H2020-MG-2014-2015

MOBILITY FOR GROWTH 2014-2015

H2020-MG-2014_TwoStages

Sustainable Urban Consolidation CentrES for conStruction

Solutions evaluation for each Pilot Site: preliminary version

Version 1.0

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

Dissemination level	**Public**
Work package and task	**Task 5.1: Comparison & evaluation**
Author(s)	**VCF**
Contributor(s)	**LIST, AFT, VPF, UNIMORE**
Due date of deliverable	**31/07/2017**
Submission date of deliverable	**31/07/2017**
Status (F: final, D: draft)	**F**

Document Control Sheet

Project number	**633338**		
Project Acronym	**SUCCESS**		
Work Package	**WP5**		
Version	**1.0**		
Issue	**Version**	**Dates**	**Content**
	0.1	27/07/2017	Initial version
	0.2	28/07/2017	Integration of partners' comments
	0.3	30/07/2017	Update by VCF
	1.0	31/07/2017	Integration of coordinator's minor comments

Classification of this report:

Draft	
Final	**X**
Confidential	
Restricted	
Public	**X**

Project coordinator:

Luxembourg Institute of Science and Technology (LIST)

5, Avenue des Hauts-Fourneaux, L-4362 Esch-sur-Alzette, LUXEMBOURG

Contact details:

FERRERO Francesco, +352 275 888 22 27, francesco.ferrero@list.lu
GUERLAIN Cindy, +352 275 888 67 46, cindy.guerlain@list.lu

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

TABLE OF CONTENTS

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

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

EXECUTIVE SUMMARY

SUCCESS chose to target the construction industry as a major impacting sector on city logistics which has unexploited improvement potentials in 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 environment-friendly, safer and seamless Supply Chain innovations.

The deliverable *D5.1 – Solutions evaluation for each Pilot Site: preliminary version* is a part of the work package WP5 of the SUCCESS project. In a first step (Task 5.1), this work package aims at performing a complete analysis of the scenarios results (WP4), including quantitative indicators and qualitative opinions and involving all the stakeholders of the project and the Scientific Advisory Board. During this stage, WP5 will give a continuous feedback to WP4 about the missing constraints and neglected aspects identified and about the additional elements that should be considered in the scenarios. In a second step (task 5.2), the objective of this work package is to provide an overall validation of the solutions for each pilot site considering the needs of all the public and private stakeholders. This deliverable is a preliminary deliverable of the task 5.1. The final results of the task 5.1 will be presented in the deliverable *D5.2 – Solutions comparison and evaluation report merging results of the 4 sites and related benchmark*.

This deliverable is divided in 5 chapters. The first chapter is a short reminder of the scenarios and Key Performance Indicators (KPIs) defined in the previous work packages and of the different steps of the simulation process performed by WP4. In the second chapter, we perform a qualitative evaluation and comparison of the scenarios based on our opinion about the capability of each scenario to improve the performance of the construction Supply Chain. This evaluation is done through the non-computable KPIs, i.e. the KPIs that cannot be computed with the help of the simulation. In the third chapter, we start performing a quantitative evaluation and comparison of the scenarios by pilot site based on the first output of the simulation process that is still running at the submittal date of this preliminary deliverable. In the fourth chapter, we describe a *Lean* decision-making method, *Choosing By Advantages*. We will use this method after the completion of the simulations. We are convinced that it is the most powerful method to ensure a collaborative decision between all the stakeholders of the project about the best scenario(s) to implement by type of construction site to optimize the performance of the Supply Chain. The final results will be presented in the deliverable D5.2. Lastly, in the fifth chapter, we explain our plan to test in some construction sites the solutions that we identified. The final results will be presented in the deliverable D5.2.

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

1 INTRODUCTION

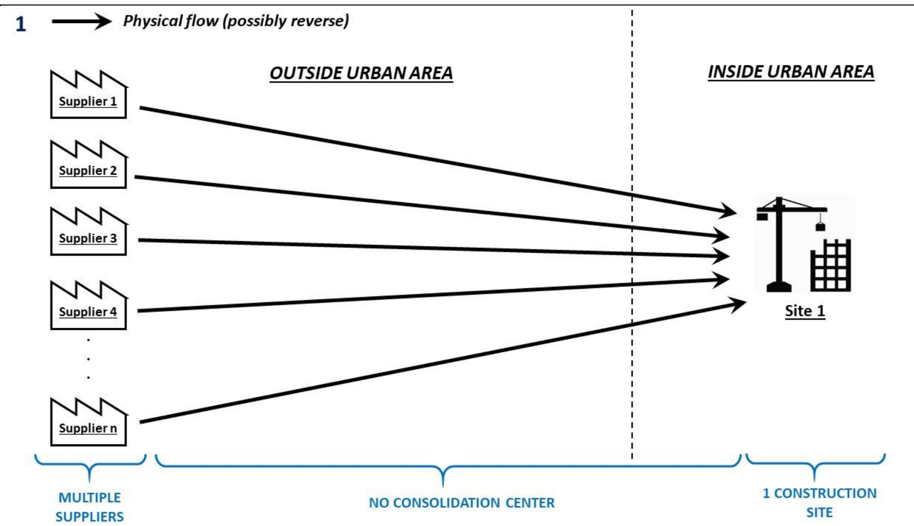
1.1 Context

The European project SUCCESS – Sustainable Urban Consolidation CentrES for ConStruction aims to explore, find and test green and efficient solutions regarding various issues in Construction Supply Chain and material freight logistics in urban areas.

To test those solutions, the SUCCESS project develops simulation tools in order to simulate several scenarios focusing on the implementation of Consolidation Centres for Construction within the framework of the pilot sites of Luxembourg, Paris, Valencia and Verona. In WP5, we evaluate and compare those scenarios to identify the best solutions for each type of construction projects represented by the pilot sites.

1.2 Scenarios simulated

Eight scenarios have been defined in WP4: two scenarios without a Construction Consolidation Centre (CCC) and six with one or more Construction Consolidation Centre(s). We describe those scenarios more in detail in the following table:

Name	Description
Scenario 1	No CCC – 1 site  Figure 1: Scenario 1 description

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

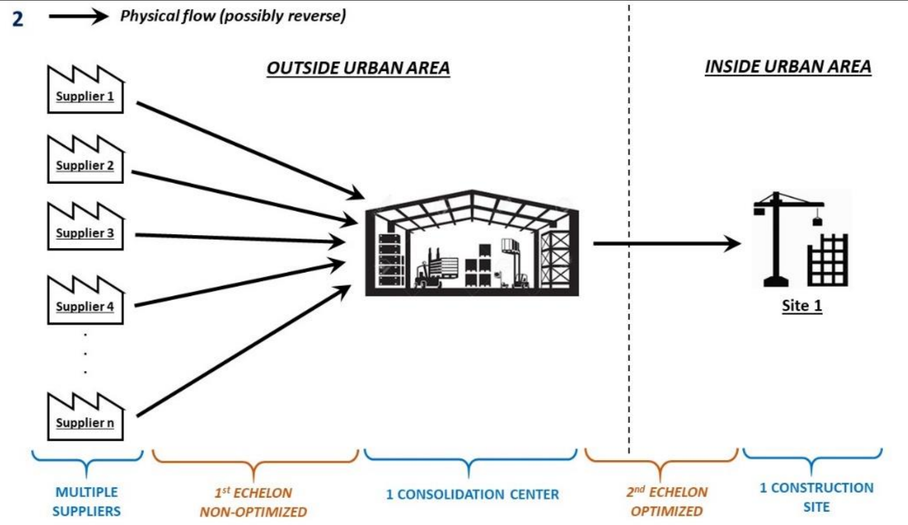
<table>
<tr>
<td rowspan="2">Scenario 2</td>
<td>1 CCC – 1 site
Optimization on 2nd echelon</td>
</tr>
<tr>
<td>


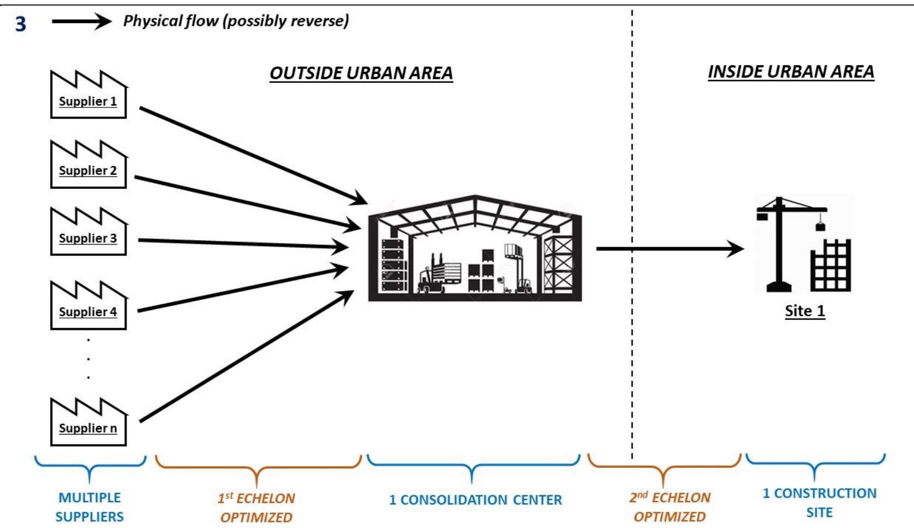
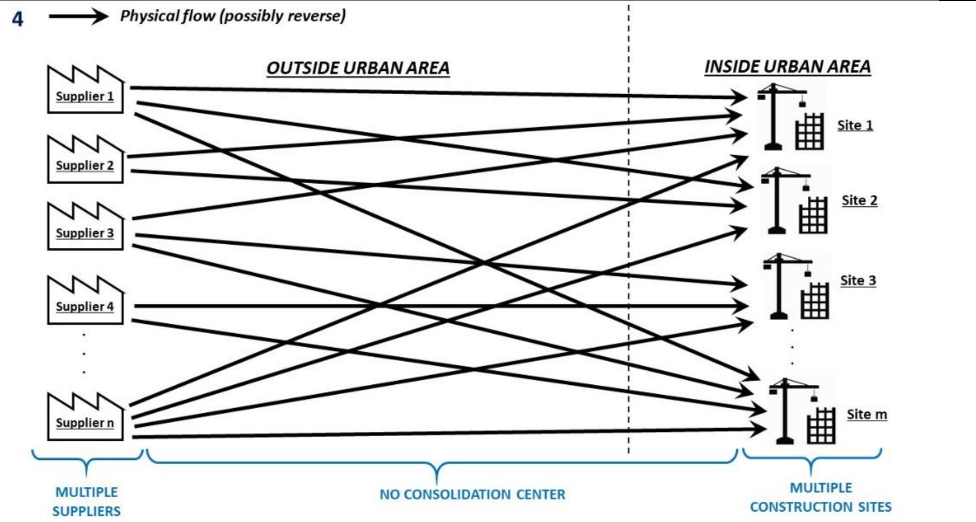
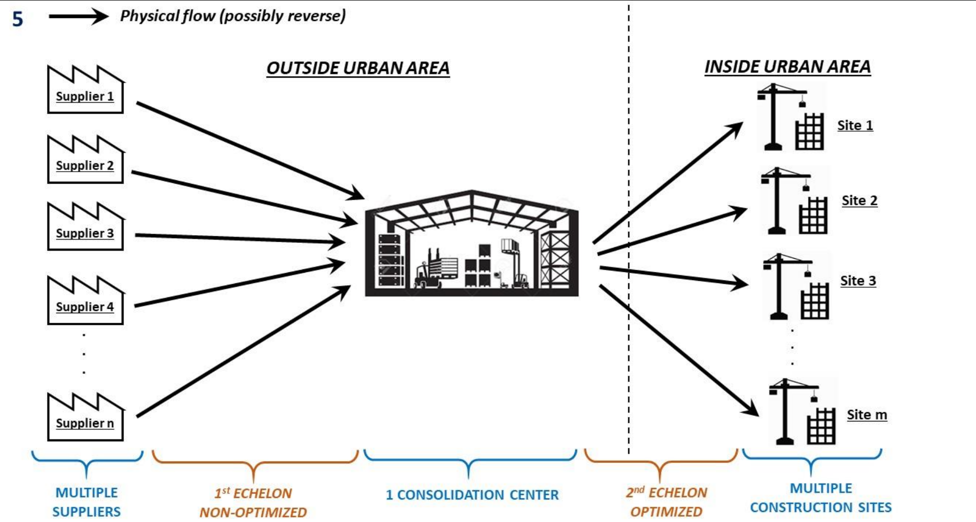
Figure 2: Scenario 2 description
</td>
</tr>
<tr>
<td rowspan="2">Scenario 3</td>
<td>1 CCC – 1 site
Optimization on 1st and 2nd echelon</td>
</tr>
<tr>
<td>


Figure 3: Scenario 3 description
</td>
</tr>
</table>

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

Scenario 4	No CCC – multiples sites  Figure 4: Scenario 4 description
Scenario 5	1 CCC – multiple sites Optimization on 2nd echelon  Figure 5: Scenario 5 description

