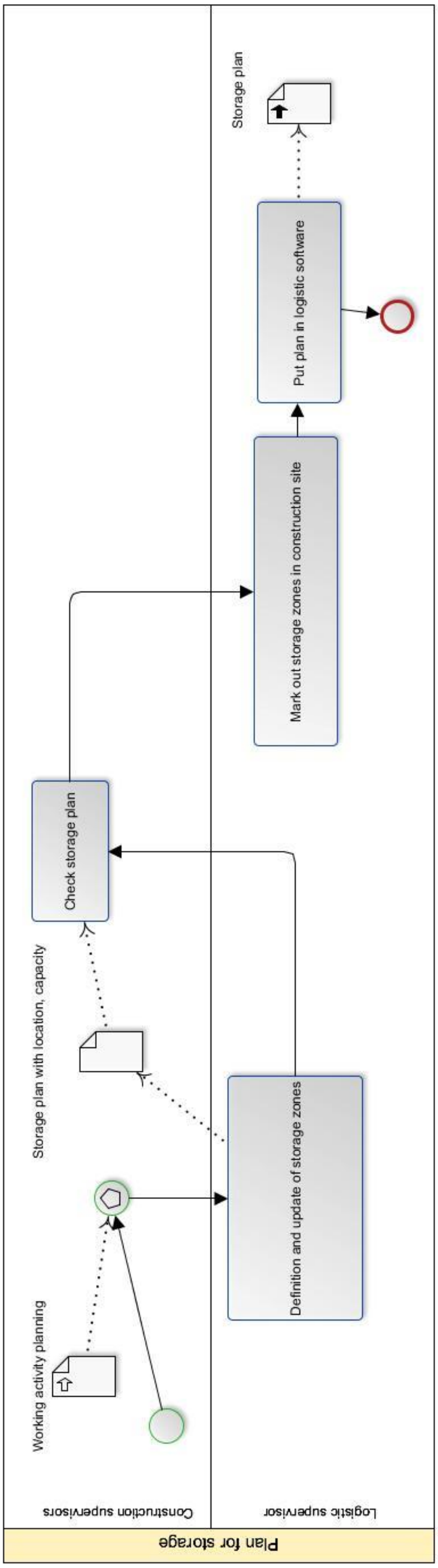
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

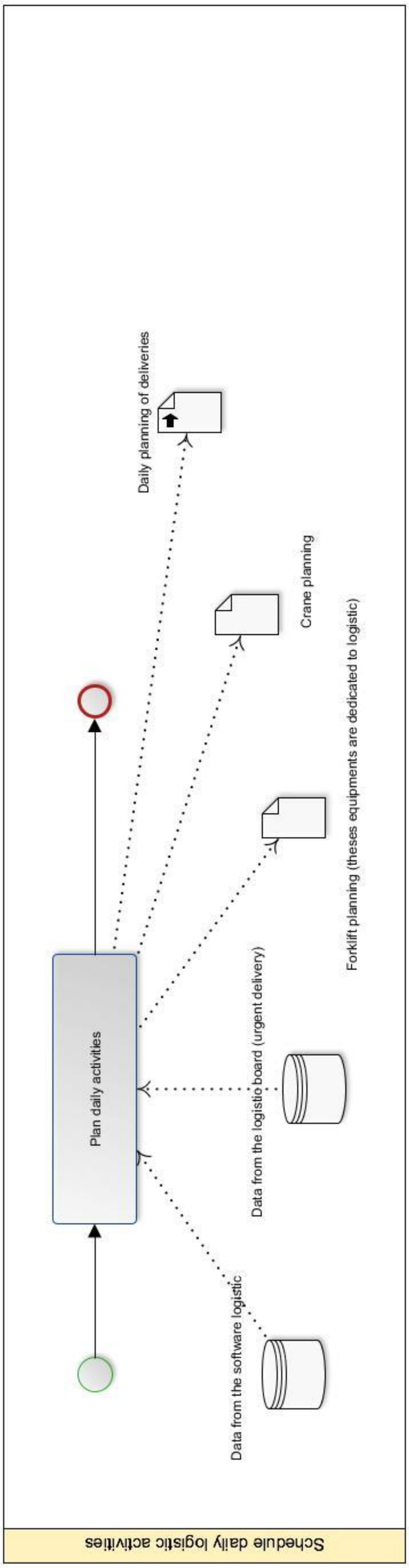
11.2.8 Process 9: Return Management



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

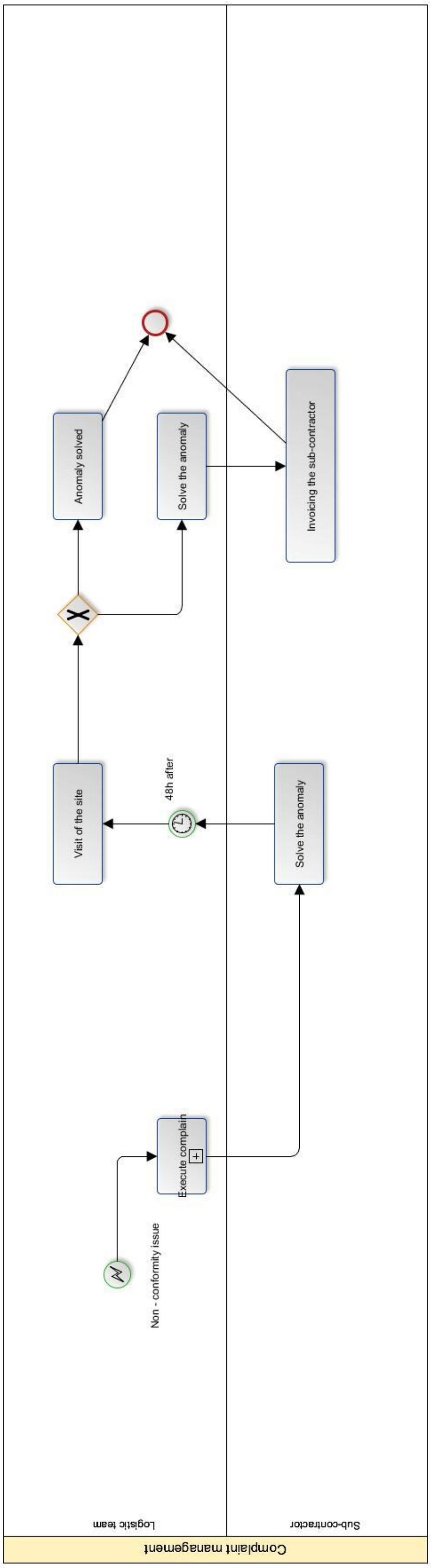
11.2.9 Process 10: Planning and Scheduling Resources





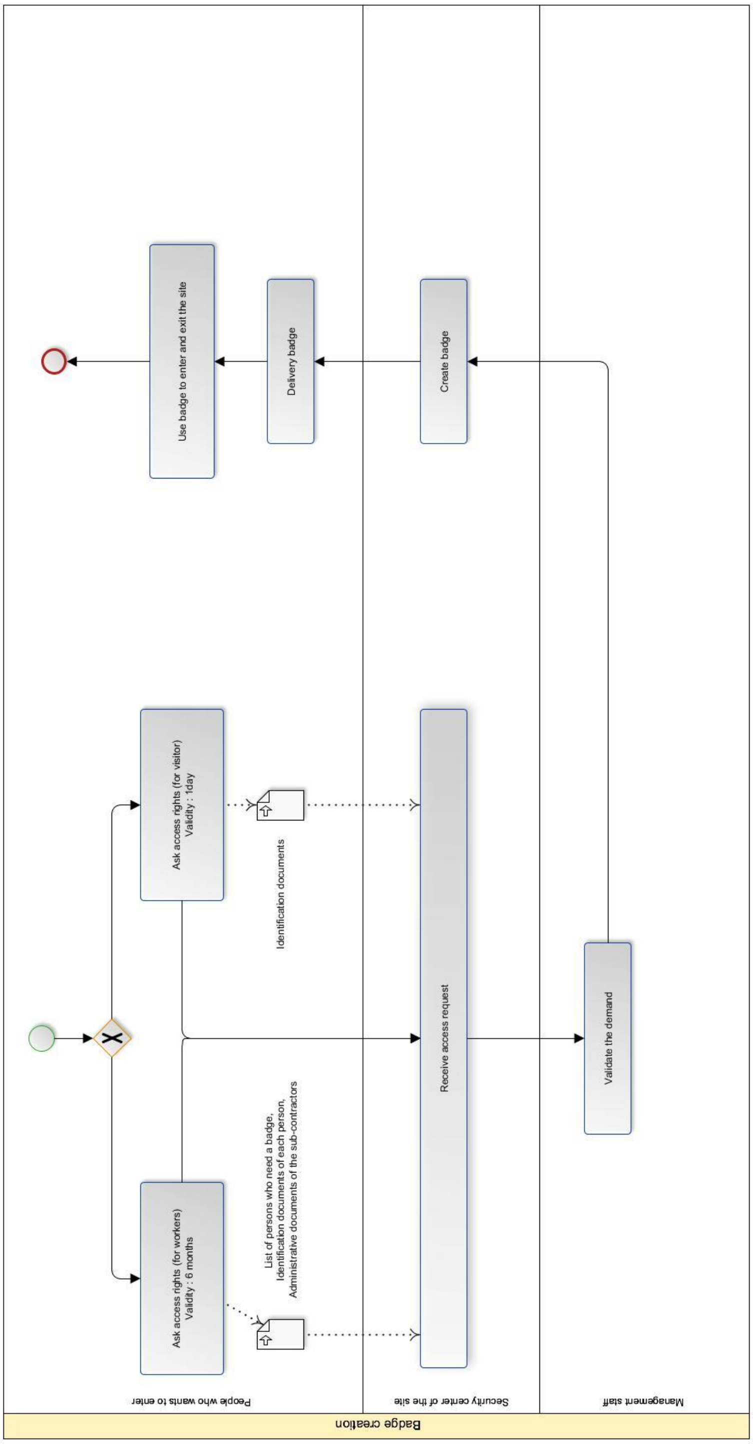
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

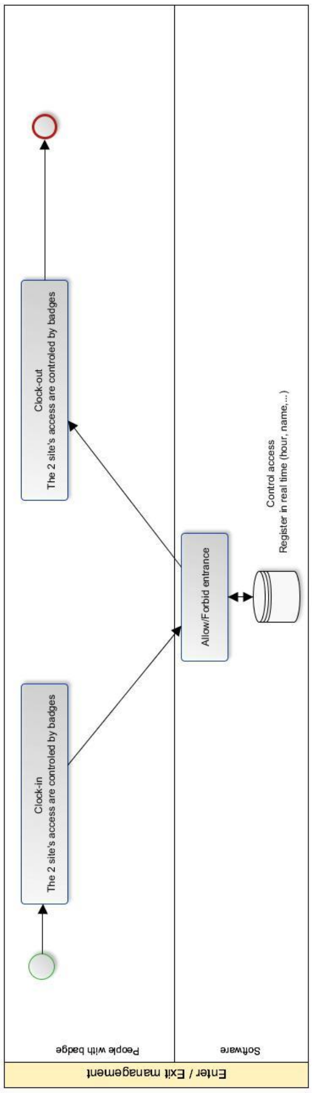
11.2.10 Process 11: Complaint Management



