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MOBILITY FOR GROWTH 2014-2015

H2020-MG-2014_TwoStages

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

Solutions evaluation and comparison

Version 1.0

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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 D5.2 – Solutions evaluation and comparison is an output of WP5. This work package aims at performing a complete evaluation and comparison of the different solutions designed and simulated in WP4. This evaluation and comparison exercise includes an analysis of quantitative indicators calculated by WP4 and qualitative opinions collected during different workshops organized during the SUCCESS project. In a second step, WP5 provides an overall validation of the solutions for each pilot site considering the needs of all the public and private stakeholders (deliverable D5.3).

In the introduction of this deliverable we will remind the context of the project, the Key Performance Indicators identified in WP2 to measure the performance of the construction Supply Chain, the scenarios designed in WP4 as potential solutions to improve the logistics activities in the construction sector, the simulation activities performed in WP4 and the activities that WP5 has shared with WP4 and WP6. Then we will describe the methodology that we implemented to perform our evaluation and comparison exercise. First, we present the decision-making method that we chose: the Choosing By Advantages method, and we explain why we chose it. We continue with the alternatives we will evaluate and compare and the description of the factors and criteria that are used to differentiate those alternatives. Finally, we present the results of the evaluation and comparison exercises that have been done for each pilot city and conclude this deliverable by describing the solution we advise to implement to improve efficiently the Supply Chain in the construction sector.

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1 INTRODUCTION

1.1 Context

The European project SUCCESS – Sustainable Urban Consolidation CentrES for ConStruction aims to explore, find and test greener and more 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 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. We mix qualitative and quantitative evaluations.

1.2 Key Performance Indicators (KPIs)

List of KPIs

Twenty KPIs have been identified in WP2 of the SUCCESS project 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.

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The KPIs defined for the SUCCESS project are the following:

Category	Code	KPI designation	Unit
Economic / haulier journey time	KPI1	Travel time (outside and inside 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 / workforce productivity	KPI7	Waiting time for material	hour
	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

Computable KPIs

Five out of the twenty KPIs described above are computed with the help of simulation tools (WP4).

Those five KPIs are:

Category	Code	KPI designation	Unit
Economic / haulier journey time	KPI1	Travel time (outside and in the city centre)	hour
Economic / haulier route	KPI6	Distance from the suppliers to the construction site	km
Environmental	KPI16	CO_2 emissions	gram
	KPI17	$PM_{2.5}$ and PM_{10} emissions	gram
Social / wellbeing for residents	KPI18	Number of deliveries	number

Table 2: List of SUCCESS project's computable KPIs

KPIs 1, 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 the result of further elaborations on this output performed with the help of the *COPERT* tool.

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Non-computable KPIs

The fifteen remaining KPIs cannot be computed with the simulation tools described in WP3 and WP4.

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 / haulier route	KPI5	Number of intermediate storage	number
Economic / workforce productivity	KPI7	Waiting time for material	hour
	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 3: List of SUCCESS project's non-computable KPIs

As those KPIs cannot be computed, they will be used to make a qualitative evaluation through their translation in different factors that we will describe in the next chapter of the report.

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:

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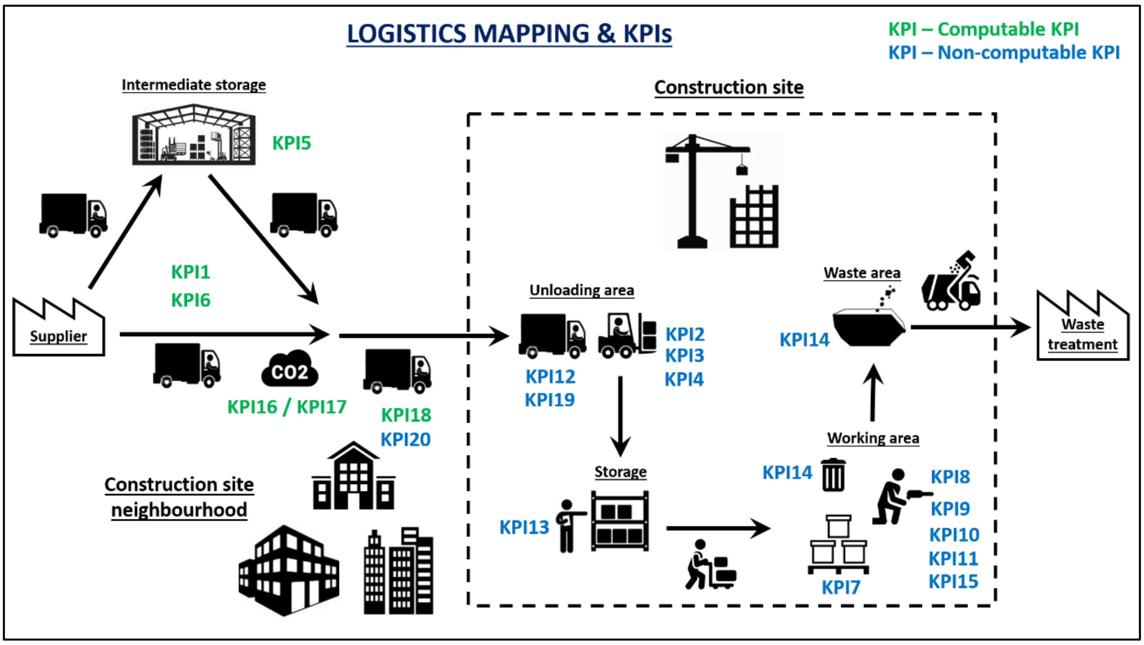
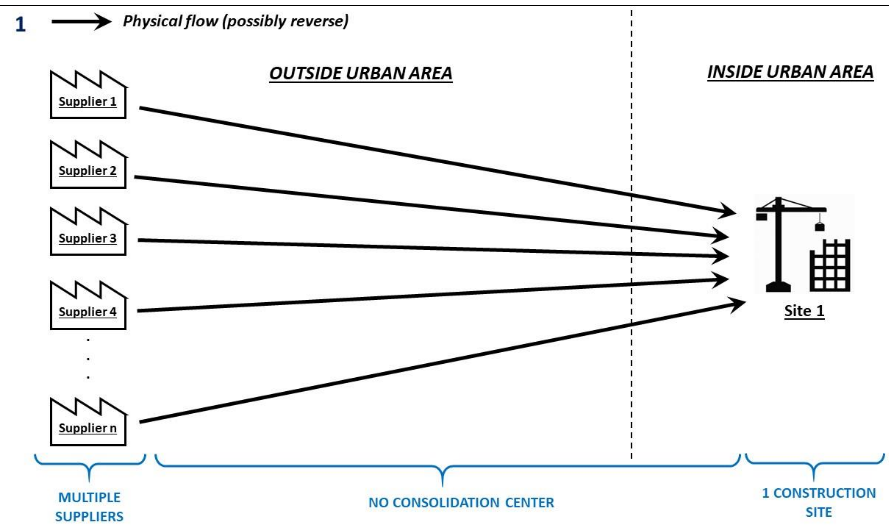


Figure 1: Logistics mapping and KPIs

Those KPIs have been defined 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.

1.3 Simulated scenarios

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 2: Scenario 1 description

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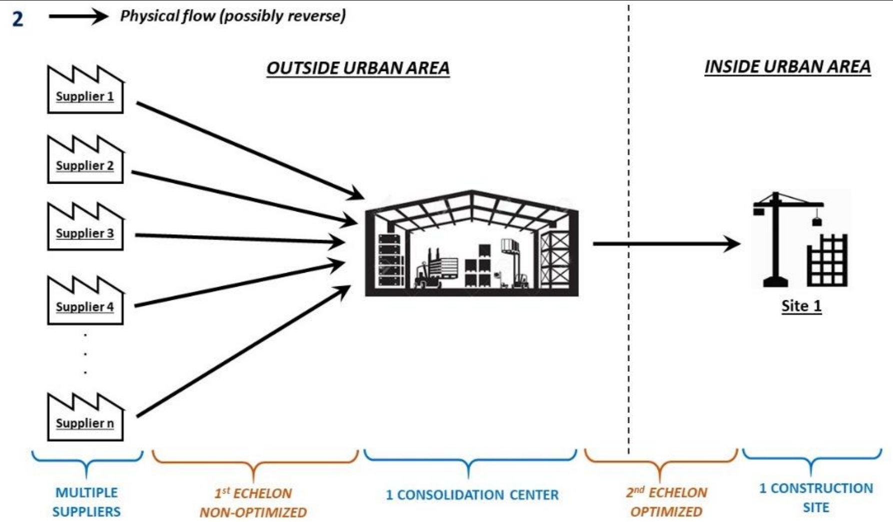
<table>
<tr>
<td>Scenario 2</td>
<td>1 CCC – 1 site
Optimization on 2^{nd} echelon


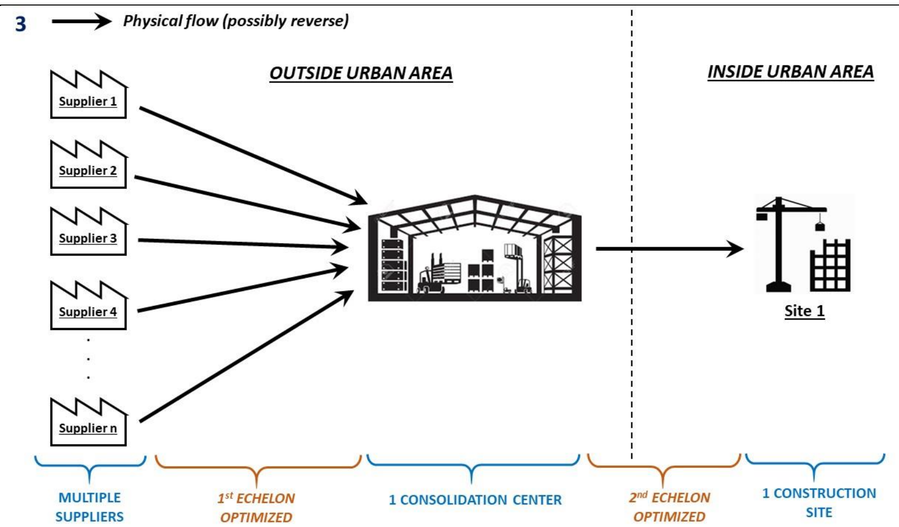
Figure 3: Scenario 2 description</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>1 CCC – 1 site
Optimization on 1^{st} and 2^{nd} echelon


Figure 4: Scenario 3 description</td>
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</table>

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Scenario 4

No CCC – multiples sites

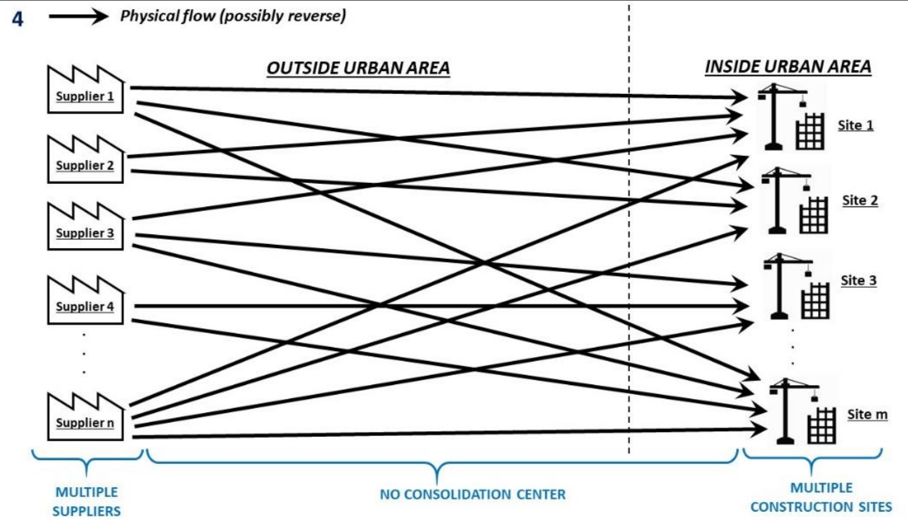

Figure 5: Scenario 4 description

Scenario 5

1 CCC – multiple sites
Optimization on 2nd echelon

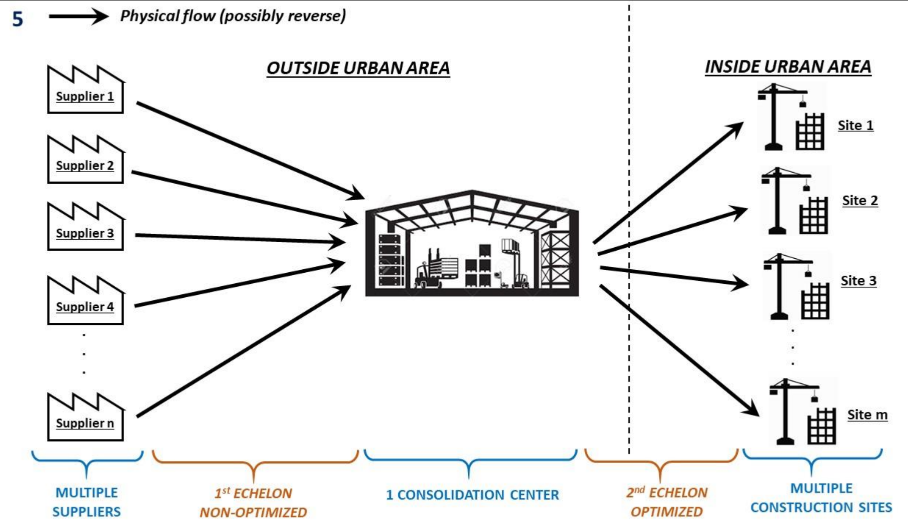

Figure 6: Scenario 5 description

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

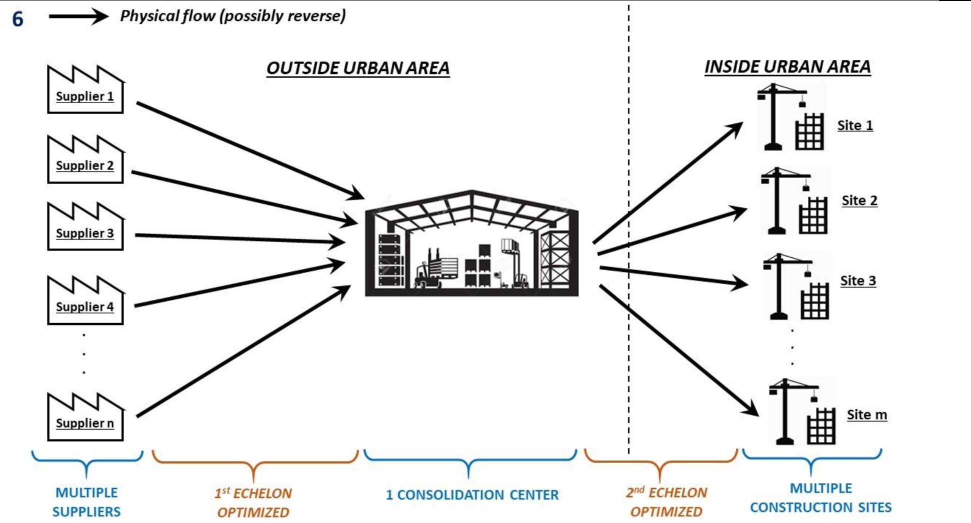

Figure 7: Scenario 6 description

</td>
</tr>
<tr>
<td rowspan="2">Scenario 7</td>
<td>Multiple CCC – multiple sites
Optimization on 2^{nd} echelon</td>
</tr>
<tr>
<td>

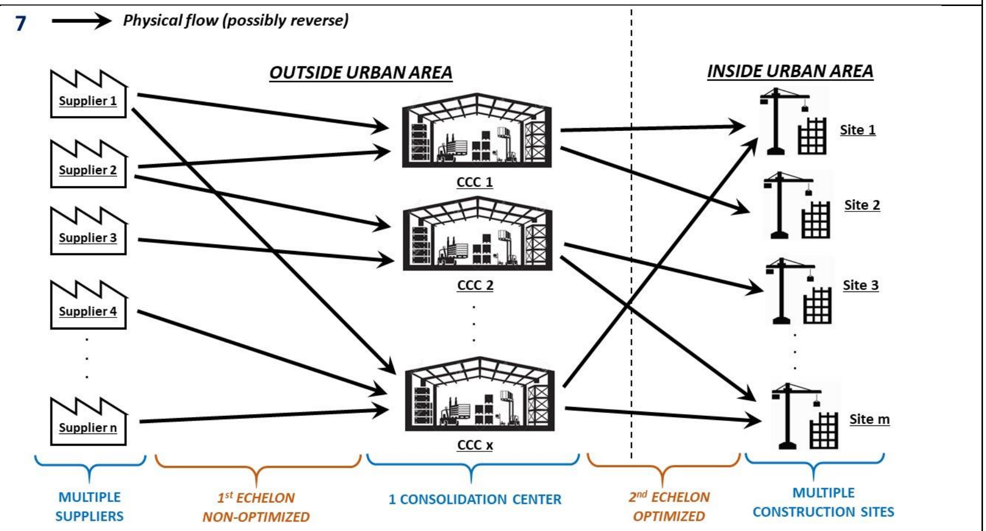

Figure 8: Scenario 7 description

</td>
</tr>
</table>

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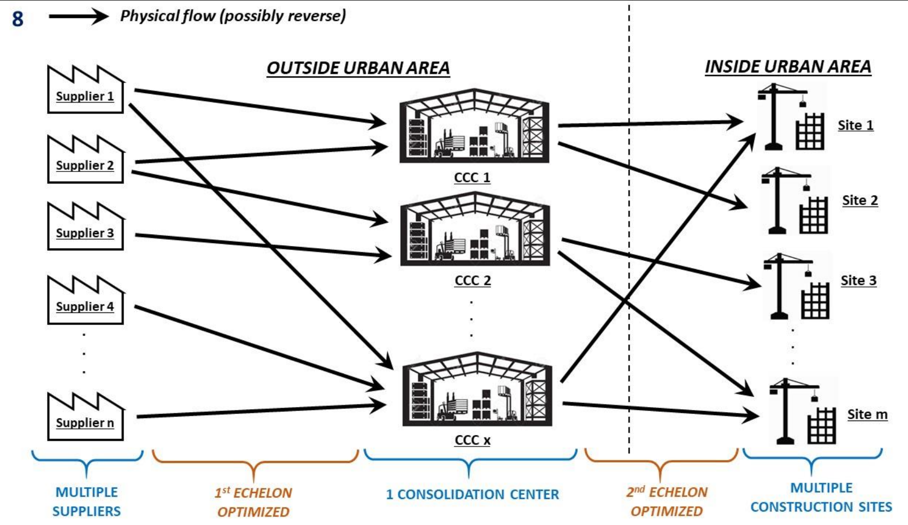
<table>
<tr><td rowspan="2">Scenario 8</td><td>Multiple CCC – multiple sites
Optimization on 1st and 2nd echelon</td></tr>
<tr><td>


Figure 9: Scenario 8 description
</td></tr>
</table>

Most of those scenarios are simulated by WP4 and some are evaluated quantitatively and qualitatively by WP5. The output data of WP4 are used by WP5 to perform the quantitative evaluation.