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

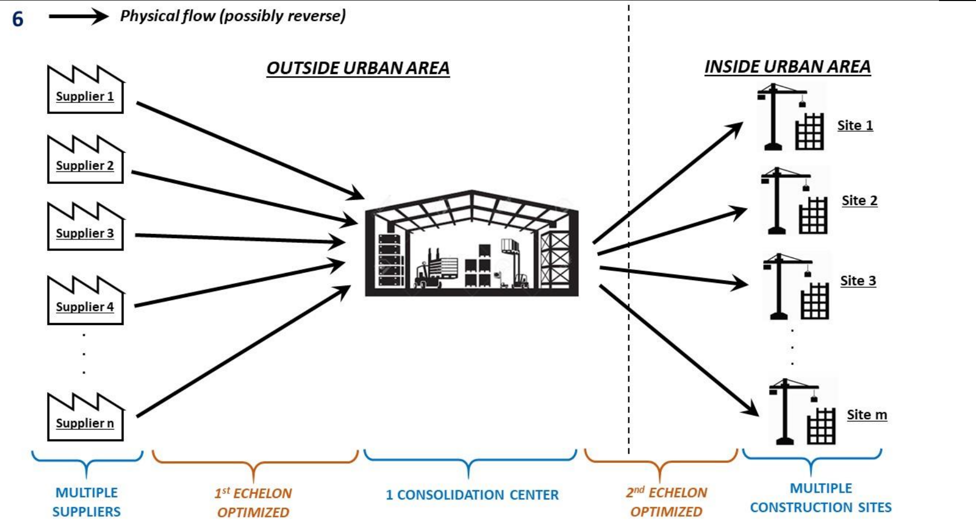
<table>
<tr><td rowspan="2">Scenario 6</td><td>1 CCC – multiple sites
Optimization on 1st and 2nd echelon</td></tr>
<tr><td>

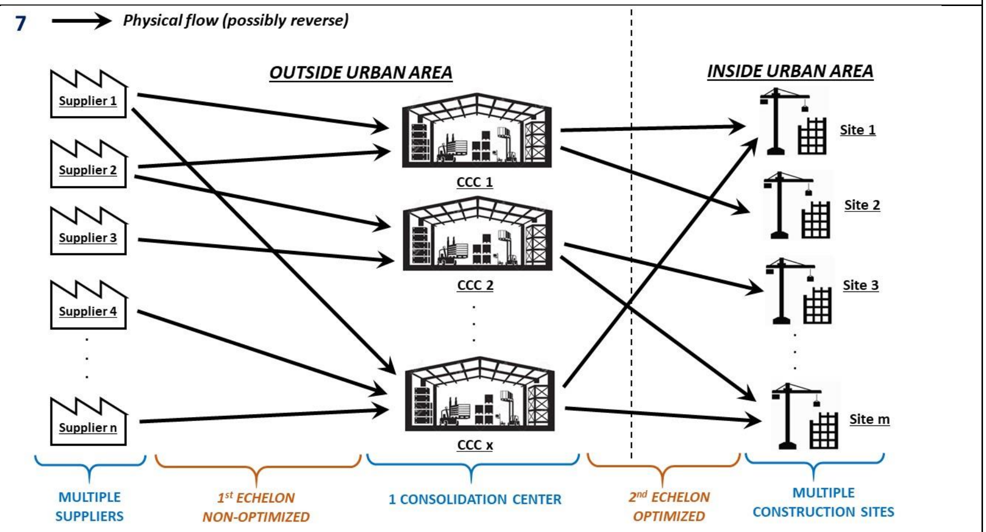
Figure 6: Scenario 6 description</td></tr>
<tr><td rowspan="2">Scenario 7</td><td>Multiple CCC – multiple sites
Optimization on 2nd echelon</td></tr>
<tr><td>

Figure 7: Scenario 7 description</td></tr>
</table>

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

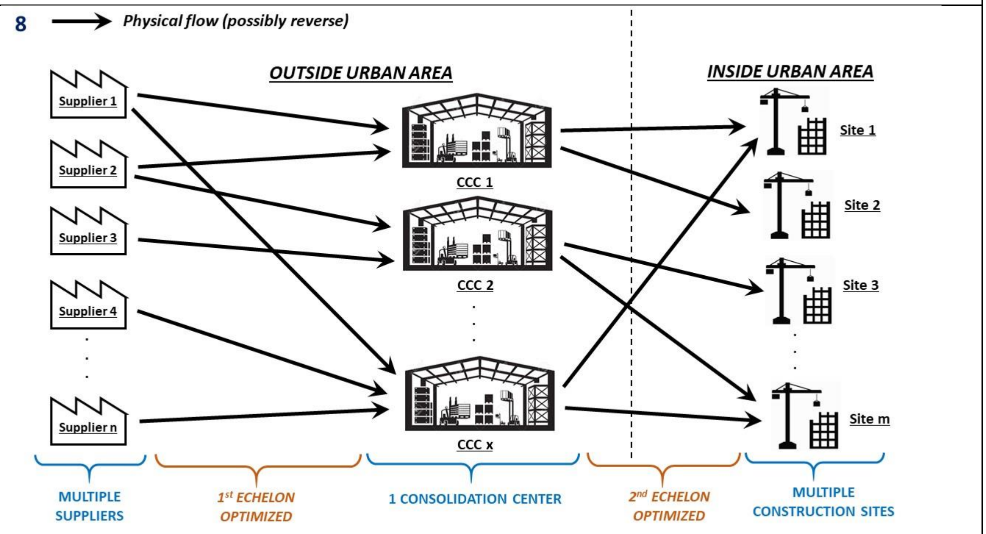
<table>
<tr><td></td><td>Multiple CCC – multiple sites
Optimization on 1st and 2nd echelon</td></tr>
<tr><td>Scenario 8</td><td>

Figure 8: Scenario 8 description</td></tr>
</table>

All those scenarios will be simulated by WP4 and evaluated quantitatively and qualitatively by WP5. The complete results of those evaluation and comparison activities will be described in the deliverable D5.2.

1.3 Simulation

For each scenario to simulate, the objectives of the simulation tools performed in WP4 are the following:

- Estimate the optimal location for the CCC implementation (if any),
- Estimate the optimal routing for all the deliveries of materials:
  - between the suppliers and the construction site in the absence of a CCC then,
  - between the suppliers and the CCC (we call it *1st echelon*) and between the CCC and the construction site (we call it *2nd echelon)* when a CCC implemented. For some of the scenarios with CCC(s), we will only optimize the 2nd echelon, while for others we will optimize both the 1st and 2nd echelons.
- Estimate the total costs of the implementation of a CCC (initial investment costs and running costs of all services proposed by the CCC to the construction site(s)). We call this tool *Cost Benefits Analysis (CBA)*.
- Estimate the environmental impact of the scenarios simulated (CO_2 and PM emissions). *COPERT* is the tool used for this estimation.
- Calculate the KPIs that can be computed with the output of the simulation (more details about KPIs are given below).

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

1.4 Key Performance Indicators (KPIs)

1.4.1 List of KPIs

Twenty KPIs have been identified in the WP2 of the SUCCESS project in order to compare the As-Is situation of the four pilot sites of the project and also to evaluate and compare the different scenarios that are simulated in order to identify the best solutions to increase the logistics performance.

To assess the potential impact of an optimized Supply Chain, as compared to the current logistic organization of the pilot sites, the KPIs refer to the three pillars of sustainability and are grouped in three categories:

- The economic category: those KPIs aim at evaluating the financial viability of implementing a new logistics organization with a CCC,
- The environmental category: those KPIs aim at comparing the environmental impact in term of pollution between the As-Is situation and the scenarios that are modelled in WP4,
- The social category: those KPIs aim at estimating the impact of the As-Is situations and tested scenarios on the daily life of people living in urban centres.

Amongst the twenty KPIs:

- 14 measure the economic impact
- 2 measure the environmental impact
- 4 measure the social impact.

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

The KPIs defined for the SUCCESS project are the following:

Category	Code	KPI designation	Unit
Economic / haulier journey time	KPI1	Travel time (outside and in the city centre)	hour
	KPI2	Truck waiting time (outside and inside the site)	hour
	KPI3	Construction site punctuality	hour
	KPI4	Loading / unloading time	hour
Economic / haulier route	KPI5	Number of intermediate storage	number
	KPI6	Distance from the suppliers to the construction site	km
Economic / material waste	KPI7	Material waste	€
Economic / workforce productivity	KPI8	Rework in connection with material issue	hour
	KPI9	Waiting time for the workforce	hour
	KPI10	Looking for material / equipment	hour
	KPI11	Several handling time	number
	KPI12	Truck punctuality	hour
Economic / supply chain management effort	KPI13	Time dedicated to logistic activities	hour
Economic / waste management costs	KPI14	Costs of unsorted bins	€
Social / safety on construction site	KPI15	Number of accidents and related causes	number
Environmental	KPI16	CO_2 equivalent	gram
	KPI17	PPM	gram
Social / wellbeing for residents	KPI18	Number of deliveries	number
	KPI19	Congestion on construction site	m^2 h
	KPI20	Rate of obstructing vehicules	%

Table 1: List of SUCCESS project's KPIs

1.4.2 Computable KPIs & quantitative evaluation

Six out of the twenty KPIs described above will be computed with the help of simulation tools.

Those six KPIs are:

Category	Code	KPI designation
Economic / haulier journey time	KPI1	Travel time (outside and in the city centre)
Economic / haulier route	KPI5	Number of intermediate storage
	KPI6	Distance from the suppliers to the construction site
Environmental	KPI16	CO_2 equivalent
	KPI17	PPM
Social / wellbeing for residents	KPI18	Number of deliveries

Table 2: List of SUCCESS project's computable KPIs

We will use those KPIs to make a quantitative evaluation of the different scenarios that are simulated in WP4. Those KPIs are the output of the simulation activities described above.

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

TKPIs 1, 5, 6 and 18 are an output of the first step of the simulation process (CCC location optimization and routing optimization) and KPIs 16 and 17 are an output of the *COPERT* tool.

1.4.3 Non-computable KPIs & qualitative evaluation

The fourteen remaining KPIs cannot be computed with the simulation tools described in WP3.

Those KPIs are:

Category	Code	KPI designation	Unit
Economic / haulier journey time	KPI2	Truck waiting time (outside and inside the site)	hour
	KPI3	Construction site punctuality	hour
	KPI4	Loading / unloading time	hour
Economic / material waste	KPI7	Material waste	€
Economic / workforce productivity	KPI8	Rework in connection with material issue	hour
	KPI9	Waiting time for the workforce	hour
	KPI10	Looking for material / equipment	hour
	KPI11	Several handling time	number
	KPI12	Truck punctuality	hour
Economic / supply chain management effort	KPI13	Time dedicated to logistic activities	hour
Economic / waste management costs	KPI14	Costs of unsorted bins	€
Social / safety on construction site	KPI15	Number of accidents and related causes	number
Social / wellbeing for residents	KPI19	Congestion on construction site	m^2 h
	KPI20	Rate of obstructing vehicules	%

Table 2: List of SUCCESS project's non-computable KPIs

As those KPIs cannot be computed, they will be used to make a qualitative evaluation of the eight scenarios of the SUCCESS project based on the As-Is situation measured in the four pilot sites and the potential improvement targets based on the benchmarking previously done (see D3.3 and D4.1).

1.4.4 KPIs and Logistics Mapping

The following graph represents the mapping of the logistics process of a typical construction site and the location of the KPIs in the process:

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

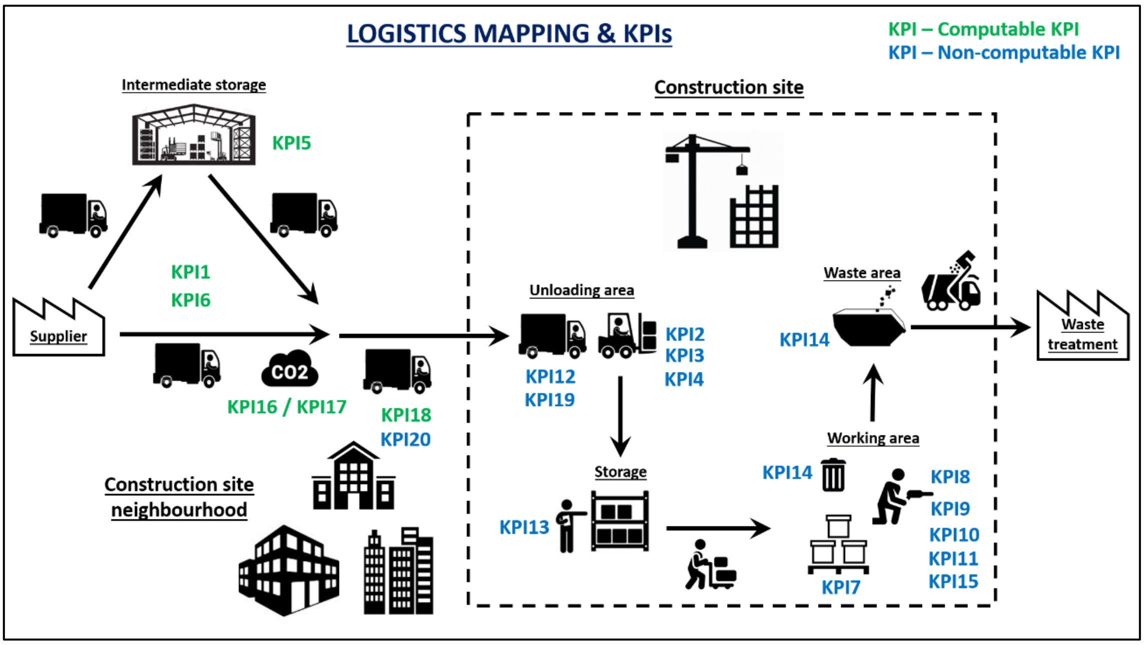


Figure 9: Logistics mapping and KPIs

Those KPIs have been defined in order to cover the main steps of the logistics process of a construction project. They enable us to evaluate the economic, environmental and social performance of this logistics process.

2 QUALITATIVE EVALUATION

2.1 Simulation and non-computable KPIs

As described in paragraph 1.3, some KPIs called *non-computable* will not be directly calculated as an output of the simulation process. In the deliverable D4.1, some assumptions of improvement targets have been taken for those KPIs. We will consider those targets in order to estimate the economic impact of the implementation of one or more CCC to the whole logistics/Supply Chain process of a construction project by comparing the added costs of a CCC to the benefits brought by its implementation. Those added costs and benefits will be calculated with a Cost Benefits Analysis (CBA) tool during the simulation process performed by WP4. WP4 and WP5 lead a common work on the configuration of the tool and the definition of the assumptions. In this document, our cost analysis will be based on first estimations. The final analysis of the CBA tool's results will be described in D5.2.