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

11.2.11 Process 12: Entrance and Exit Management

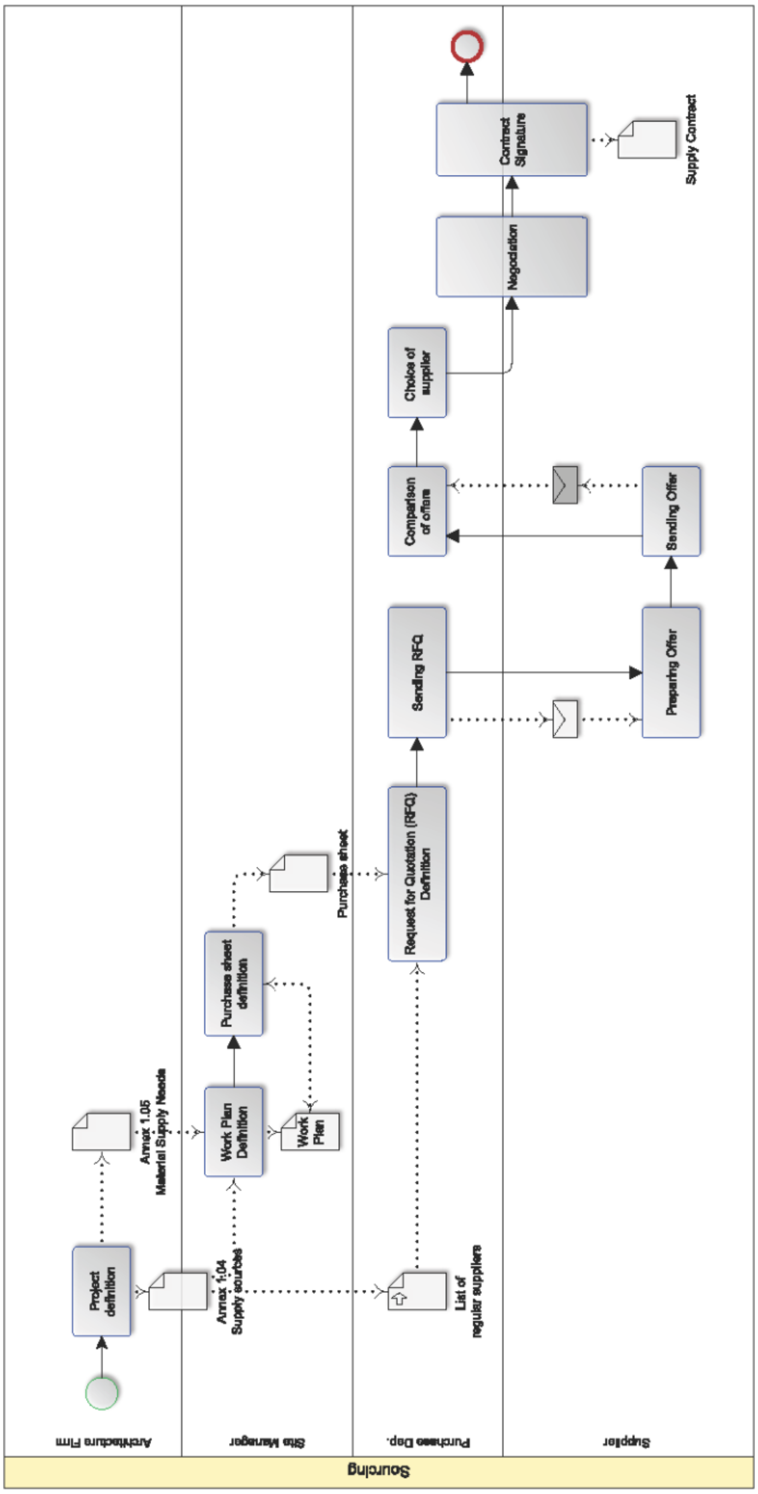




This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

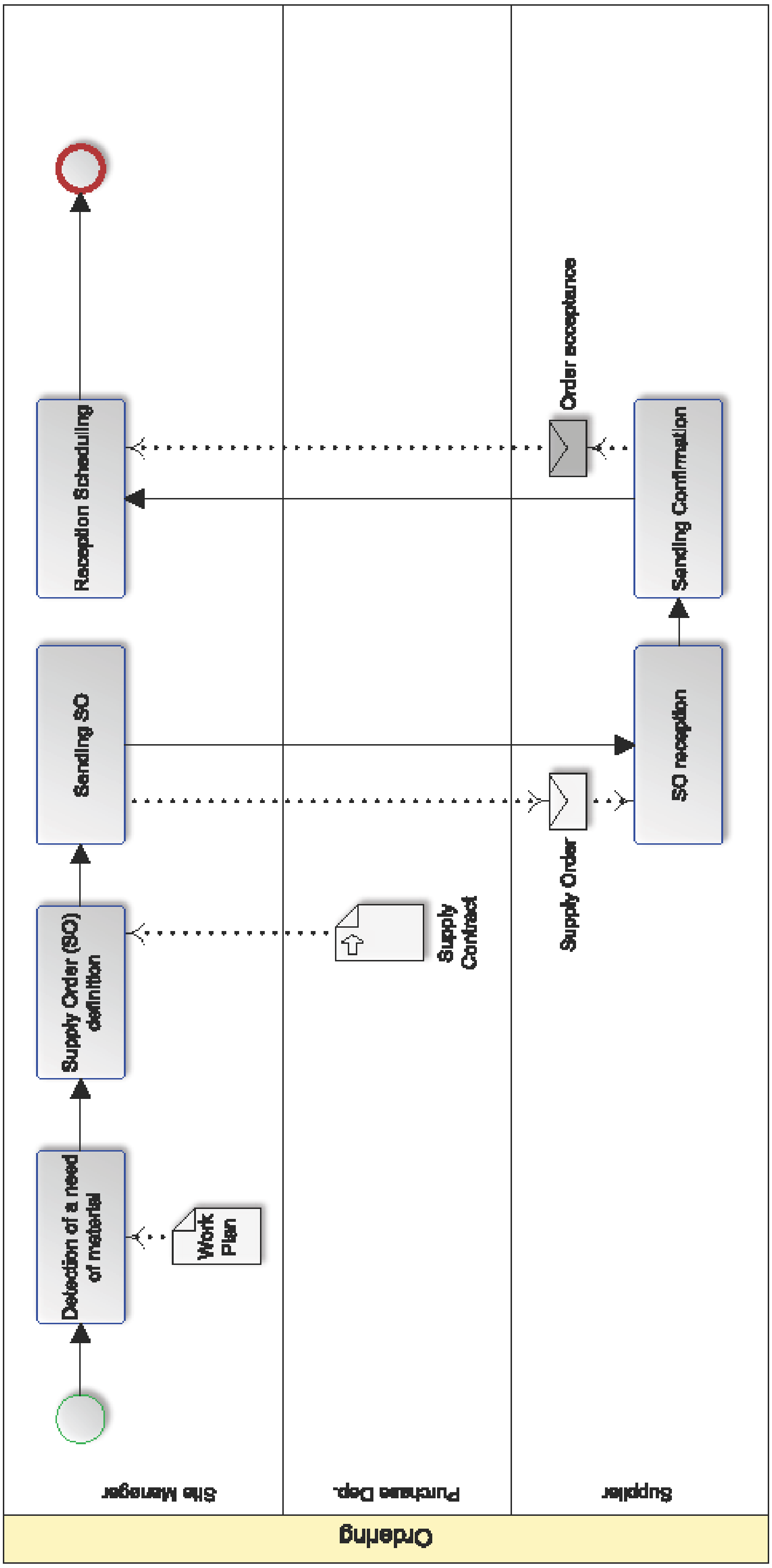
11.3 Process Maps: Valencia

11.3.1 Process 1: Sourcing



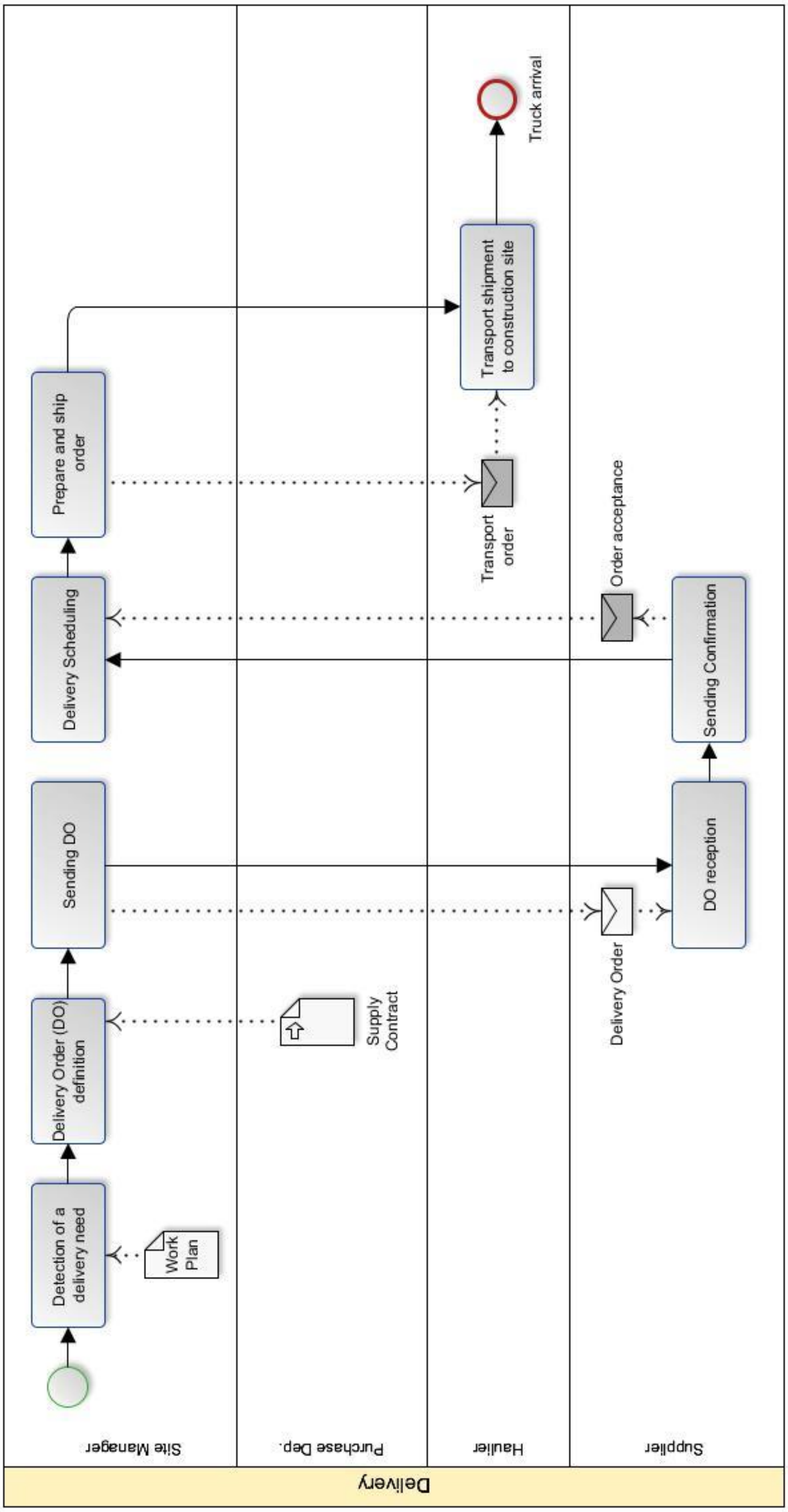
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

11.3.2 Process 2: Ordering



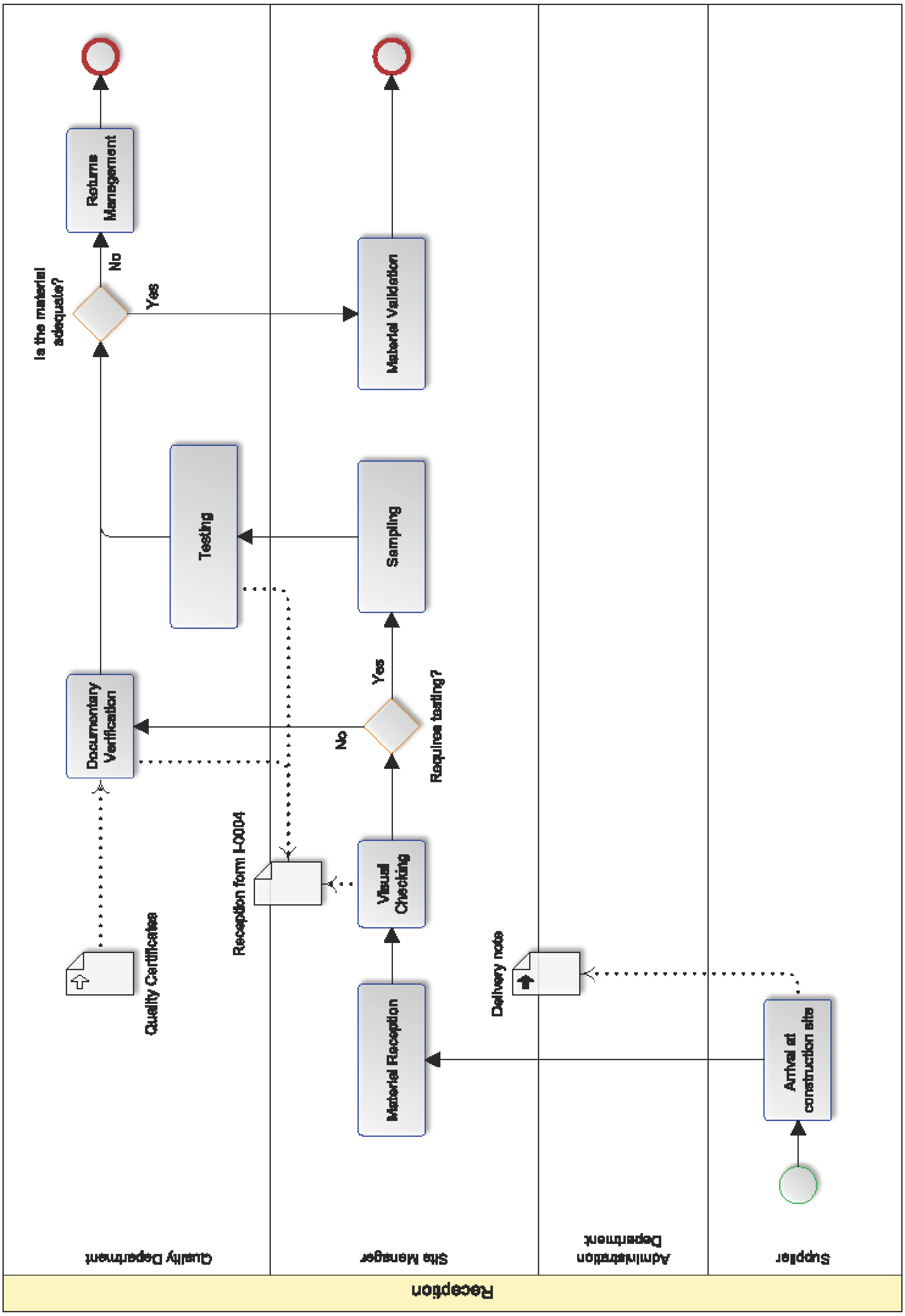
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

11.3.3 Process 3: Delivery



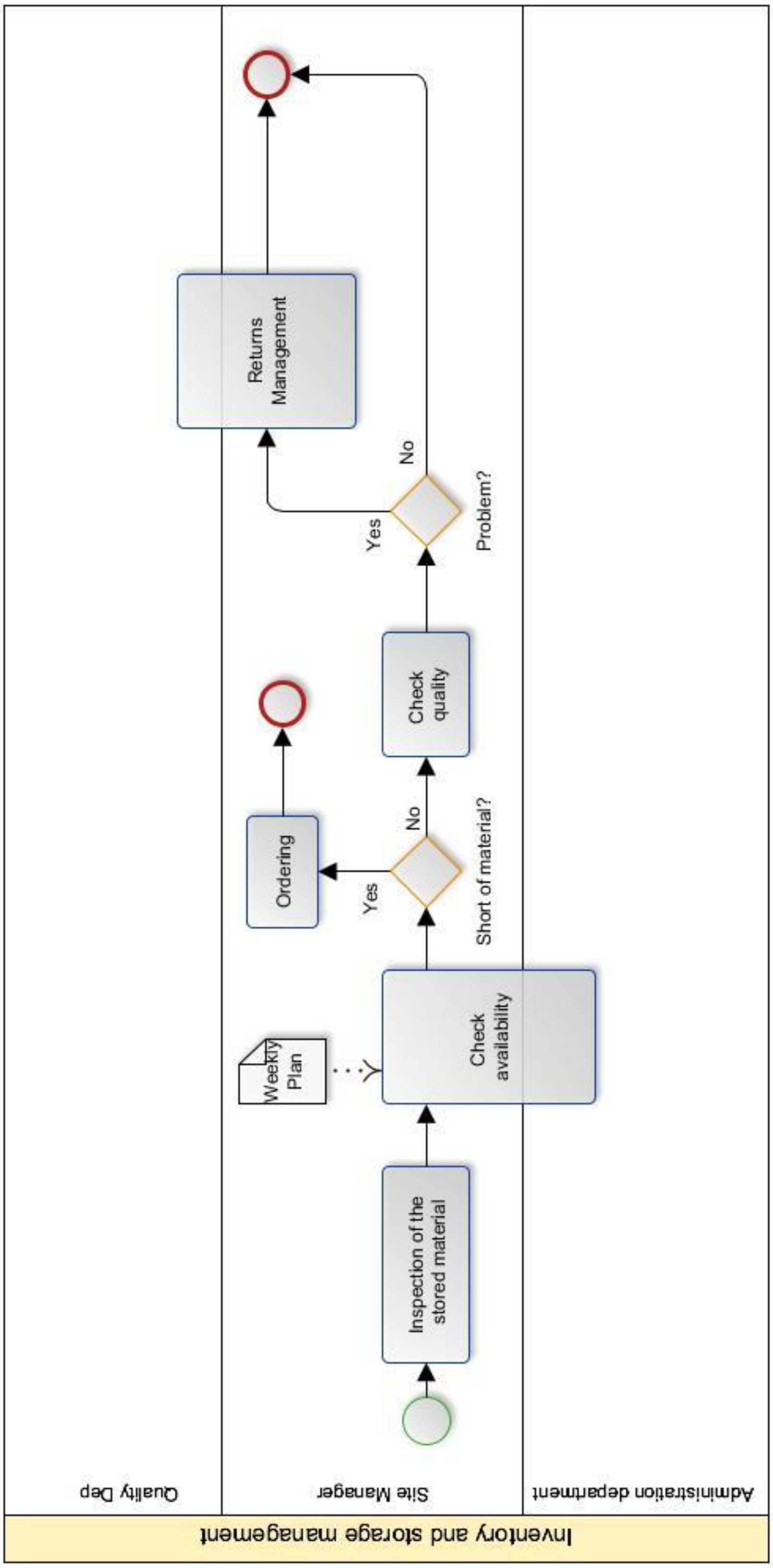
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

11.3.4 Process 4: Material Reception and Expedition



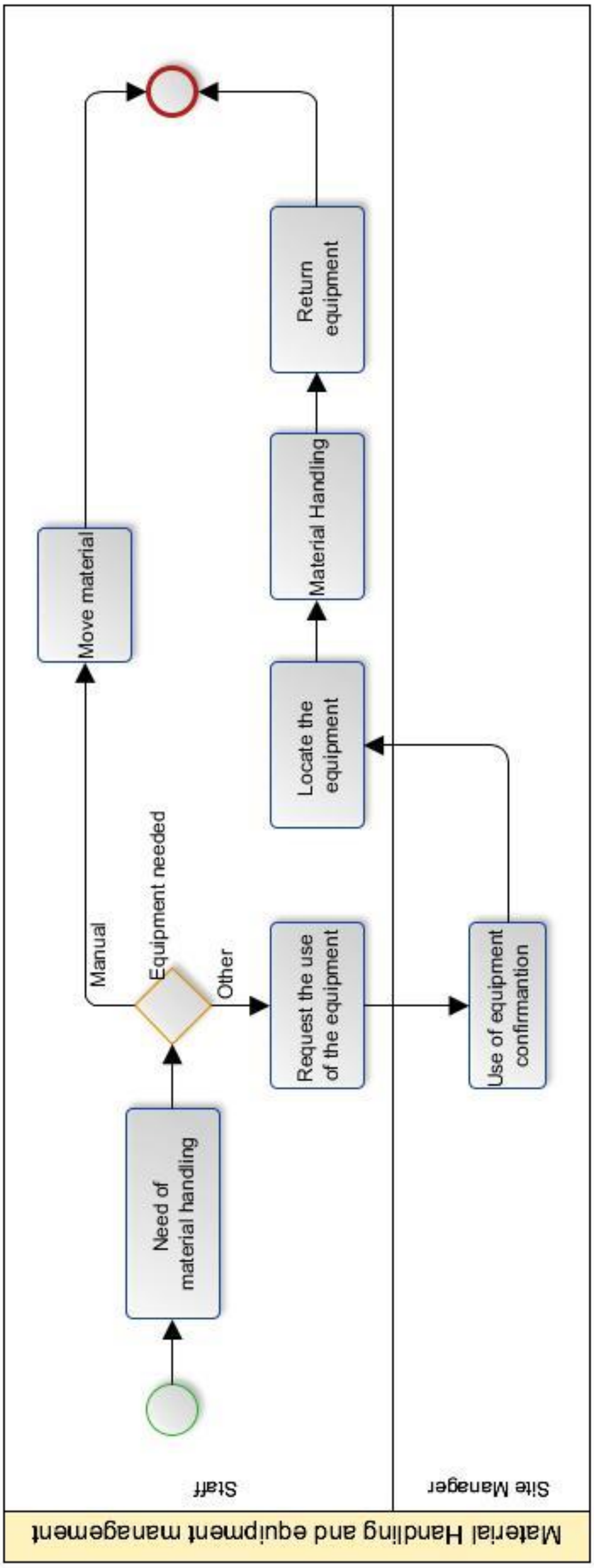
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