1.4 Simulation

For each scenario to simulate, the objectives of the simulation 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 is 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.
- Make a first estimation of the costs and benefits generated by the implementation of a CCC. We call this tool *Cost Benefits Analysis*.
- Estimate the environmental impact of the simulated scenarios by calculating the pollutant emissions (CO_2, $PM_{2.5}$, PM_{10}, NOx…). *COPERT* is the tool used for this estimation.
- Calculate the KPIs that can be computed with the output of the simulation.

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1.5 Relation with WP4 and WP6

A continuous feedback to WP4 has been given during the running of task T4.3 – Solution test and simulation. Meetings were organized every week between WP4 and WP5 to discuss and fine-tune the assumptions, input and settings of the simulation and analyse the results provided.

Among all the subjects discussed, we can list the main ones:

- Definition of the list of materials that go through the CCC. During the data collection, all materials deliveries were collected during the different phases of the pilot projects: concrete works, Mechanical, electrical, and plumbing (MEP) works, finishing works… We considered that all materials needed on site will not go through the CCC. Indeed, some materials like the ready-mix concrete must be consumed immediately on the construction sites and cannot be stored. Other large and voluminous equipment and materials like MEP machines or big steel structure must also be directly delivered to the site where they are immediately put in place and often require specific handling equipment like mobile cranes.
- We also had a big discussion between WP4 and WP5 about the frequency we must consider in the simulation for the deliveries between the suppliers and the site(s), the suppliers and the CCC(s) and the CCC(s) and the site(s). We decided to manage the deliveries coming from the suppliers on a weekly basis (for example for consolidation when the 1st echelon is optimized). But the deliveries between the CCC(s) and the construction site(s) are organized on a daily basis as one of the main objectives of a CCC is to deliver the site just-in-time.
- Load factor target with a CCC: 100% for deliveries to the construction sites.
- Truck fleet and loading rules: we decided to have a sufficient number of size of vehicles in order to maximize the load factor for each delivery sent from the CCC while minimizing the total number of deliveries.

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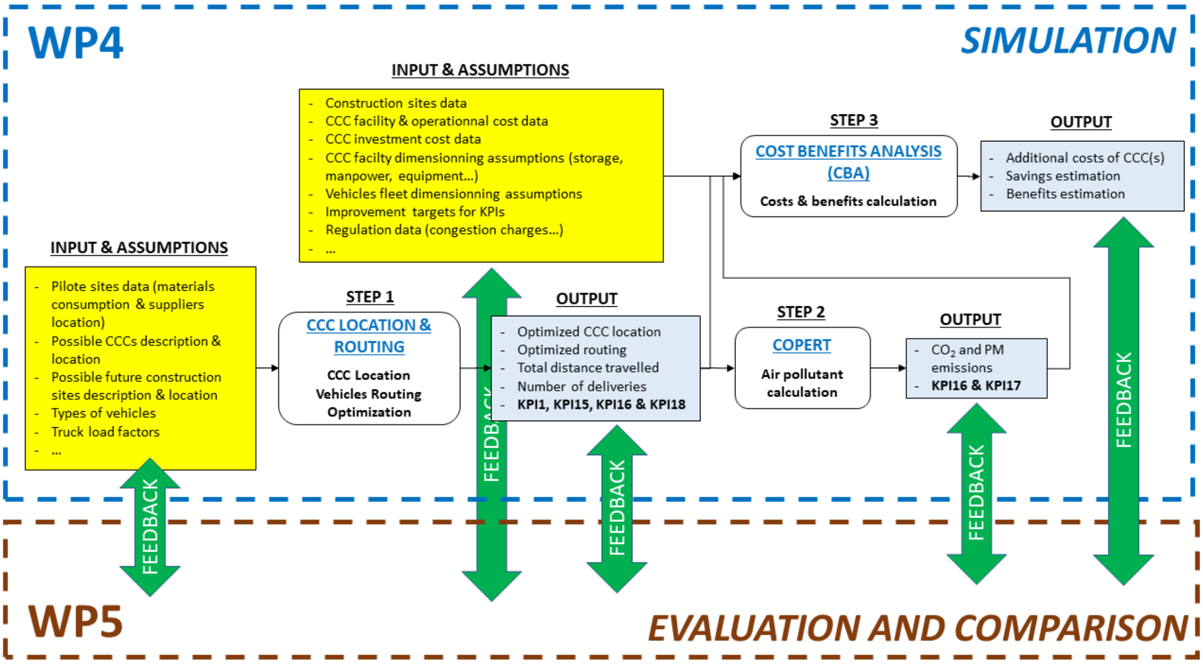

Figure 10: WP4 simulation process & interface WP4/WP5

WP5 also worked closely with WP6 during the third Joint Transfer Exercise (JTE) that was held in Brussels (Belgium) on November 14th and 15th 2017 at the Belgian Building Research Institute (BBRI). A specific workshop on the Construction Consolidation Centre was organized to discuss and share about the benefits and experiences of CCC with non-partner cities and other stakeholders participating in the JTE. A feedback on this workshop will be given in the conclusion of this deliverable (the complete feedback of the JTE can be retrieved in deliverable D6.5).

2 METHODOLOGY – CHOOSING BY ADVANTAGES

2.1 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

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

- Goal-programming and multi-objective optimization methods (Linear Optimization)
- Value-based methods (AHP (Analytic Hierarchy Process) and WRC (Weighting Rating and Calculating))
- Outranking methods (ELECTRE)
- Choosing By Advantages

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.

According to Paz Arroyo (*Why CBA is superior to other decision-making methods?*[1] *(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. »

Like 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 the relevant factors that differentiate the alternatives are. Goal Programming methods are made for optimizing an infinite number of possible alternatives, but when there are few alternatives (2 to*

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

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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, which 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 the advantages of one alternative over another are 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 projects. Outranking methods, avoid weighting factors as AHP and WRC do, but they do not produce a ranking of the alternatives.»*

2.2 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

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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 will be chosen among the **eight scenarios** defined in the project.
- **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 an alternative.
- **Step 5:** decide **the advantages** of each alternative. An advantage is a difference between attributes of two alternatives. It 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**.

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*[2]).

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:

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

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- 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 4: List of the attributes for each alternative

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 table below:

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 5: 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. Model 1 has an advantage of 9 km/litre higher than model 2 and model 3 has an advantage of 2 km/litre higher than model 2. For the factor "Trunk space": the least-preferred attribute is 2 litres for model 2. Models 1 and 3 have an advantage of 3 litres compared to model 2. For the factor "Reliability": the least-preferred attribute is "reliable" for models 1 and 3. Model 2 has an advantage of being more reliable than models 1 and 3. The advantages are summarized in the following table (underlined in green):

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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 6: 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 model 1's 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 weigh other advantages by making comparisons. We assign a weight of 20 to 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 models 1 and 3's advantage of having 3 more litres 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 model 2's advantage of being more reliable than models 1 and 3 because we consider that it is a significant difference compared to the paramount advantage.

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

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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 7: Weighting of the advantages

Step 7: before comparing the importance of the advantages between the three 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:

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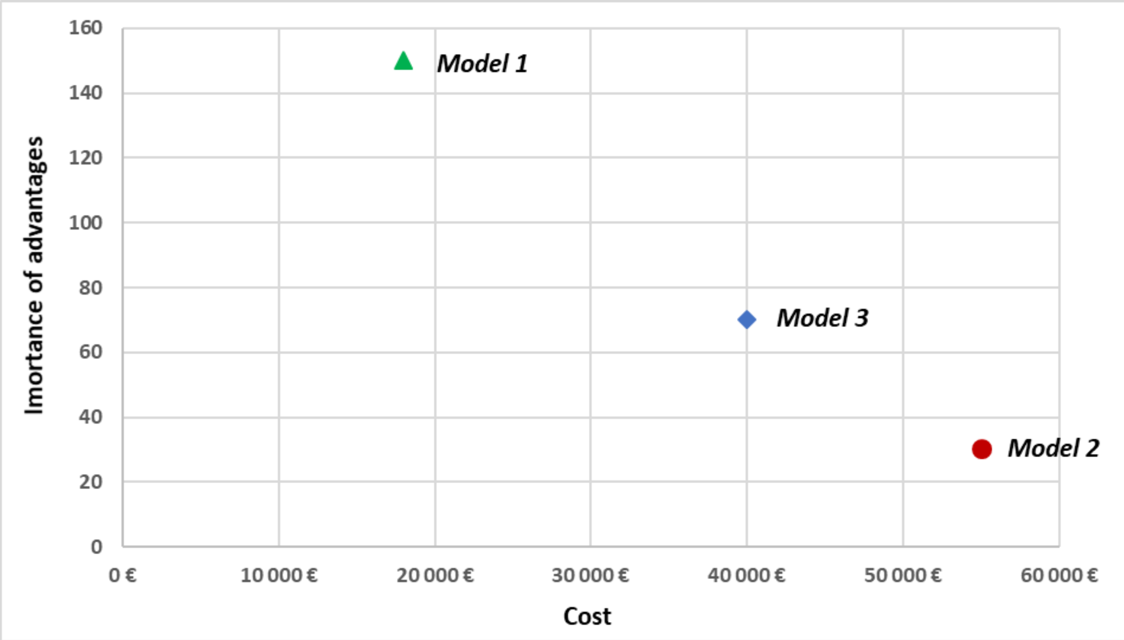

Figure 11: Cost vs Importance of advantages

At the end, we decide to choose 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.

2.3 Alternatives to assess

In the deliverable "D3.3 - Business models for construction logistics optimisation and CCC introduction", each pilot city has identified the business models that they consider as the most suitable ones considering their commercial, financial and organizational feasibility. In the following table, we remind the characteristics of those business models and we give their correspondence with the eight scenarios described in 1.2.

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Pilot	Business Model #	Description	Nb CCC	Duration	CCC operated by	Echelon managed		Nb Construction Companies	Nb Sites	Scénarios							
						1st	2nd			Scénario 1	Scénario 2	Scénario 3	Scénario 4	Scénario 5	Scénario 6	Scénario 7	Scénario 8
Luxembourg	1	Public-Private Agreement (PPP)	1	Temporary	Construction company		X	1	1 (several buildings)		X						
Luxembourg	2	Promoted by private sector	1	Permanent	Logistics operator		X	Several	Several (<10M€)					X			
Paris	1	Promoted by private sector	1	Permanent	Construction company	X	X	1	Several						X		
Paris	2	Promoted by private sector (consortium)	1	Permanent	Logistics operator	X	X	Several	Several						X		
Paris	3	Promoted by the public sector	1	Permanent	Logistics operator	X	X	Several	Several						X		
Paris	4 - Virtual / Digital CCC	Promoted by private sector		Permanent						N/A							
Verona	1	Public-Private Agreement (PPP)	1	Permanent	Logistics operator	X	X	Several	Several						X		
Verona	2	Promoted by private sector	1	Temporary	Construction company	X	X	1	Several						X		
Valencia	1	Promoted by private sector	1	Temporary	Logistics operator	X	X	1	Several						X		
Valencia	2	Promoted by private sector	1	Permanent	Construction company	X	X	1	Several						X		
Valencia	3	Public-Private Agreement (PPP)	1	Permanent	Logistics operator	X	X	Several	Several						X		
Valencia	4	Promoted by private sector	1	Permanent	Logistics operator	X	X	1	Several						X		

Table 8: business models per pilot city described in deliverable D3.3

We notice that all the pilots show mainly an interest in scenarios 5 or 6, that is to say the logistics solution of one CCC delivering multiples sites. Luxembourg City also proposed a business model in link with scenario 2: one CCC for a major construction site. But as this construction site is composed of several buildings we can consider this scenario as a sub-scenario of scenario 5 because each building can be seen as an independent construction site.

No immediate interest has been shown for scenarios 7 and 8. Those scenarios, with multiple CCCs, can be considered as a fine tuning of scenarios 5 and 6. Indeed, after a first experience with one CCC has been launched and has shown its added-value on a sufficient period of time, it could be declined on a larger scale by implementing a network of CCCs if it is justified by the volume of the flows of materials to manage. A network of CCCs can give the opportunity to go deeper in the optimization of the delivery trips (reduction of number of km travelled) by not depending on the location of one and only one CCC. Let's consider the example below taken from the simulation done in WP4 for Paris. From the data used for scenarios 5 and 6, we have extracted the location of the CCC identified as the best located one among the selected ones (in the north-west of Paris), the location of one construction site (in the centre of Paris) and the location of one supplier (in the east of Paris).

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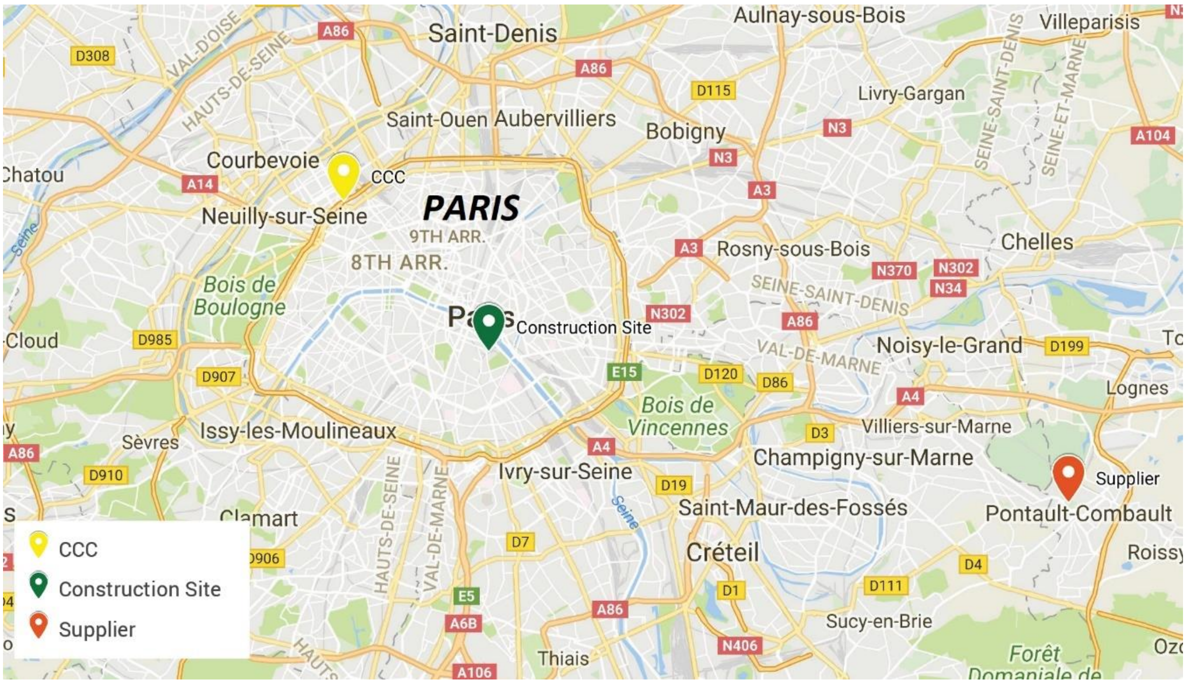

Map 1: extract of data used to simulate Paris scenarios 5 & 6 (the best located CCC, 1 construction site and 1 supplier)

If the selected CCC has indeed been identified as the best located one when considering all the construction sites and suppliers locations of our data set, it is obvious that for this construction site and this supplier only its location is not the best one. The best CCC location for this site and this supplier alone would be somewhere in the East of Paris between the site and the supplier locations (with an objective to minimize the number of km travelled). So we can say that solutions with multiple CCCs can be a new step of optimization at the conditions that the volumes of materials to deliver are big enough in order not to lose the advantages in terms of consolidation that would generate an increase of the number of deliveries compared with solutions with one CCC. The simulations done in WP4 for Paris confirm the global advantage of scenarios 7 and 8 compared to scenarios 5 and 6 (less km travelled, less global pollutant emissions, almost equivalent number of deliveries to construction sites…).

So, we will choose scenarios 4, 5 and 6 as the alternatives to evaluate and compare in our Choosing By Advantages exercise: scenarios 1, 2 and 3 are sub-cases adding no value in our evaluation and scenarios 7 and 8 must be considered as a future step of optimization on a larger scale (a network of CCCs) after we get some proofs of concept on first CCC experiences.

2.4 Factors and criteria

We have decided to choose 17 factors to differentiate the different alternatives that we will assess in the present deliverable. Those factors are listed in the table below.