In the following paragraphs, we will propose and evaluate the levers of improvement that can be activated and the measures that can be deployed to improve the Supply Chain of a construction site. Then, those levers will be used as criteria to evaluate qualitatively the eight scenarios that are simulated. We will perform this evaluation with the help of a multi-criteria evaluation method.

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

2.2 Economic KPIs

2.2.1 KPI2 – Truck waiting time

Definition: the truck waiting time is the period during which the driver waits for the unloading of his truck since his arrival on the site or near the site for each delivery (the loading/unloading time is not included).

This time can be broken down as the sum of the waiting time outside the construction site and the waiting time inside the construction site.

As-Is situation and improvement target

The As-Is situation of the pilot sites described in D2.4 and the optimized target proposed in D4.1 are:

Site	Average waiting time inside the site (hh:mm)	Average waiting time outside the site (hh:mm)	**Average waiting time** (hh:mm)	**Improvement target (%)**
Luxembourg	00:11	00:13	**00:24**	**-80%**
Paris	00:36	00:00	**00:36**	**-80%**
Valencia	00:03	00:14	**00:18**	**-80%**
Verona	00:13	00:22	**00:35**	**-80%**

Table 4: KPI2 - As-Is situation in pilot sites and improvement target

Improvement levers and measures to implement

We consider that we can achieve this target. To decrease the As-Is waiting time measured by 80%, we need to activate the following levers of improvement and deploy the following measures:

Improvement levers	Measures to implement
Delivery Planning	Implement a strong delivery planning with realistic delivery time windows and clear communication channels
Vehicles and packaging standardization	Standardize the vehicles and the types of packaging to ensure that the delivery area and the available resources (manpower and equipment) fit with the deliveries to operate in order to keep the delivery duration under control. Reduce the variability in term of type of deliveries. The packaging can be standardized by working with the suppliers. But the standardization of the packaging rules can be more easily reachable when a CCC is implemented.
Load rate	By consolidating the deliveries, we can reduce the number of deliveries. Less deliveries = more margin in the delivery time windows duration -> more flexibility
Logistics resources availability on site	Ensure that all the needed resources are available at the right time to operate the deliveries in the planned delivery time window duration (manpower and equipment) -> site logistics organization (skilled manpower to operate logistics operations)

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

Trip duration variability	Reduce the variability of the trip duration (trucks arriving late or in advance) between the last storage and the construction site -> CCC implementation

Table 5: KPI2 – Improvement levers and measures to implement

Improvement levers and scenarios

Levers	**Scenario 1** No CCC – 1 site	**Scenario 2** 1 CCC – 1 site opt. 2nd echelon	**Scenario 3** 1 CCC – 1 site opt. 1st & 2nd echelon	**Scenario 4** No CCC – multiple sites	**Scenario 5** 1 CCC – multiple sites opt. 2nd echelon	**Scenario 6** 1 CCC – multiple sites opt. 1st & 2nd echelon	**Scenario 7** multiple CCC – multiple sites opt. 2nd echelon	**Scenario 8** multiple CCC – multiple sites opt. 1st & 2nd echelon
Delivery Planning	[green]	[green]	[green]	[green]	[green]	[green]	[green]	[green]
Vehicles and packaging standardization	[yellow]	[green]	[green]	[yellow]	[green]	[green]	[green]	[green]
Load rate	[grey]	[green]	[green]	[grey]	[green]	[green]	[green]	[green]
Logistics resources availability on site	[green]	[green]	[green]	[green]	[green]	[green]	[green]	[green]
Trip duration variability	[grey]	[green]	[green]	[grey]	[green]	[green]	[green]	[green]

Legend – Levers activation

Cannot be activated: [grey] Can be partially activated: [yellow] Can be fully activated: [green]

Table 6: KPI2 – Improvement levers and scenarios

Two levers (delivery planning and availability of logistics resources on site) can be fully activated in all the scenarios and do not depend on the implementation of a CCC as they are totally linked to the logistics process on the construction site. The number of deliveries and the variability of the trip duration between the last storage area and the site are levers that can be activated only in the case when a CCC is implemented thanks to the consolidation of the deliveries allowed by the CCC and the geographical proximity of the CCC that reduces the risks of events impacting the duration trip between the CCC and the construction site. The standardization of the vehicles and the packaging of materials is partially possible by working directly with the suppliers but may be long to implement because of the high number of suppliers that should be involved in this optimization. With a CCC, this lever will be easier to activate as the CCC has its own fleet of vehicles and is free to define and implement an efficient packaging plan in coordination with the construction site(s) (we consider here that a repackaging/kitting process is put in place in the CCC).

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

Costs and benefits

The reduction of this truck waiting time will help the hauliers to increase their productivity as this waiting time is a wastage that brings no added-value to their client, that is to say the subcontractors or suppliers. As a consequence, we can reduce the whole transportation costs of the construction project and use this benefit to finance the implementation of the CCC.

2.2.2 KPI3 – Construction site punctuality

Definition: the construction site's punctuality is the time between the planned unloading time (scheduled delivery time) and the real unloading starting time.

"Construction site punctuality = Scheduled delivery time – unloading starting time"

As-Is situation and improvement target

According to D2.4 et D4.1, for the four pilot sites the percentage of the trucks arriving on site on time that were unloaded on planned time fluctuates between **18% and 84%** depending on the site. The benchmarking done in D4.1 shows that we can reach a target of **99%** in the construction sites that are supplied by a CCC.

But we can easily say that the implementation of a CCC alone is not a sufficient condition to reach this 99% target. Indeed, in the case where a good logistics organization is not put in place on site, meaning a bad availability of resources or a bad lay-out of the delivery area, we can easily guess that the punctuality of the site cannot reach a high level of service. The logistics/Supply Chain process of a construction site must be considered as a whole, from the order sent to the supplier to the materials put in the place in the working area on site.

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

Improvement levers and measures to implement

To reach a high level of site punctuality for the unloading activities, we can activate the following levers of improvement and deploy the following measures. As this KPI is highly linked with *KPI2 – Truck waiting time*, the levers and measures are the same as KPI2.

Improvement levers	Measures to implement
Delivery Planning	Implement a strong delivery planning with realistic delivery time windows and clear communication channels
Vehicles and packaging standardization	Standardize the vehicles and the types of packaging to ensure that the delivery area and the available resources (manpower and equipment) fit with the deliveries to operate in order to keep the delivery duration under control. Reduce the variability in term of type of deliveries. The packaging can be standardized by working with the suppliers. But the standardization of the packaging rules can be more easily reachable when a CCC is implemented.
Load rate	By consolidating the deliveries, we can reduce the number of deliveries. Less deliveries = more margin in the delivery time windows duration -> more flexibility
Logistics resources availability on site	Ensure that all the needed resources are available at the right time to operate the deliveries in the planned delivery time window duration (manpower and equipment) -> site logistics organization (skilled manpower to operate logistics operations)
Trip duration variability	Reduce the variability of the trip duration (trucks arriving late or in advance) between the last storage and the construction site -> CCC implementation

Table 7: KPI3 – Improvement levers and measures to implement

Improvement levers and scenarios

Levers	**Scenario 1** No CCC – 1 site	**Scenario 2** 1 CCC – 1 site opt. 2nd echelon	**Scenario 3** 1 CCC – 1 site opt. 1st & 2nd echelon	**Scenario 4** No CCC – multiple sites	**Scenario 5** 1 CCC – multiple sites opt. 2nd echelon	**Scenario 6** 1 CCC – multiple sites opt. 1st & 2nd echelon	**Scenario 7** multiple CCC – multiple sites opt. 2nd echelon	**Scenario 8** multiple CCC – multiple sites opt. 1st & 2nd echelon
Delivery Planning								
Vehicles and packaging standardization								
Load rate								
Logistics resources availability on site								
Trip duration variability								

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

Legend – Levers activation

Cannot be activated: [grey] Can be partially activated: [yellow] Can be fully activated: [green]

Table 8: KPI3 – Improvement levers and scenarios

Costs and benefits

A better punctuality of the construction site for the unloading activity will reduce the time that the trucks spend on site and will increase the time they can use for added-value activities and as a consequence it will increase the productivity of the haulier companies.

2.2.3 KPI4 – Loading / unloading time

Definition: the loading/unloading time per delivery is the time during which the goods are loaded or unloaded. It is calculated with the following formula:

"Loading/unloading time = End of loading/unloading – start of loading/unloading"

As-Is situation and improvement target

The equipment used in the 4 pilot sites for unloading are multiple: by hand, forklift, mobile crane, truck crane, tower crane, pump, mechanic shovel…

If we only consider the unloading activities, here are the times measured in the pilot sites:

Site	Average unloading time (hh:mm)	Average unloading time per equipment (hh:mm)		
		Crane	Forklift	Self-discharged[1]
Luxembourg	**00:58**	00:51	01:10	**00:29**
Paris	**00:45**	00:51	00:53	**00:33**
Valencia	**00:46**	00:56	00:44	**00:46**
Verona	00:34	00:54	00:28	-

[1]: self-discharged trucks are trucks equipped with their own unloading equipment.

Table 9: KPI4 - As-Is situation in pilot sites and improvement target

Those figures show us that in all the cases (except Valencia between forklift and self-discharged) the activities of unloading are taking less time for the trucks that are equipped with self-discharging equipment than for the trucks that must be unloaded by crane or forklift provided by the construction site.

We can easily conclude that the availability and the appropriateness of the unloading equipment have a big impact on the efficiency of the unloading activities. In Luxembourg's and in Paris' sites, using self-discharging equipment makes the unloading activities at least 35% shorter than the ones operated with crane or forklift.

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

Improvement levers and measures to implement

To increase the efficiency of the unloading and loading activities on the construction site, we advise to activate the following levers of improvement and deploy the following measures:

Improvement levers	Measures to implement
Loading/unloading area organization	The loading/unloading area should be studied upstream in order to take into account all the specific constraints of the project (type of materials, type of equipment, prefabrication elements…) in order to define the right resources to implement -> A risk analysis is highly advised
Skilled logistics manpower	Subcontract the logistics operations to a logistics operator (clearly identify the limit between the construction activities and the logistics/Supply Chain activities in the added-value chain) or develop new internal competencies in logistics (recruitment + training)
Resources availability	Ensure that all the needed resources are available at the right time to operate the deliveries in the planned delivery time window duration (manpower and equipment) -> site logistics organization (skilled manpower to operate logistics operations)
Packaging plan	Establish a packaging plan with the suppliers/CCC in order to define the rules in term of packaging type, type of trucks used, loading plans in the trucks…
Vehicles and packaging standardization	Standardize the vehicles and the types of packaging to ensure that the delivery area and the available resources (manpower and equipment) fit with the deliveries to operate to keep the delivery duration under control. Reduce the variability in term of type of deliveries.

Table 10: KPI4 – Improvement levers and measures to implement

Improvement levers and scenarios

Levers	**Scenario 1** No CCC – 1 site	**Scenario 2** 1 CCC – 1 site opt. 2nd echelon	**Scenario 3** 1 CCC – 1 site opt. 1st & 2nd echelon	**Scenario 4** No CCC – multiple sites	**Scenario 5** 1 CCC – multiple sites opt. 2nd echelon	**Scenario 6** 1 CCC – multiple sites opt. 1st & 2nd echelon	**Scenario 7** multiple CCC – multiple sites opt. 2nd echelon	**Scenario 8** multiple CCC – multiple sites opt. 1st & 2nd echelon
Loading/unloading area organization								
Skilled logistics manpower								

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

Logistics resources availability (manpower and equipments)								
Packaging plan								
Vehicles and packaging standardization								

Legend – Levers activation

Cannot be activated: Can be partially activated: Can be fully activated:

Table 11: KPI4 – Improvement levers and scenarios

Three levers (loading/unloading area's organization, skilled logistics manpower and logistics resources availability on site) can be fully activated in all the scenarios and do not depend on the implementation of a CCC as they are totally linked to the part of the Supply Chain process that takes place in the construction site. The two last levers (packaging plan and vehicles and packaging standardization) can be more easily activated with a CCC than without a CCC because it will be obviously difficult and long to standardize the rules in term of packaging and type of trucks between all the suppliers/subcontractors involved in a construction project.

Costs and benefits

As for KPIs 2 and 3, the reduction of the loading/unloading time will decrease the time the trucks spend on the construction site helping the hauliers to increase their productivity. Consequently, we can reduce the overall transportation costs of the construction project and use this benefit to finance the implementation of a CCC.

In the report *Using Construction Consolidation Centres to reduce construction waste and carbon emissions (WRAP, 2011)*, WRAP estimates that « a **10-20% reduction in delivery cost** » is achievable by the implementation of a CCC. We are also convinced that there is a big potential for substantially improving the productivity of the hauliers' activity, not only by implementing a CCC but more generally by rethinking the logistics organisation inside and outside the construction sites. The Cost Benefit Analysis performed in WP4 will provide us the data to estimate more precisely the target we can achieve. Those results will be described in D5.2.

2.2.4 KPI7 – Material waste

Definition: the material waste is defined here as the monetary value of all the materials damaged, stolen, lost or remaining at the end of the project without being taken in place.

As-Is situation and improvement target

Due to the difficulties to get accurate data from the subcontractors about the quantities of materials damaged, stolen or lost during the life of the construction

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

project, we are not able to provide the As-Is situation of the 4 pilot sites in term of material waste.

According to WRAP (WRAP, 2011), « if just one half of material waste were eliminated material costs would reduce by 7.5% ». Knowing the big part that the materials represent in the whole budget of a construction project, working on the reduction of the material waste must be considered as a high priority.