11.3.5 Process 5: Inventory and Storage Management



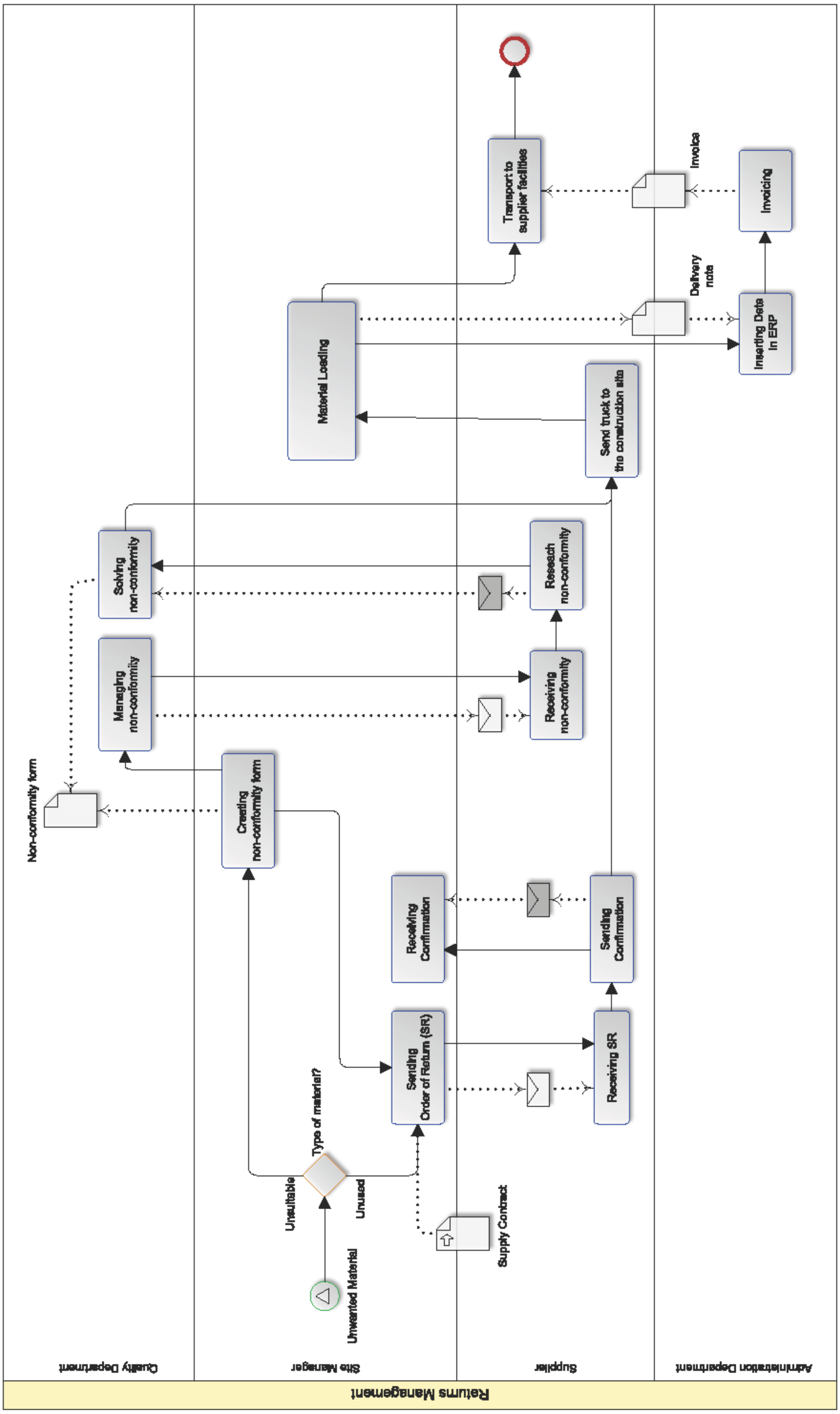
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

11.3.6 Process 6: Material Handling and Equipment Management



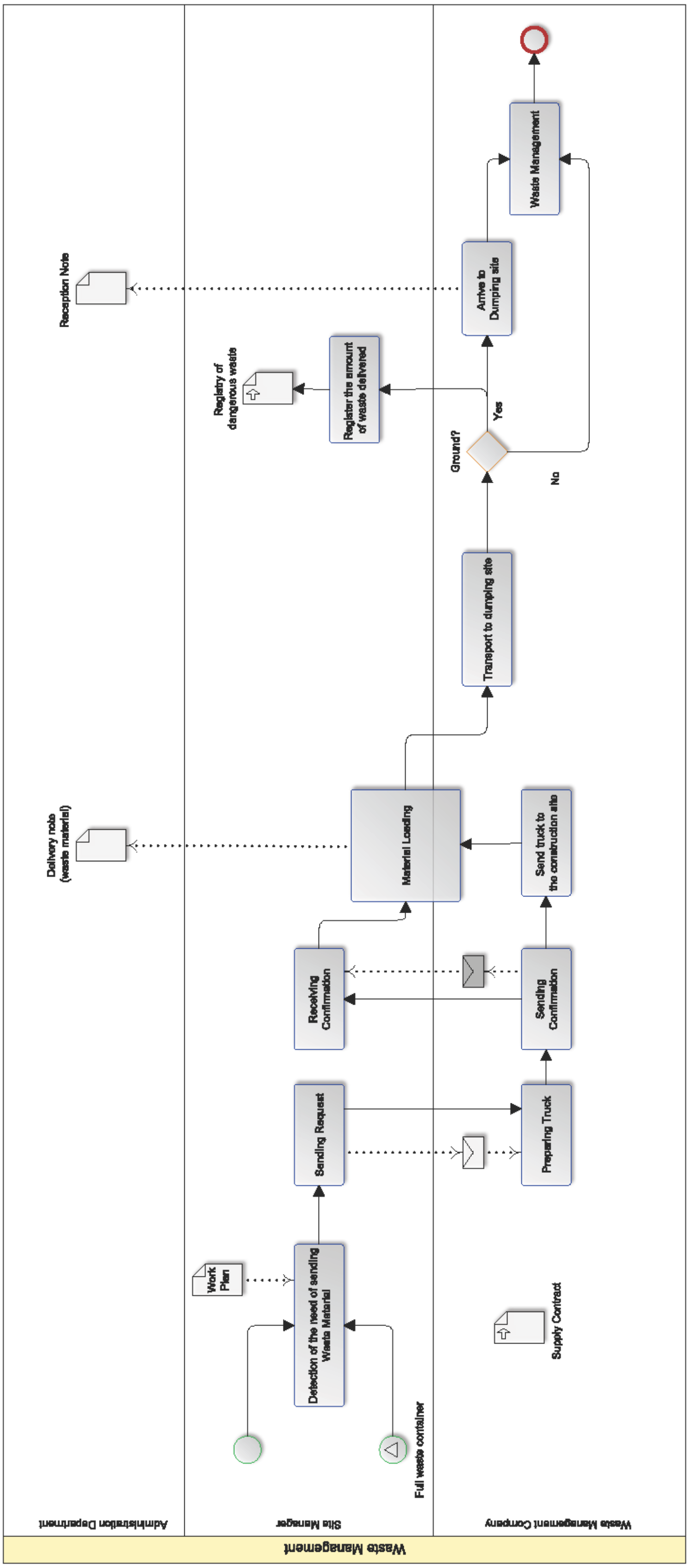
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

11.3.7 Process 8: Waste Management



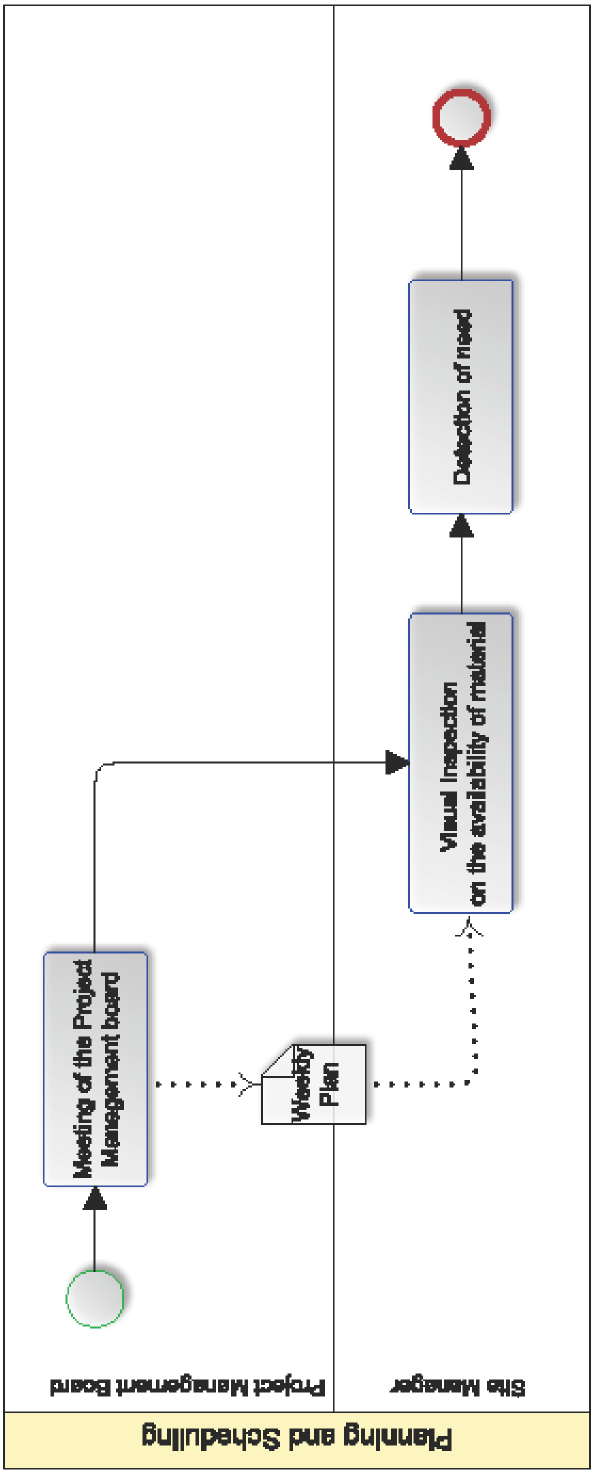
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

11.3.8 Process 9: Return Management



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

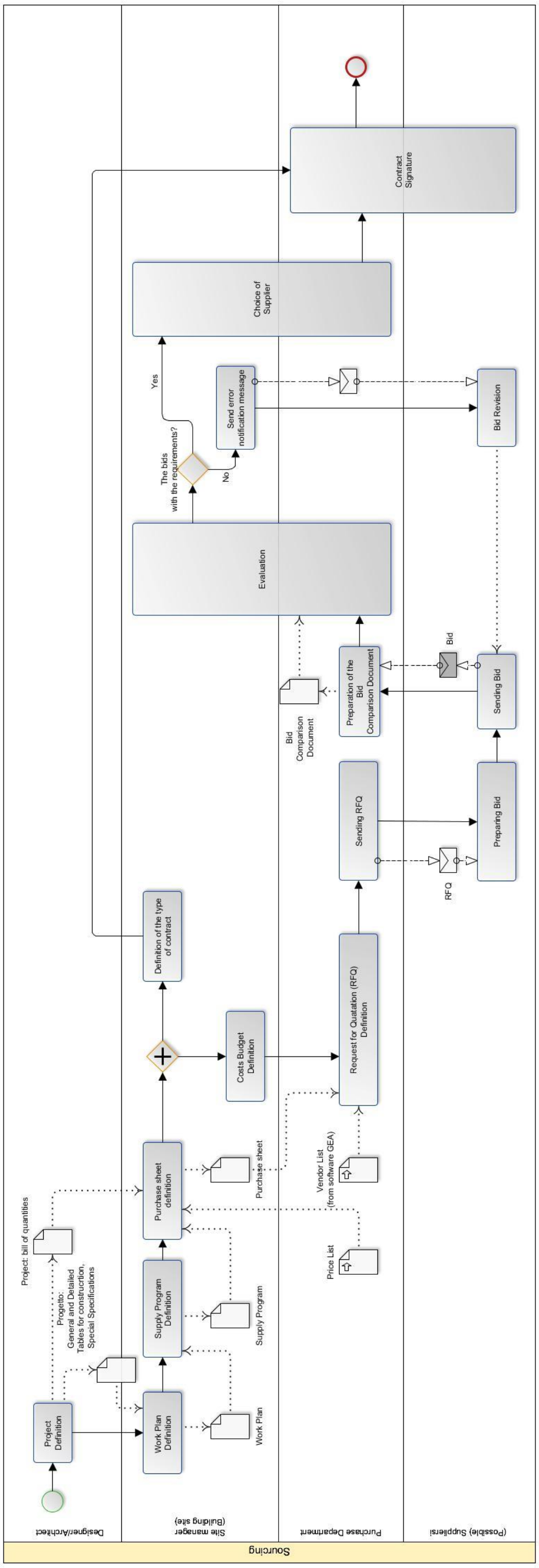
11.3.9 Process 10: Planning and Scheduling Resources



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

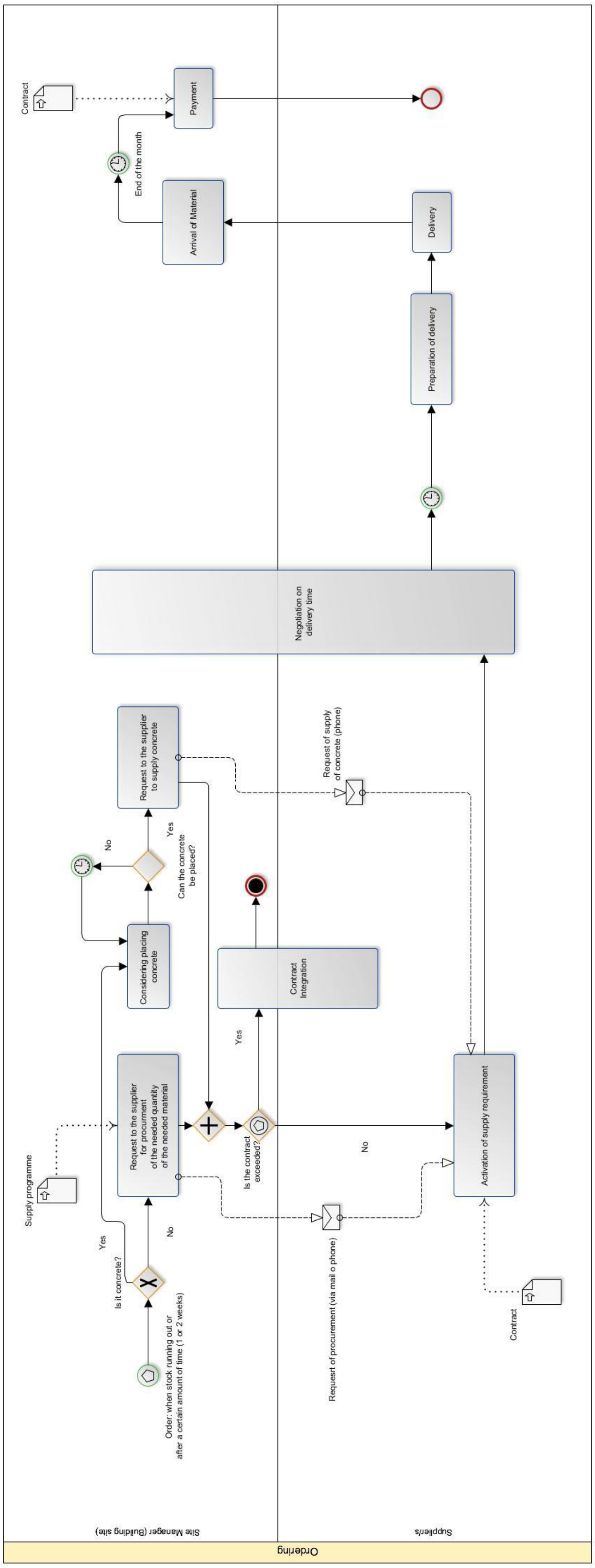
11.4 Process Maps: Verona

11.4.1 Process 1: Sourcing



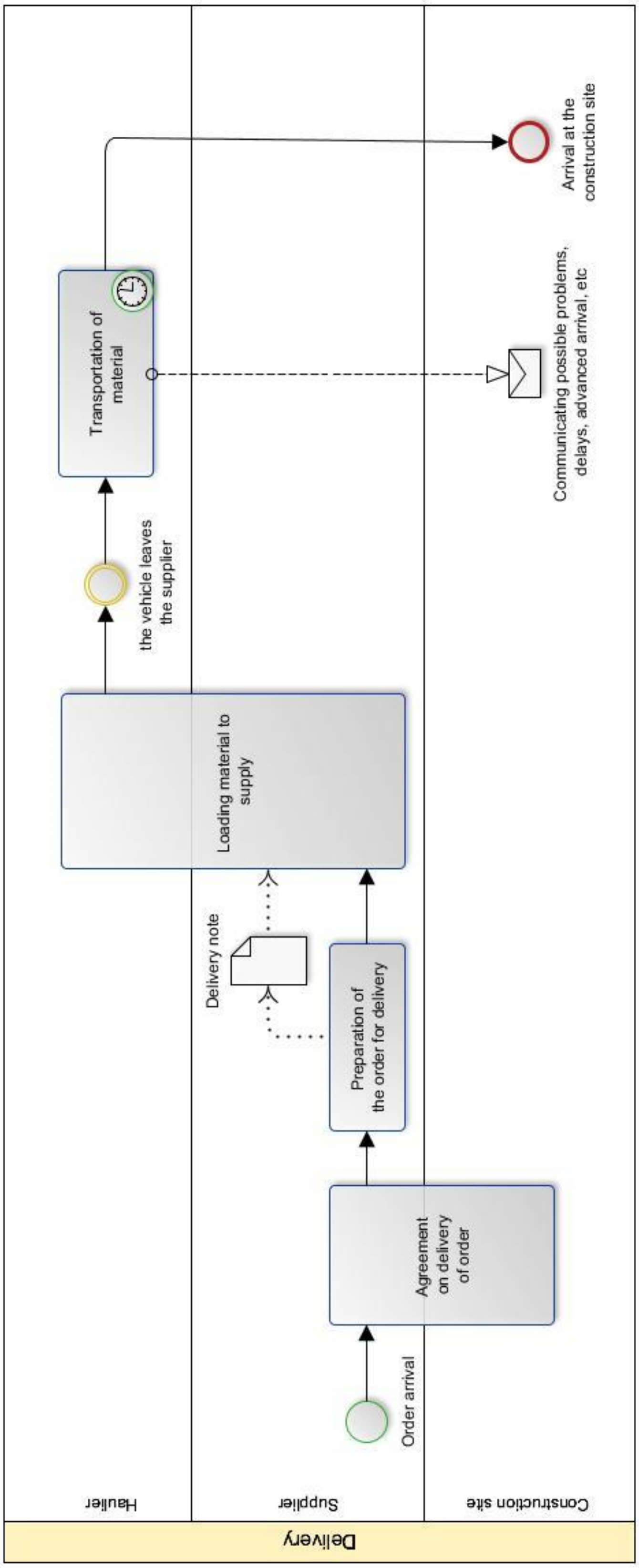
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