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FACTORS
F1. Number of deliveries at the construction sites
F2. CO_2 emissions
F3. $PM_{2.5}$ & PM_{10} emissions in urban area
F4. Potential short-term improvement of pollutant emissions performance of the trucks delivering the construction sites
F5. Deliver the construction sites in Just-In-Time
F6. Goods packaging optimization (kitting) / Standardization of unloading equipment used on construction sites
F7. Tracking and tracing system implementation
F8. Delivery time windows flexibility
F9. Use of reverse logistics / Recycling of waste and non-used materials
F10. Deliveries punctuality (according to delivery planning)
F11. Impact of urban access regulations (low-emission zones, urban road tolls...)
F12. Sensitivity of site operations to supplier delivery delays
F13. Space availability for prefabrication, systems preassembly and mock-up building out of working zones
F14. Safety level inside and outside the construction sites
F15. Materials delivery reliability (the right reference in the right quantity) at the construction sites
F16. Materials and equipment security level
F17. Quality of the drivers reception (facilities)

Table 9: List of factors

In the following part of this paragraph we will describe more in detail each factor and precise on which characteristic it helps at differentiating the alternatives we compare and evaluate. For each factor we will precise the criterion used to define the most preferred alternative.

F1 – Number of deliveries at the construction sites

Freight activities have a big impact in terms of nuisances for the urban citizens: noise, congestion, road accidents… According to the European Construction Industry Federation, the construction sector represents about 10% of Europe's GDP. As construction activities involve the delivery of a wide range of materials to construction sites, we can assume that the construction sector represents an important part of the total urban freight. As the objective of SUCCESS project is to propose solutions to reduce those nuisances and improve the quality of life in the urban areas, this factor aims at identifying the alternatives that are minimizing the number of deliveries at construction sites located in the city centre. This factor is an output of WP4.

For this factor the criterion is **"the fewer deliveries, the better".**

F2 – CO_2 emissions

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In France transport activities are responsible for 29% of the greenhouse gas emissions. In the European Union the transport sector is responsible for 23% of the greenhouse gas emissions.

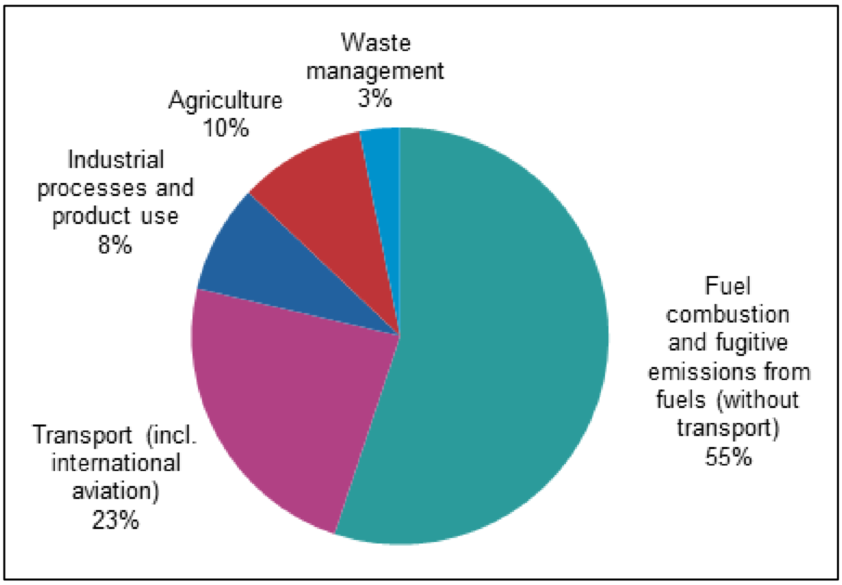

Figure 12: Percentage of greenhouse gas emissions by source sector, in EU, 2015[3]

Freight activities generated by the construction sector represent a significant part of those emissions. So, the construction sector has a very important role to play to reduce the global emissions of greenhouse gases (e.g. CO_2).

The attributes of the alternatives for this factor are an output of the task 4.3 (deliverable D4.3).

For this factor the criterion is obviously **"the lower CO_2 emissions, the better"**.

F3 – $PM_{2.5}$ and PM_{10} emissions in urban areas

PM emissions are a big matter of public health as they can be the cause of many diseases: lung cancer, heart attacks… Those emissions must be reduced drastically and in the short-term to increase the life conditions of urban citizens. According to the European Environment Agency air pollution is responsible for 487,600 premature deaths in European Union in 2014. $PM_{2.5}$ are the most toxic pollutants as they are responsible for 399,000 deaths in EU. Even if emissions of many air pollutants have decreased substantially over the past decades the European Environment Agency adds: "Around 90% of city dwellers in Europe are exposed to pollutants at concentration higher than the air quality levels deemed harmful to health. For example, fine particulate matter ($PM_{2.5}$) in air has been estimated to reduce life expectancy in the EU by more than eight months."[4] The European Commission estimates that the human health damage

[3] http://ec.europa.eu/eurostat/statistics-explained/index.php/Greenhouse_gas_emission_statistics_-_emission_inventories
[4] https://www.eea.europa.eu/themes/air/intro#tab-see-also

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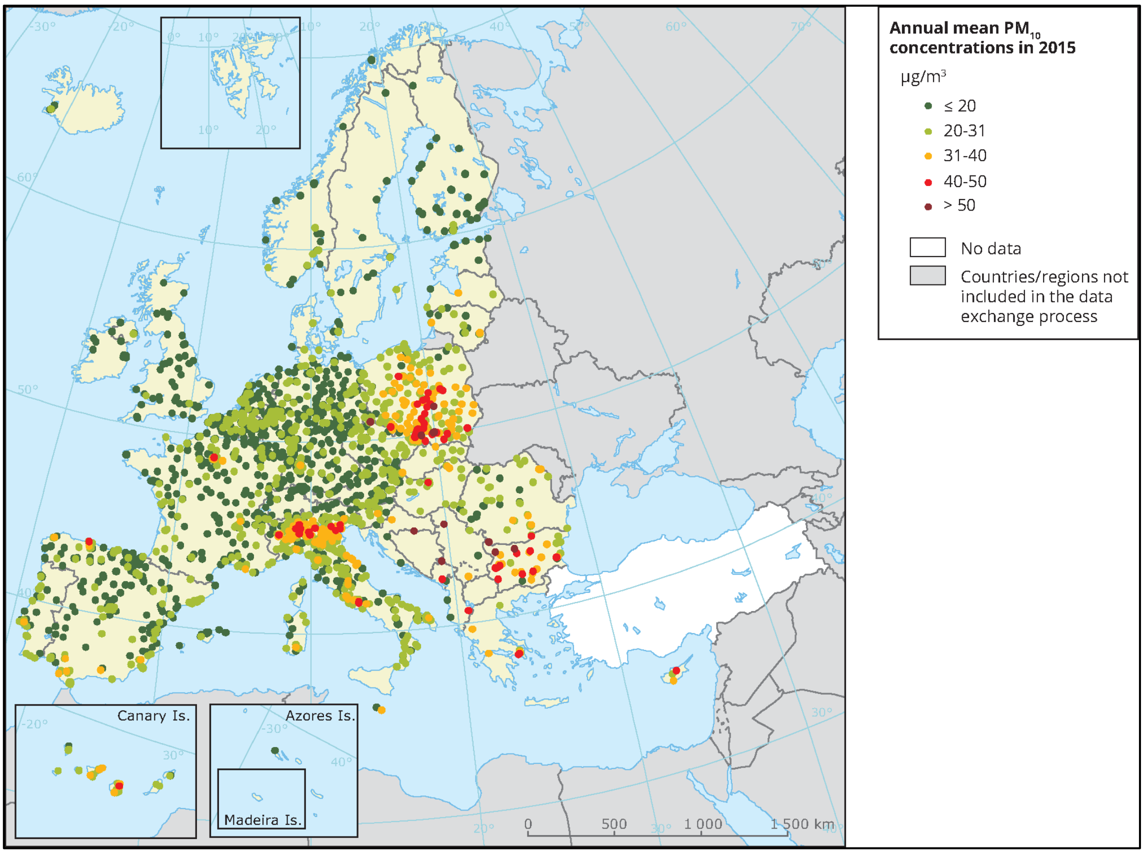
from air pollution costs the European economy between 427 and 790 billion € per year.[5]

The following maps show the annual mean PM_{10} and $PM_{2.5}$ concentrations in 2015 in Europe.



Map 2: Concentrations of PM_{10} in 2015 (EU annual limit value = 40 µg/m³)[6]

[5] http://urbanaccessregulations.eu/low-emission-zones-main/what-are-low-emission-zones

[6] https://www.eea.europa.eu/publications/air-quality-in-europe-2017

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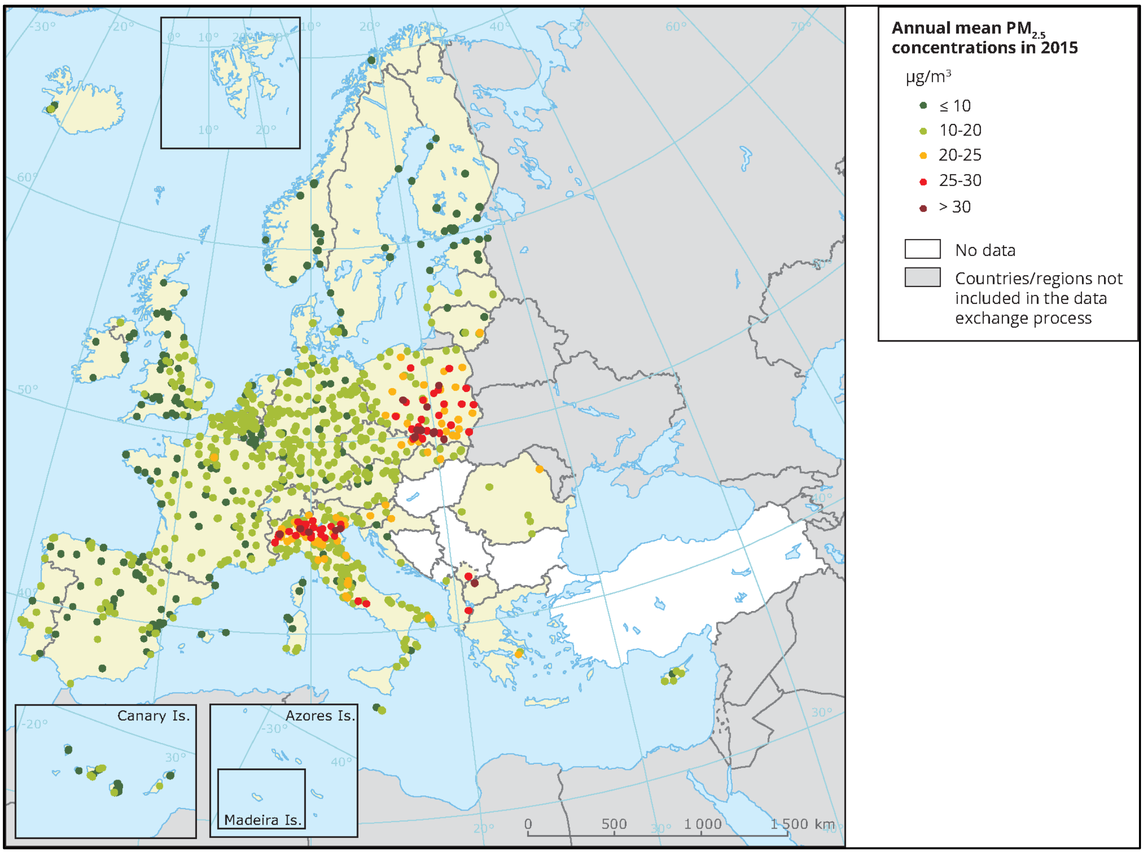

Map 3: Concentrations of $PM_{2.5}$ in 2015 (EU annual limit value = 25 μg/m³)[7]

The attributes of the alternatives for this factor are an output of the task 4.3 (deliverable D4.3).

For this factor the criterion is **"the lower PM emissions, the better"**.

F4 – Potential short-term improvement of pollutant emissions performance of the trucks delivering the construction sites

New technologies emerge to replace traditional diesel engine vehicles that are responsible for most of the pollutant emissions that transport activities generate by low-emission vehicles.

We can list different energy alternatives to diesel: electricity, hydrogen, natural gas, bio-gas… Those alternatives have 2 main advantages: less pollutant emissions and less noise. So, the deployment of those new technologies for transport activities in urban areas in a near future could seriously decrease the negative impacts of transport activities to the well-being and health of city residents.

We give below two examples of low-emission technologies used for transport activities in urban areas:

[7] https://www.eea.europa.eu/publications/air-quality-in-europe-2017

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- The French retailing company Carrefour uses bio-methane gas trucks to deliver its supermarkets in Paris city centre. Those trucks do not emit particulates and emit 75% less CO_2 when compared to diesel trucks.

Photo 1: Low-emission truck used by Carrefour in Paris

- The cement company Vicat in partnership with the transport company Jacky Perrenot, the truck manufacturer Iveco and the concrete machines manufacturer Cifa has developed a new concrete mixer truck equipped with a natural gas engine. This new truck offers the following performance compared to a traditional concrete mixer truck: 96% less CO_2 emissions, 92% less PM emissions and 70% less NO_x emissions[8].

8 https://www.batirama.com/article/15213-un-nouveau-camion-toupie-zero-co2-pour-livrer-le-beton.html

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Photo 2: Low-emission concrete mixer truck developed by Vicat, Jacky Perrenot, Iveco and Cifa

Those new technologies are still more expensive than the traditional diesel trucks but offer new perspectives to move to a new level in the pollutant emissions reduction. We will assess in our evaluation which alternatives can offer a real opportunity to push the use of those new technologies in the short-term.

The criterion chosen for this factor is **"the faster improvement, the better".** The most preferred alternative will be the one that can offer the highest short-term improvement of the performance of the truck fleet(s) delivering the construction sites, performance evaluated in terms of pollutant emissions.

F5 – Deliver the construction sites Just-In-Time

Most of the construction sites in urban areas have the same constraint: the lack of space outside the working zones (that is to say the zones of the project where works have to be executed). Therefore, a construction site cannot be considered as a place where materials can be stored but as a working place where all parts of the final building are assembled. An analogy can be made with a factory in the industrial sector: raw materials and spare parts are stored in specific stores and are then manufactured in the workshop area.

Nevertheless, in many construction projects, we can see important volumes of materials stored despite the lack of storage space with the following consequences:

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- As the goods are not stored in a zone dedicated for storage, they are not well secured and can be easily stolen,
- Storage zones are not correctly identified with materials stored in zones normally dedicated to pedestrian traffic or construction tasks which generate risks of accidents,
- Multiple handlings of the goods that generate risks of damage and loss.

Photo 3: Plumbing materials stored in a non-secured zone (risk of theft) on a construction site

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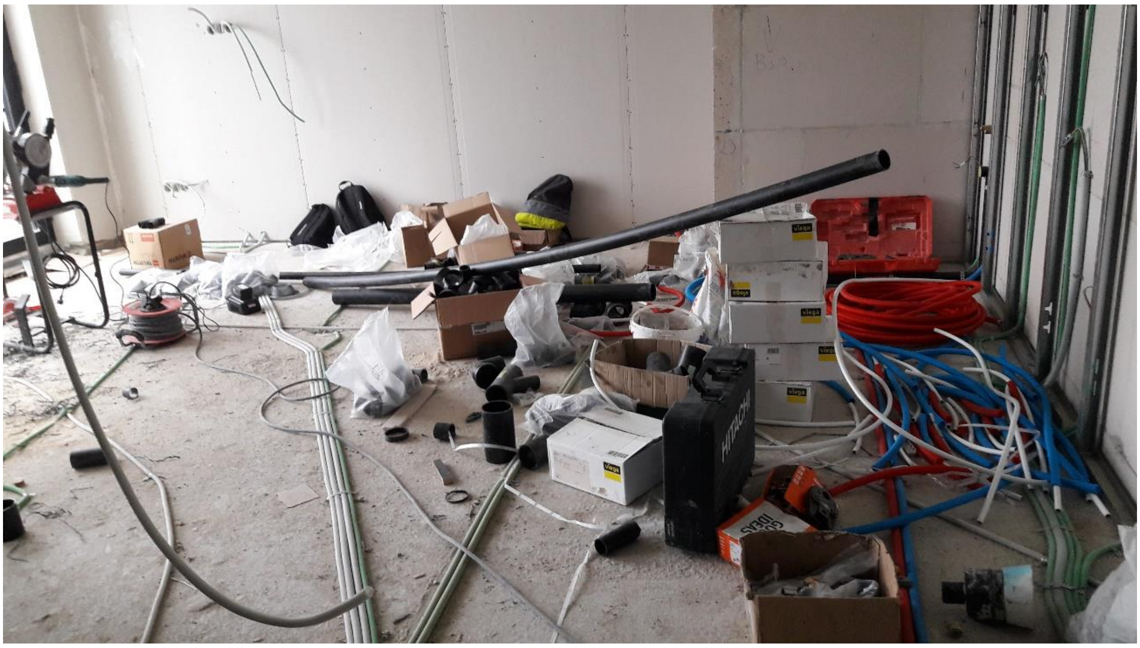

Photo 4: Plumbing materials stored in the middle of a working area (risk of accident) on a construction site

The best solution to overcome this constraint is to deliver the construction sites Just-In-Time that is to say deliver the exact quantity of materials needed to execute the coming works. The objective is to move from a "push flow" system to a "pull flow" system: the deliveries must be pulled by the construction activities.

The criterion chosen here is **"the more Just-In-Time deliveries, the better"**. The most preferred alternative will be the one that will make the implementation of Just-In-Time deliveries the easiest.