Improvement levers and measures to implement

Here are some levers of improvement we can activate and some measures we can deploy in order to reduce the waste of material in construction sites:

Improvement levers	Measures to implement
BIM - Building Information Modelling	The BIM is a very powerful tool to increase the knowledge of the works to execute. The BIM helps to make more precise bills of quantities. As a direct consequence, the needed quantities of materials are precisely defined and the site can give clear orders to the CCC (the just needed quantity) -> better works nomenclatures = better Material Request Planning = less quantity ordered in excess -> less quantity remaining at the end of the project
Zoning and Packaging/Kitting	Define a clear zoning plan for the construction activities. The delivery zoning should match perfectly with the construction zoning in order to ensure that the right materials will be at the right place at the right time to start the task with the full materials needed. A repackaging has to be done upstream in order that each package delivered is for one zone only.
Dynamic storage plan	A clear storage plan must be defined at any time in order to clearly identify where the packages have to be delivered in the construction site. A clear labelling of the storage areas should be done in order to precise the name/code of the zone on the labelling of the package. This storage area is dynamic as it has to evolve continuously to follow the progress of the construction works.
Delivery and Storage Management System	An IT system equivalent to a WMS (Warehouse Management System) in a logistics platform could be implemented to have a direct access to the history of all the movements of materials done on site and in the storage area where each package has been delivered in the case we are looking for a missing package (in order to be more reactive in the problem solving / traceability) -> Reduce the risk of materials loss
Storage duration in the working place	The shortest the materials are stored on site the less risk of damage and robbery there is before the materials are put in place -> Just In Time Delivery (see KPI8)

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

Materials security control	It is highly difficult to ensure a complete security of the stock of materials on the construction site -> solution: CCC (with JIT, see above point) or specific secured areas on site (containers, temporary closed rooms in the building…)
Reverse logistics (Unused materials recycling)	The over-ordered materials at the end of a project usually end up in the waste skips. With a CCC, those extra quantities of materials can be sent back to the CCC through the reverse logistics and put back in stock. At the end of the project, a reuse of those materials can be found (use them for another project for example) and those materials will be no more considered as a waste economically speaking (materials resold = earnings for the project)

Table 12: KPI7 – Improvement levers and measures to implement

Improvement levers and scenarios

Levers	**Scenario 1** No CCC – 1 site	**Scenario 2** 1 CCC – 1 site opt. 2nd echelon	**Scenario 3** 1 CCC – 1 site opt. 1st & 2nd echelon	**Scenario 4** No CCC – multiple sites	**Scenario 5** 1 CCC – multiple sites opt. 2nd echelon	**Scenario 6** 1 CCC – multiple sites opt. 1st & 2nd echelon	**Scenario 7** multiple CCC – multiple sites opt. 2nd echelon	**Scenario 8** multiple CCC – multiple sites opt. 1st & 2nd echelon
BIM - Building Information Modelling	Green	Green	Green	Green	Green	Green	Green	Green
Zoning and Packaging/Kitting	Grey	Green	Green	Grey	Green	Green	Green	Green
Dynamic storage plan	Green	Green	Green	Green	Green	Green	Green	Green
Deliveries and Storage Management System	Grey	Green	Green	Grey	Green	Green	Green	Green
Storage duration in the working place	Grey	Green	Green	Grey	Green	Green	Green	Green
Materials security control	Yellow	Green	Green	Yellow	Green	Green	Green	Green
Reverse logistics	Grey	Green	Green	Grey	Green	Green	Green	Green

Legend – Levers activation

Cannot be activated: (grey) Can be partially activated: (yellow) Can be fully activated: (green)

Table 13: KPI7 – Improvement levers and scenarios

BIM and a dynamic storage plan are two levers that can be activated in all the scenarios as they do not depend on the implementation of a CCC. A repackaging/kitting system between the suppliers and the construction site can be implemented only in the case of a CCC as it needs space and a strong logistics organization with skilled people in order to prepare packages with the just needed quantities of materials per work zone on the construction site. The

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

same for the use of a delivery and storage management system that can be put in place only if a clear logistics process is implemented between the delivery of the materials in the CCC and the delivery of the final packages in the work zones where the materials are needed. To reduce the risk of damage and robbery in the working place, the materials have to be delivered at the right time that is to say just before the task starts: a Just In Time process must be implemented. To do so, a buffer stock is needed between the suppliers and the construction site: a CCC is in this case the solution. As an assembly workshop in the automotive industry, the construction site is mainly the place where all the components of a building are assembled: the space should be mainly dedicated to the construction activities. The working place does not also offer a sufficient level of security to protect the materials from robbery. Some solutions can be found in the construction site to stock small quantities of materials like containers or temporary closed rooms in the building but the CCC appears as the best solution to stock big quantity of materials in a much secured area.

Costs and benefits

The activation of the levers previously described can help the construction sites to reduce their material waste consistently. The activation of all those levers passes by the implementation of a CCC. As said before, based on previous CCC experiences, WRAP (WRAP, 2011) estimates that with a CCC we can eliminate 50% of the current material wastage which means that the total material costs of a construction project can be reduced by 7.5% (in this case, WRAP takes the assumption that 15% of the materials are wasted in a construction project). In our evaluation, we will consider that eliminating 50% of the current material wastage is an achievable target. But we estimate that a figure of 10% should be taken as the percentage of the materials wasted on average on a given site.

Based on the French BT01 price index used to update the construction costs on a monthly basis, we will consider that the costs of materials represent 35% of the total construction costs of a project.

2.2.5 KPIs 8 to 12 – Site workforce productivity

In this paragraph, we will analyse the KPIs that have been defined to track the performance of the site's workforce. Those KPIs evaluate non-value-added tasks linked with five sources of waste of time:

- KPI8 – Rework in connection with material issue
- KPI9 – Waiting time for the workforce performing a task
- KPI10 – Looking for material/equipment
- KP11 – Several handlings time
- KP12 – Truck punctuality

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

Definition:

In the deliverable D2.2, those five indicators are defined as followed:

KPI8 – Rework in connection with material issue: this indicator corresponds to the time spent to carry out a material installation already performed due to several moving in order to obtain free area for storage. It includes the required time for uninstalling the defective material.

KPI9 – Waiting time for the workforce performing a task: this indicator corresponds to the waiting time of the workforce due to a lack of material or a defect on uncontrolled delivered material. It should not be confused with other waiting times for the workforce and more specifically with a waiting time generated by delayed deliveries for example.

KPI10 – Looking for material/equipment: this indicator corresponds to the average time (and variations) when the workforce is looking for material (some other losses related to this activity such as walking around the site to go to the storage, checking plans, requesting information, reading plans will be included).

KP11 – Several handlings time: even if it is necessary, handling time is a non-value-added activity. Ideally materials should be handled directly from the truck to the point of use. Unnecessary handling times to track: count the number of times a selected material is moved within storage areas before its final installation and measure the time spent by the workforce for the several handling times.

KP12 – Truck punctuality: the punctuality of deliveries and pick-ups is defined as the time between the planned delivery time and the truck arrival time near the construction.

"Truck punctuality = planned delivery time – arrival time near the construction site"

As-Is situation and improvement target

In the four pilot sites, the measures gave the following figures for KPIs 8 and 9 and 10 (as a percentage of the workforce working time):

	KPI8 Rework in connection with material issue	**KPI9** Waiting time for the workforce	**KPI10** Looking for material/equipment	**Total = KPI8 + KPI9 +KPI10**
Luxembourg	9%	3%	7%	**19%**
Paris	0%	1%	16%	**17%**
Valencia	1%	6%	12%	**19%**
Verona	0%	1%	1%	2%

Table 14: KPI8 to KPI10 - As-Is situation in pilot sites

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

Except in Verona, the average time wasted due to rework, waiting time and looking for material/equipment represents almost **20%** of the total workforce working time. We have here a big potential in term of gain of productivity.

For *KPI11 – Several handlings time*, here are the data collected in the pilot sites:

	Number of materials moving detected	Total duration of several handlings (hh:mm)	Average duration of one handling (hh:mm)
Luxembourg	227	14:16	00:29
Paris	24	08:05	00:20
Valencia	0	-	-
Verona	22	34:00	01:32

Table 15: KPI11 - As-Is situation in pilot sites

Except in Valencia where no multiple handling has been detected possibly due to the large availability of space on site, we notice that each movement of materials generates at least a waste of **20 min**.

The improvement target that we can consider for KPIs 8 to 11 is detailed below in the *Costs and benefits* paragraph.

For *KPI12 – Truck punctuality*, the distribution between the trucks that are late, on time and ahead of schedule by pilot site is:

	Trucks late (%)	Trucks on time (%)	Trucks ahead of schedule (%)
Luxembourg	14%	61%	25%
Paris	30%	17%	53%
Valencia	2%	76%	22%
Verona	50%	23%	27%

Table 16: KPI12 - As-Is situation in pilot sites

In D4.1 a target of 3% as the maximum of trucks late is proposed. We think that this target is achievable only in case of the implementation of a CCC and with the condition that the CCC is close to the construction site (less than 10-15 km / particularly in cities with a high risk of road congestion).

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

Improvement levers and measures to implement

To eliminate or at least reduce the wastage of workforce time measured by KPIs 8 to 12 and consequently increase the productivity of the construction workforce on site, we advise to activate the following levers of improvement and deploy the following measures:

Improvement levers	Measures to implement
Reliable production planning	Last Planner System (LPS): increase the production planning reliability by implementing a collaborative planning system insisting on the commitment of each partner and focusing on continuous problem solving. This way, we increase the quality of the work done and we reduce drastically the rework on site.
Interface Production planning / Delivery planning	Develop a strong interface between the production planning and the delivery planning in order to ensure that the production pulls the deliveries -> implement a Just In Time process (JIT) by either using a Material Request Planning IT system[1] or a Kanban system[2] (benchmarking to do in the industrial sector) -> CCC solution
Zoning and Packaging/Kitting	Define a clear zoning plan for the construction activities. The delivery zoning should match perfectly with the construction zoning in order to ensure that the right materials will be at the right place at the right time to start the task with the full materials needed. A repackaging has to be done upstream in order that each package delivered is for one zone only.
Prefabrication	Execute a maximum of the assembly activities out of the construction site in order to reduce the complexity of the tasks to perform on site / Tasks executed in a dedicated area out of the site can be better organized and anticipated by implementing a process closer to an industrial process (better conditions of work (ergonomics, lighting...) -> a part of the CCC can be dedicated to this prefabrication activity
Materials quality	A Quality Control Plan can be implemented in the CCC at the delivery from the suppliers and at the shipping to the construction site in order to ensure that the materials comply with the expected quality level.
BIM - Building Information Modelling	The BIM is a very powerful tool to increase the knowledge of the works to execute. In particular the BIM helps to make precise bills of quantities. As a direct consequence, the needed quantities of materials are precisely defined and the site can give clear orders to the CCC (the just needed quantity) -> better works nomenclatures = better Material Request Planning

[1] https://en.wikipedia.org/wiki/Material_requirements_planning
[2] https://en.wikipedia.org/wiki/Kanban

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

Construction and Logistics activities separation	To optimize their productivity, construction teams have to focus on the work activities. Deliveries have to be anticipated in the work area before the works starts (for instance the night before the works start). A specific logistics team helps to optimize the logistics resources (forklift...) and avoid waiting times due to looking for equipment to move some materials from a point A to a point B.
Labelling and traceability	Implement an efficient labelling and traceability system (RFID, QR codes…) in order to have an efficient dispatch of the packages per zone and to easily identify the delivery mistakes and quickly redispatch the packages that were not delivered in the right place
Deliveries and Storage Management System	An IT system equivalent to a WMS (Warehouse Management System) in a logistics platform could be implemented in order to have a direct access to the history of all the movements of materials done on site and the storage area where each package has been delivered in the case we are looking for a missing package (in order to be more reactive in the problem solving).
Dynamic storage plan	A clear storage plan has to be defined at any time in order to clearly identify where the packages have to be delivered in the construction site. A clear labelling of the storage areas has to be done in order to precise the name/code of the zone on the labelling of the package. This storage area is dynamic as it has to evolve continuously to follow the progress of the construction works. -> implement "5S" Lean Management tool
Reverse logistics	The reverse trips between the construction site(s) and the CCC are a good opportunity to remove systematically from the construction sites all the materials, packaging and equipment that are no more used: pallets, racks, cable drums, over-ordered materials… When staying for days or weeks on the construction site, those elements lower the productivity of the workforce because they congest the work environment.

Table 17: KPIs 8 to 12 – Improvement levers and measures to implement

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

Improvement levers and scenarios

Levers	**Scenario 1** No CCC – 1 site	**Scenario 2** 1 CCC – 1 site opt. 2nd echelon	**Scenario 3** 1 CCC – 1 site opt. 1st & 2nd echelon	**Scenario 4** No CCC – multiple sites	**Scenario 5** 1 CCC – multiple sites opt. 2nd echelon	**Scenario 6** 1 CCC – multiple sites opt. 1st & 2nd echelon	**Scenario 7** multiple CCC – multiple sites opt. 2nd echelon	**Scenario 8** multiple CCC – multiple sites opt. 1st & 2nd echelon
Reliable production planning	Can be fully activated	Can be fully activated	Can be fully activated	Can be fully activated	Can be fully activated	Can be fully activated	Can be fully activated	Can be fully activated
Interface Production planning / Delivery planning	Can be fully activated	Can be fully activated	Can be fully activated	Can be fully activated	Can be fully activated	Can be fully activated	Can be fully activated	Can be fully activated
Zoning and Packaging/Kitting	Cannot be activated	Can be fully activated	Can be fully activated	Cannot be activated	Can be fully activated	Can be fully activated	Can be fully activated	Can be fully activated
Prefabrication	Cannot be activated	Can be partially activated	Can be partially activated	Cannot be activated	Can be partially activated	Can be partially activated	Can be partially activated	Can be partially activated
Material quality	Cannot be activated	Can be fully activated	Can be fully activated	Cannot be activated	Can be fully activated	Can be fully activated	Can be fully activated	Can be fully activated
BIM - Building Information Modelling	Can be fully activated	Can be fully activated	Can be fully activated	Can be fully activated	Can be fully activated	Can be fully activated	Can be fully activated	Can be fully activated
Construction and Logistics activities separation	Can be partially activated	Can be fully activated	Can be fully activated	Can be partially activated	Can be fully activated	Can be fully activated	Can be fully activated	Can be fully activated
Labelling and traceability	Cannot be activated	Can be fully activated	Can be fully activated	Cannot be activated	Can be fully activated	Can be fully activated	Can be fully activated	Can be fully activated
Deliveries and Storage Management System	Cannot be activated	Can be fully activated	Can be fully activated	Cannot be activated	Can be fully activated	Can be fully activated	Can be fully activated	Can be fully activated
Dynamic storage plan	Can be fully activated	Can be fully activated	Can be fully activated	Can be fully activated	Can be fully activated	Can be fully activated	Can be fully activated	Can be fully activated
Reverse logistics	Cannot be activated	Can be fully activated	Can be fully activated	Cannot be activated	Can be fully activated	Can be fully activated	Can be fully activated	Can be fully activated

Legend – Levers activation

Cannot be activated: (grey) Can be partially activated: (yellow) Can be fully activated: (green)

Table 18: KPI8 to KPI12 – Improvement levers and scenarios

Half of the levers can be partially or fully activated in scenarios 1 and 4 that are scenarios without CCC. In the scenarios with CCC, nine levers out of ten can be activated. Only the prefabrication solution can be partially implemented as the main objective of a CCC is to manage the following activities: unloading of the deliveries coming from the suppliers, stock management, packages preparation and shipping of the packages to the construction site. But a part of the facilities can be dedicated to pre-assembly activities to minimize the quantity of materials that are assembled on the construction site.