11.4.2 Process 2: Ordering



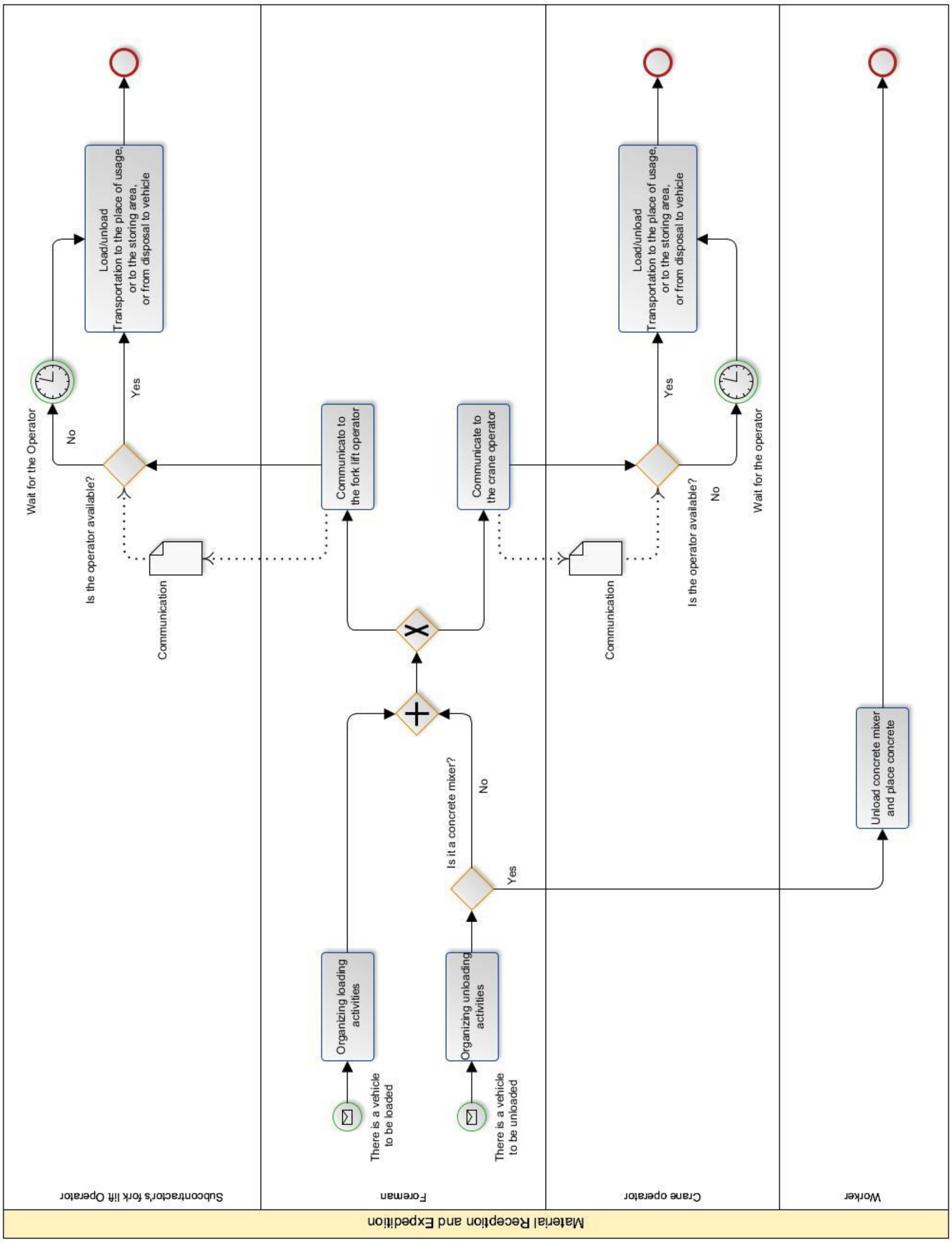
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

11.4.3 Process 3: Delivery



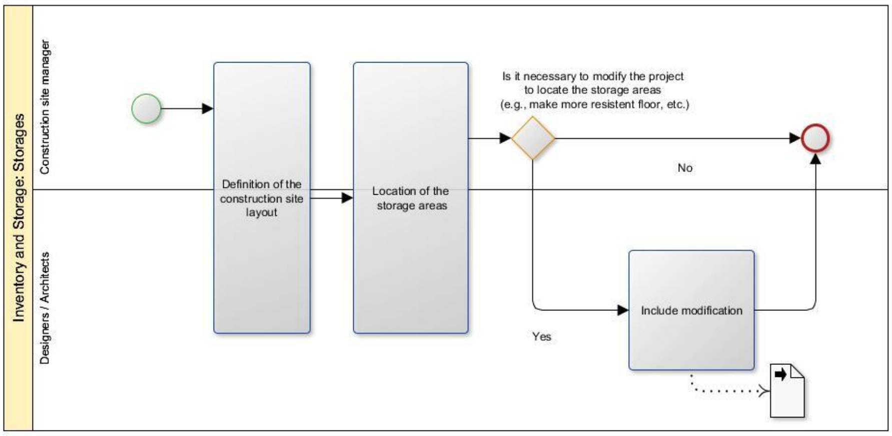
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

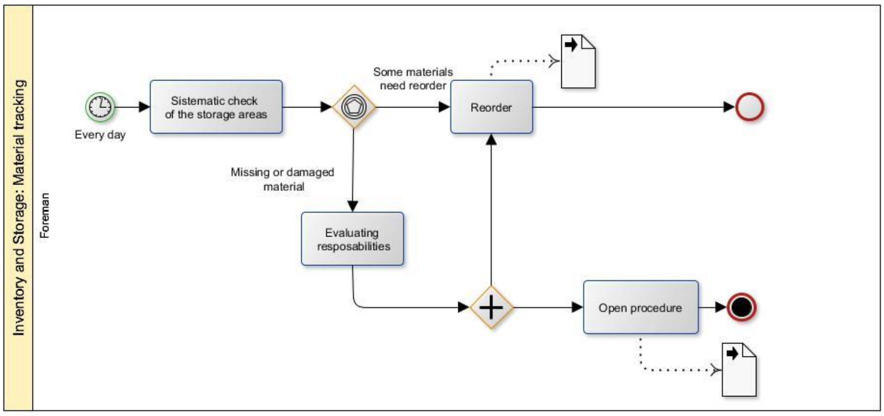
11.4.4 Process 4: Material Reception and Expedition

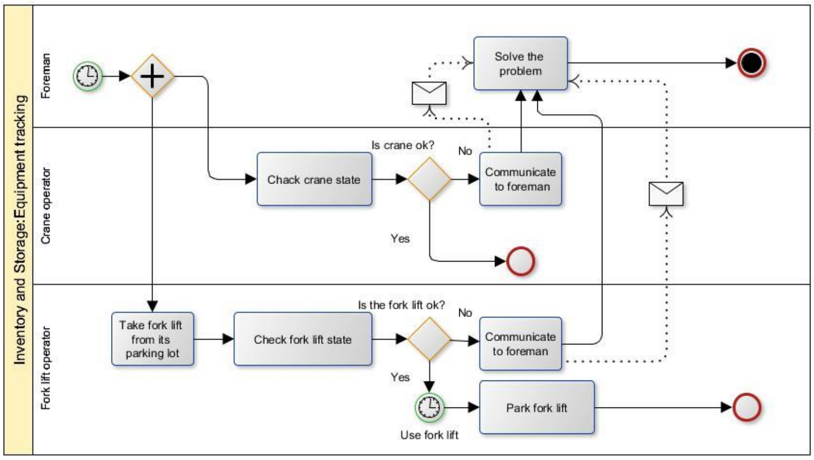


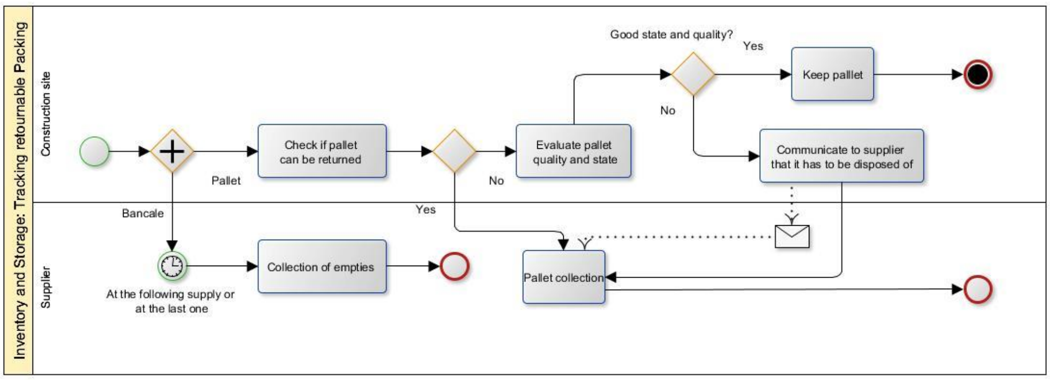
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

11.4.5 Process 5: Inventory and Storage Management



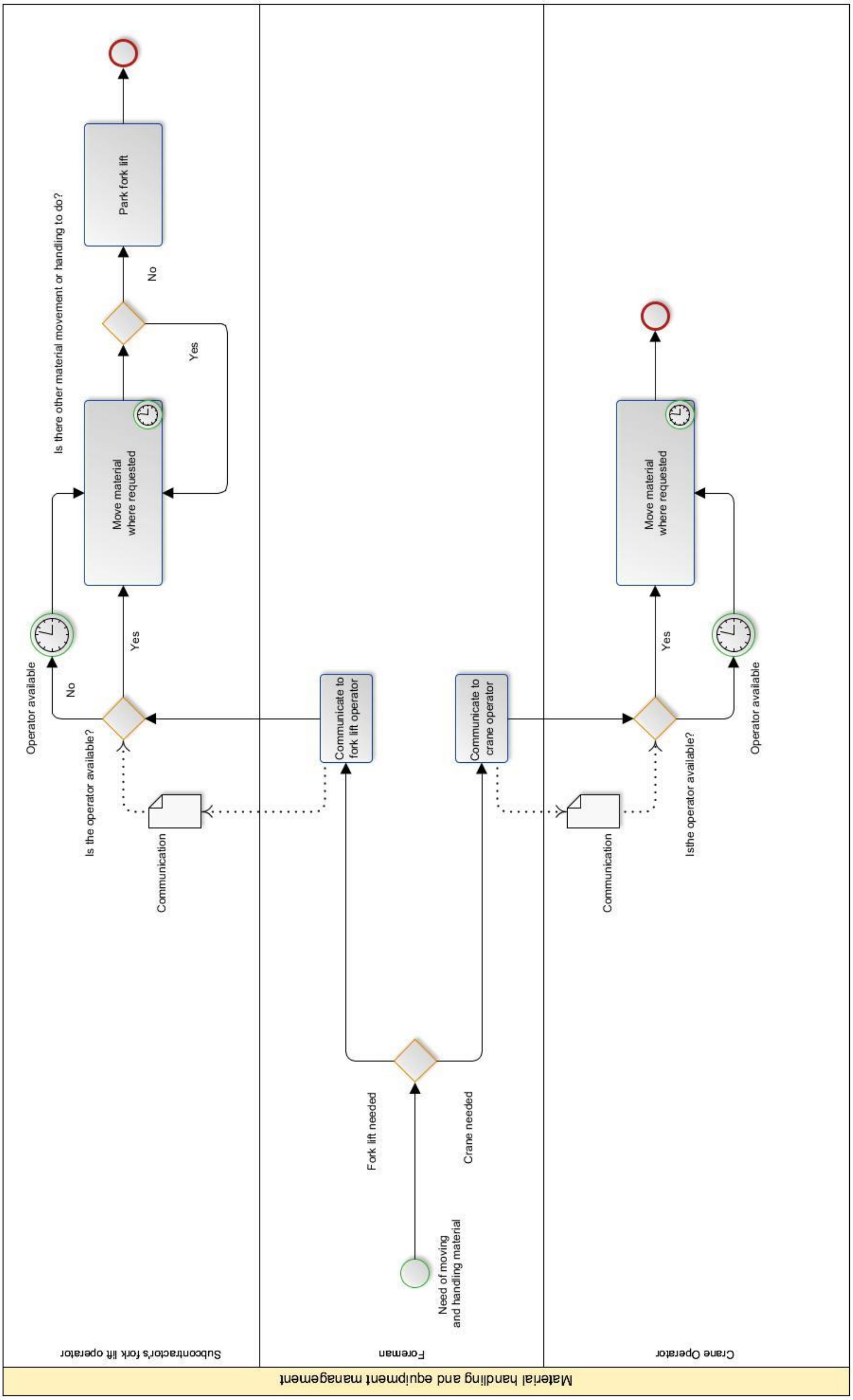






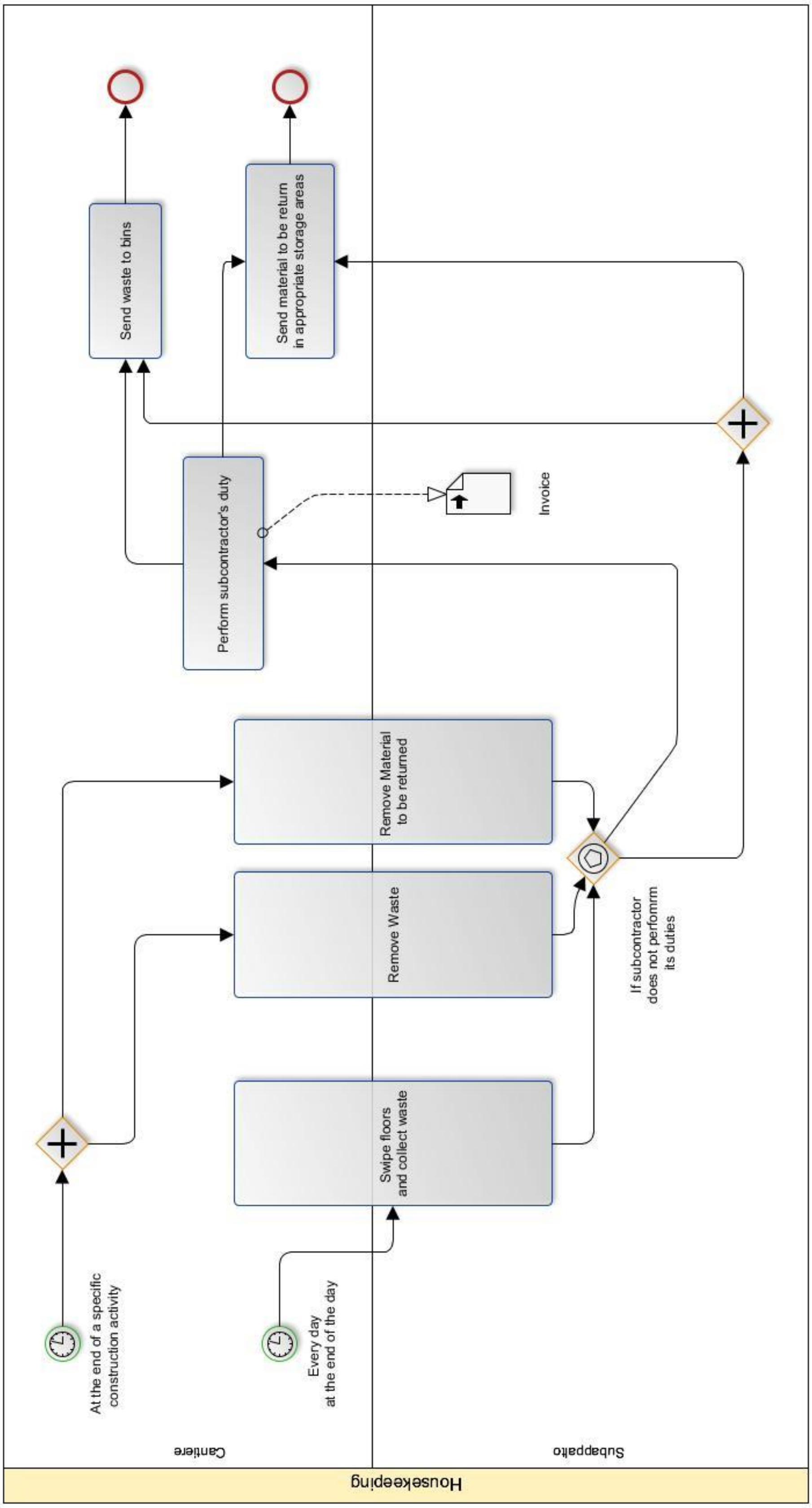
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