F6 – Good packaging optimization (kitting) & Standardisation of unloading equipment used on construction sites

On construction sites handling constraints are important: big diversity of packaging, availability of handling equipment (like forklifts), size of lifts and elevators… In addition, the packaging plan often does not match with the way the works are organized on the construction site as the suppliers have their own packaging standards that most of the time do not suit with the specific needs of their clients. It generates multiple unpacking and handling activities on site. Another important fact: packaging is a big source of waste on the construction projects: pallets, cardboard (see example below), plastic…

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Photo 5: Cardboard packaging for sanitary accessories generating a big volume of waste

All those facts push us to find solutions to optimize the packaging system of the materials delivered on site. Solutions exist like the use of kitting. The kitting consists in packing different materials in one kit, each kit being prepared for a specific task and zone of the project: installation of sanitary accessories in an apartment, installation of electrical fixtures in a hotel room… Each kit contains the exact quantity of materials needed and is delivered in the working zone just before the works start (Just-In-Time). The kits can be designed to adapt to the handling constraints of the site. For example, in a project where the elevator is too tight for standard pallets, we can imagine kits suitable with the size of the elevator. Finally, in order to tackle the problem of handling equipment's availability, kits that can be manually handled should be preferred when it is possible (depending on the weight of the materials to handle).

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An example of kitting is proposed below. This solution has been developed on an apartment renovation project in Paris through a partnership between Vinci Construction France and KS Services, a French logistics company.

Photo 6: Example of kit (trolley) containing the sanitary materials needed to equip a flat[9]

The criterion chosen here is **"the more the packaging is optimized, the better".** The most preferred alternative will be the one that will make the goods packaging optimization (use of kitting) the most feasible.

F7 – Tracking and tracing system implementation

Tracking materials consists of determining the location of the items during their way through the logistics chain from the supplier to the delivery at the last location of use, that is to say the working zone in the construction site where the materials are put in place. The tracing part consists of determining the source of

[9] Partnership Vinci Construction France / KS Services (http://www.groupeks.com)

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the problem of a non-compliant delivery: quality problem (defective materials), incorrect delivery (wrong quantity and/or wrong reference) … The tracking and tracing system is the link between the information systems and the physical reality of the flows of materials. This system has a big added-value for any Supply Chain as it gives the capacity to know at any time the exact status of the logistics flows and helps to detect and to react to any hazards before they cause significant problems like impacting the construction activities on site. Many tracking systems are available on the market: bar-codes, QR codes, RFID…

For this factor we consider the criterion **"the easier implementation, the better"**.

F8 – Delivery time windows flexibility

According to the European Commission:

"Congestion in the EU is often located in and around urban areas and costs nearly EUR 100 billion, or 1% of the EU's GDP, annually."[10]

INRIX released on February 2018 its *INRIX 2017 Global Traffic Scorecard* which is a large and detailed study of congestion to date. It includes data on 1,360 cities in 38 countries. This study gives interesting figures about congestion in the 25 most congested German cities in 2017. The results are shown below:

[10] https://ec.europa.eu/transport/themes/urban/urban_mobility_en

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RANK	CITY	PEAK HOURS SPENT IN CONGESTION	INRIX CONGESTION INDEX	AVERAGE CONGESTION RATE	TOTAL COST PER DRIVER	TOTAL COST TO THE CITY
1	Munchen	51	9.1	16%	€ 2,984	2.9bn
2	Hamburg	44	8.0	14%	€ 2,646	3.5bn
3	Berlin	44	8.3	14%	€ 2,811	6.9bn
4	Stuttgart	44	7.9	13%	€ 2,386	918m
5	Ruhrgebiet	40	7.5	10%	€ 2,129	2.2bn
6	Cologne	40	7.0	11%	€ 2,107	1.4bn
7	Heilbronn	38	7.6	14%	€ 2,317	154m
8	Frankfurt	36	5.9	10%	€ 1,820	906m
9	Würzburg	35	7.3	14%	€ 2,382	241m
10	Karlsruhe	34	6.4	12%	€ 2,166	468m
11	Dusseldorf	33	5.5	10%	€ 1,823	769m
12	Wiesbaden	32	5.2	9%	€ 1,604	542m
13	Pforzheim	32	6.5	13%	€ 2,310	159m
14	Reutlingen	31	5.9	12%	€ 2,514	203m
15	Sindelfingen	31	5.1	10%	€ 1,628	118m
16	Hanover	31	5.6	10%	€ 1,752	624m
17	Nuremberg	30	5.7	11%	€ 1,889	640m
18	Mannheim	28	5.0	8%	€ 1,500	323m
19	Bonn	28	4.5	8%	€ 1,482	295m
20	Bielefeld	28	5.0	10%	€ 1,793	170m
21	Wuppertal	27	4.7	8%	€ 1,557	337m
22	Krefeld	27	4.6	9%	€ 1,554	220m
23	Regensburg	26	4.8	10%	€ 1,652	99m
24	Darmstadt	26	4.0	8%	€ 1,354	76m
25	Freiburg	24	4.7	10%	€ 1,835	251m

Table 10: Top 25 German Cities Congestion Ranking[11]

The methodology to calculate each figure is explained in the report. About the economic cost of congestion, it is calculated as follow:

The total economic cost of congestion to households consists of two types of cost: direct and indirect. The direct costs are borne directly by car drivers through their use of the roads in congestion and include the value or opportunity cost of the time they spent needlessly in congestion, plus the additional fuel cost and the social cost of emissions released by the vehicle. The indirect costs are borne by households through the increase in the prices of goods and services due to congestion faced by businesses.[12]

For the city of Berlin only, the congestion cost is estimated at EUR 6.9 billion in 2017.

The construction sector, as an important actor of the urban freight, has its part in the creation of urban congestion. The SUCCESS project aims at finding solutions to minimize this negative impact. One of the solutions that we

[11] INRIX 2017 Global Traffic Scorecard (page 35) – INRIX research – Graham Cookson – February 2018 (http://inrix.com/)
[12] INRIX 2017 Global Traffic Scorecard (page 35) – INRIX research – Graham Cookson – February 2018 (http://inrix.com/)

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identified is a different organization of the deliveries time windows. Today, those time windows mainly depend on the opening working hours of the construction sites that are between 7 am and 6 pm for most of the sites.

The following curve shows the evolution of the congestion index in the Paris region:

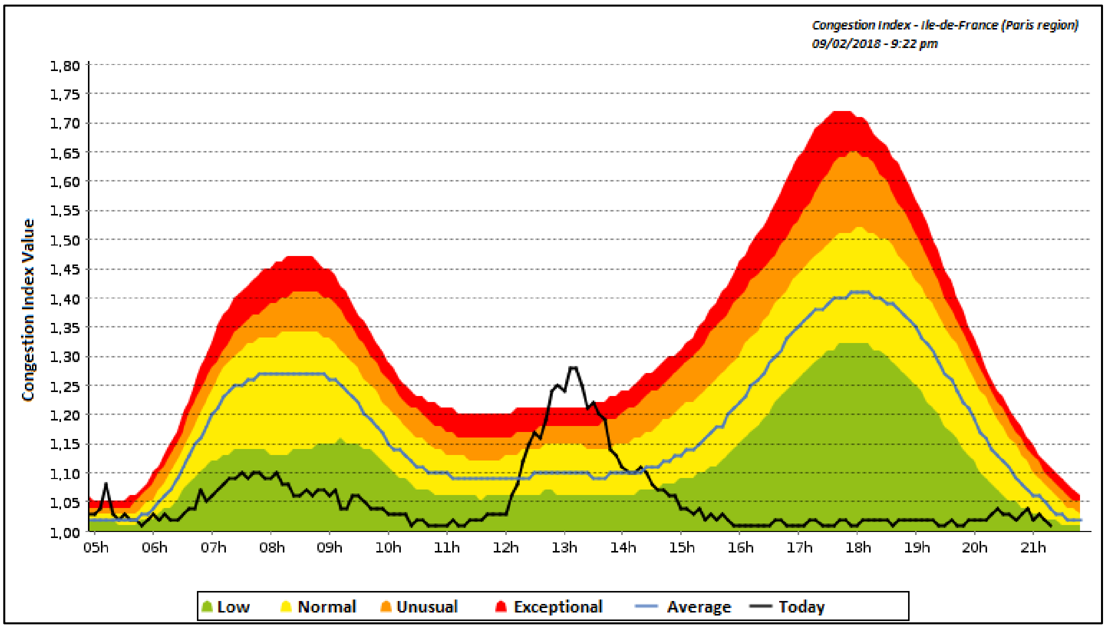

Figure 13: congestion index in Ile-de-France (Paris region) – Source : Sytadin[13]

If we look at the average curve (in blue on the graph), we can identify 3 different times windows:

- 6:30 am – 11 am and 3 pm – 8:30 pm: peak hours with high congestion,
- 11 am – 3 pm: moderate congestion
- 8:30 pm – 6:30 am: low or no congestion

In order to minimize the impact of the construction activities on urban congestion and the consequences of congestion for the construction sector in terms of costs (the extra costs generated by congestion are pure waste), we should prefer the alternative that provides as much flexibility as possible for the delivery time windows by matching with the low or no congestion time windows (8:30 pm – 6:30 am for Paris, that is to say preferring the deliveries at night).

The criterion chosen here is **"the more flexible, the better"**. The most preferred alternative will be the one that will be the most flexible in the planning of the delivery time windows.

F9 – Use of reverse logistics / Recycling of waste and non-used materials

The reverse logistics on construction projects is often un-used as most of the trucks, after unloading, leave the sites empty. The SUCCESS project aims at finding ways to use as much as possible this freight capacity to reduce the

[13] http://www.sytadin.fr/sys/barometres_de_la_circulation.jsp.html#

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impact of the construction sector on the urban congestion and increase the productivity of activities on construction sites.

Among the main outgoing flows of a construction site we can list:

- ➢ Waste that is collected by waste management companies directly on site with their own truck fleet,
- ➢ Equipment and tools that are used for specific tasks (scaffolding, formworks, shoring…) and sent back by the companies when the works are done,
- ➢ Returnable material (like pallets),
- ➢ Unused materials (when it is reused as in many cases it is unfortunately thrown away increasing the volume of waste produced on the construction sites).

Our objective is to identify the logistics alternative(s) that maximize the use of the reverse logistics to manage those outgoing flows. In this way we will minimize the urban freight that is generated today by those flows (trucks sent empty on the construction sites to load the output listed above).

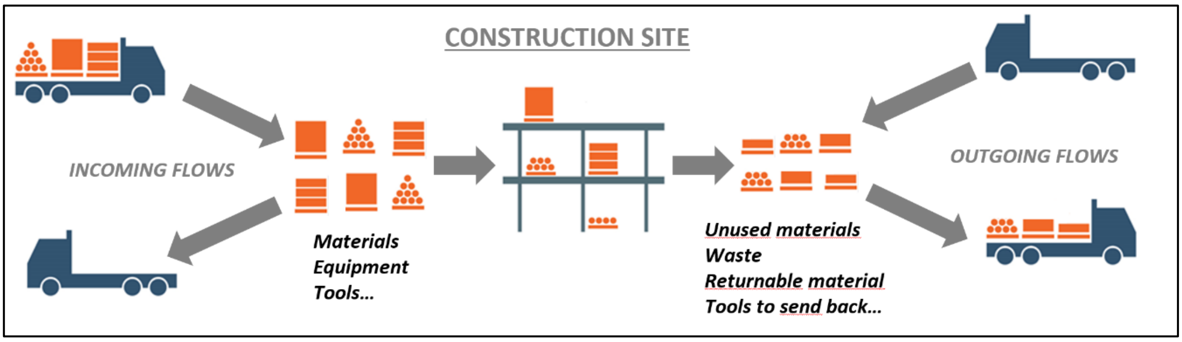

Figure 14: Logistics organization scheme with no use of reverse logistics

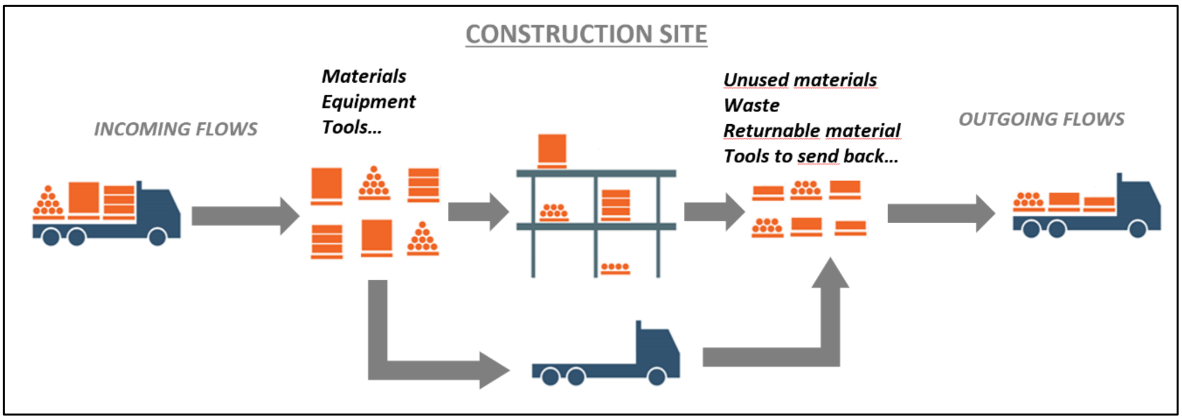

Figure 15: Logistics organization scheme with use of reverse logistics

The criterion chosen here is **"the more the reverse logistics is used, the better".** We will prefer the alternative that will most efficiently use the capacity of the reverse logistics.

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F10 – Deliveries punctuality (according to delivery planning)

We can talk about deliveries punctuality only for construction sites that manage a delivery planning. We will consider this case even if many construction sites still have nowadays no clear planning management of their deliveries, with all the negative impacts this involves: waiting time for drivers, congestion at the entrance of the construction site, unavailability of unloading equipment, difficulty to plan the start of construction activities (will the materials be delivered in the morning? In the afternoon?) …

The deliveries punctuality is calculated as the percentage of deliveries that arrive on site during the planned time window. In order to guarantee a continuous flow of work of the logistics activities on the construction site with a minimum of wastage for all actors, the deliveries punctuality should be as close as possible to 100%.

With this factor we will evaluate which alternative can ensure the best punctuality rate. So, the criterion chosen is **"the more on time, the better".**

F11 – Impact of urban access regulations (low-emission zones, urban road tolls…)

Many cities in EU struggle with the balance of congestion, air pollution, noise levels, accessibility, damage to historic buildings and other pressures of urban life. Most of the pollution in urban areas comes from the traffic and congestion has a significant impact on the economy. Some cities have decided to implement some measures to tackle these issues. The two main measures we can identify in EU cities are the urban road tolls and the low-emission zones.

An urban road toll is where entry to an area is subject to payment. In most cities the money raised from the schemes is spent improving transport in the city. The urban toll can be operated by camera enforcement, an electronic transponder, or by paying on entry to the area.[14]

[14] http://urbanaccessregulations.eu/urban-road-charging-schemes

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Country	City	Vehicles affected	Costs
Italy	Milan	All vehicles, except motorcycle	2 – 5€ / day
Malta	La Valletta	All vehicles, except motorcycle	0.82 – 6.52 € / day
Norway	Bergen, Haugesund, Kristiansand, Namsos, Oslo, Stavanger, Tonsberg, Trondheim	All vehicles	1.20 – 6€ / day
Sweden	Stockholm	All vehicles, except motorcycle	1.10 – 6.60€ / day
United Kingdom	London	All vehicles, except motorcycle	13 – 17€ / day

Table 11: Urban road tolling scheme in some European cities[15]

Low emission zones are areas where the most polluting vehicles are regulated. Usually this means that vehicles with higher emissions cannot enter the area. In some low emission zones the most polluting vehicles have to pay more if they enter the low emission zone. Low emission zones are often the most effective measure that towns and cities can take to improve air pollution. Low emissions zones reduce emissions of fine particulates, nitrogen dioxide and (indirectly) ozone, the three main air pollutants of concern in Europe.[16] It is important to add that all low emission zones affect heavy duty goods vehicles which makes this measure a main concern for the transport of construction materials and equipment.

Vehicle Type	City/Country	Current emission standard 2017
Heavy duty vehicles	Finland	Euro 3 for buses and Euro 5 for garbage trucks
	London, UK	Euro 4 (PM)
	Denmark	Fit filter if less than Euro 4
	Sweden	8 years old / Euro 5, 6

Table 12: Example of low emissions zones in some European countries affecting heavy duty vehicles[17]

This factor is deeply linked with factors F1 – Number of deliveries at the construction sites, F3 – $PM_{2.5}$ and PM_{10} emissions in urban areas and F4 – Potential short-term improvement of pollutant emissions performance of the trucks delivering the construction sites as the construction sites the less affected by those road access regulations will be the ones optimizing their number of deliveries and using a maximum of low-emission vehicles for their materials deliveries.

[15] http://urbanaccessregulations.eu/urban-road-charging-schemes/overview-of-urban-road-charging-schemes
[16] http://urbanaccessregulations.eu/low-emission-zones-main/what-are-low-emission-zones
[17] http://urbanaccessregulations.eu/overview-of-lezs

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

So the criterion chosen here is **“the less impact, the better”** as we will prefer the alternative that is the less impacted by existing or potential future urban road access regulations.

F12 – Sensitivity of site operations to supplier delivery delays

Due to some hazards (weather (e.g. snow…), mechanical breakdown, supplier disorganization…), important delays can occur in supplier deliveries, mainly for suppliers located far from construction sites. Those delays have a direct impact on the construction activities as the planned tasks cannot start at the planned date which has a negative impact on the manpower productivity and forces construction companies to reallocate their resources to unplanned activities.

We will estimate in our evaluation which alternative can absorb those delays with a minimum impact on the planned construction activities.

The criterion chosen here is **“the less sensitive, the better”.**

F13 – Space availability for prefabrication, systems preassembly and mock-up building out of working zones

For some works, a preassembly or preparation activity is sometimes required upstream to the set up and an area has to be dedicated to host a temporary workshop when this activity cannot be done in the working area.