THE CIVITAS INITIATIVE IS CO-FINANCED BY THE EUROPEAN UNION

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

As a conclusion, the implementation of a CCC (and the linked scenarios) appears clearly as the best solution to take advantage of the improvements that identified levers can potentially bring.

Costs and benefits

According to WRAP (WRAP, 2011), « several studies show that operatives save **30 min** per day through better logistics which gives a **6% productivity improvement** ». In three of the four pilot sites, we previously saw that the average time wasted due to rework, waiting time and looking for material/equipment represents almost **20%** of the total workforce's working time. So, by deploying the measures described above, we estimate that we can aim at reducing by **30%** the time wasted due to logistics issues. We will take this target for our evaluation.

Based on the French BT01 price index used to update the construction costs on a monthly basis, we consider that the workforce costs represent around **35%** of the total construction costs of a project. So, the benefits we can get from an optimized logistics/Supply Chain process appears significant.

2.2.6 KPI13 – Time dedicated to logistics activities

Definition: it is an evaluation of the time dedicated to all the logistics activities. This evaluation has been performed through a list of logistics activities defined to evaluate the hours that could be saved with a CCC. The time dedicated to logistics activities is the time spent by one resource on each of the defined activities during one ordinary week (the activities are described in D2.2).

A qualitative analysis of this KPI has already been done in D4.1. In term of optimization, the main target here is to work at reducing the non-added-value logistics activities like the activity *managing the delivery issues*. Whatever is the logistics organization implemented on site, the logistics workforce will represent a very small part of the whole workforce of the project.

In our evaluation, we will consider that the analysis of the KPI is included in the analysis done for KPIs 8 to 12 as the main concern is the same: workforce's productivity.

2.2.7 KPI14 – Costs of unsorted bins

Definition: in some cases, different types of waste must be placed in a single bin. So, the waste will be sorted by the subcontractor who collects the waste. This sorting causes costs that could be avoided. The cost of unsorted waste is the price invoiced by the subcontractor.

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

As-Is situation and improvement target

The As-Is situation of the pilot sites (D2.4) and the optimized target proposed in D4.1 are:

	Current cost per month	Improvement target	Expected cost per month after improvement
Luxembourg	770 €	**-80%**	154 €
Paris	7131 €	**-80%**	1426 €
Valencia	690 €	**-80%**	138 €
Verona	1468 €	**-80%**	294 €

Table 19: KPI14 - As-Is situation in pilot sites and improvement target

Improvement levers and measures to implement

This target of 80% is achievable. For the reduction of the costs of the unsorted bins, we should activate the following levers of improvement and deploy the following measures:

Improvement levers	Measures to implement
Repackaging/Kitting system	Implementation of a repackaging system in the CCC to reduce the quantity of waste produced on site by removing a big part of the original packaging in the CCC (cardboard, plastic, wood…) / implementation of a waste sorting in the CCC
Handling systems	Develop new manual handling systems in order to reduce the quantity of pallets and logistics equipment needed on site: new systems like metallic trolley… that are reusable along all the life of the construction projects.
Design of original packaging	Work with the suppliers/producers on the optimization of the packaging in order to reduce the quantity of waste by the original materials packaging
Waste management plan	Define a clear organization for the management of waste on the construction sites by defining the rules to follow by the people on site: different bin colours per type of waste, a set of bins close to each work zone (a sufficient quantity of sets in order to avoid useless movements of the workforce -> ratio to define, 1 set for 100 m^2, 200 m^2, …). Organize a clear timeframe for the emptying of the bins without disturbing the production: could be ideally done at night.
Manpower's awareness	Increase the awareness of all the actors working on the construction site through trainings, awareness sessions, display boards in the working zones (Visual Management) …

Table 20: KPI14 – Improvement levers and measures to implement

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

Improvement levers and scenarios

Levers	Scenario 1 No CCC – 1 site	Scenario 2 1 CCC – 1 site opt. 2nd echelon	Scenario 3 1 CCC – 1 site opt. 1st & 2nd echelon	Scenario 4 No CCC – multiple sites	Scenario 5 1 CCC – multiple sites opt. 2nd echelon	Scenario 6 1 CCC – multiple sites opt. 1st & 2nd echelon	Scenario 7 multiple CCC – multiple sites opt. 2nd echelon	Scenario 8 multiple CCC – multiple sites opt. 1st & 2nd echelon
Repackaging/Kitting system	Grey	Green	Green	Grey	Green	Green	Green	Green
Handling systems	Grey	Yellow	Yellow	Grey	Green	Green	Green	Green
Design of original packaging	Green	Green	Green	Green	Green	Green	Green	Green
Waste management plan	Yellow	Green	Green	Yellow	Green	Green	Green	Green
Manpower awareness	Green	Green	Green	Green	Green	Green	Green	Green

Legend – Levers activation

Cannot be activated: Grey Can be partially activated: Yellow Can be fully activated: Green

Table 21: KPI14 – Improvement levers and scenarios

Working on the optimization of the original packaging of the goods and developing the manpower's awareness in term of waste sorting are two measures that can be implemented in all the scenarios of the simulation process as they do not require the implementation of a CCC. Implementing a kitting/repackaging process and developing new sustainable and reusable handling systems can only be put in place in a CCC environment as it requires space, mainly for the kitting/repackaging activities, and also skilled manpower as any mistake in the preparation of the packages can highly impact the productivity of the working force in the construction site. Finally, a waste management plan appears as a mandatory tool in order to plan all the activities needed to process in an efficient way the treatment of all the waste generated in the construction site. We consider that this lever can only be partially activated without the use of a CCC as the lack of space on a construction site could prevent the provision of the quantity of bins needed to proceed with a complete sorting on site (full bins can be treated in a CCC through a reverse flow).

Costs and benefits

Through the Cost Benefit Analysis (CBA) tool delivered by WP4, we will estimate for each scenario the benefits we can get by considering an improvement

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

target of 80%. But to balance those benefits, we will have to consider the extra costs generated by the implementation of some of the measures described. Indeed, some of them are not without cost impact as for instance the development of new handling systems. The results of this analysis will be described in D5.2.

2.3 Social KPIs

2.3.1 KPI15 – Number of accidents

Definition: this number of accidents is defined as an unexpected event leading to physical or mental injury. The facts and circumstances of those accidents are recorded to identify the root causes.

As-Is situation and improvement target

The As-Is situation of the four sites in term of accidents linked with logistics issues is the following:

	Number of accidents due to logistics issues	Total number of accidents	Root causes	Target number of accidents due to logistics issues
Luxembourg	2	10	- No appropriate handling means - Confined and not adapted storage area	**0**
Paris	2	11	- Waste handling	**0**
Valencia	1	-	- Materials manipulating	**0**
Verona	0	-	-	**0**

Table 22: KPI15 - As-Is situation in pilot sites and improvement target

The target is to reach **"vision zero"**, i.e. **zero accidents** due to logistics issues. Safety is one of the primary concerns in the construction sector.

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

Improvement levers and measures to implement

To eliminate all the accidents linked with logistics activities, we should activate the following levers of improvement and deploy the following measures:

Improvement levers	Measures to implement
Dynamic storage plan	A clear storage plan must be defined at any time in order to clearly identify where the packages have to be delivered in the construction site. A clear labelling of the storage areas has to be done in order to precise the name/code of the zone on the labelling of the package. This storage area is dynamic as it has to evolve continuously to follow the progress of the construction works. -> implement "5S" Lean Management tool
Handling systems	Develop new manual handling systems in order to reduce the quantity of pallets and logistics equipment needed on site: new systems like trolley… that are reusable along all the life of the construction projects. Less equipment like forklifts used on site can highly reduce the risks of accident.
Zoning and Packaging/Kitting	Define a clear zoning plan for the construction activities. The delivery zoning has to match perfectly with the construction zoning in order to ensure that the right materials will be at the right place at the right time to start the task with the full materials needed. A repackaging/kitting has to be done upstream in order that each package delivered is for one zone only. Direct impact: less stock on site and better storage area organization -> better working conditions and less risks of accident
Skilled logistics manpower	Subcontract the logistics operations to a logistics operator (clearly identify the limit between the construction activities and the logistics/Supply Chain activities in the added-value chain) or develop new internal competencies in logistics (recruitment + training)

Table 23: KPI15 – Improvement levers and measures to implement

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

Improvement levers and scenarios

Levers	**Scenario 1** No CCC – 1 site	**Scenario 2** 1 CCC – 1 site opt. 2nd echelon	**Scenario 3** 1 CCC – 1 site opt. 1st & 2nd echelon	**Scenario 4** No CCC – multiple sites	**Scenario 5** 1 CCC – multiple sites opt. 2nd echelon	**Scenario 6** 1 CCC – multiple sites opt. 1st & 2nd echelon	**Scenario 7** multiple CCC – multiple sites opt. 2nd echelon	**Scenario 8** multiple CCC – multiple sites opt. 1st & 2nd echelon
Dynamic storage plan	green	green	green	green	green	green	green	green
Handling systems	grey	yellow	yellow	grey	green	green	green	green
Zoning and Packaging/Kitting system	grey	green	green	grey	green	green	green	green
Skilled logistics manpower	green	green	green	green	green	green	green	green

Legend – Levers activation

Cannot be activated: grey Can be partially activated: yellow Can be fully activated: green

Table 24: KPI15 – Improvement levers and scenarios

Having skilled logistics manpower and implementing a dynamic storage plan are measures to implement on the construction site and they can be activated in all the scenarios, with or without CCC. But developing new handling systems and deploying a kitting system require the use of a CCC (space needed).

Costs and benefits

As said previously, the safety of the workforce on the construction sites is a primary concern for the construction sector. Every accident is one too many. We will not take into account this KPI in the Cost Benefits Analysis (CBA) of the different scenarios but we will assign a high weight to this factor in all our different evaluations.

2.3.2 KPI19 - Congestion on construction sites

Definition: congestion on construction site is defined as the space used by vehicles at the construction site as soon as they enter the site and until they leave the site. This indicator reflects the inconvenience related to deliveries. The implementation of a CCC and the optimisation of the Supply Chain should reduce congestion on and around the site and reduce the nuisance for the neighbourhood.

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

As-Is situation and improvement target

As said in D2.4, it is difficult to interpret this indicator without investigating the methodology used to calculate it. Congestion highly depends on the frequency of trucks entering the construction site. For this indicator, we will not focus on the As-Is situation and on a potential improvement target. We will concentrate on the identification of the levers that can help to eliminate or at least decrease the risk of congestion in the construction site.

This indicator is closely linked with the 3 following KPIs:

- KPI2 – Truck waiting time
- KPI3 – Construction site punctuality
- KPI18 – Number of deliveries

Improvement levers and measures to implement

As this indicator is linked to the KPIs 2, 3 and 18, we can activate the following levers of improvement and deploy the following measures already identified for those indicators:

Improvement levers	Measures to implement
Delivery Planning	Implement a strong delivery planning with realistic delivery time windows and clear communication channels
Vehicles and packaging standardization	Standardize the vehicles and the types of packaging to ensure that the delivery area and the available resources (manpower and equipment) fit with the deliveries to operate in order to keep the delivery duration under control. Reduce the variability in term of type of deliveries. The packaging can be standardized by working with the suppliers. But the standardization of packaging rules can be more easily reachable when a CCC is implemented.
Load rate	By consolidating the deliveries, we can reduce the number of deliveries. Less deliveries = more margin in the duration of delivery time windows -> more flexibility
Availability of logistics resources on site	Ensure that all the needed resources (manpower and equipment) are available at the right time to operate the deliveries in the planned delivery time window -> site logistics organization (skilled manpower to operate logistics operations)
Variability of trips' duration	Reduce the variability of the duration of trips (trucks arriving late or in advance) between the last storage and the construction site -> CCC implementation
Organization of the loading/unloading area	The loading/unloading area should be studied upstream in order to take into account all the specific constraints of the project (type of materials, type of equipment, prefabrication elements…) in order to define the right resources to implement -> A risk analysis is highly advised

Table 25: KPI19 – Improvement levers and measures to implement

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

Improvement levers and scenarios

Levers	Scenario 1 No CCC – 1 site	Scenario 2 1 CCC – 1 site opt. 2nd echelon	Scenario 3 1 CCC – 1 site opt. 1st & 2nd echelon	Scenario 4 No CCC – multiple sites	Scenario 5 1 CCC – multiple sites opt. 2nd echelon	Scenario 6 1 CCC – multiple sites opt. 1st & 2nd echelon	Scenario 7 multiple CCC – multiple sites opt. 2nd echelon	Scenario 8 multiple CCC – multiple sites opt. 1st & 2nd echelon
Delivery Planning	fully	fully	fully	fully	fully	fully	fully	fully
Vehicles and packaging standardization	partially	fully	fully	partially	fully	fully	fully	fully
Load rate	cannot	fully	fully	cannot	fully	fully	fully	fully
Availability of logistics resources on site	fully	fully	fully	fully	fully	fully	fully	fully
Variability of trips' duration	cannot	fully	fully	cannot	fully	fully	fully	fully
Organization of the loading/unloading area	fully	fully	fully	fully	fully	fully	fully	fully

Legend – Levers activation

Cannot be activated: [grey] Can be partially activated: [yellow] Can be fully activated: [green]

Table 26: KPI19 – Improvement levers and scenarios

Costs and benefits

Less congestion means less waiting time for the drivers before unloading or loading their trucks. As this waiting time is a pure waste, by improving this KPI, the hauliers will benefit from a gain of productivity in their drivers activity.