11.4.6 Process 6: Material Handling and Equipment Management



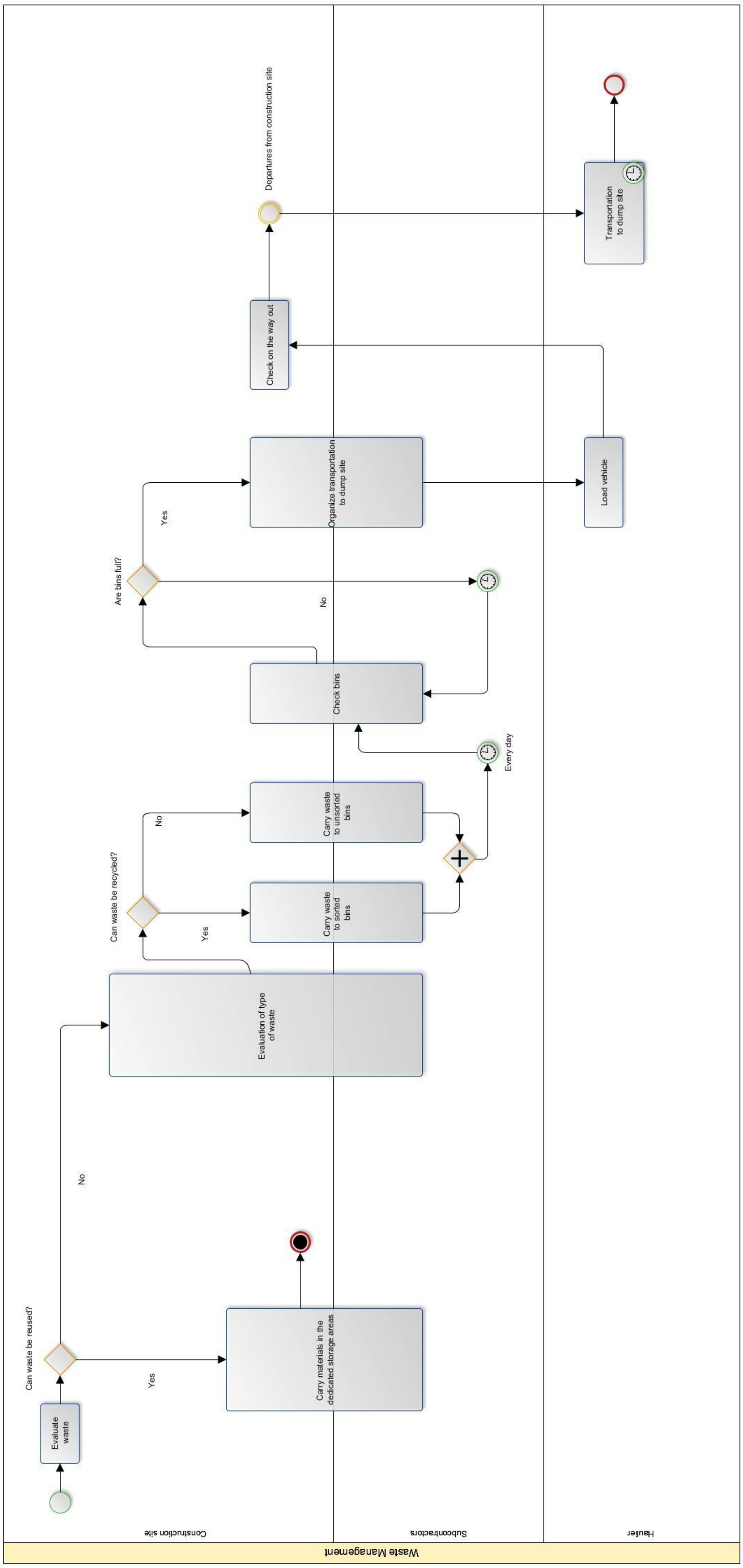
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

11.4.7 Process 7: Housekeeping



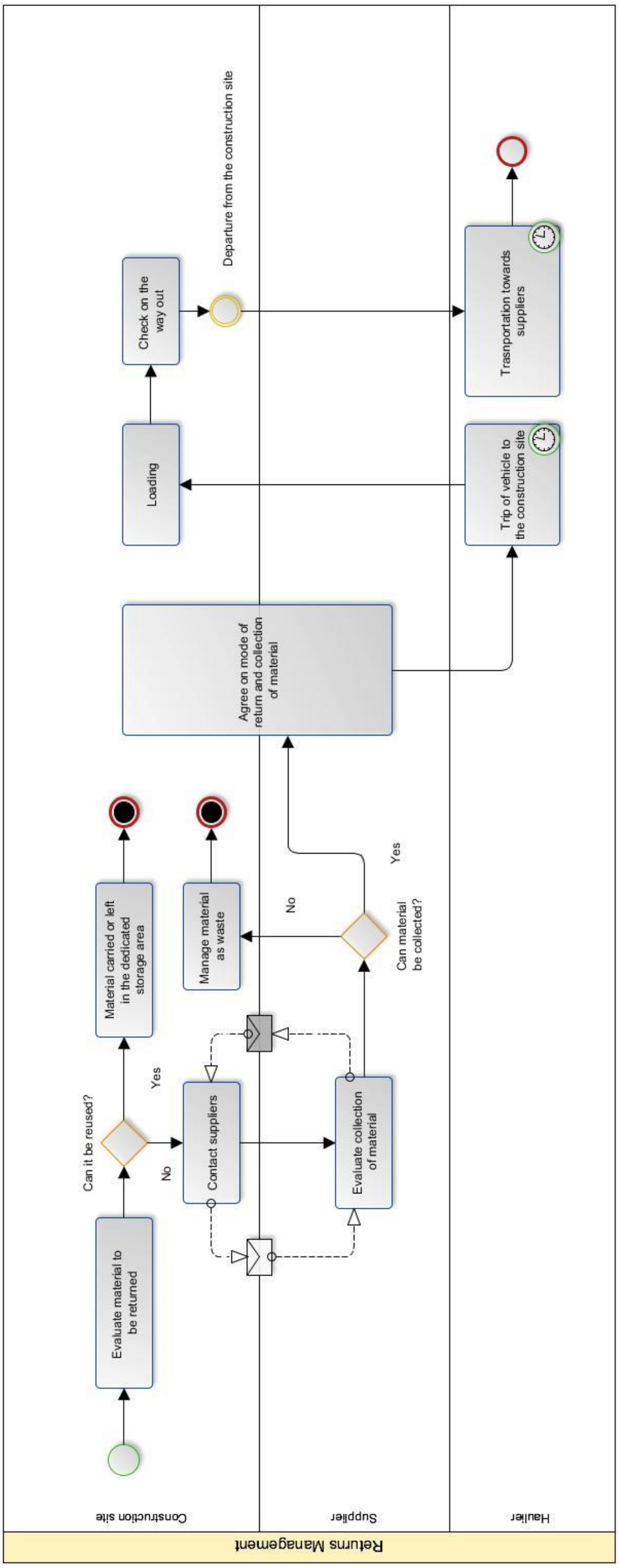
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

11.4.8 Process 8: Waste Management



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

11.4.9 Process 9: Return Management



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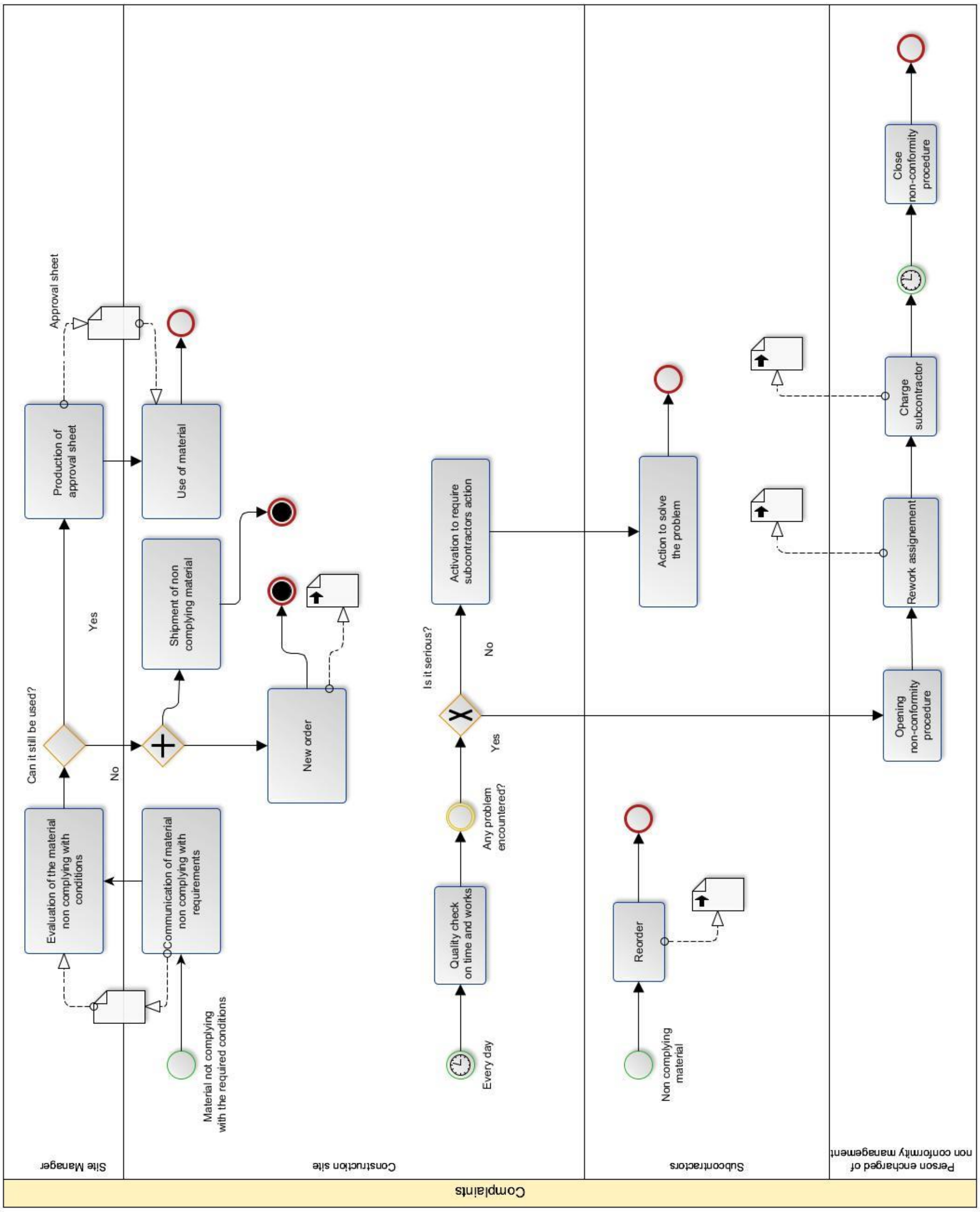
11.4.10 Process 11: Complaint Management



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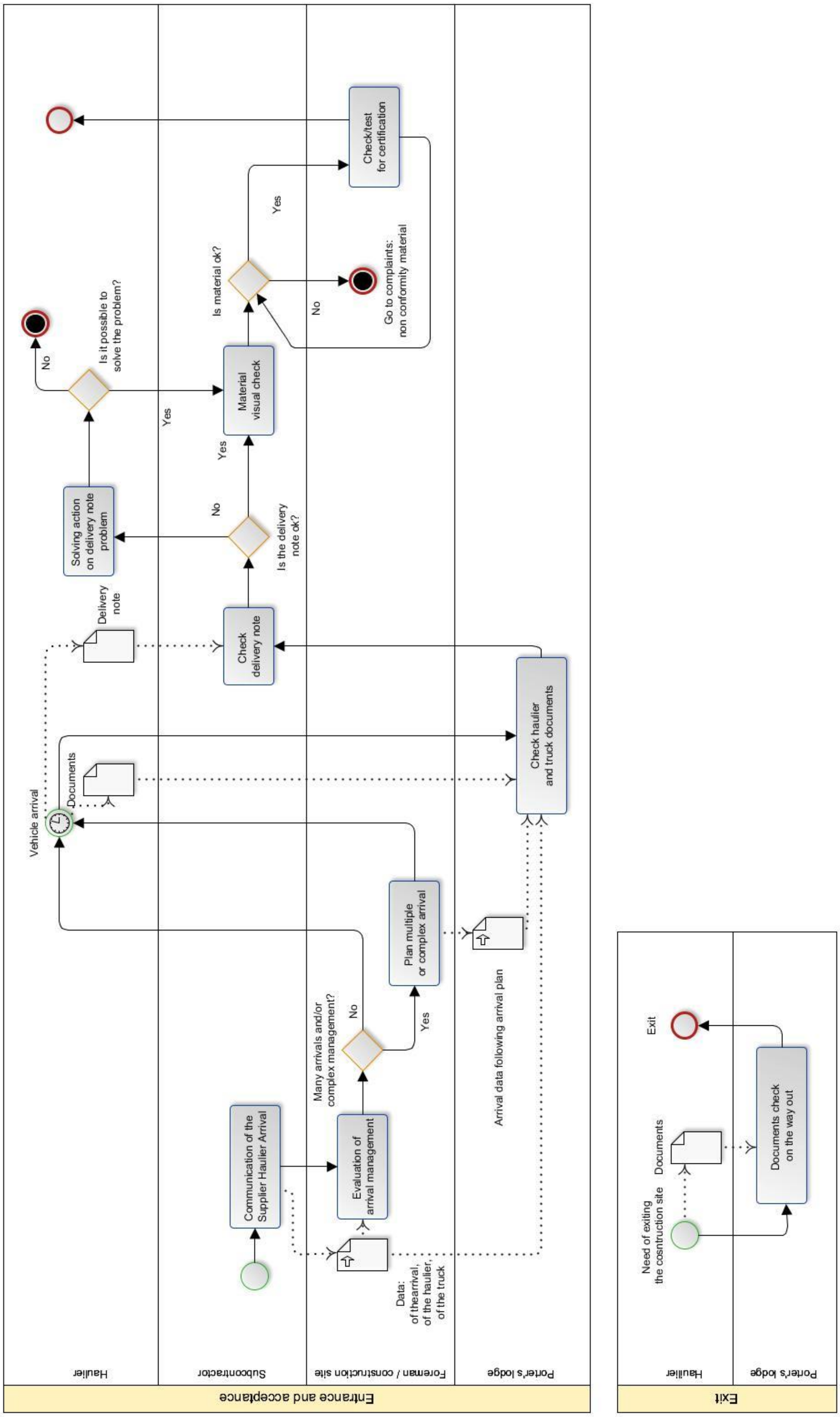
11.4.11 Process 12: Entrance and Exit Management