We can give the example of an apartment project where painted baseboards have to be installed in each apartment. In our case, 2 subcontractors are involved in this task with the following sub-tasks:

- The non-painted baseboards are delivered on site by the joinery company,
- The painter paints the baseboards in a temporary workshop installed on site,
- The joiner installs the painted baseboards.

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

Photo 7: Temporary painting workshop on construction site to paint the baseboards

This kind of temporary workshop installed on site does not provide the perfect conditions in terms of working ergonomics, dust protection and level of temperature (mainly during winter time). In addition, the works are fully stopped during the time the workshop operates with risks of project delay as a possible consequence. Ideally this kind of workshop where prefabrication, preparation or preassembly activities operate should be installed out of site working areas.

The realization of internal mock-ups is also a critical point on many construction projects. Mock-ups aim at finalizing the design of the project with the architect team and the client. So, a mock-up should be finalized the most upstream possible before the start of the finishing activities on site in order to have a sufficient period of time to finalize the execution studies, get the approval on the execution documents, launch the orders and fabricate the needed materials and equipment (long-lead items require a lead time of several weeks (6 weeks or more)). Unfortunately, in many projects the mock-ups are executed in the final building; it cannot be launched before the civil works are finished, the first windows installed and the waterproofing works partially started. Here again, late decisions on the final design of the project can cause delays and budget overruns.

We will prefer the alternative that can provide the most available space out of the working zones of the project for prefabrication, preassembly and mock-up activities. The chosen criterion for this factor is: **“the more available space, the better”**.

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

F14 – Safety level inside and outside the construction sites

According to the European Road Safety Observatory (ERSO), 25% of fatalities in accidents involving HGVs, Heavy Good Vehicles, occurs on urban roads[18]. ERSO defines Heavy Good Vehicles as good vehicles of over 3,5 tons maximum permissible gross weight. Road accidents involving HGVs tend to be more severe than other accidents because of the mass of these vehicles.

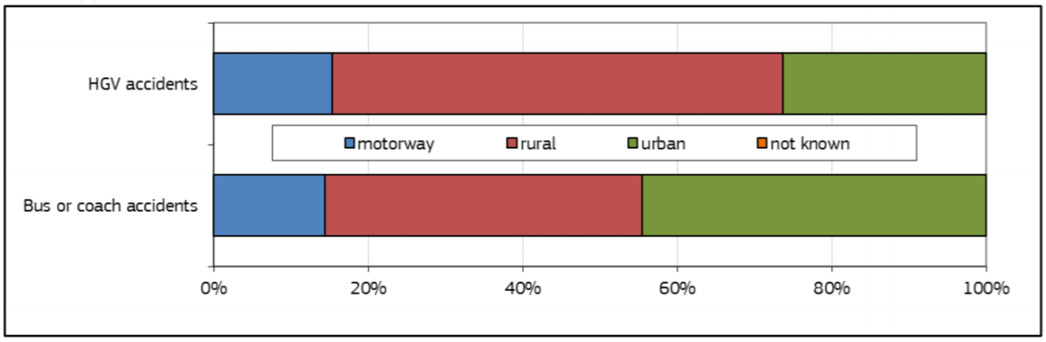

Figure 16: Distribution of fatalities in accidents involving HGVs and buses or coaches by road type, EU, 2013[19]

Among all accidents involving HGVs, the first victims of fatalities are car occupants which represent 50% of all fatalities in 2015 in EU. Then we have pedestrians with 15% of the fatalities, HGV occupants (13%) and pedal cyclists (7%).

	Accidents involving			
	HGVs fatalities	%	Buses or Coaches fatalities	%
HGV occupant	507	13%	10	1%
Bus or Coach occupant	51	1%	127	17%
Car occupant	1908	50%	264	36%
Light GV occupant	195	5%	12	2%
Moped rider	64	2%	8	1%
Motorcycle rider	199	5%	49	7%
Pedal cyclist	282	7%	54	7%
Pedestrian	579	15%	196	27%
Other/unknown	63	2%	7	1%
EU	**3.848**	**100%**	**727**	**100%**

Table 13: Number and distribution of fatalities in accidents involving HGVs and buses or coaches by road user type, EU, 2015[20]

[18] https://ec.europa.eu/transport/road_safety/sites/roadsafety/files/pdf/statistics/dacota/bfs2016_hgvs.pdf

[19] Source: CARE database / https://circabc.europa.eu/sd/a/70db5621-0012-4dc4-b463-d83d7046d128/bfs2015_hgvs.pdf

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Among all road fatalities in urban area in 2015 in EU, 39% of the victims are pedestrian for a total number of 9,735 fatalities. Outside urban area, pedestrians represent 10% of the 16,121 fatalities counted in EU in the same period. So, 70% of the pedestrian fatalities occurs in urban area.

	Inside urban area				Outside urban area			
	Driver	Passenger	Pedestrian	Total	Driver	Passenger	Pedestrian	Total
BE	65%	6%	28%	224	79%	17%	5%	470
BG	38%	19%	43%	312	54%	35%	11%	589
CZ	50%	9%	42%	220	68%	21%	11%	514
DK	69%	8%	23%	62	72%	16%	11%	116
DE	56%	7%	36%	1.048	79%	15%	7%	2.411
EE	36%	5%	55%	22	59%	13%	25%	56
IE	51%	14%	34%	35	69%	18%	12%	153
EL	64%	10%	27%	388	74%	20%	6%	405
ES	37%	7%	56%	441	71%	20%	10%	1.248
FR	57%	12%	31%	987	73%	20%	6%	2.472
HR	60%	16%	24%	220	73%	20%	6%	128
IT	60%	9%	30%	1.502	75%	18%	7%	1.926
CY	54%	8%	38%	37	65%	25%	10%	20
LV	27%	14%	59%	44	47%	25%	28%	122
LT	-	-	-	-	-	-	-	-
LU	40%	0%	60%	5	77%	10%	13%	31
HU	52%	12%	36%	261	57%	29%	14%	383
MT	54%	31%	15%	13	-	-	-	0
NL	75%	2%	21%	126	81%	12%	6%	222
AT	48%	12%	40%	128	77%	14%	9%	351
PL	40%	12%	48%	1.248	58%	23%	19%	1.690
PT	56%	8%	37%	304	67%	21%	12%	289
RO	38%	18%	44%	1.154	49%	32%	19%	739
SI	54%	13%	31%	39	77%	19%	5%	81
SK	31%	14%	55%	157	57%	25%	19%	214
FI	59%	10%	32%	73	77%	19%	5%	193
SE	55%	3%	42%	67	69%	20%	11%	186
UK	45%	10%	45%	618	71%	17%	12%	1.112
EU	**50%**	**11%**	**39%**	**9.735**	**70%**	**20%**	**10%**	**16.121**
IS	100%	0%	0%	119	46%	46%	8%	134
NO	59%	0%	41%	3	75%	22%	3%	13
CH	50%	9%	40%	22	81%	12%	7%	95

Table 14: Inside/outside urban area fatalities by road user and country, 2015 our latest available year[21]

The previous figures show that the accidents involving HGVs and pedestrians are an important matter and that we have to see how we can reduce the impact of goods freight on urban road fatalities. The SUCCESS project focuses on solutions we can implement to reduce the accidents involving vehicles delivering construction materials.

[20] Source: CARE database, data available in May 2017 / https://ec.europa.eu/transport/road_safety/sites/roadsafety/files/pdf/statistics/dacota/bfs2017_hgvs.pdf

[21] Source: CARE database, data available in May 2017 / https://ec.europa.eu/transport/road_safety/sites/roadsafety/files/pdf/statistics/dacota/bfs2017_urbanareas.pdf

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A solution can be found in the time windows of deliveries in urban area as shown by the following figure.

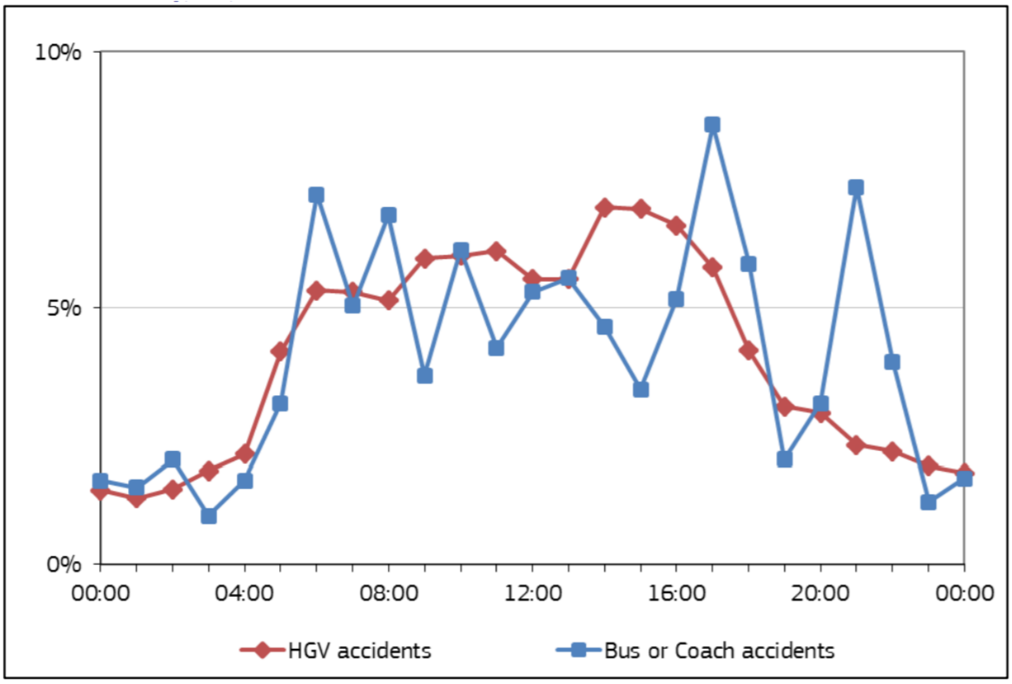

Figure 17: Distribution of fatalities in accidents involving HGVs and buses or coaches by time of the day, EU, 2013[22]

This graph shows that most of the road accidents involving HGVs occur between 4am and 9pm. We can estimate that we would reduce the risks of accidents linked with good freight if a higher priority would be given to night time windows for deliveries.

Delivering goods at night would also help to reduce the risks of accidents inside the construction sites. At night there is no construction activity so the risk of accidents between a worker and a vehicle circulating in the site is null. Other potential causes of accidents inside the site linked with logistics issues exists. In the four pilot sites we identified the following: no appropriate handling means, not adapted storage area, waste handling, materials handling… In Luxembourg City and Paris, about 20% of the total accidents are due to logistics issues[23].

The chosen criterion for this factor is: **"the higher level, the better"**. We will prefer the alternative that can provide the highest level of safety inside and outside the construction sites.

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[22] Source: CARE database / https://circabc.europa.eu/sd/a/70db5621-0012-4dc4-b463-d83d7046d128/bfs2015_hgvs.pdf
[23] Deliverable D2.4 – Pilot sites quantitative As-Is Analysis including KPI of the As-Is situation

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F15 – Materials delivery reliability (the right reference in the right quantity) at the construction sites

The materials delivery reliability at the working zones means that the right products reference in the right quantity must be delivered in the right working zone before the works start. We can add that the materials should also be in conformity with the quality level expected by the client.

If the wrong reference is delivered the works cannot start at the planned time which might result in project delays and waiting time with a workforce. If the reference is the right one but is not delivered in the right quantity the consequences are the following:

- insufficient quantity: the task cannot be fully completed and the workforce has to come back to the task after the remaining quantity is delivered which can impact the productivity. The following task might be postponed which involves a modification of the works planning at the last moment with consequences on the workforce productivity (allocate resources on unplanned activities).
- excessive quantity: the extra quantity remaining at the end of the task might not be reallocated to another task and might at the end be lost, stolen, damaged or thrown in the waste containers. It generates a complete wastage for the project.

In the case of a quality problem, the consequences are the same with a direct impact on the profitability of the project.

The chosen criterion for this factor is: **"the more reliable, the better"**. We will prefer the alternative that can offer the most reliable deliveries service.

F16 – Materials and equipment security level

We note today in many European countries an increasing trend in the number of the thefts committed in the construction sites. It is difficult to get figures precising the annual amount that those thefts represent. According to the French Building Confederation[24], the annual cost of the thefts and other criminal acts committed in construction sites located in France is evaluated at least at 1% of the global annual turnover of the French building sector that is to say more than 1 billion €. The matter of materials and equipment security in the construction Supply Chain should be seriously addressed. Construction sites can be easy targets for the following reasons: poor overall site security, unsecured jobsites, particularly at night and over weekends, lack of product identification systems, excess of materials stored on construction sites…

Solutions exists to secure the materials and equipment inventory. 2 examples are described below: secured container and wire mesh partitions.

[24] http://www.ffbatiment.fr/

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Photo 8: Example of container that can be used on construction site to store materials in a secured place

Photo 9: Example of wire mesh partitions that can be installed to create a secured storage area

We consider this factor in order to evaluate which logistics alternative can offer the best conditions to secure all the materials and equipment needed on construction sites before they are effectively put in place and used on site.

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The criterion chosen here is **"the higher level, the better".** The most preferred alternative will be the one that will offer the highest security level for materials and equipment.

F17 – Quality of the drivers reception (facilities)

Considering the facts that several drivers have to travel long distance due to suppliers located far from the construction sites and that they often have to wait at the construction sites before being able to unload their trucks it is important to provide facilities to the drivers in order to ensure that they can take a rest in good conditions (access to toilets, availability of coffee machines or drinks distributors…) before continuing their travel. It is a matter of road safety as tiredness is a significant factor in 20% accidents involving heavy commercial vehicles according to the European Commission[25]. This factor has been proposed by transport companies we had a workshop with during the SUCCESS local event organized in Paris in November 2017.

For this factor the criterion is **"the higher quality, the better".** The alternative that we will consider as the most preferred will be the one that can offer the highest qualify for facilities provided to drivers.

[25] https://ec.europa.eu/transport/road_safety/topics/behaviour/professional-drivers_en

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SUMMARY

The factors and criteria are summarised in the following table:

FACTORS	CRITERION
F1. Number of deliveries at the construction sites	the fewer deliveries, the better
F2. CO_2 emissions	the lower CO_2 emissions, the better
F3. $PM_{2.5}$ & PM_{10} emissions in urban area	the lower PM emissions, the better
F4. Potential short-term improvement of pollutant emissions performance of the trucks delivering the construction sites	the faster improvement, the better
F5. Deliver the construction sites in Just-In-Time	the more deliveries in Just-In-Time, the better
F6. Goods packaging optimization (kitting) / Standardization of unloading equipment used on construction sites	the more the packaging is optimized, the better
F7. Tracking and tracing system implementation	the easier implementation, the better
F8. Delivery time windows flexibility	the more flexible, the better
F9. Use of reverse logistics / Recycling of waste and non-used materials	the more the reverse logistics is used, the better
F10. Deliveries punctuality (according to delivery planning)	the more on time, the better
F11. Impact of urban access regulations (low-emission zones, urban road tolls...)	the less impact, the better
F12. Sensitivity of site operations to supplier delivery delays	the less sensitive, the better
F13. Space availability for prefabrication, systems preassembly and mock-up building out of working zones	the more available space, the better
F14. Safety level inside and outside the construction sites	the higher level, the better
F15. Materials delivery reliability (the right reference in the right quantity) at the construction sites	the more reliable, the better
F16. Materials and equipment security level	the higher level, the better
F17. Quality of the drivers reception (facilities)	the higher quality, the better

Table 15: List of factors and criteria

Factors and project KPIs

The table below indicates the KPIs covered by each factor:

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Project KPIs

FACTORS	KPI1 - Travel time (outside and inside the city centre)	KPI2 - Truck waiting time (outside and inside the site)	KPI3 - Construction site punctuality	KPI4 - Loading / unloading time	KPI5 - Number of intermediate storage	KPI6 - Distance from the suppliers to the construction site	KPI7 - Waiting time for material	KPI8 - Rework in connection with material issue	KPI9 - Waiting time for the workforce	KPI10 - Looking for material / equipment	KPI11 - Several handling time	KPI12 - Truck punctuality	KPI13 - Time dedicated to logistic activities	KPI14 - Costs of unsorted bins	KPI15 - Number of accidents and related causes	KPI16 - CO2 equivalent	KPI17 - $PM_{2.5}$ and PM_{10} emissions	KPI18 - Number of deliveries	KPI19 - Congestion on construction site	KPI20 - Rate of obstructing vehicules
F1. Number of deliveries at the construction sites															x			x	x	x
F2. CO_2 emissions																x				
F3. $PM_{2.5}$ & PM_{10} emissions in urban area																	x			
F4. Potential short-term improvement of pollutant emissions performance of the trucks delivering the construction sites																x	x			
F5. Deliver the construction sites in Just-In-Time							x	x	x	x	x		x		x			x		
F6. Goods packaging optimization (kitting) / Standardization of unloading equipment used on construction sites			x	x					x	x	x		x		x					
F7. Tracking and tracing system implementation								x	x	x			x							
F8. Delivery time windows flexibility	x	x	x	x								x							x	x
F9. Use of reverse logistics / Recycling of waste and non-used materials														x	x					
F10. Deliveries punctuality (according to delivery planning)		x	x									x							x	x
F11. Impact of urban access regulations (low-emission zones, urban road tolls...)																			x	x
F12. Sensitivity of site operations to supplier delivery delays									x											
F13. Space availability for prefabrication, systems preassembly and mock-up building out of working zones								x		x	x				x					
F14. Safety level inside and outside the construction sites															x					
F15. Materials delivery reliability (the right reference in the right quantity) at the construction sites								x	x	x										
F16. Materials and equipment security level										x										
F17. Quality of the drivers reception (facilities)																				

Table 16: Factors and KPIs

2 KPIs are not covered by the factors we have identified and will not be considered in our evaluation: KPI5 – Number of intermediate storage and KPI6 – Distance from the suppliers to the construction site. We think that those 2 KPIs are not relevant to evaluate the immediate impact of the construction Supply Chain on the urban environment and on the productivity of construction activities on site.