2.3.3 KPI20 - Rate of obstructing vehicles

Definition: the number of obstructing vehicles derived from the number of double parked vehicles and illegal parking on sidewalks. The rate of obstructing vehicles is compared to the total number of delivery vehicles.

As-Is situation and improvement target

The rate of obstructing vehicles measured in the four pilot sites and the target that we should aim at are:

	Obstructing vehicles rate (%)	Target (%)
Luxembourg	33,3%	0%
Paris	57,5%	0%

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

Valencia	0,0%	**0%**
Verona	11,6%	**0%**

Table 27: KPI20 - As-Is situation in pilot sites and improvement target

The obstructing vehicles rate varies a lot from a pilot site to another as it depends a lot on the configuration of the construction site (inside and outside the site). The Paris pilot has a high rate due to a lack of space inside the site and a location in a very urbanized area.

Improvement levers and measures to implement

We consider that the levers and the measures we can identify to improve this KPI are the same as the ones listed for *KPI19 – Congestion on construction sites*.

Costs and benefits

The cost benefit analysis depends on the regulations of the city (charges applied or not). A deeper analysis might be done during the Cost Benefit Analysis of WP4.

2.4 Method of evaluation

To evaluate qualitatively the eight scenarios, we will use a multi criteria evaluation method.

The objects to evaluate here are the eight scenarios that are simulated in the WP4 of the SUCCESS project. In this qualitative evaluation, we will evaluate those scenarios through several factors. We will define those factors based on the categories that have been defined to rank the non-computable KPIs:

- Haulier journey time
- Material waste
- Workforce productivity
- Supply Chain management effort on site
- Waste management costs
- Safety on construction site
- Wellbeing of the residents

As said previously, we will include the *Supply Chain management effort on site* category in the *Workforce productivity* category.

The SUCCESS project aims at defining solutions to improve the logistics/Supply Chain in the construction sector. Therefore, the objective of this evaluation is to identify the scenarios that are the most capable of improving the seven categories of KPIs listed above. So, we will evaluate the scenarios through the following factors:

- Capability to improve the haulier journey time
- Capability to decrease the material waste

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

- Capability to improve the workforce productivity
- Capability to decrease the waste management costs
- Capability to improve the safety on site
- Capability to improve the wellbeing of the residents

The objective of the project is to maximize those 6 factors. We will rate the scenarios for each factor using a five-point rating scale. Through this rating, we will estimate for each factor the level of capability of the scenarios to improve the global Supply Chain of a construction project. We will use the following rating scale:

Score	Capability level
1	Very low
2	Low
3	Medium
4	High
5	Very high

Table 28: Capability rating scale

We will rate each scenario in an objective way using the levers of improvement (criteria) that have been listed above for the fourteen non-computable KPIs. To estimate the right score of the scenario per factor, we will consider for each category of KPIs the percentage of levers that can be activated amongst all the levers listed. For one category and one scenario, we will count the levers according to the following rule:

- 1 if the lever can be fully activated
- 0.5 if the lever can be partially activated
- 0 if the lever cannot be activated

Then, we will sum the figures and divide this sum by the total number of levers listed: we will call "a" the number that we get. We consider that all the levers have the same weight.

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

Finally, we will rate the scenarios by applying the rules described in the following table:

If		Score	Capability level
a = 0	Then	1	Very low
0 < a < 0.3		2	Low
0.3 ≤ a ≤ 0.7		3	Medium
0.7 < a < 1		4	High
a = 1		5	Very high

Table 29: value of "a" and capability rating scale

Here is an example of how to calculate "a" for a scenario and a factor and then deduce the score and capability level:

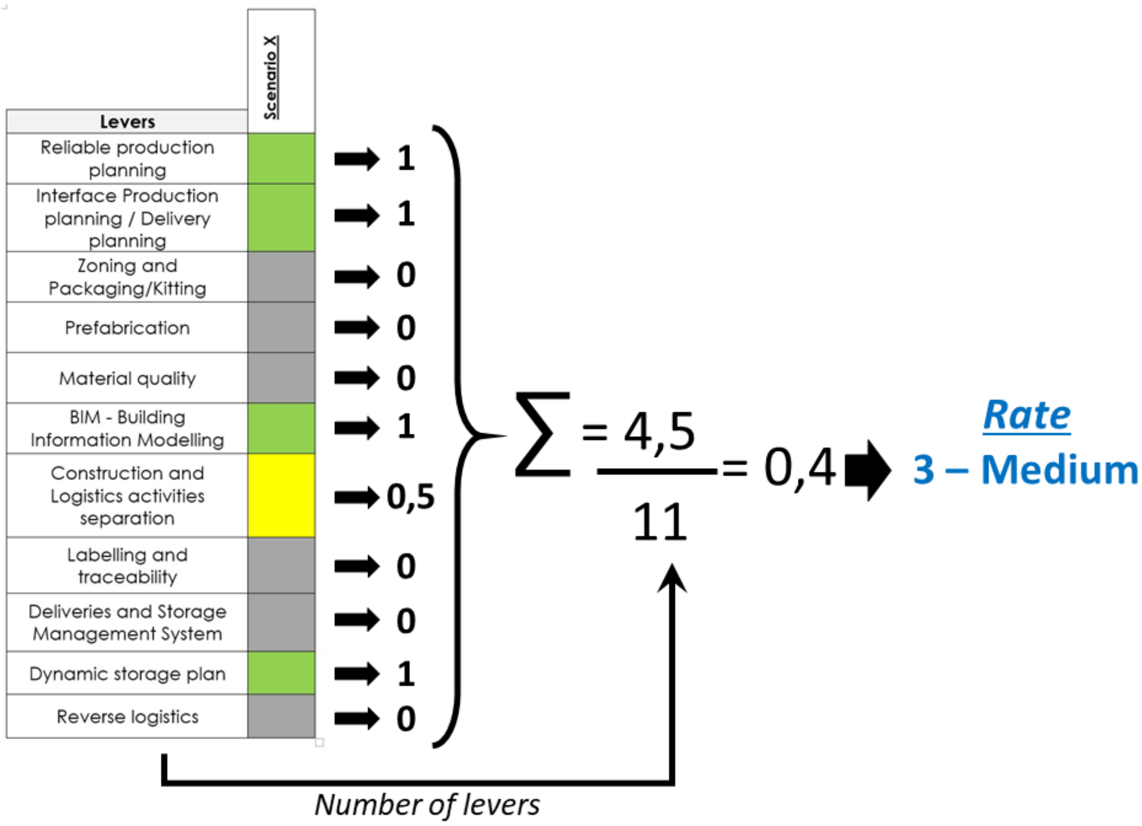


Figure 10: Example of capability level calculation

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

We will present the results of the different steps of the rating through this format of table:

Factors	**Scenario 1** No CCC – 1 site	**Scenario 2** 1 CCC – 1 site opt. 2nd echelon	**Scenario 3** 1 CCC – 1 site opt. 1st & 2nd echelon	**Scenario 4** No CCC – multiple sites	**Scenario 5** 1 CCC – multiple sites opt. 2nd echelon	**Scenario 6** 1 CCC – multiple sites opt. 1st & 2nd echelon	**Scenario 7** multiple CCC – multiple sites opt. 2nd echelon	**Scenario 8** multiple CCC – multiple sites opt. 1st & 2nd echelon
Capability to improve haulier journey time								
Capability to decrease the material waste								
Capability to improve the workforce productivity								
Capability to decrease the waste management costs								
Capability to improve the safety on site								
Capability to improve the wellbeing of the residents								

Table 30: Factors rating per scenario table format

After rating all the criteria for the eight scenarios, we will calculate a global score for each scenario. To do so, we have different possibilities: either consider that all the criteria have the same weight (= 1) or apply different weights. In our evaluation, we will use cost-related weights in order to take into account the potential cost benefits the different criteria can bring to the construction companies.

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

Let's take first the case of the Paris site in order to estimate approximately the cost benefits we could intercept by activating all the levers that we identified. The following table summarizes those potential cost benefits per category:

Category	Estimation description	Estimated cost benefits
Haulier journey time	Paris pilot turnover: 230 M€ We estimate here that the total transportation costs represent 5% of the turnover and that we can decrease by 10% the delivery costs through the improvement of the hauliers' productivity. Cost benefit estimation = 230 M€ x 5% x 10%	1,15 k€
Material waste	Paris pilot turnover: 230 M€ Materials costs count for 35% of the turnover. As seen above, we can expect a material costs reduction by 50%x10% = 5%. Cost benefit estimation = 230 M€ x 35% x 5%	4,02 M€
Workforce productivity	Paris pilot turnover: 230 M€ Workforce costs count for 35% of the turnover. In Paris, the waste of time due to logistics issues equals 17% of the total workforce time. We aim at reducing this waste by 30%. Cost benefit estimation = 230 M€ x 35% x 17% x 30%	4,10 M€
Waste management costs	For the Paris site, we considered that we can reduce the cost of the unsorted bins by 5 706 € per month. So, for a duration of 24 months: Cost benefit estimation = 24 x 5.706 €	137 k€
Safety on site	Those two categories are linked to important social matters and have a big impact on citizens' health but cannot be valued as a cost benefit.	N/A
Wellbeing of the residents		

Table 31: Cost benefits estimation per category

We define weights in proportion to the estimated cost benefits. We assign a weight equal to the highest weight to the *safety on site* category. And to the *wellbeing of the residents* category, a weight equal to half of the weight of the *safety on site* is assigned.

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

By doing the same exercise with the 3 other pilot sites we get the following weights table for our evaluation:

Category	Weight			
	Luxembourg	Paris	Valencia	Verona
Haulier journey time	10	11	7	6
Material waste	36	40	27	22
Workforce productivity	41	41	31	2
Waste management costs	1	1	1	1
Safety on site	41	41	31	22
Wellbeing of the residents	20	20	15	11

Table 32: Category weights

Those weights are applied to the scores in order to calculate a global score per scenario and per pilot site. Those scores will give a first evaluation of the scenarios for each pilot site based on the fourteen non-computable KPIs.

2.5 Results

The results of the rating are:

- "a" calculation:

Factors	**Scenario 1** No CCC – 1 site	**Scenario 2** 1 CCC – 1 site opt. 2nd echelon	**Scenario 3** 1 CCC – 1 site opt. 1st & 2nd echelon	**Scenario 4** No CCC – multiple sites	**Scenario 5** 1 CCC – multiple sites opt. 2nd echelon	**Scenario 6** 1 CCC – multiple sites opt. 1st & 2nd echelon	**Scenario 7** multiple CCC – multiple sites opt. 2nd echelon	**Scenario 8** multiple CCC – multiple sites opt. 1st & 2nd echelon
Capability to improve haulier journey time	0.63	1	1	0.63	1	1	1	1
Capability to decrease the material waste	0.36	1	1	0.36	1	1	1	1
Capability to improve the workforce productivity	0.41	0.95	0,95	0.41	0.95	0.95	0.95	0.95
Capability to decrease the waste management costs	0.50	0.90	0,90	0.50	1	1	1	1
Capability to improve the safety on site	0.50	0.88	0,88	0.50	1	1	1	1

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

Capability to improve the wellbeing of the residents	0.58	1	1	0.5	1	1	1	1

Table 33: value of "a" per factor/scenario

- Capability level

Factors	**Scenario 1** No CCC – 1 site	**Scenario 2** 1 CCC – 1 site opt. 2nd echelon	**Scenario 3** 1 CCC – 1 site opt. 1st & 2nd echelon	**Scenario 4** No CCC – multiple sites	**Scenario 5** 1 CCC – multiple sites opt. 2nd echelon	**Scenario 6** 1 CCC – multiple sites opt. 1st & 2nd echelon	**Scenario 7** multiple CCC – multiple sites opt. 2nd echelon	**Scenario 8** multiple CCC – multiple sites opt. 1st & 2nd echelon
Capability to improve haulier journey time	Medium	Very high	Very high	Medium	Very high	Very high	Very high	Very high
Capability to decrease the material waste	Medium	Very high	Very high	Medium	Very high	Very high	Very high	Very high
Capability to improve the workforce productivity	Medium	High	High	Medium	High	High	High	High
Capability to decrease the waste management costs	Medium	High	High	Medium	Very high	Very high	Very high	Very high
Capability to improve the safety on site	Medium	High	High	Medium	Very high	Very high	Very high	Very high
Capability to improve the wellbeing of the residents	Medium	Very high	Very high	Medium	Very high	Very high	Very high	Very high

Table 34: Factor capability level per scenario

- Score

Factors	**Scenario 1** No CCC – 1 site	**Scenario 2** 1 CCC – 1 site opt. 2nd echelon	**Scenario 3** 1 CCC – 1 site opt. 1st & 2nd echelon	**Scenario 4** No CCC – multiple sites	**Scenario 5** 1 CCC – multiple sites opt. 2nd echelon	**Scenario 6** 1 CCC – multiple sites opt. 1st & 2nd echelon	**Scenario 7** multiple CCC – multiple sites opt. 2nd echelon	**Scenario 8** multiple CCC – multiple sites opt. 1st & 2nd echelon
Capability to improve haulier journey time	3	5	5	3	5	5	5	5
Capability to decrease the material waste	3	5	5	3	5	5	5	5
Capability to improve the workforce productivity	3	4	4	3	4	4	4	4
Capability to decrease the waste management costs	3	4	4	3	5	5	5	5