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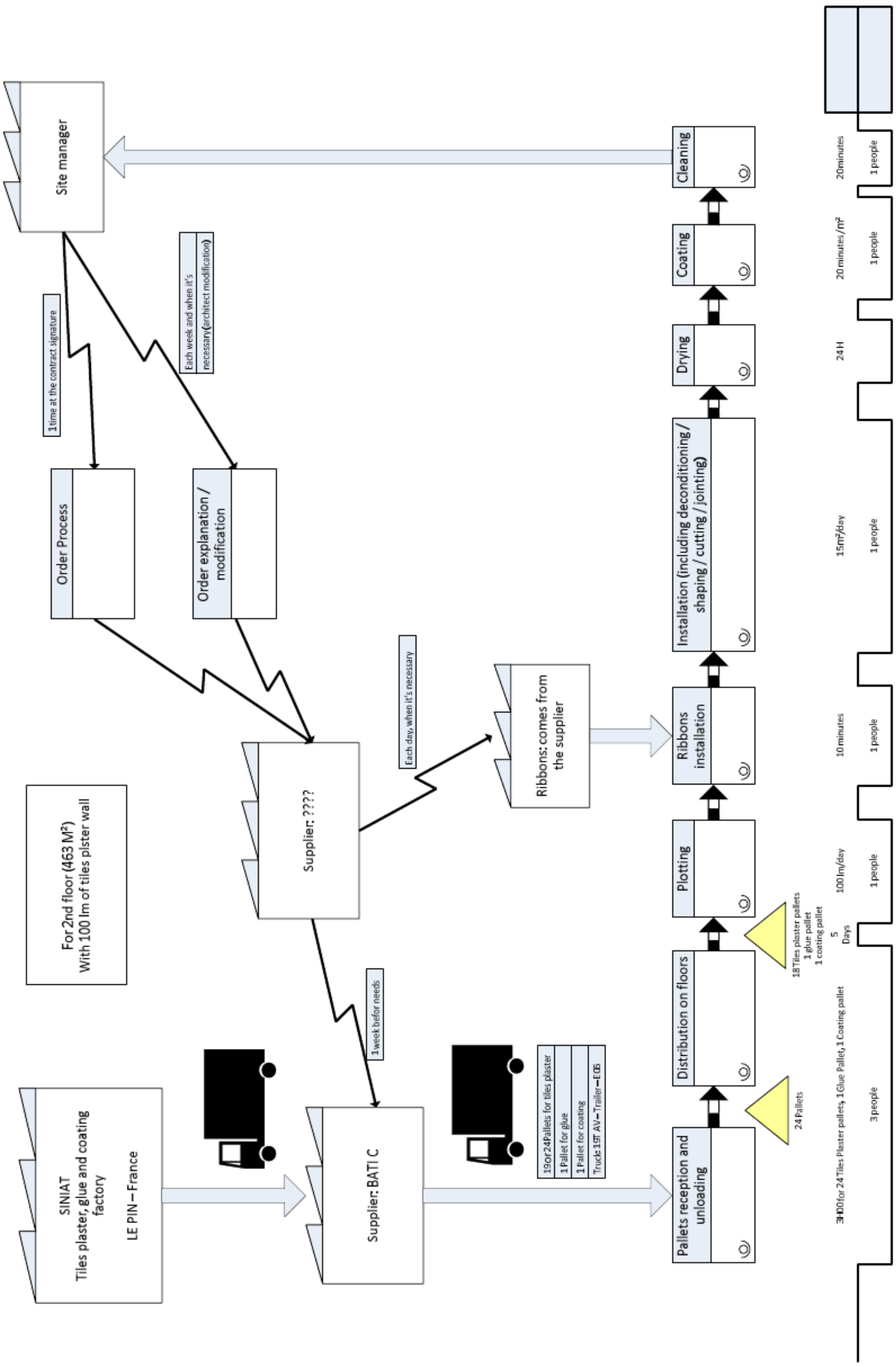
12 Annex F: The Value Stream Maps

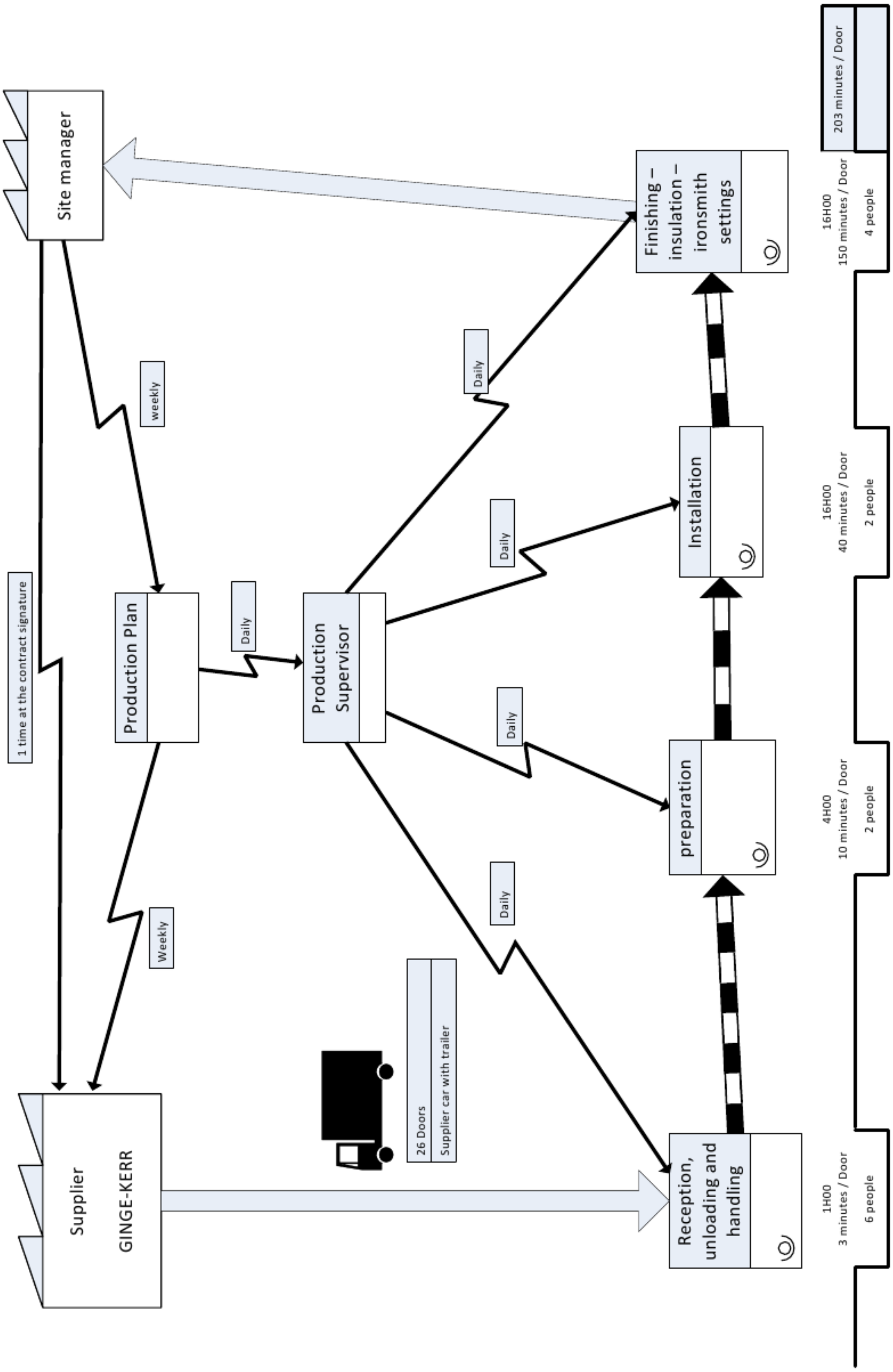
12.1 Value Stream Maps: Luxembourg

12.1.1 Plaster wall tiles



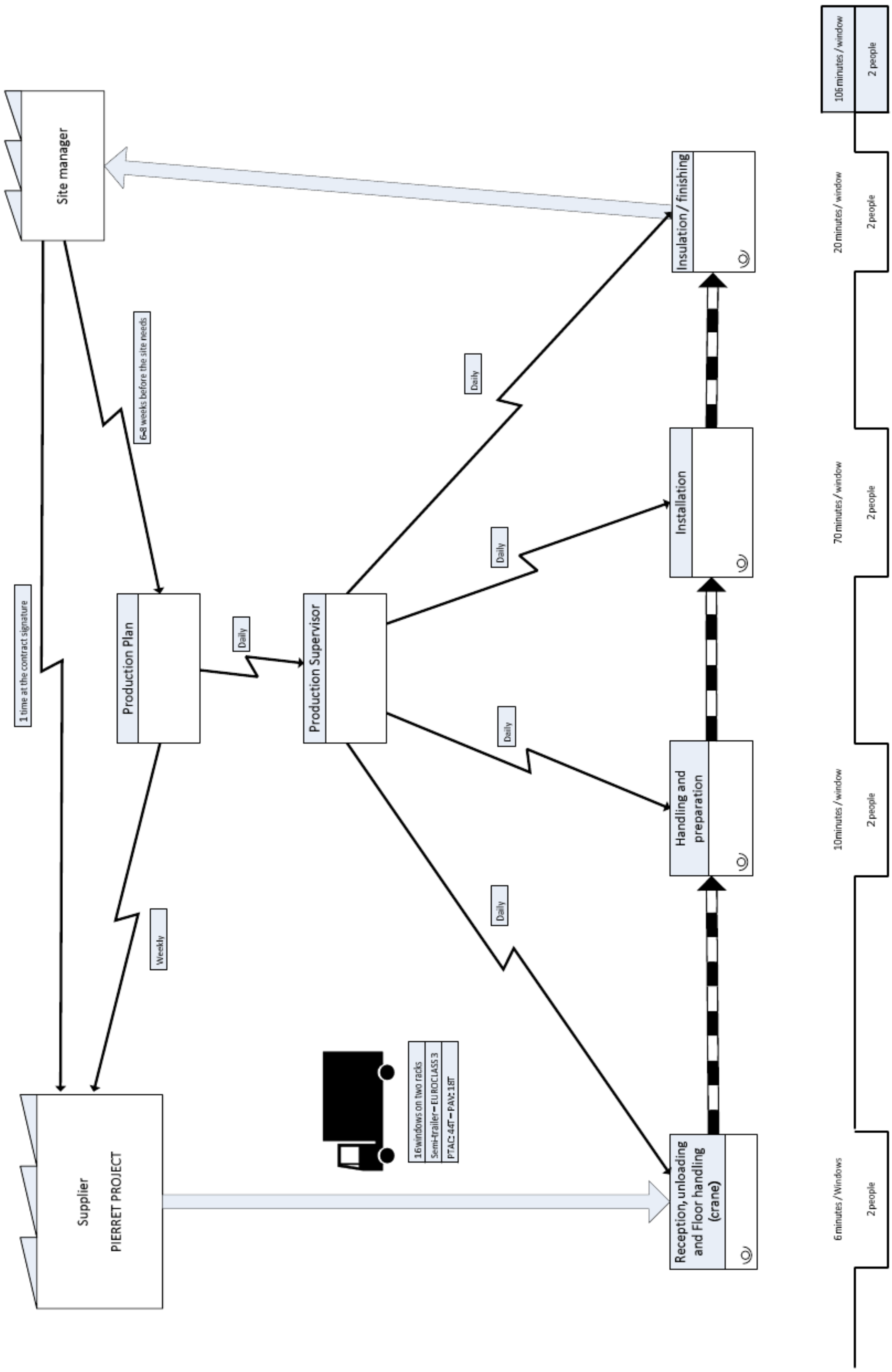
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

12.1.2 Doors



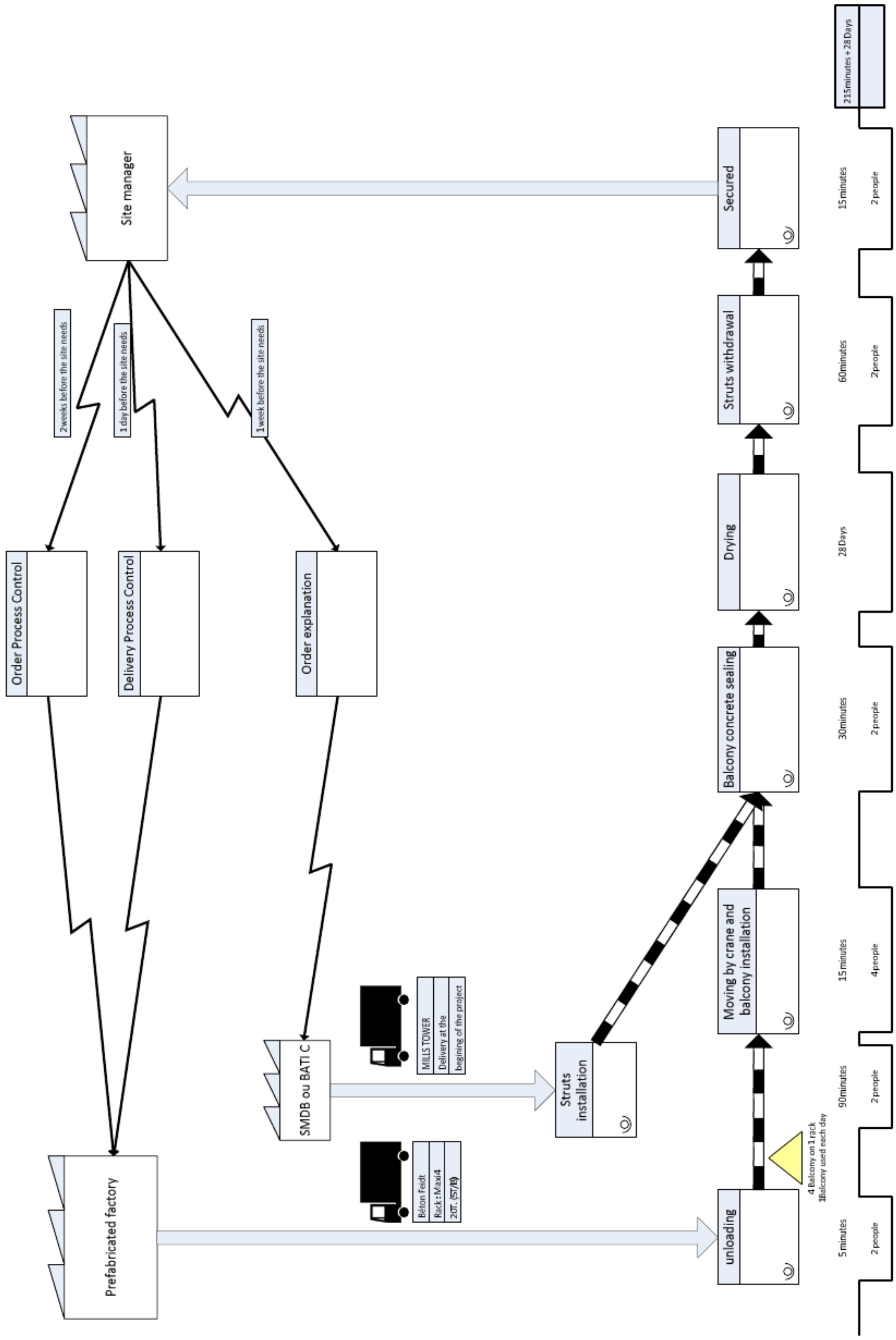
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