Nevertheless those 2 points keep important on the long term to improve the upstream Supply Chain. The CCC can be the right solution to remove or at least reduce the intermediate storage between materials manufacturers and the construction sites by simplifying the distribution network. This implies a better collaboration and transparency between manufacturers and construction companies in terms of information flows and planning (provide more accurate forecasts to manufacturers to match the production planning in the factory with the materials needs on construction site). The final objective is to reduce the lead time (time between the order passing and the delivery on site). The distance between the manufacturers and the construction sites is also essential and will require a deep involvement of clients, engineering companies and architects. To make their buildings more environmentally friendly they should promote as much as possible local manufacturers. Public authorities must play an important role by favouring local supplies in public contracts.

THE CIVITAS INITIATIVE IS CO-FINANCED BY THE EUROPEAN UNION

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2.5 Method implementation

A Choosing By Advantages workshop has been organized in each pilot city with project partners in order to assess the scenarios 4, 5 and 6 in the context of each pilot site. The evaluation and comparison exercise is based on the results given by deliverable D4.3 for factors F1, F2 and F3 and on a qualitative analysis for the other factors. The qualitative analysis considers the own experience of each participant of the workshop about construction logistics issues, the information collected during the life of SUCCESS project (best practices, benchmark, data collected on the pilot sites…), the feedback of the local events organized in pilot cities and the feedbacks of the Joint Transfer Exercises organized with non-partner cities.

The workshops took place in four steps:

- Step 1: identify the attribute for each alternative and each factor
- Step 2: decide the advantages of each alternative (for each factor: what is the least preferred alternative? what are the advantages of other alternatives compared to the least preferred one?)
- Step 3: decide the weight of each advantage. We chose to assign a weight of 100 to the paramount advantage and then decrease the weight by multiples of 5 for the following advantages (95, 90, 85…) with a minimum weight that cannot be lower than 5.
- Step 4: synthesis of results and feedback on the Choosing By Advantages method (new method for almost all workshop participants).

The results of the workshop are shown in the following chapter.

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3 SOLUTIONS EVALUATION AND COMPARISON

3.1 Luxembourg city

3.1.1 Evaluation and comparison results

Workshop attendees:

- Participant: LIST
- Facilitator: Vinci Construction France

Legend: Yellow = Least preferred attribute for each factor; Green = Best advantage for each factor

FACTORS	ALTERNATIVES											
	Scenario 4 No CCC / Multiple sites				Scenario 5 1 CCC / Multiple sites / Optimization 2nd echelon				Scenario 6 1 CCC / Multiple sites / Optimization 1st and 2nd echelons			
F1. Number of deliveries at the construction sites Criterion: the fewer deliveries, the better	Attribute:	59 311			Attribute:	27 045			Attribute:	27 045		
	Advantage:		Importance:	0	Advantage:	32 266 fewer	Importance:	15	Advantage:	32 266 fewer	Importance:	15
F2. CO_2 emissions Criterion: the lower CO_2 emissions, the better	Attribute:	4 523 tons			Attribute:	3 485 tons			Attribute:	2 887 tons		
	Advantage:		Importance:	0	Advantage:	1 038 tones lower	Importance:	90	Advantage:	1 636 tons lower	Importance:	95
F3. $PM_{2.5}$ & PM_{10} emissions in urban area Criterion: the lower PM emissions, the better	Attribute:	353 kg			Attribute:	336 kg			Attribute:	336 kg		
	Advantage:		Importance:	0	Advantage:	17 kg lower	Importance:	100	Advantage:	17 kg lower	Importance:	100
F4. Potential short-term improvement of pollutant emissions performance of the trucks delivering the construction sites Criterion: the faster improvement, the better	Attribute:	no direct influence on the evolution of the trucks fleets of the hauliers / multiple hauliers deliver the construction sites			Attribute:	the truck fleet is managed directly by the CCC for the 2nd echelon			Attribute:	the truck fleet is managed directly by the CCC for the 2nd echelon		
	Advantage:		Importance:	0	Advantage:	faster	Importance:	85	Advantage:	faster	Importance:	85
F5. Deliver the construction sites in Just-In-Time Criterion: the more deliveries in JIT, the better	Attribute:	possible but difficult directly from the suppliers and requires to work with a small number of suppliers (might have a negative impact on the number of deliveries)			Attribute:	enough volume to implement Just-in-Time deliveries / only one point of contact for the construction sites instead of multiple ones (suppliers) / more flexibility			Attribute:	enough volume to implement Just-in-Time deliveries / only one point of contact for the construction sites instead of multiple ones (suppliers) / more flexibility		
	Advantage:		Importance:	0	Advantage:	more deliveries in JIT	Importance:	70	Advantage:	more deliveries in JIT	Importance:	70
F6. Goods packaging optimization (kitting) / Standardization of unloading equipment used on construction sites Criterion: the more the packaging is optimized, the better	Attribute:	possible but limited to a certain number of materials / mono supplier kitting / work with the suppliers on the packaging optimization (long-term action)			Attribute:	multi supplier kitting / work with the suppliers on the packaging optimization (long-term action) / more power to negociate thanks to bigger volume managed			Attribute:	multi supplier kitting / work with the suppliers on the packaging optimization (long-term action) / more power to negociate thanks to bigger volume managed		
	Advantage:		Importance:	0	Advantage:	more optimized	Importance:	65	Advantage:	more optimized	Importance:	65
F7. Tracking and tracing system implementation Criterion: the easier implementation, the better	Attribute:	depends on the suppliers system / few suppliers have a traceability system shared with their clients / no standardization of the traceability system / no communication between subcontractors on the inventory of materials			Attribute:	tracking and tracing system can be easily implemented for materials passing by the CCC / only one system			Attribute:	tracking and tracing system can be easily implemented for materials passing by the CCC / only one system		
	Advantage:		Importance:	0	Advantage:	easier	Importance:	55	Advantage:	easier	Importance:	55
F8. Delivery time windows flexibility Criterion: the more flexible, the better	Attribute:	limited flexibility linked with availability of handling equipement and unloading area on the construction site			Attribute:	limited flexibility linked with availibity of handling equipment / easier for the suppliers that can deliver the CCC at any time			Attribute:	limited flexibility linked with availibity of handling equipment / easier for the suppliers that can deliver the CCC at any time		
	Advantage:		Importance:	0	Advantage:	more flexible	Importance:	35	Advantage:	more flexible	Importance:	35
F9. Use of reverse logistics / Recycling of waste and non-used materials Criterion: the more the reverse logistics is used, the better	Attribute:	limited use because of the lack of storage area on the construction site (example: pallets, plastic, formworks, reusable materials, unused materials…)			Attribute:	use of the available capacity in the trucks going back to the CCC and capacity of storage area in the CCC to store return flows			Attribute:	use of the available capacity in the trucks going back to the CCC and capacity of storage area in the CCC to store return flows		
	Advantage:		Importance:	0	Advantage:	more use & recycling	Importance:	75	Advantage:	more use & recycling	Importance:	75
F10. Deliveries punctuality (according to delivery planning) Criterion: the more on time, the better	Attribute:	punctuality will depend on the distance travelled by the truck, on the road traffic, on the trip organization (in case the truck delivers multiple sites…)			Attribute:	less sensitivity for deliveries coming from the CCC (lower distance between CCC and sites) / direct trip			Attribute:	less sensitivity for deliveries coming from the CCC (lower distance between CCC and sites) / direct trip		
	Advantage:		Importance:	0	Advantage:	better punctuality	Importance:	30	Advantage:	better punctuality	Importance:	30
F11. Impact of urban access regulations (low-emission zones, urban road tolls) Criterion: the less impact, the better	Attribute:	all suppliers have to stick with the urban regulations which generate big constraints (size of trucks, Euro class, weight, extra cost (toll)…)			Attribute:	Suppliers don't have to stick anymore with the urban regulations / Easier to implement in the CCC a trucks fleet respecting the urban regulations (low-emissions trucks, adapted truck size…)			Attribute:	Suppliers don't have to stick anymore with the urban regulations / Easier to implement in the CCC a trucks fleet respecting the urban regulations (low-emissions trucks, adapted truck size…)		
	Advantage:		Importance:	0	Advantage:	less impact	Importance:	5	Advantage:	less impact	Importance:	5

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FACTORS	ALTERNATIVES								
	Scenario 4 No CCC / Multiple sites			Scenario 5 1 CCC / Multiple sites / Optimization 2nd echelon			Scenario 6 1 CCC / Multiple sites / Optimization 1st and 2nd echelons		
F12. Sensitivity of site operations to supplier delivery delays Criterion: the less sensitive, the better	Attribute:	directly impacted by delivery delays and lack of storage area on site for buffer inventory		Attribute:	a buffer inventory can be implemented in the CCC (available storage area)		Attribute:	a buffer inventory can be implemented in the CCC (available storage area)	
	Advantage:		Importance: 0	Advantage:	less sensitive	Importance: 40	Advantage:	less sensitive	Importance: 40
F13. Space availability for prefabrication, systems preassembly and mock-up building out of working zones Criterion: the more available space, the better	Attribute:	lack of space on construction site or in the subcontractors workshop to make preassembly or prefabrication		Attribute:	a specific space can be dedicated in the CCC for prefabrication, preassembly and mockup / mockup can be done earlier in the construction process (can't be done before the civil works completion when done on site)		Attribute:	a specific space can be dedicated in the CCC for prefabrication, preassembly and mockup / mockup can be done earlier in the construction process (can't be done before the civil works completion when done on site)	
	Advantage:		Importance: 0	Advantage:	more available space	Importance: 50	Advantage:	more available space	Importance: 50
F14. Safety level inside and outside the construction sites Criterion: the higher level, the better	Attribute:	over-storage on site generates high ricks for accident / higher number of deliveries generates more accidents linked to the transport		Attribute:	less materials stored on site / fewer deliveries / vehicules more adapted to urban area constraints		Attribute:	less materials stored on site / fewer deliveries / vehicules more adapted to urban area constraints	
	Advantage:		Importance: 0	Advantage:	higher level	Importance: 80	Advantage:	higher level	Importance: 80
F15. Materials delivery reliability (the right reference in the right quantity) at the construction sites Criterion: the more reliable, the better	Attribute:	quality control done on site and at the last minute		Attribute:	quality control done in the CCC and earlier (buffer stock in the CCC)		Attribute:	quality control done in the CCC and earlier (buffer stock in the CCC)	
	Advantage:		Importance: 0	Advantage:	more reliable	Importance: 45	Advantage:	more reliable	Importance: 45
F16. Materials and equipment security level Criterion: the higher level, the better	Attribute:	lack of space to secure materials and equipment on site		Attribute:	CCC could offer a secured area (CCTV, security guards, only one area of storage…)		Attribute:	CCC could offer a secured area (CCTV, security guards, only one area of storage…)	
	Advantage:		Importance: 0	Advantage:	higher level	Importance: 25	Advantage:	higher level	Importance: 25
F17. Quality of the drivers reception (facilities) Criterion: the higher quality, the better	Attribute:	A construction site doesn't offer convenient facilities for workers and drivers. Access to showers, WC, food corner, rest area, parking…		Attribute:	CCC could offer much better facilities than a construction site could propose to drivers particularly drivers who travel on a long distance.		Attribute:	CCC could offer much better facilities than a construction site could propose to drivers particularly drivers who travel on a long distance.	
	Advantage:		Importance:	Advantage:	higher	Importance: 20	Advantage:	higher	Importance: 20
Total Importance			0			885			890

3.1.2 Conclusion

Based on the factors we identified, the scenarios 5 and 6 appear clearly as the best alternatives to improve the construction logistics and Supply Chain compared to scenario 4. The scenario 6 optimising the 1st and 2nd echelon has a slight advantage on scenario 5.

Whatever the weighting we give to the factors, the scenarios 5 and 6 will always be more interesting scenarios than the scenario 4 in which we don't use a CCC.

The methodology helps to better understand the benefits of implementing a CCC and share a common vision between stakeholders with different interests. Stakeholders all agree with the benefits that a CCC provides. However, previous experiences show that the lack of economic viability of a CCC is the main reason why the initiative is not implemented or fails. It is essential but very difficult to evaluate the stakeholders' willingness to pay for a service.

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3.2 Paris

3.2.1 Evaluation and comparison results

The Choosing By Advantages exercise for Paris pilot has consisted in synthesizing the feedback of the two evaluation workshops organized during the SUCCESS local event that took place in Paris on November 7th 2017, the results of the simulations run for Paris pilot and point of view of French SUCCESS partners.

The Paris local event attending stakeholders, both public and private, were:

- AFT (SUCCESS partner)
- Vinci Construction France (SUCCESS partner)
- Municipality of Paris
- ARES Services (logistics company)
- KS Services (logistics company)
- GEMO (Construction Project Management company)
- GEODIS (transport and logistics company)
- Veolia Environnement (waste management company)
- Interface Transport (logistics engineering company)
- GFI Consulting (IS company)
- MPI (Consulting company)
- CRFPTL (Board for professional training in logistics and transport)

Legend: Least preferred attribute for each factor (yellow) — Best advantage for each factor (green)

FACTORS		ALTERNATIVES					
		Scenario 4 **No CCC / Multiple sites**		**Scenario 5** **1 CCC / Multiple sites / Optimization 2nd echelon**		**Scenario 6** **1 CCC / Multiple sites / Optimization 1st and 2nd echelons**	
F1. Number of deliveries at the construction sites Criterion: the fewer deliveries, the better	Attribute:	61 617 deliveries		35 410 deliveries		35 410 deliveries	
	Advantage:		Importance:	26 207 fewer	Importance: 95	26 207 fewer	Importance: 95
F2. CO_2 emissions Criterion: the lower CO_2 emissions, the better	Attribute:	7 254 tons		5 665 tons		5 621 tons	
	Advantage:		Importance:	1 589 tons lower	Importance: 75	1 633 tons lower	Importance: 80
F3. $PM_{2.5}$ & PM_{10} emissions in urban area Criterion: the lower PM emissions, the better	Attribute:	549 kg		472 kg		472 kg	
	Advantage:		Importance:	77 kg lower	Importance: 85	77 kg lower	Importance: 85
F4. Potential short-term improvement of pollutant emissions performance of the trucks delivering the construction sites Criterion: the faster improvement, the better	Attribute:	we can have more than 50 different suppliers delivering one site / imply to renew the fleets of many transport companies which will take time		one CCC means one truck fleet to deliver the construction sites: in this case we can consider feasible to implement quickly a fleet only equipped with low-emission vehicles (electrical, hydrogen, gas)		one CCC means one truck fleet to deliver the construction sites: in this case we can consider feasible to implement quickly a fleet only equipped with low-emission vehicles (electrical, hydrogen, gas)	
	Advantage:		Importance:	faster	Importance: 100	faster	Importance: 100
F5. Deliver the construction sites in Just-In-Time Criterion: the more deliveries in JIT, the better	Attribute:	No space on site to organize a JIT delivery of working zones from an inventory managed locally / Unrealistic to deliver in JIT on a daily basis directly from suppliers located far from the sites as it would generate huge transport costs and increase the number of km travelled and the pollutant emissions / from closer suppliers it would increase the number of deliveries per day on site with consequences on congestion		A CCC as a logistics platform can store materials, prepare orders per task and packages per working zone to deliver the sites in JIT + consolidation of deliveries		A CCC as a logistics platform can store materials, prepare orders per task and packages per working zone to deliver the sites in JIT + consolidation of deliveries	
	Advantage:		Importance:	more deliveries in JIT	Importance: 90	more deliveries in JIT	Importance: 90
F6. Goods packaging optimization (kitting) / Standardization of unloading equipment used on construction sites Criterion: the more the packaging is optimized, the better	Attribute:	more adapted packaging to site logistics constraints can be developped and implemented with suppliers but no consolidation is possible i.e. packages including goods from different suppliers (kitting)		New packaging systems can be developped and implemented in the CCC and materials from different sources consolidated in the same package (kitting)		New packaging systems can be developped and implemented in the CCC and materials from different sources consolidated in the same package (kitting)	
	Advantage:		Importance:	more optimized	Importance: 65	more optimized	Importance: 65