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

Capability to improve the safety on site	3	4	4	3	5	5	5	5
Capability to improve the wellbeing of the residents	3	5	5	3	5	5	5	5

Table 35: Factor capability score per scenario

After applying the weights per factor, we get this final scoring for each pilot site:

Pilot site	Scenario 1 No CCC – 1 site	Scenario 2 1 CCC – 1 site opt. 2nd echelon	Scenario 3 1 CCC – 1 site opt. 1st & 2nd echelon	Scenario 4 No CCC – multiple sites	Scenario 5 1 CCC – multiple sites opt. 2nd echelon	Scenario 6 1 CCC – multiple sites opt. 1st & 2nd echelon	Scenario 7 multiple CCC – multiple sites opt. 2nd echelon	Scenario 8 multiple CCC – multiple sites opt. 1st & 2nd echelon
Luxembourg	3	4.44	4.44	3	4.72	4.72	4.72	4.72
Paris	3	4.46	4.46	3	4.73	4.73	4.73	4.73
Valencia	3	4.44	4.44	3	4.72	4.72	4.72	4.72
Verona	3	4.61	4.61	3	4.97	4.97	4.97	4.97

Table 36: Global capability score per scenario and per pilot site

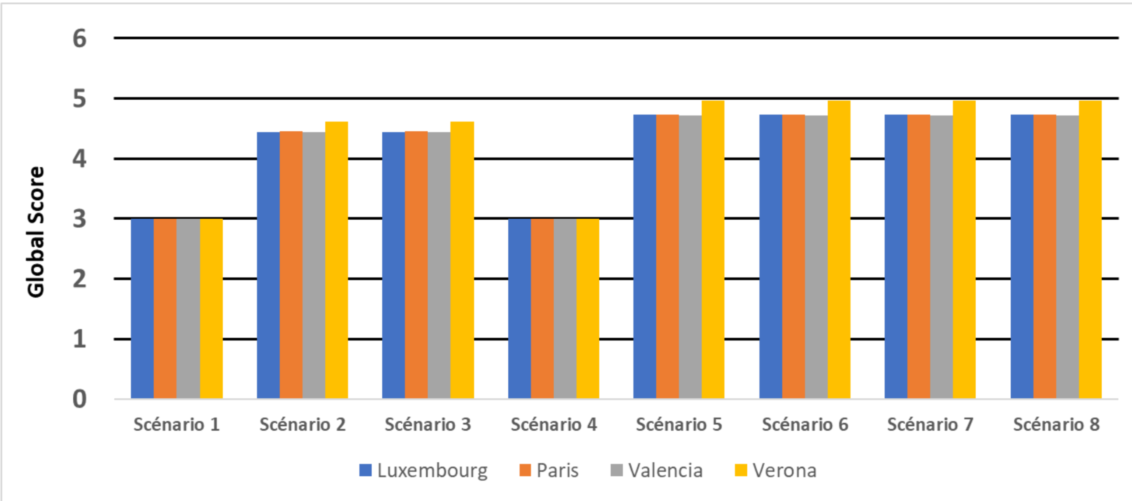


Figure 11: Global capability score per scenario & per pilot site (graph)

2.6 Conclusion

The results given by this first qualitative evaluation show that for the 4 pilot sites the scenarios with one or multiples CCCs have a better capability to improve

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

the global Supply Chain with clear improvements on both economic and social aspects.

Amongst all the scenarios with CCC(s), the ones delivering multiple sites offer a slightly better potential for improvement. We can explain it by the fact that a CCC delivering multiple sites offers more flexibility and can better optimize the use of its resources as compared to a CCC delivering one site.

Furthermore, as in any new organization or facility, we should consider the ramp-up period necessary to launch a new activity. By running a CCC on a long term, we can develop a continuous improvement culture more easily and benefit of the experience feedback to increase step by step the added-value to the customer. With a long-term view, it will also be more profitable to invest in innovation and new technologies. By customer, we mean here the construction site teams that need an efficient Supply Chain to optimize their operations. On the strategic side, it seems essential for the construction companies to develop a strong logistics/Supply Chain awareness and culture as operations and Supply Chain are heavily linked.

In D5.2, we will add a complete quantitative evaluation to this qualitative one in order to identify which scenario is the best alternative for each pilot site. In the following paragraph, we present the first results of this quantitative evaluation for the site of Valencia.

3 QUANTITATIVE EVALUATION

3.1 Simulation process: input, output and KPIs calculation

The simulations are performed by WP4 for each scenario and each pilot site of the project. The main steps, input and output of the simulation process are described in the figure below. Throughout the performing period of the simulations, WP5 will give a continuous feedback to WP4 about the input and assumptions taken and about the results (output) provided.

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

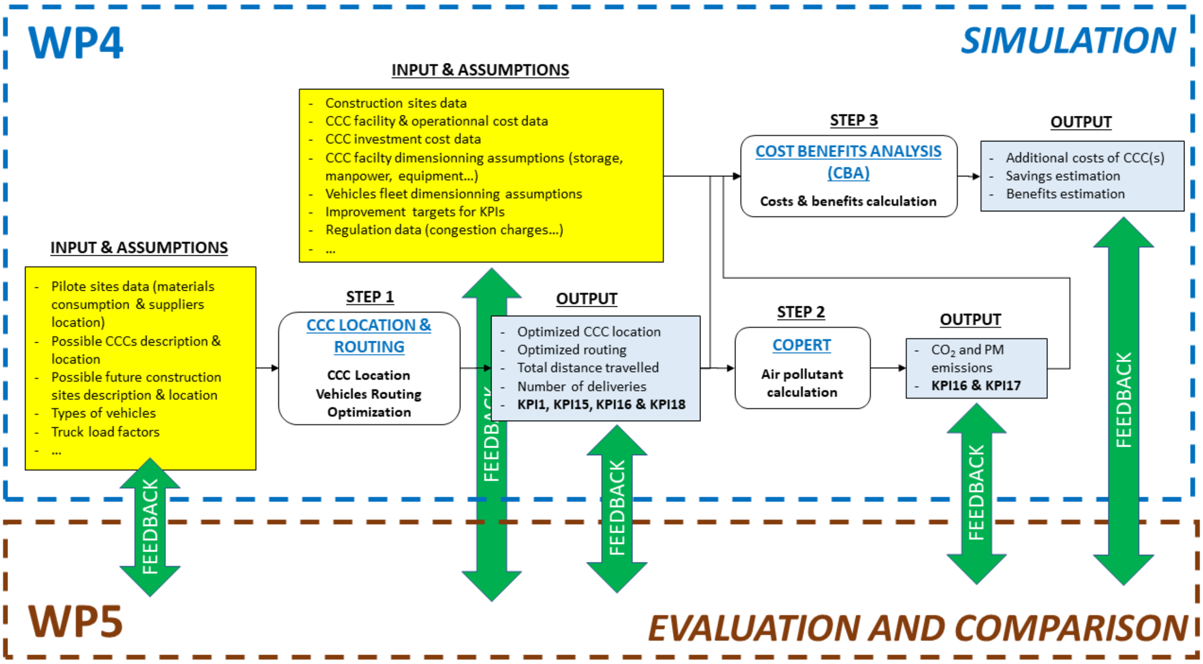


Figure 12: WP4 simulation process & interface WP4/WP5

In this deliverable, we present the evaluation and comparison of the first results of the simulations performed by WP4. The complete results will be presented in D5.2 after the simulations will be completed.

3.2 Baselines: scenarios 1 and 4

Scenarios 1 and 4 are the two scenarios without CCC.

Name	Description
Scenario 1	No CCC – 1 site
Scenario 4	No CCC – multiples sites

Table 37: Description of scenarios 1 and 4

Those scenarios will be used as a baseline as they are representative of the real situation of the pilot sites which logistics process does not include a CCC. We will consider those scenarios as a comparison reference for the scenarios with CCC:

- Scenario 1 as a reference/baseline for scenarios 2 and 3,
- Scenario 4 as a reference/baseline for scenarios 5, 6, 7 and 8.

In the following paragraph, we will systematically compare the results of the scenarios to the baseline to evaluate the improvements that the scenarios with CCC can bring to the global performance of the Supply Chain.

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

3.3 Evaluation and comparison

3.3.1 Scenarios 2 & 3 (1 CCC - 1 site)

Those 2 scenarios aim at simulating a logistics organization with 1 CCC and 1 construction site. In scenario 2, we optimize only the 2nd echelon, that is to say the deliveries between the CCC and the construction site. In scenario 3, we optimize the deliveries both between the suppliers and the CCC (1st echelon) and between the CCC and the construction site.

Name	Description
Scenario 2	1 CCC – 1 site Optimization on 2nd echelon
Scenario 3	1 CCC – 1 site Optimization on 1st and 2nd echelon

Table 38: Description of scenarios 2 and 3

At the date of the submission of this deliverable, the simulation process is ongoing.

We will present in this preliminary version the first results for the Valencia pilot site for which scenarios 2 and 3 have been simulated for the CCC location and routing optimization part. Those results are detailed below.

3.3.1.1 *Valencia*

For those simulations, we took the following assumptions:

- Truck load rate = 80% for the deliveries from the suppliers
- Truck load rate = 100% for the deliveries from the CCC (this rate is too optimistic and will be adjusted in the future simulations)
- Use of 3 axle trucks only between the CCC and the construction site
- We chose two possible locations for the CCC: a private CCC (called "CCC1") and a public CCC (called "CCC2"). We will show the results for those two CCCs.

We will provide as a first step the results for KPIs 6 (Distance from suppliers to the construction site) and 18 (Number of deliveries).

We get the following results:

KPI	Scenario 1	Scenario 2		Scenario 3	
		CCC1	CCC2	CCC1	CCC2
KPI6 – Total distance from suppliers to construction site (km)	521,820 km	602,097 km	539,020 km	510,017 km	460,457 km
Number of vehicles from suppliers to construction site (KPI18)	10,910				

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

Number of vehicles from suppliers to CCC		10,910	10,910	8,122	8,122
Number of vehicles from CCC to construction site (KPI18)		6,957	6,957	6,957	6,957

Table 39: Valencia site – Simulation results for scenarios 1, 2 and 3

After analysing those figures, we can conclude:

- Both scenarios 2 and 3 give the possibility to reduce by **36%** the number of deliveries to the construction site which is a very interesting improvement in term of risk of congestion and environmental impacts inside the city centre,
- In scenario 2, the total distance travelled is higher than in the baseline. It means that without optimization of the 1st echelon, the choice of the CCC location is important if we don't want to increase the total distance travelled and the pollutant emissions (CO_2 and PM),
- In scenario 3, the 1st echelon optimization balances the non-optimized location of CCC1 and CCC2. In this case the total distance travelled is less than in the baseline for both CCC locations. The number of vehicles from the suppliers also decreases by **25%**.
- General conclusion: the scenario 3 is the one offering the best advantages in term of reduction of travelled km, pollution emissions and number of deliveries (between the suppliers and the CCC and between the CCC and the construction site). But this simulation will have to be updated by adapting some assumptions like the load rate and the type of trucks used. Indeed, a load rate of 100% between the CCC and the construction site is not realistic and should be considered around 85%. For the trucks, we should consider a fleet of vehicles mixing at least three or four types of trucks: van, 2 axle truck, 3 axle truck, 4 axle truck… It is also important to insist on the importance of the CCC's location. This location must be well studied upstream to ensure a significant reduction of the km travelled.

We have here a first example of the kind of qualitative evaluation and comparison we can perform based on the results of the simulations. In D5.2, we will add the results and analysis for KPIs 1, 5, 16 and 17 and the complete results and analysis for the three other pilot sites: Luxembourg, Paris and Verona.

3.3.2 Scenarios 5 & 6 (1 CCC & multiple sites)

The results of the simulation of those scenarios will be described in D5.2.

3.3.3 Scenario 7 & 8 (multiple CCC & multiple sites)

The results of the simulation of those scenarios will be described in D5.2.

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

4 A "LEAN" EVALUATION: CHOOSING BY ADVANTAGES

4.1 Why the Choosing By Advantages method?

"I believe CBA is the most powerful and effective approach for making decisions available. I am most impressed with the way it uses both objective and subjective data. Once you can understand and apply CBA, I challenge you to find a decision making process that offers a more important advantage. We use the approach informally for all manner of daily choices and more formally when the stakes are large."

Gregory A. Howell, MSCE Stanford
President, Lean Construction Institute
Feb 8, 2011

Today, four types of multiple-criteria decision-making methods exist in the literature:

- Goal-programming and multi-objective optimization methods (Linear Optimization)
- Value-based methods (e.g., AHP and WRC)
- Outranking methods (e.g., ELECTRE)
- Choosing By Advantages (e.g., CBA Tabular Method)

It is obvious but a good decision-making method can increase the chances of arriving at the best decision.

« Among the most important of all the decisions the world's people will ever make are their decisions about how to make decisions, because their decisions about how to make decisions will strongly influence all the other decisions they will ever make. Furthermore, human performance — including organizational performance — is a decision-making process. Therefore, by improving the way they make decisions, the world's people will be able to make substantial improvements in both individual and organizational performance. And this will improve their quality of life. » (Jim Suhr (1999))

Research has shown the importance of the selection of the decision-making methods. Using different decision-making methods with the same information may lead to different decisions or evaluation. All decision-making methods are not the same.