12.1.3 Windows



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

12.1.4 Prefabricated Balconies



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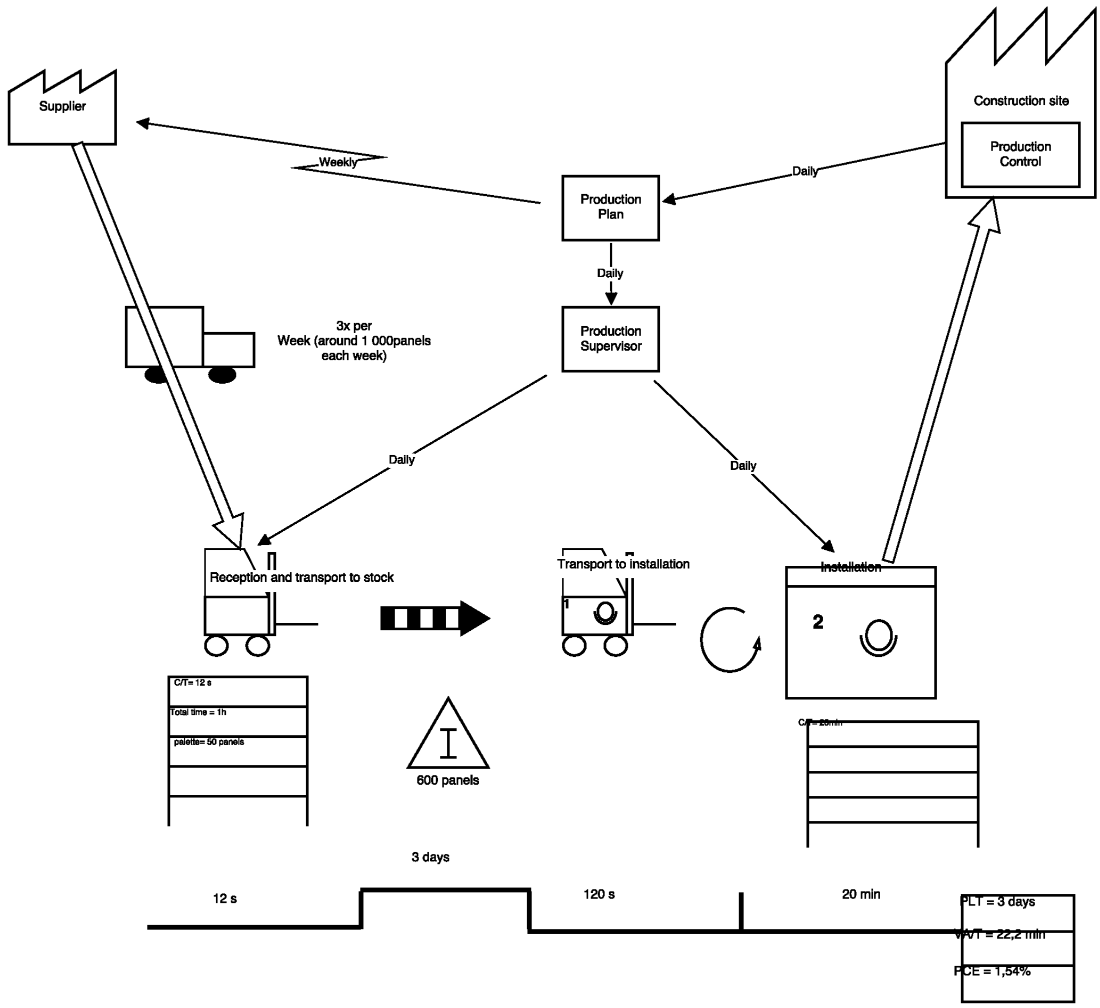
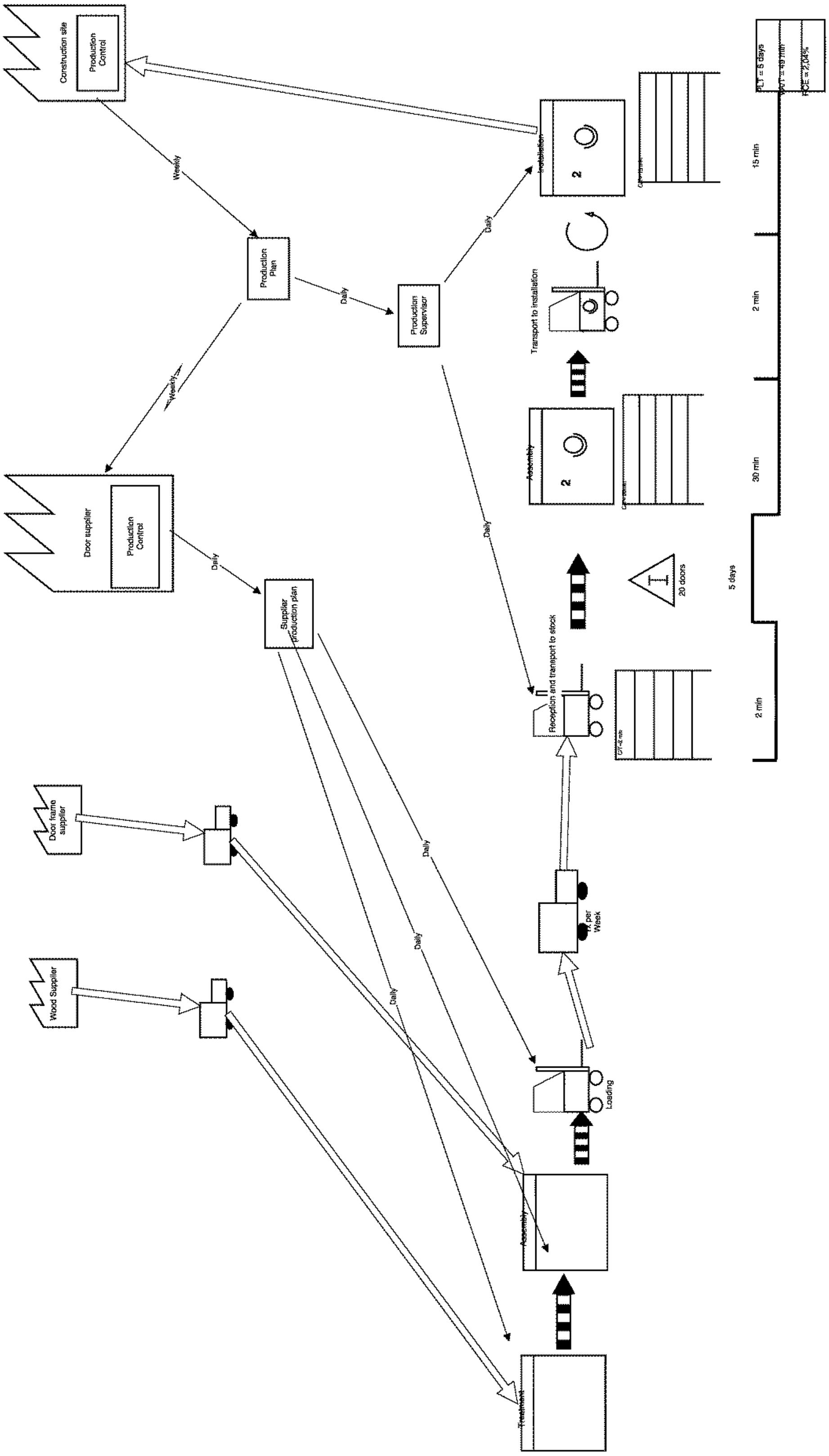
12.2 Value Stream Maps: Paris

12.2.1 Plasterboard



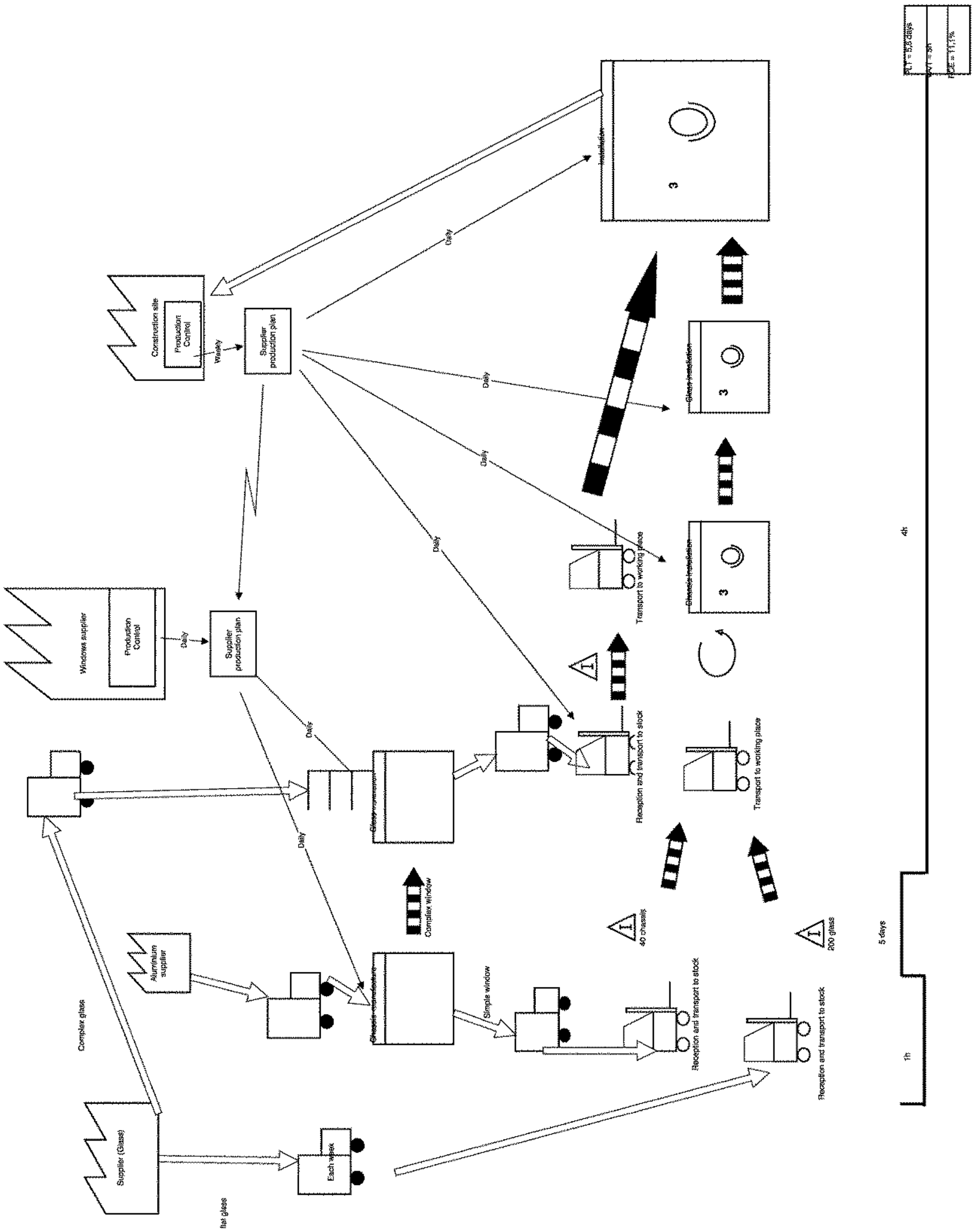
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