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FACTORS	ALTERNATIVES		
	Scenario 4 No CCC / Multiple sites	Scenario 5 1 CCC / Multiple sites / Optimization 2nd echelon	Scenario 6 1 CCC / Multiple sites / Optimization 1st and 2nd echelons
F7. Tracking and tracing system implementation Criterion: the easier implementation, the better	Attribute: Many suppliers with different traceability systems (when there is one) / Would take time to standardize the tracking system applied on all materials packages delivered on site	Attribute: A commun system can be implemented for all the packages leaving the CCC to be delivered on site to ensure a good traceability of all materials from the CCC to their consumption on the construction site	Attribute: A commun system can be implemented for all the packages leaving the CCC to be delivered on site to ensure a good traceability of all materials from the CCC to their consumption on the construction site
	Advantage: Importance:	Advantage: easier Importance: 25	Advantage: easier Importance: 25
F8. Delivery time windows flexibility Criterion: the more flexible, the better	Attribute: Many transport companied involved: difficult to align all companies to the constraints of the construction sites and specially for trucks coming from far.	Attribute: With a specific fleet dedicated to the transport of the materials from the CCC to the sites, the working time can be organized to fit with the best time windows according to the sites constraints: night shift to deliver all materials at night for example + 1 or 2 drivers on day shift for emergency deliveries at day time.	Attribute: With a specific fleet dedicated to the transport of the materials from the CCC to the sites, the working time can be organized to fit with the best time windows according to the sites constraints: night shift to deliver all materials at night for example + 1 or 2 drivers on day shift for emergency deliveries at day time.
	Advantage: Importance:	Advantage: more flexible Importance: 55	Advantage: more flexible Importance: 55
F9. Use of reverse logistics / Recycling of waste and non-used materials Criterion: the more the reverse logistics is used, the better	Attribute: Most of the delivery trucks leave the sites empty. Some leave the site with returnable materials (like pallets when the quantity collected is sufficient) or no more used equipment. Waste management companies pick up the waste at site. Difficult to implement a compliant waste sorting (many unsorted bins in Paris pilot (it costs more than 7000€/month to the site): difficult to make workers respect the sorting rules + no space to organize an area where waste sorting could be done by a dedicated team on site. Low or no recycling of non-used materials.	Attribute: The delivery trucks can be used to bring back to CCC returnable materials, equipment and tools. A sorting area can be implemented in the CCC: reverse logistics is then used to bring the unsorted waste to the CCC. When sorted, the waste management companies pick up the waste at the CCC (so fewer pick-up at the construction sites and less congestion in city centre). As materials can be delivered more easily in just in time, less rick to have non-used materials on site. Non-used materials will be kept stored in the CCC and a recycling solution can be found at the end of the project (circular economy).	Attribute: The delivery trucks can be used to bring back to CCC returnable materials, equipment and tools. A sorting area can be implemented in the CCC: reverse logistics is then used to bring the unsorted waste to the CCC. When sorted, the waste management companies pick up the waste at the CCC (so fewer pick-up at the construction sites and less congestion in city centre). As materials can be delivered more easily in just in time, less rick to have non-used materials on site. Non-used materials will be kept stored in the CCC and a recycling solution can be found at the end of the project (circular economy).
	Advantage: Importance:	Advantage: more used Importance: 60	Advantage: more used Importance: 60
F10. Deliveries punctuality (according to delivery planning) Criterion: the more on time, the better	Attribute: Trucks coming from far are more exposed to the road hazards (traffic jam, breakdown, wrong estimation of the travel time). Or trucks anticipate their arrival with a long waiting time at the site entrance as a consequence. 30% of the trucks were late ine the Paris pilot.	Attribute: CCC must be located at 15 km maximum from the construction sites. Low exposition to road hazards.	Attribute: CCC must be located at 15 km maximum from the construction sites. Low exposition to road hazards.
	Advantage: Importance:	Advantage: more on time Importance: 45	Advantage: more on time Importance: 45
F11. Impact of urban access regulations (low-emission zones, urban road tolls) Criterion: the less impact, the better	Attribute: In Paris low-emission zones are activated during pollution peak periods and the municipality plans to implement an urban road toll. All delivery vehicles can be potentially impacted.	Attribute: All delivery can also be impact but thanks to consolidation fewer deliveries results in less financial impact globally and a CCC fleet less pollutant in average than the haulier fleets reduces the impact of low-emission zones during the peaks of pollution	Attribute: All delivery can also be impact but thanks to consolidation fewer deliveries results in less financial impact globally and a CCC fleet less pollutant in average than the haulier fleets reduces the impact of low-emission zones during the peaks of pollution
	Advantage: Importance:	Advantage: less impact Importance: 35	Advantage: less impact Importance: 35
F12. Sensitivity of site operations to supplier delivery delays Criterion: the less sensitive, the better	Attribute: No space for buffer/security stock on site	Attribute: Space available to implement a normative stock policy (stock min, stock max, security stock) + If one reference is common to more than 1 site, then we have the possibility to pick in the stock of another site to ensure that there is no shortage in the site that suffers from a delivery delay.	Attribute: Space available to implement a normative stock policy (stock min, stock max, security stock) + If one reference is common to more than 1 site, then we have the possibility to pick in the stock of another site to ensure that there is no shortage in the site that suffers from a delivery delay.
	Advantage: Importance:	Advantage: less sensitive Importance: 30	Advantage: less sensitive Importance: 30
F13. Space availability for prefabrication, systems preassembly and mock-up building out of working zones Criterion: the more available space, the better	Attribute: In most urban construction sites, there is no and very few space free out of working zones.	Attribute: A space can be dedicated in the CCC for those activities apart the logistics activities with good conditions in terms of security, dust protection, light, temperature…	Attribute: A space can be dedicated in the CCC for those activities apart the logistics activities with good conditions in terms of security, dust protection, light, temperature…
	Advantage: Importance:	Advantage: more available Importance: 50	Advantage: more available Importance: 50
F14. Safety level inside and outside the construction sites Criterion: the higher level, the better	Attribute: Accidents outside the construction sites can involve delivery trucks (with cars or pedestrians). The rate of obstructing vehicules measured in Paris pilot is 57% and those obstructing vehicules generate important risks of accidents. In pilot sites an important number of accidents are due to logistics issues: not adapted storage area, no appropriate handling means..	Attribute: Less stock on site (JIT from CCC) = better pedestrian ways, standardization of packaging = less handling issues Fewer deliveries on site and deliveries planned out of the road peak time can reduce the risks of accidents due to delivery trucks.	Attribute: Less stock on site (JIT from CCC) = better pedestrian ways, standardization of packaging = less handling issues Fewer deliveries on site and deliveries planned out of the road peak time can reduce the risks of accidents due to delivery trucks.
	Advantage: Importance:	Advantage: higher level Importance: 70	Advantage: higher level Importance: 70
F15. Materials delivery reliability (the right reference in the right quantity) at the construction sites Criterion: the more reliable, the better	Attribute: A quality control can be implemented at the unloading area in order to check that the quantities and references delivered are in compliance with the delivery note	Attribute: A first quality control can be done when the materials are delivered at the CCC (before entering the stock) and a second one before the packages are delivered to the construction sites. Double check.	Attribute: A first quality control can be done when the materials are delivered at the CCC (before entering the stock) and a second one before the packages are delivered to the construction sites. Double check.
	Advantage: Importance:	Advantage: more reliable Importance: 15	Advantage: more reliable Importance: 15

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FACTORS	ALTERNATIVES											
	Scenario 4 No CCC / Multiple sites				Scenario 5 1 CCC / Multiple sites / Optimization 2nd echelon				Scenario 6 1 CCC / Multiple sites / Optimization 1st and 2nd echelons			
F16. Materials and equipment security level Criterion: the higher level, the better	Attribute:	Difficult to secure all the storage areas on site, during and out of the opening hours, as those areas are multiple, evolving many times during the life of the project and not equipped most of the time with efficient security systems.			Attribute:	Materials and equipment stored in an area dedicated for inventory with all security systems required depending on the values of the materials stored (CCTV, guards, access control...)			Attribute:	Materials and equipment stored in an area dedicated for inventory with all security systems required depending on the values of the materials stored (CCTV, guards, access control...)		
	Advantage:		Importance:		Advantage:	higher level	Importance:	40	Advantage:	higher level	Importance:	40
F17. Quality of the drivers reception (facilities) Criterion: the higher quality, the better	Attribute:	No facilities dedicated to drivers and site facilities are sometimes far from truck parking area or unloading area with no authorized access to drivers who have to wait in their truck			Attribute:	Facilities for drivers to take a rest can be easily fit out in the CCC			Attribute:	Facilities for drivers to take a rest can be easily fit out in the CCC		
	Advantage:		Importance:		Advantage:	higher quality	Importance:	20	Advantage:	higher quality	Importance:	20
Total Importance			0				955				960	

3.2.2 Conclusion

Showing advantages for all the factors we identified, scenarios 5 and 6 are considered by all stakeholders as the best alternatives to increase the performance of the current construction Supply Chain and reduce its negative impacts for urban dwellers. Scenario 6 has a slight advantage on scenario 5 as the optimization of the 1st echelon helps to increase the consolidation of the materials transport between the suppliers and the CCC with a resulting additional benefit impact on the pollutant emissions.

The implementation of a CCC is seen as a good answer to the problems of congestion, urban pollution and low productivity in the construction sector by offering the opportunity to reduce drastically the number of deliveries, to push on short term a larger-scale use of low-emission vehicles fleets in urban areas and to free the urban construction sites from their storage constraints by delivering them in Just-In-Time.

There was a real consensus during the discussions about the fact that the logistics companies are the best actors to run a CCC as they have the skills and the experience to provide a high standard logistics service. In the value chain of the construction sector the position of each actor should be clearly redefined: the construction professionals (main contractor and subcontractors) must concentrate on their core business (the construction processes) which is crucial with the shortage of skilled workers the construction industry suffers from today in some big European cities like Paris. Logistics companies can be the good partners to help the construction companies to redesign their Supply Chain and make it more efficient and greener.

The subject of the sustainability of the CCCs and their economic model was raised. To be sustainable the CCCs must manage sufficient and permanent flows of materials. Like any new business a ramp-up time will be needed before reaching the breakeven point. We think that this model must be put in place on a large scale to be sustainable in the long-term. When talking about the economic model it appears that the way the construction projects are budgeted today must be totally reviewed to identify more in details the real

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logistics costs at each step of the value chain. A specific budget must be allocated for logistics activities from the very start of any project to avoid discussions about who must support the logistics costs during the life of the project (materials movement on the construction site, invoicing of CCC services…). This new budget scheme involves a new contractual scheme between all the actors of the project with a redefinition of the role of everyone in the construction value chain. Another point has been raised about the responsibility of the materials along the logistics chain and the insurance issues. This subject should not be a blocking point as logistics companies are used to manage those transfers of responsibility with their clients of other sectors (industry, food, retail…). Logistics companies attending the workshop (Ares Services and KS Services) are already testing new solutions that could be implemented on a larger-scale in a near future. Public authorities can play an important role in pushing those new solutions and ensuring their sustainability. The role and the location of those consolidations centres must be clearly addressed in the urban planning by taking into account the future cities development and allocating dedicated lands for those activities. Municipality can also enforce new rules in the public contracts signed with construction companies: logistics charter (require a 100% load factor to access the area of the construction site), environmental certification (require only low-emission delivery trucks to get the certification, 100% of sorted waste…) … The generalization of urban access regulations can also be a great incentive to push the construction sector to accelerate its transition to a new Supply Chain model: greener, safer and more competitive.

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3.3 Valencia

3.3.1 Evaluation and comparison results

Workshop attendees:

- Participants: InnDEA, FEVEC and Fundacion Valenciaport
- Facilitator: Vinci Construction France

Legend: Least preferred attribute for each factor (yellow) — Best advantage for each factor (green)

FACTORS	ALTERNATIVES											
	Scenario 4 No CCC / Multiple sites				Scenario 5 1 CCC / Multiple sites / Optimization 2nd echelon				Scenario 6 1 CCC / Multiple sites / Optimization 1st and 2nd echelons			
F1. Number of deliveries at the construction sites Criterion: the fewer deliveries, the better	Attribute:	41 544			Attribute:	17 810			Attribute:	17 810		
	Advantage:		Importance:		Advantage:	23 734 fewer	Importance:	100	Advantage:	23 734 fewer	Importance:	100
F2. CO_2 emissions Criterion: the lower CO_2 emissions, the better	Attribute:	4 509 tons			Attribute:	3 391 tons			Attribute:	3 104 tons		
	Advantage:		Importance:		Advantage:	1 118 tons lower	Importance:	60	Advantage:	1 405 tons lower	Importance:	65
F3. $PM_{2.5}$ & PM_{10} emissions in urban area Criterion: the lower PM emissions, the better	Attribute:	391 kg			Attribute:	263 kg			Attribute:	263 kg		
	Advantage:		Importance:		Advantage:	128 kg lower	Importance:	70	Advantage:	128 kg lower	Importance:	70
F4. Potential short-term improvement of pollutant emissions performance of the trucks delivering the construction sites Criterion: the faster improvement, the better	Attribute:	need to change the trucks of many transport companies (more than 50)			Attribute:	only one trucks fleet (CCC) to improve: less than 10 trucks - In Spain some transport companies start moving to gas engine			Attribute:	only one trucks fleet (CCC) to improve: less than 10 trucks - In Spain some transport companies start moving to gas engine		
	Advantage:		Importance:		Advantage:	faster	Importance:	75	Advantage:	faster	Importance:	75
F5. Deliver the construction sites in Just-In-Time Criterion: the more deliveries in JIT, the better	Attribute:	many actors generating complicated coordination, need space on site to dispatch the materials in the working area, need a lot of ressources (manpower and equipment) for logistics operations on site (unloading, handling in the working zones...)			Attribute:	less actors, less ressources, easier management, materials can be consolidated in one delivery			Attribute:	less actors, less ressources, easier management, materials can be consolidated in one delivery		
	Advantage:		Importance:		Advantage:	more deliveries in JIT	Importance:	80	Advantage:	more deliveries in JIT	Importance:	80
F6. Goods packaging optimization (kitting) / Standardization of unloading equipment used on construction sites Criterion: the more the packaging is optimized, the better	Attribute:	limited to the materials delivered by each supplier (no consolidation possible with materials from different suppliers), difficulty to have full load of the trucks delivering the site, each supplier has his own standard for packaging and unloading			Attribute:	Materials of different suppliers can be consolidated, packaging systems easier to transport and handle (less accident), possible to set up some customer-based packages (fits with client needs), more standard equipment and tools for loading, unloading and handling on construction site			Attribute:	Materials of different suppliers can be consolidated, packaging systems easier to transport and handle (less accident), possible to set up some customer-based packages (fits with client needs), more standard equipment and tools for loading, unloading and handling on construction site		
	Advantage:		Importance:		Advantage:	more optimized	Importance:	95	Advantage:	more optimized	Importance:	95
F7. Tracking and tracing system implementation Criterion: the easier implementation, the better	Attribute:	no need additional requirement (traceability system of the suppliers), many different traceability systems that are not compatible, more complicated management (different IT systems)			Attribute:	one unique IT and traceability system, easier management, more expensive to implement in this configuration, more time required to implement			Attribute:	one unique IT and traceability system, easier management, more expensive to implement in this configuration, more time required to implement		
	Advantage:		Importance:		Advantage:	easier	Importance:	25	Advantage:	easier	Importance:	25
F8. Delivery time windows flexibility Criterion: the more flexible, the better	Attribute:	coordinating all suppliers is complicated, no full load, each supplier has his own schedule (the suppliers have time constraints)			Attribute:	consolidation of goods (full load), easy to coordinate (1 actor = CCC), flexibility of the CCC time window (can deliver at any time (night...)), truck fleet fitting better with the needed load (more appropriate), less impacted by congestion			Attribute:	consolidation of goods (full load), easy to coordinate (1 actor = CCC), flexibility of the CCC time window (can deliver at any time (night...)), truck fleet fitting better with the needed load (more appropriate), less impacted by congestion		
	Advantage:		Importance:		Advantage:	more flexible	Importance:	90	Advantage:	more flexible	Importance:	90
F9. Use of reverse logistics / Recycling of waste and non-used materials Criterion: the more the reverse logistics is used, the better	Attribute:	require space on site because the supplier will wait that enough equipment is ready to return before taking it back, more waste generated (no recycling of boxes...), more unsorted bins, complicated to implement reverse logistics			Attribute:	centralized reverse logistics, easier management, less waste (less unsorted bins at the end)			Attribute:	centralized reverse logistics, easier management, less waste (less unsorted bins at the end)		
	Advantage:		Importance:		Advantage:	more used	Importance:	30	Advantage:	more used	Importance:	30
F10. Deliveries punctuality (according to delivery planning) Criterion: the more on time, the better	Attribute:	the suppliers can be far from site, so more risks and more difficult to deliver on time			Attribute:	flexibility to reorganize the delivery planning at the last moment if there is any problem in the unloading area of the construction site (for example crane is out of order...), better knowledge of the environment of the road between CCC and the site (time needed, risks of congestion...), distance between CCC and site (less than between suppliers and site)			Attribute:	flexibility to reorganize the delivery planning at the last moment if there is any problem in the unloading area of the construction site (for example crane is out of order...), better knowledge of the environment of the road between CCC and the site (time needed, risks of congestion...), distance between CCC and site (less than between suppliers and site)		
	Advantage:		Importance:		Advantage:	more punctual	Importance:	35	Advantage:	more punctual	Importance:	35