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

According to Paz Arroyo (*Why CBA is superior to other decision-making methods?*[3] *(2015)*:

« A "good" decision-making method is one that is consistent, one that helps in organizing the information in a transparent fashion, one that is anchored to the context of the decision, one that helps in preventing double counting information, one that helps in reaching consensus, one that can be documented, and one that helps in explaining the decision easily. »

As Gregory A. Howell, Paz Arroyo believes that Choosing By Advantages (CBA) method is superior to the other existing multiple-criteria decision-making methods for the following reasons:

- *« CBA is superior to Goal Programming methods when it comes to understand what are the relevant factors that differentiate the alternatives. Goal Programming methods are made for optimizing an infinite number of possible alternatives, but when there are few alternatives (2 to 10) it makes more sense to use CBA and understand what differentiate each other instead of setting an objective formula. »*

- *« CBA is superior to Value-based methods, when it comes to consistency and collaboration. Research has proven than AHP and WRC, the most used MCDM methods, are flawed when removing irrelevant factors that do not differentiate the alternatives. AHP and WRC weigh factors, AHP though pairwise comparison and WRC directly. However, factors cannot be weighted in a consistent manner, since they are a representation of a general idea, and it does not represent a context-based judgment. For example, when choosing a construction method could you say that productivity is more important than safety? Or that safety is more important than productivity? These are questions that lead to an endless and useless argumentation process that says nothing about the real alternatives that are available for choosing. By contrast, CBA is based on understanding what are the advantages of one alternative over another and then based on actual advantages decision-makers need to assess the importance of those advantages. Therefore, CBA helps decision makers to focus on the decision context and avoid unnecessary discussions. »*

- *« CBA is more practical than outranking methods, because one can create a ranking of the best alternatives, which is very useful to compare value vs. cost, to prioritize alternatives, and to allocate money to*

[3] http://leanconstructionblog.com/why-choosing-by-advantages-is-the-best-available-decision-making-method.html

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

projects. Outranking methods, avoid weighting factors as AHP and WRC do, but they do not produce a ranking of the alternatives. »

4.2 Method description

The Lean Construction Institute describes the CBA method as follow:

« CBA is a decision-making system that acknowledges all decisions are essentially subjective – but then guides the participants towards basing the subjectivity on objectively discovered and documented facts. »

Choosing By Advantages is a collaborative and transparent decision-making system developed by Jim Suhr and described in his book *The Choosing By Advantages Decision-making System (1999)*. The CBA method can be used for moderately complex to very complex decisions allowing for documenting these decisions in a transparent fashion.

The main purpose of this method is to help decision makers to differentiate alternatives and to understand the importance of those differences. In the Choosing By Advantages method, decisions are based on advantages of alternatives which are positive differences, not advantages and disadvantages; this avoids double counting. By following this method, decisions are anchored to relevant facts.

The steps of the Choosing By Advantages method are the following:

- **Step 1:** list **the alternatives**. The alternatives are people, things, or plans from which one will be chosen. In the SUCCESS project, the alternatives are the **eight scenarios**.
- **Step 2:** identify **the factors** that we will use to differentiate the alternatives. The factors are elements for comparison of alternatives. Factors contain data that are required to decide or evaluate.
- **Step 3:** decide **the criteria** for judging. The criteria are used to evaluate the attributes of the alternatives. A criterion is a standard, rule, or test on which a judgment or decision can be based.
- **Step 4:** identify the **attributes.** An attribute is a characteristic, quality or quantity of one alternative.
- **Step 5:** decide **the advantages** of each alternative. An advantage is a difference between attributes of the 2 alternatives. I can be a benefit, a gain, an improvement or a betterment.
- **Step 6:** decide the importance of each advantage by **weighing the advantages**.
- **Step 7:** evaluate **cost data**.

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

Let's consider an example in order to explain the Choosing By Advantages method in a real case (example based on the one described by Paz Arroyo in *Step by Step Guide to Applying Choosing By Advantages*[4].

In our example, we decide to buy a car and we will apply the CBA method to choose a car amongst several alternatives.

Step 1: we identify three models of car that have important advantages over other models. Those three models are our alternatives. We call them **model 1**, **model 2** and **model 3**.

Step 2: we define the factors with the purpose of differentiating between alternatives. In the CBA method, it is important to identify which factors will reveal significant difference amongst alternatives. We will consider the following factors:

- **Fuel economy** (km/litre)
- **Trunk space** (litre)
- **Reliability**

Step 3: we decide the criteria for judging. We will use the criteria to evaluate the attributes of the alternatives. For each factor, we decide to use the following criteria:

- Fuel economy: **"higher is better"**
- Trunk space: **"more is better"**
- Reliability: **"more is better"**

Step 4: we identify the attributes of each alternative. They are summarized in the following table:

Factor	Alternatives		
	Model 1	Model 2	Model 3
Fuel Economy (km/litre)	17 km/litre	8 km/litre	10 km/litre
Trunk Space (litre)	5 litres	2 litres	5 litres
Reliability	Reliable	Extremely reliable	Reliable

Table 40: List of the attributes for each alternative

[4] http://leanconstructionblog.com/applying-choosing-by-advantages-step-by-step.html

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

Step 5: we identify the least preferred attribute for each factor according to the criterion. The least preferred attributes are underlined in yellow in the below table:

Factor	Alternatives		
	Model 1	Model 2	Model 3
Fuel Economy (km/litre) ***"Higher is better"***	17 km/litre	8 km/litre	10 km/litre
Trunk Space (litre) ***"More is better"***	5 litres	2 litres	5 litres
Reliability ***"More is better"***	Reliable	Extremely reliable	Reliable

Table 41: Identification of the least preferred attribute per factor

Then we decide on the advantage of each alternative's attribute relative to the least-preferred one:

- For the factor "Fuel Economy": the least-preferred attribute is 8 km/litre for model 2. The model 1 has an advantage of 9 km/litre higher than the model 2 and the model 3 has an advantage of 2 km/litre higher than the model 2.
- For the factor "Trunk space": the least-preferred attribute is 2 litres for model 2. The models 1 and 3 have an advantage of 3 litres compared to the model 2.
- For the factor "Reliability": the least-preferred attribute is "reliable" for the models 1 and 3. The model 2 has an advantage of being more reliable than the models 1 and 3.

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

The advantages are summarized in the following table (underlined in green):

Factor	Alternatives					
	Model 1		Model 2		Model 3	
Fuel Economy (km/litre) *"Higher is better"*	17 km/litre		8 km/litre		10 km/litre	
	Advantage:	Importance:	Advantage:	Importance:	Advantage:	Importance:
	9 km/litre higher				2 km/litre higher	
Trunk Space (litre) *"More is better"*	5 litres		2 litres		5 litres	
	Advantage:	Importance:	Advantage:	Importance:	Advantage:	Importance:
	3 litres more				3 litres more	
Reliability *"More is better"*	Reliable		Extremely reliable		Reliable	
	Advantage:	Importance:	Advantage:	Importance:	Advantage:	Importance:
			more reliable			
Total						

Table 42: Evaluation of the advantages relative to the least preferred attribute

Step 6: we decide the importance of each advantage. First, we select the paramount advantage which is the most important advantage among all. We choose the model 1 advantage of 9 km/litre for fuel economy as the paramount advantage because we consider it as the most important difference and we assign a weight of 100 to this advantage.

Secondly, we use the paramount advantage as a reference to weight other advantages by making comparisons. We assign a weight of 20 to the model 3 for having 2 km/litre higher advantage in fuel economy because it is not as important as the paramount advantage. We give a weight of 50 to the models 1 and 3 advantage of having 3 litres more of trunk space because we estimate that it is a medium difference compared to the paramount advantage. And we assign a weight of 30 to the model 2 advantage of being more reliable than the models 1 and 3 because we consider that it is a significant difference compared to the paramount advantage.

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

After the weighting is finished, we sum the weights for each alternative and we get the following table (weight underlined in blue):

Factor	Alternatives					
	Model 1		Model 2		Model 3	
Fuel Economy (km/litre) *"Higher is better"*	17 km/litre		8 km/litre		10 km/litre	
	Advantage:	Importance:	Advantage:	Importance:	Advantage:	Importance:
	9 km/litre higher	**100**			2 km/litre higher	**20**
Trunk Space (litre) *"More is better"*	5 litres		2 litres		5 litres	
	Advantage:	Importance:	Advantage:	Importance:	Advantage:	Importance:
	3 litres more	**50**			3 litres more	**50**
Reliability *"More is better"*	Reliable		Extremely reliable		Reliable	
	Advantage:	Importance:	Advantage:	Importance:	Advantage:	Importance:
			more reliable	**30**		
Total	**150**		**30**		**70**	

Table 43: Weighting of the advantages

Step 7: before comparing the importance of the advantages between the 3 alternatives, we will evaluate the cost of each model. Here are the approximate costs of each model:

- Model 1: 18,000 €
- Model 2: 55,000 €
- Model 3: 40,000 €

To represent at the same time the importance of the advantages and the costs, we use the following graph:

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

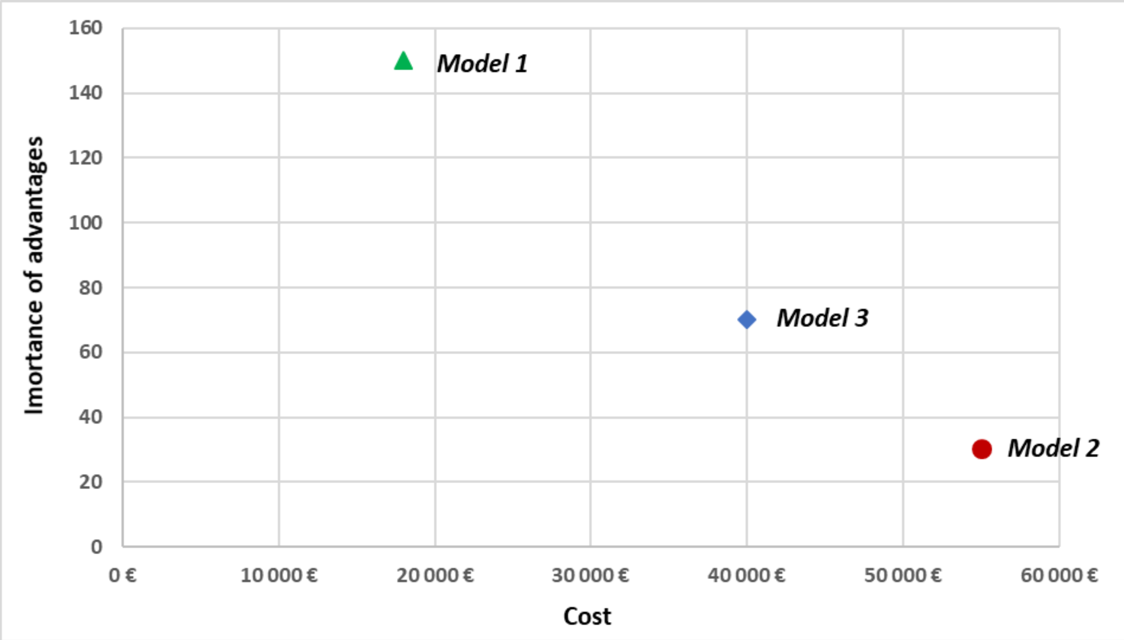


Figure 13: Cost vs Importance of advantages

At the end, we decide to choose the model 1 as it is the one offering at the same time the greatest benefit and the cheapest cost. Our decision could be reconsidered if we would incorporate new information like other alternatives or other factors. In this case, the tables we used above can be quickly and easily updated; that is one of the advantages of the *CBA* method.

4.3 Application and results

In D5.1, we describe the *Choosing By Advantages (CBA)* method and we will apply it in a higher stage of the simulation process (WP4) that is ongoing at the submission date of this document. The output of the simulation will be used as input for the application of the *CBA* method to evaluate and compare the eight scenarios of the SUCCESS project. The results will be described in D5.2.

As a collaborative method, *CBA* is the perfect tool to find a clear consensus between all the partners of the SUCCESS project on the best solutions to apply in order to improve the Supply Chain in the four pilot sites and more generally in the construction sector.

5 SOLUTIONS TESTING

WP5 aims also at testing some of the improvements levers/solutions identified in some construction sites (not necessarily in the pilot sites). In D5.2, we will describe the tests done and give a feedback on the capability of those solutions to reach the targets for improvement that we identified.

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

6 CONCLUSION

This preliminary phase of the analysis of the scenarios mainly based on a qualitative evaluation confirms the big potential of improvement the CCC(s) can bring to the logistics activities of the construction sector. In the second phase of this evaluation and comparison activity, we will focus on the quantitative part by analysing the output of the ongoing simulations performed by WP4 for the four pilot sites in Luxembourg, Paris, Valencia and Verona. We aim at identifying the best scenario for each pilot site by taking into account their characteristics, the site's complexity and the urban complexity. In this qualitative evaluation, we will perform a cost benefit analysis in order to assess the economic sustainability of the CCC by considering different business models (CCC operated by a logistics operator, CCC operated by a construction company…). Then, as the last step of the evaluation, we will apply the *Choosing By Advantages* decision-making method in order to ensure a collaborative decision involving all the stakeholders of the project and taking into account equally the economic, environmental and social factors.

All those results will be presented in D5.2 as the final report of task T5.1 of WP5.

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

7 REFERENCES

Arroyo Paz, PhD. Why CBA is superior to other decision-making methods? (2015) - http://leanconstructionblog.com/why-choosing-by-advantages-is-the-best-available-decision-making-method.html

Arroyo Paz, PhD. Why Decision-making Methods Matter? (2015) - http://leanconstructionblog.com/why-decision-making-methods-matter.html

Arroyo Paz, PhD. Step By Step Guide to Applying Choosing By Advantages (2015) - http://leanconstructionblog.com/applying-choosing-by-advantages-step-by-step.html

Suhr Jim. The Choosing By Advantages Decision-making System (1999)

Lean Construction Institute. Choosing By Advantages - https://www.leanconstruction.org/media/docs/chapterpdf/israel/Choosing_by_Advantages.pdf

WRAP. Using Construction Consolidation Centres to reduce construction waste and carbon emissions (2011) - www.wrap.org.uk/sites/files/wrap/CCC%20combined.pd

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