12.2.2 Doors



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

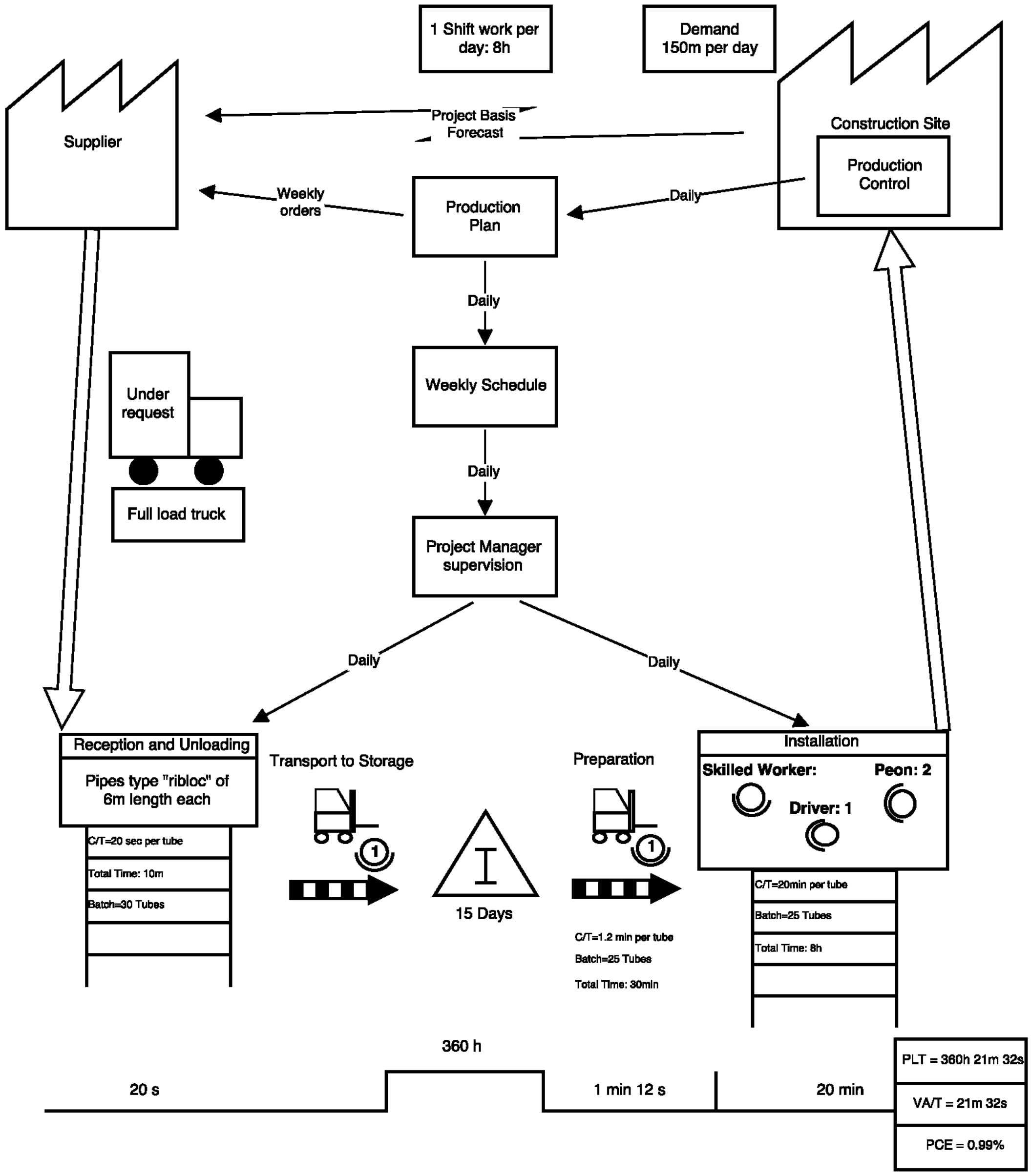
12.2.3 Windows



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

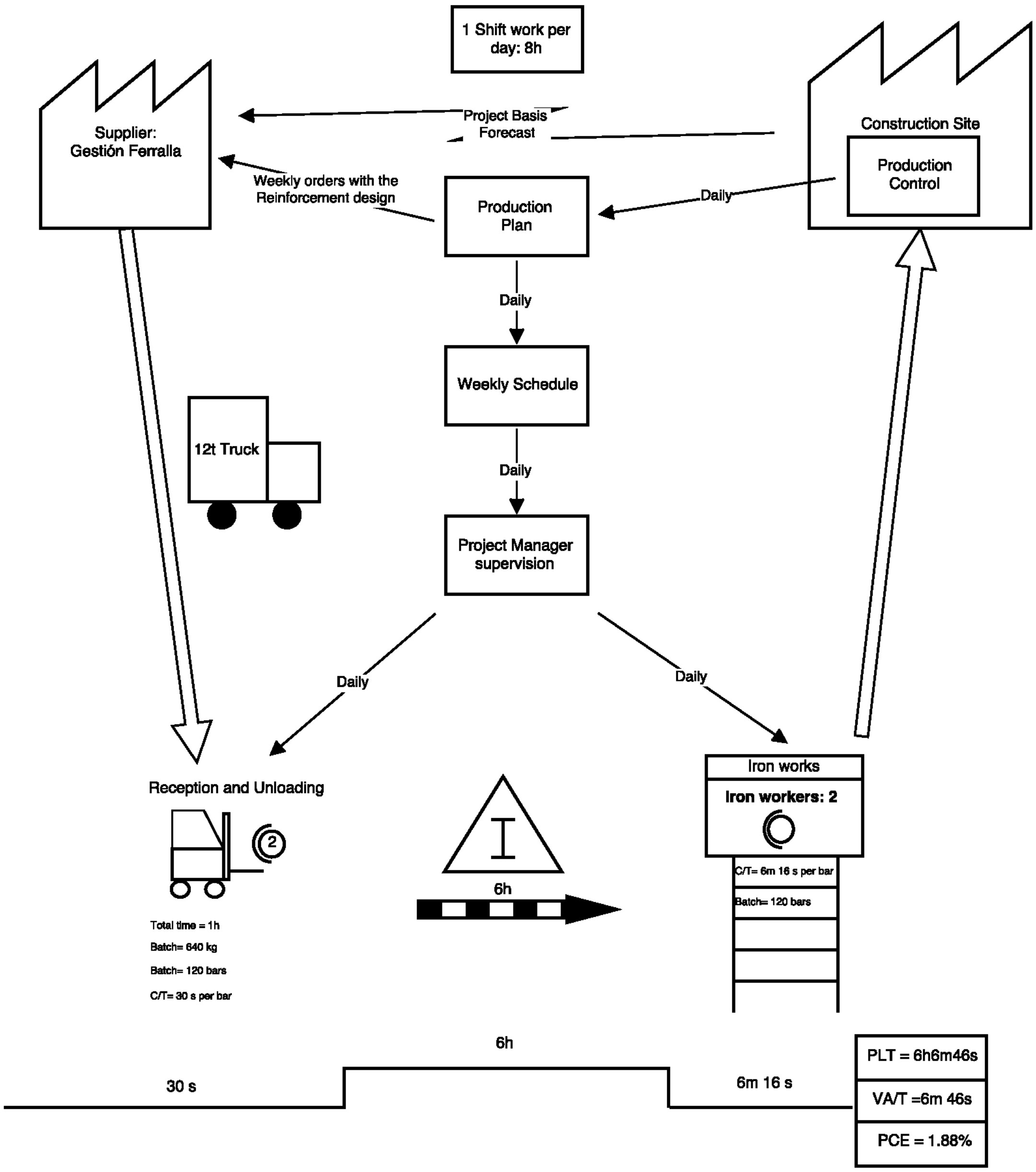
12.3 Value Stream Maps: Valencia

12.3.1 Pipelines



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

12.3.2 Corrugated Steel



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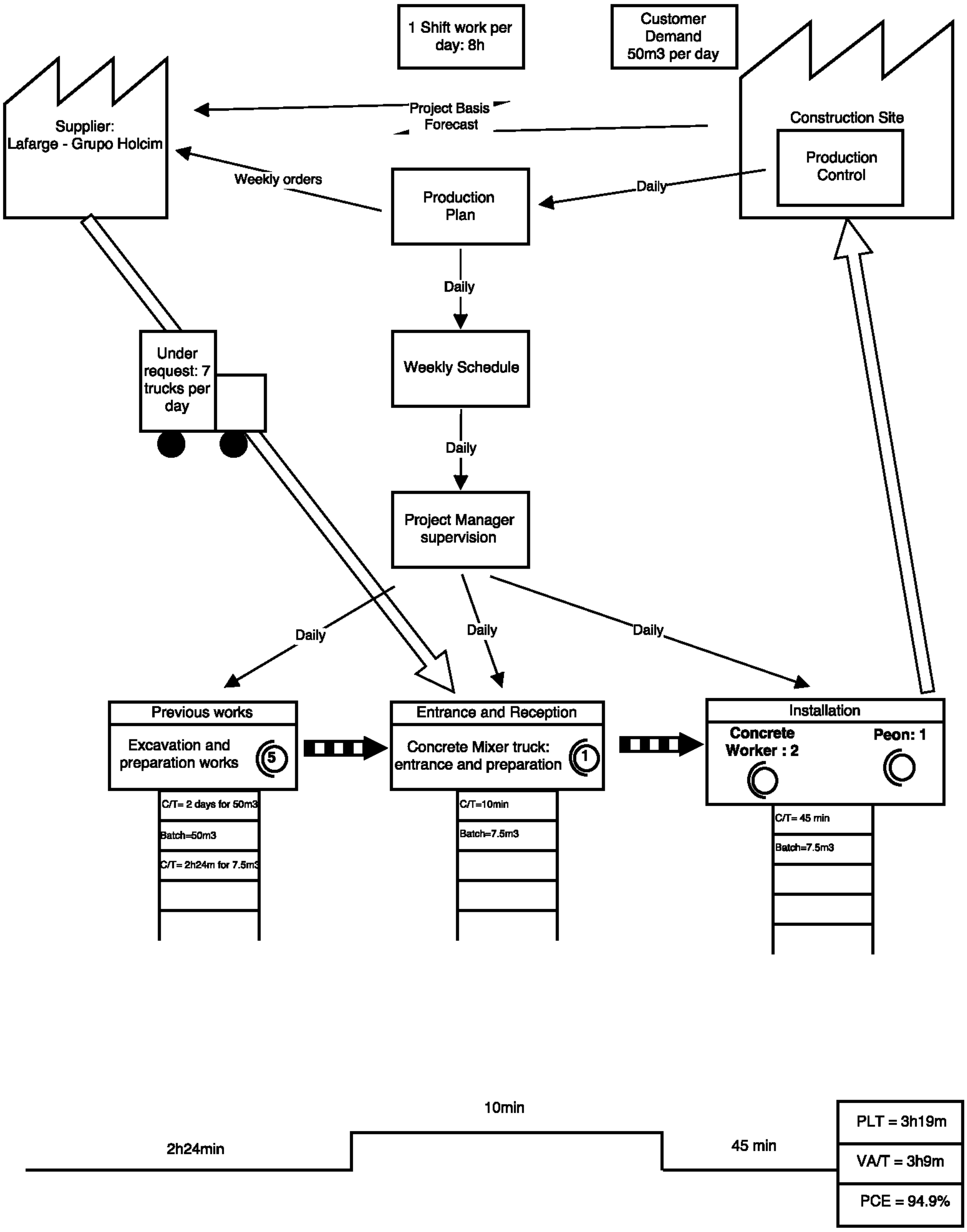
12.3.3 Concrete



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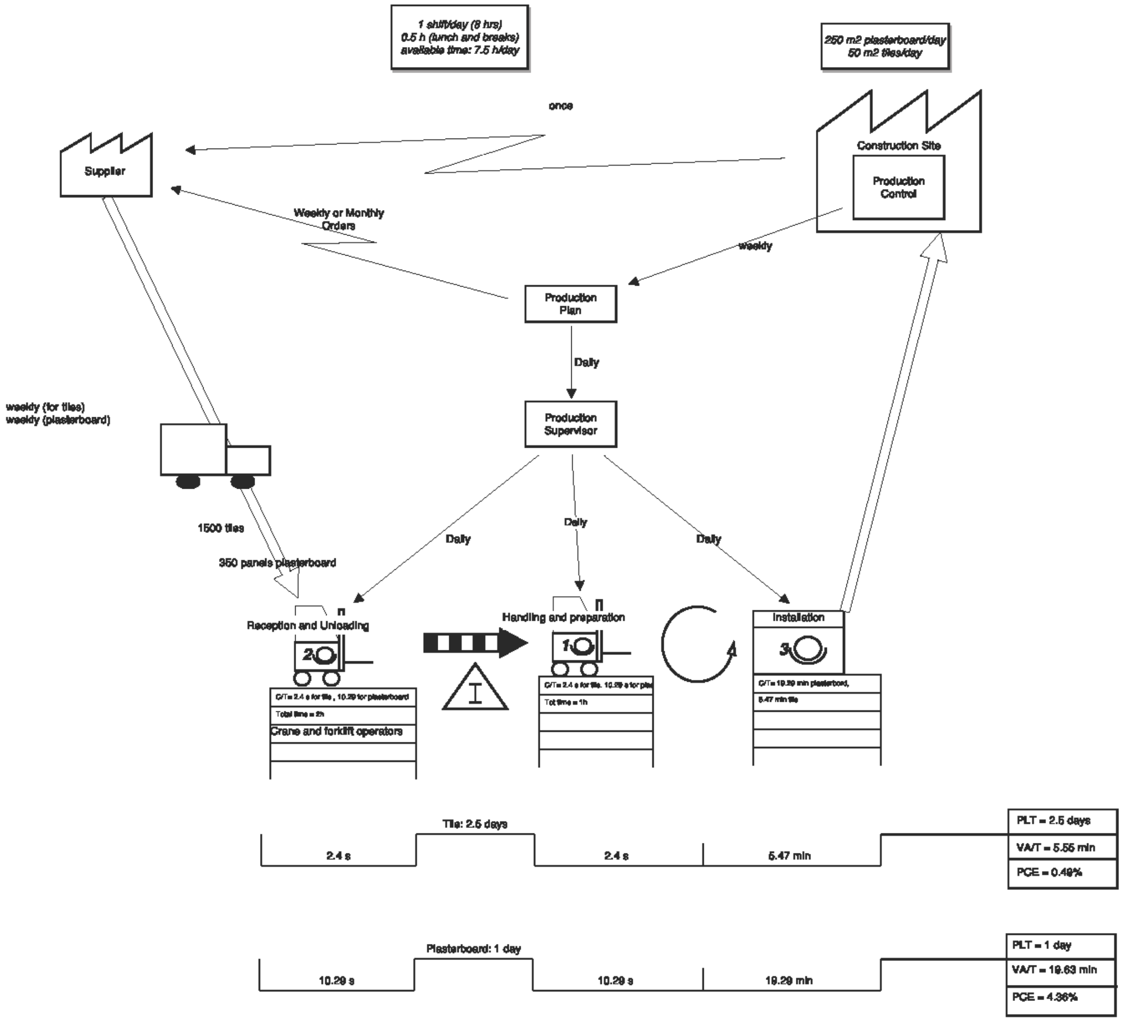
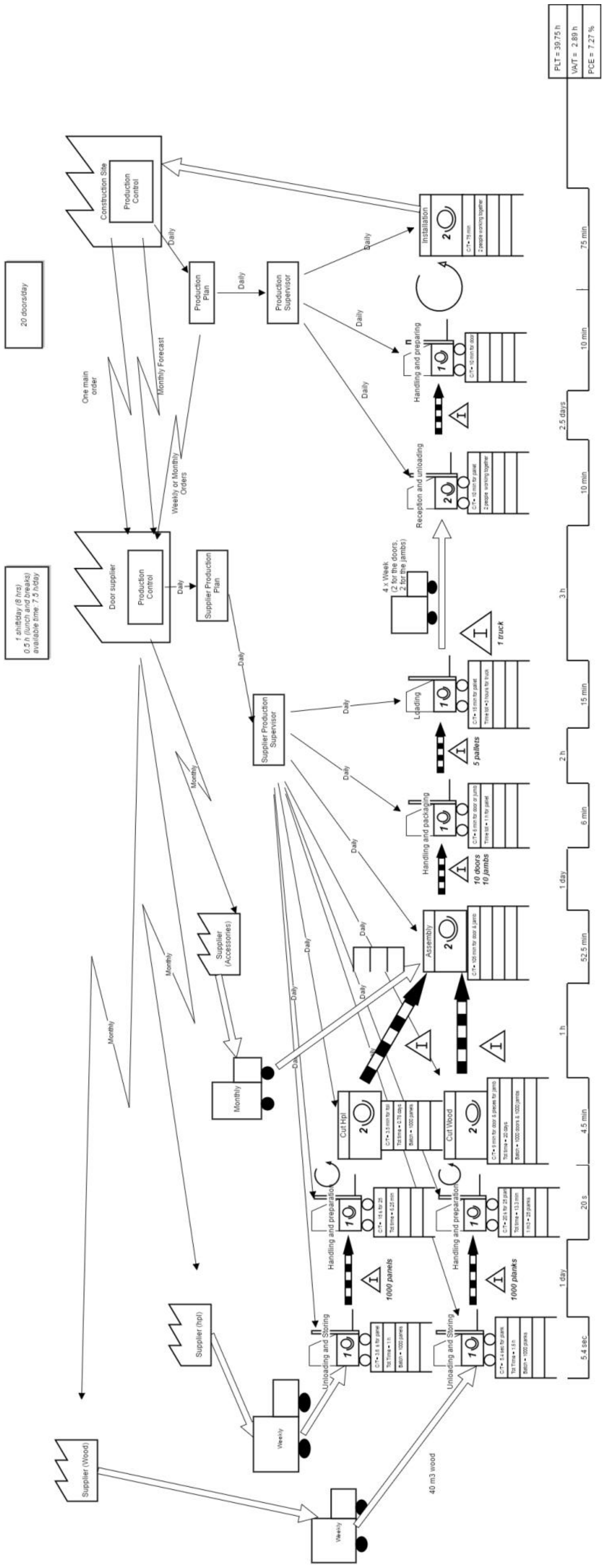
12.4 Value Stream Maps: Verona

12.4.1 Plasterboard and Tiles



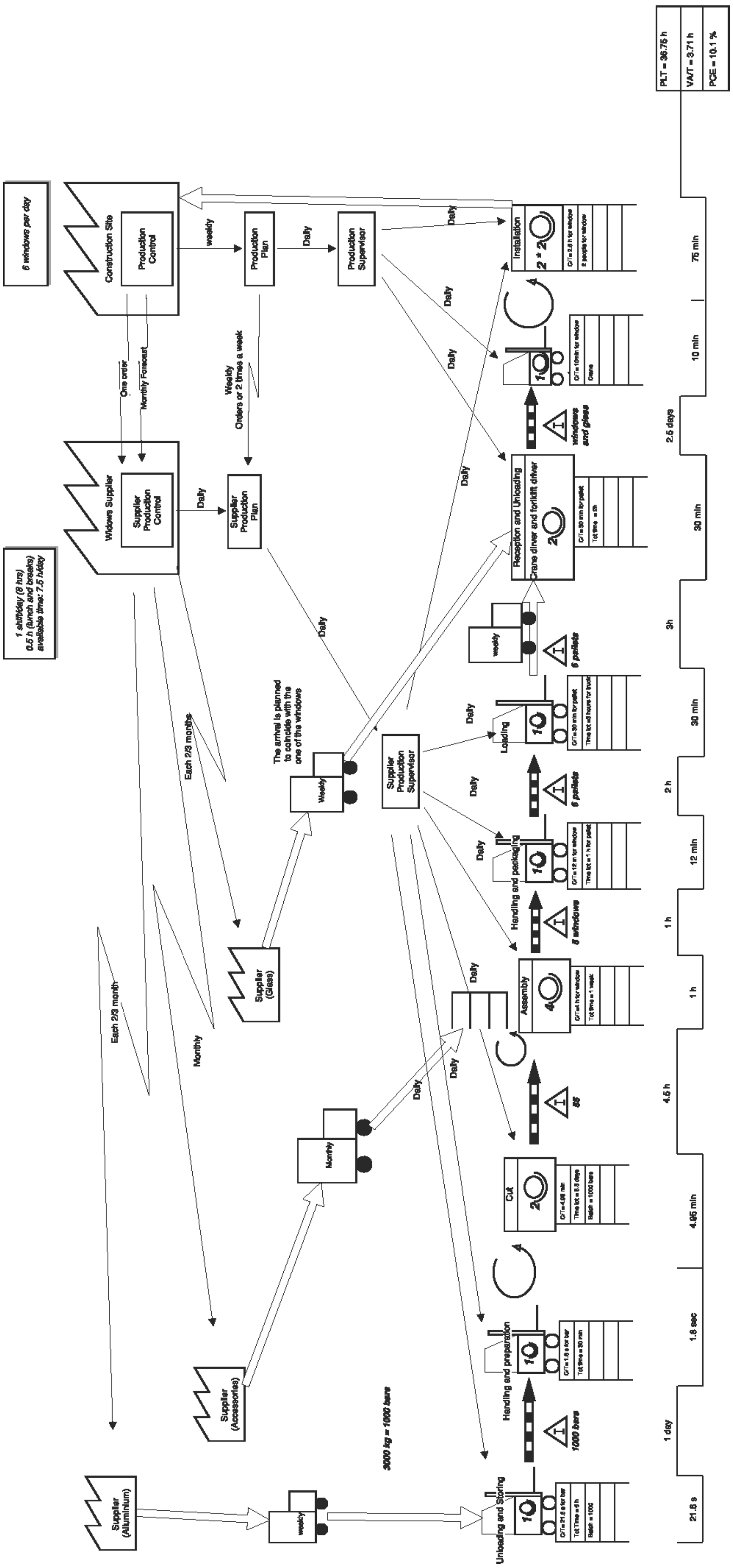
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

12.4.2 Doors



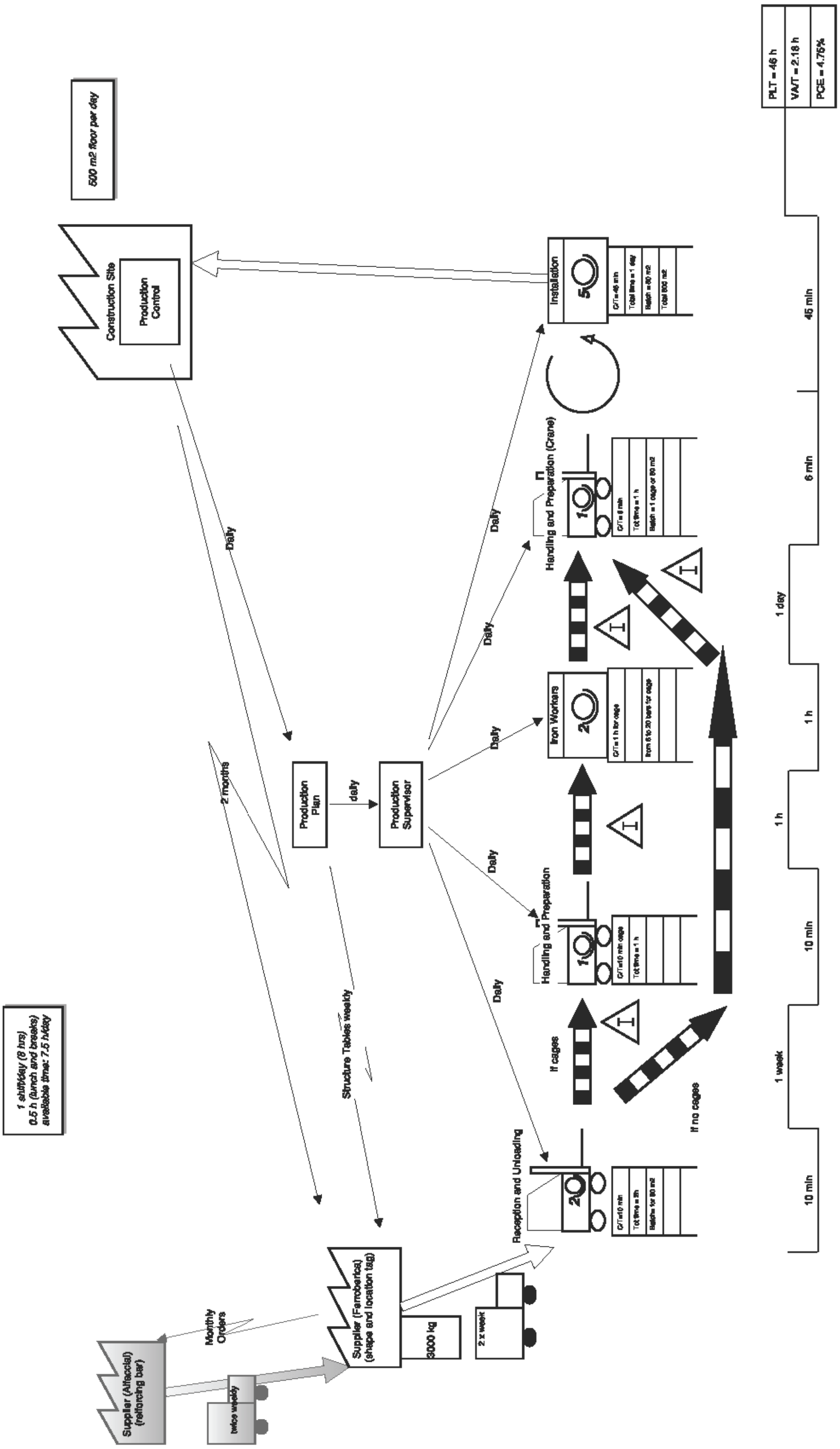
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

12.4.3 Windows



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 633338.

12.4.4 Reinforcement iron bars



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