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FACTORS	ALTERNATIVES											
	Scenario 4 No CCC / Multiple sites				Scenario 5 1 CCC / Multiple sites / Optimization 2nd echelon				Scenario 6 1 CCC / Multiple sites / Optimization 1st and 2nd echelons			
F11. Impact of urban access regulations (low-emission zones, urban road tolls) Criterion: the less impact, the better	Attribute:	for restricted access zones, each supplier would need small and low-emission trucks (difficult to implement), ask specific access rights to authorities in case your need to close the street or else (case of Valencia for some deliveries in city center (small access))...			Attribute:	one trucks fleet: easy to adapt the fleet to the urban access regulations			Attribute:	one trucks fleet: easy to adapt the fleet to the urban access regulations		
	Advantage:		Importance:		Advantage:	less impact	Importance:	55	Advantage:	less impact	Importance:	55
F12. Sensitivity of site operations to supplier delivery delays Criterion: the less sensitive, the better	Attribute:	small inventory on site cause of the lack of space, depends on supplier deliveries (no security stock on site to cover any delivery delay)			Attribute:	Higher stock (bigger space to build a security stock), have several suppliers for one item in case you have a problem with one supplier, shared stock between different sites for some items			Attribute:	Higher stock (bigger space to build a security stock), have several suppliers for one item in case you have a problem with one supplier, shared stock between different sites for some items		
	Advantage:		Importance:		Advantage:	less sensible	Importance:	50	Advantage:	less sensible	Importance:	50
F13. Space availability for prefabrication, systems preassembly and mock-up building out of working zones Criterion: the more available space, the better	Attribute:	less space for pre-fabrication, more affection to the construction activities, less safety, less time to perform the activities			Attribute:	more and dedicated space for pre-fabrication & mock up,best equipment, no affection to the construction activities, more safety, more time to perform the activities and mock up			Attribute:	more and dedicated space for pre-fabrication & mock up,best equipment, no affection to the construction activities, more safety, more time to perform the activities and mock up		
	Advantage:		Importance:		Advantage:	more space	Importance:	40	Advantage:	more space	Importance:	40
F14. Safety level inside and outside the construction sites Criterion: the higher level, the better	Attribute:	More deliveries leads to more risk and safety issuess, less coordination between site & drivers, less skilled and expertised staff			Attribute:	Less operations leads to less accidents, more standard operations, easier handling , loading and unloading operations, dedicated and safety areas, more skilled staff			Attribute:	Less operations leads to less accidents, more standard operations, easier handling , loading and unloading operations, dedicated and safety areas, more skilled staff		
	Advantage:		Importance:		Advantage:	higher safety	Importance:	60	Advantage:	higher safety	Importance:	60
F15. Materials delivery reliability (the right reference in the right quantity) at the construction sites Criterion: the more reliable, the better	Attribute:	Last minute quality check, difficult to react to material issues			Attribute:	double checking for material inspection, less damaged material on site, easier and faster reaction to material issues			Attribute:	double checking for material inspection, less damaged material on site, easier and faster reaction to material issues		
	Advantage:		Importance:		Advantage:	more reliable	Importance:	85	Advantage:	more reliable	Importance:	85
F16. Materials and equipment security level Criterion: the higher level, the better	Attribute:	Less security on site, higher risk of theft and stolen items, smaller area dedicated to security storage			Attribute:	Higher security on the CCC (dedicated space by customer), lower risk of theft and stolen items, better security systems (cameras, guards, etc.)			Attribute:	Higher security on the CCC (dedicated space by customer), lower risk of theft and stolen items, better security systems (cameras, guards, etc.)		
	Advantage:		Importance:		Advantage:	higher security	Importance:	45	Advantage:	higher security	Importance:	45
F17. Quality of the drivers reception (facilities) Criterion: the higher quality, the better	Attribute:	No dedicated facilites except the ones for the site workers. Higher risk of accidents and more safety issues			Attribute:	Possibility of dedicated facilites inside the CCC, lower risk of accidents and safety issues, better equipment and tools for loading/unloading operations			Attribute:	Possibility of dedicated facilites inside the CCC, lowerr risk of accidents and safety issues, better equipment and tools for loading/unloading operations		
	Advantage:		Importance:		Advantage:	higher quality	Importance:	20	Advantage:	higher quality	Importance:	20
Total Importance				0				1015				1020

3.3.2 Conclusion

The methodology proposed for the multi-criteria assessment and comparison of different scenarios is an effective approach because it focuses on the advantages instead in the factors previously defined for decision making. Other multiple-criteria decision-making methods rank the importance of different factors and this approach could lead to different evaluations depending on the point of view and interest of the user of the methodology. However, this method is a collaborative system that helps decision makers to differentiate alternatives and to understand the importance of those differences, avoiding decisions based on pre-defined ideas.

In reference to the scenarios with and without CCC in the specific case of Valencia, after the discussion among representatives of the main stakeholders (Public Authorities, Construction Industry & Research Institutes) the main result of the multi-criteria assessment was that, in general terms, the key advantage of a CCC implementation is the reduction of the number of deliveries. In our opinion, the reduction of deliveries and optimization of the delivery processes

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allows a better supply chain management and their related benefits (e.g. higher reliability, more punctuality, easier and faster reaction to unexpected events, etc.). Besides, consolidating in a CCC and reducing the number of deliveries are linked to positive environmental effects of the transport due to the reduction of the total kilometers travelled. Finally, other added value services of the CCC (security, kitting, areas for pre-construction, etc.) are also important, especially for the construction companies, due to the performance improvements that they could reach on the different tasks on site.

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3.4 Verona

3.4.1 Evaluation and comparison results

Workshop attendees:

- Participants: ITL, CMB and Regione Emilia-Romagna
- Facilitator: Vinci Construction France

As the consolidation of the results of the workshop organized between Italian partners was still ongoing on the submission date of deliverable D5.2, it will be included in a next version.

3.4.2 Conclusion

As the consolidation of the results of the workshop organized between Italian partners was still ongoing on the submission date of deliverable D5.2, it will be included in a next version.

3.5 Cost data evaluation

Evaluate the cost of each alternative is a very difficult exercise. Indeed, because of a lack of visibility of the real costs distribution in the construction sector, we cannot estimate what are the logistics costs in a project organized as in scenario 4, that is to say without a CCC. By logistics costs we mean the sum of the cost of all tasks related to logistics: transport costs from suppliers to construction site, unloading, materials movement on site, orders passing…

Considering the impossibility to estimate an accurate logistics costs baseline (scenario 4) with the construction actors, we decided to run a Cost Benefit Analysis in WP4 to analyse the financial feasibility of the CCC model by considering two business models: CCC operated by a construction company and CCC operated by a logistics company. This analysis aims at estimating the extra costs generated by the implementation of a CCC and the benefits we can gain from a CCC due to productivity improvement on site, reduction of materials wastage, reduction of regulations financial impact (urban road tolls…)… The results presented in the deliverable D4.3 show that for Luxembourg, Paris and Valencia pilots the benefits cover the operational costs of the CCC but not in Verona. We mainly explain it by the fact that the average volume of materials passing by the CCC every week is between five and seven times lower than in the three other pilots. So, in the case of Verona we do not reach the breakeven point.

We advise to launch deeper financial studies (ideally on a real CCC) based on the models described in the following figures. It requires a complete transparency from all the construction actors (manufacturers, suppliers, main contractors, subcontractors, haulier companies…) to be able to identify clearly all the logistics costs along the construction value chain.

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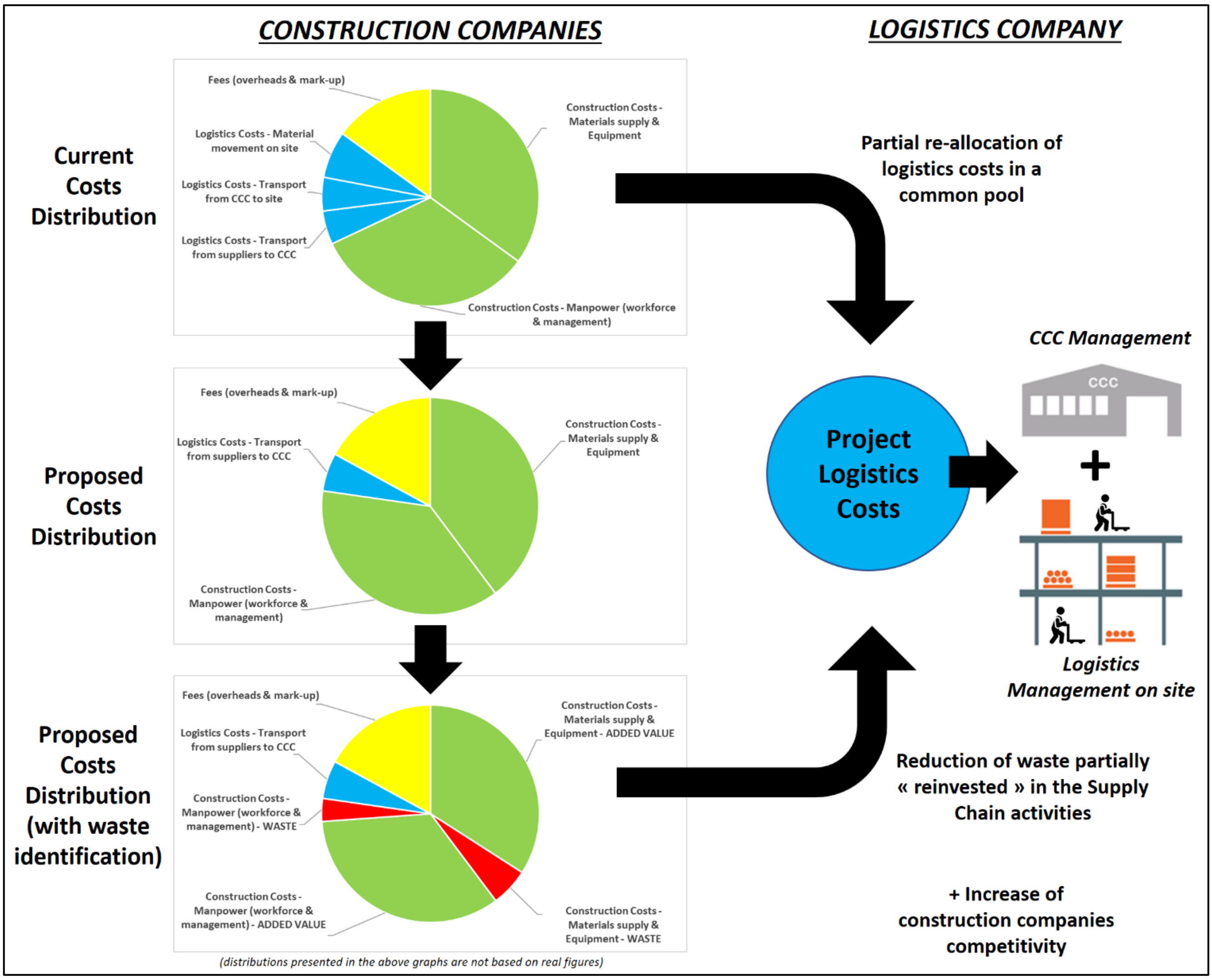

Figure 18: Current and proposed logistics financial models

3.6 Focus on factors F1, F2 and F3 (simulation output)

Factor F1 – Number of deliveries at the construction sites

In all pilot sites, the implementation of a CCC goes with a reduction of the number of deliveries at the construction sites. The percentage of reduction per pilot site is shown in the following table:

	Nb deliveries				
Pilot site	Scenario 4	Scenario 5		Scenario 6	
	Value	Value	% / SC4	Value	% / SC4
Luxembourg	59 311	27 045	-54%	27 045	-54%
Paris	61 617	35 410	-43%	35 410	-43%
Valencia	41 544	17 810	-57%	17 810	-57%
Verona	21 714	3 360	-85%	3 360	-85%

Table 17: Deliveries reduction per pilot (scenarios 5 & 6 versus scenario 4)

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We notice an important range of reduction percentage from 43% for Paris to 85% for Verona. We explain this behaviour by the size of the construction sites. Indeed, the smaller the construction sites are the smaller is the volume of materials to deliver and the bigger is the potential of consolidation between the CCC and the construction sites by consolidating materials from different suppliers in one vehicle.

The following graph clearly shows the link between the percentage of deliveries reduction and the average site budget:

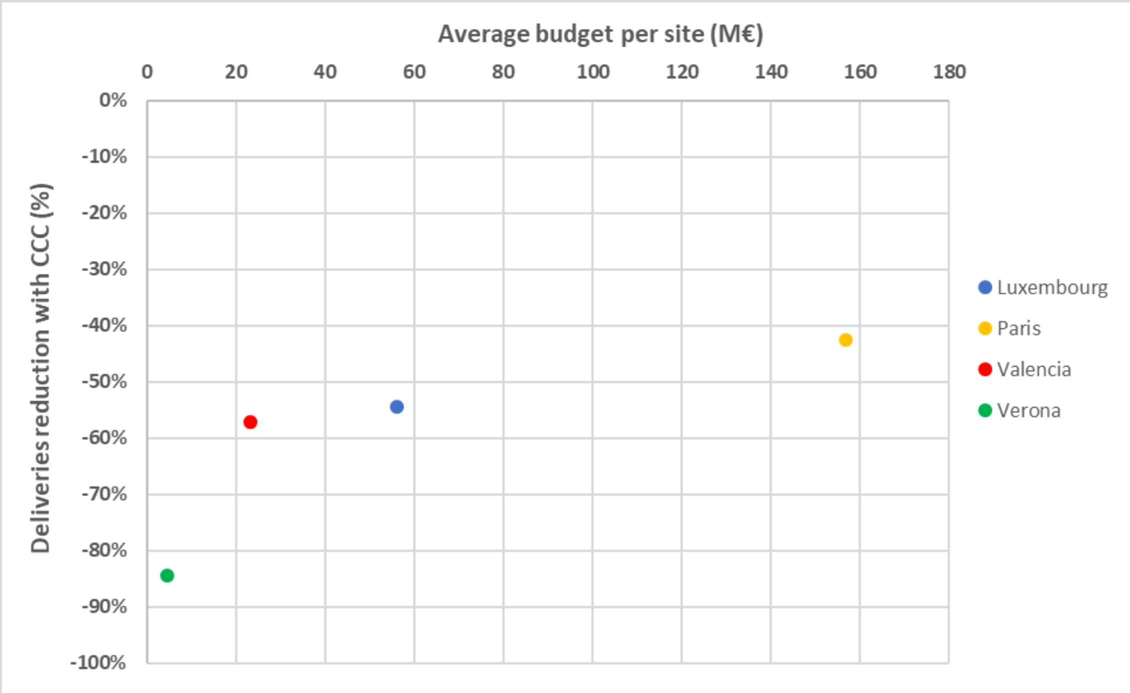

Figure 19: Deliveries reduction versus average budget per site (for the 4 pilot cities)

Factor F2 – CO_2 emissions

The CO_2 emissions for scenarios 4, 5 and 6 are:

Pilot site	CO2 emissions (ton)				
	Scenario 4	Scenario 5		Scenario 6	
	Value	Value	% / SC4	Value	% / SC4
Luxembourg	4 523	3 485	-23%	2 887	-36%
Paris	7 255	5 666	-22%	5 621	-23%
Valencia	4 509	3 391	-25%	3 104	-31%
Verona	2 172	2 030	-7%	1 763	-19%

Table 18: CO_2 emissions per pilot (scenarios 4, 5 & 6)

Concerning the scenario 5, we can see a different behaviour in Verona compared with the 3 other pilot cities. In Verona, the total reduction of CO_2 emissions between scenarios 4 and 5 is only 7% when it is between 22% and 25% for Luxembourg, Paris and Valencia. Those CO_2 emissions are closely linked with the number of km travelled. Those figures are presented in the following table.

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	Total distance travelled for delivery (km)				
Pilot site	Scenario 4	Scenario 5		Scenario 6	
	Value	Value	% / SC4	Value	% / SC4
Luxembourg	9 646 123	7 845 548	-19%	5 621 542	-42%
Paris	12 008 146	9 225 370	-23%	9 079 591	-24%
Valencia	8 865 146	6 877 029	-22%	5 807 425	-34%
Verona	6 091 885	5 714 773	-6%	4 716 083	-23%

Table 19: Distance travelled per pilot (scenarios 4, 5 & 6)

We explain the difference of behaviour between Verona and the other pilots by the fact that the construction sites in Verona are small ones compared with Luxembourg, Paris and Valencia. Average budget per site is:

- Luxembourg: 56,2 M€
- Paris: 156,9 M€
- Valencia: 23,3 M€
- Verona: 4,5 M€

The consequence of the small sizes of Verona sites is the low consolidation of the deliveries between the suppliers and the CCC for each material. Indeed, in this case, the period of consumption of each material is very short when it can be weeks or months in bigger projects. So, during a given week, the probability of having deliveries for one material to several sites is very low and no consolidation is possible.

Then we notice that when we optimize the 1st echelon (between suppliers and CCC) in scenario 6, we decrease again the emissions of CO_2 compared to scenario 5 in Luxembourg, Valencia and Verona when it remains almost unchanged in Paris. We explain it by the size of the projects in Paris. Due to the big volumes ordered by those projects, the deliveries from suppliers are already highly consolidated in scenario 5 on a weekly basis making the effect of the optimization of the 1st echelon almost null for Paris.

Factor F3 – $PM_{2.5}$ and PM_{10} emissions in urban area

The $PM_{2.5}$ and PM_{10} emissions in urban area mainly depend on the number of deliveries to the construction sites, so the decrease of particulates emissions between scenario 4 and scenarios 5 and 6 follow the same trend as the one for the number of deliveries at the construction sites that we saw previously.

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	$PM_{2.5}$ and PM_{10} emissions in urban area (kg)				
Pilot site	Scenario 4	Scenario 5		Scenario 6	
	Value	Value	% / SC4	Value	% / SC4
Luxembourg	353	336	-5%	336	-5%
Paris	549	472	-14%	472	-14%
Valencia	391	263	-33%	263	-33%
Verona	108	27,4	-75%	27,4	-75%

Table 20: $PM_{2.5}$ and PM_{10} emissions per pilot (scenarios 4, 5 & 6)

But we notice that the decrease of particulates emissions is lower than the decrease of deliveries. For instance for Paris, the number of deliveries to the construction site decreases by 43% when the particulates emissions in the urban area decrease by 14% only. We explain it by the fact that the mix of trucks delivering the construction sites varies between scenario 4 and scenarios 5 and 6 as shown in the following table.

		Van / Light truck	2 axes truck < 7.5T	2 axes truck < 14T	3 axes truck	Total
Scenario 4	Nb deliveries	5 174	3 801	2 368	50 274	61 617
	%	*8,4%*	*6,2%*	*3,8%*	*81,6%*	100,0%
Scenarios 5 & 6	Nb deliveries	95	130	215	34 970	35 410
	%	*0,3%*	*0,4%*	*0,6%*	*98,8%*	100,0%

Table 21: Vehicles mix for construction sites delivery (scenarios 4, 5 & 6)

In scenarios 5 and 6, the percentage of big vehicles is higher. And bigger is the vehicle higher is the particulates emission per km travelled (for the same euro class). So, the impact of deliveries decrease on the particulates emissions is mitigated by the use of bigger and more polluting trucks. For Luxembourg, the decrease of particulates emissions is surprisingly low compared with the decrease of deliveries questioning the compliance of the calculation of those emissions for this pilot city (COPERT).

4 GENERAL CONCLUSION

The different evaluation and comparison workshops that we have organized along the SUCCESS project lead us to conclude that the CCC is a key solution to improve sustainably the performance of the logistics activities in the construction field by reducing all the negative impacts of those activities to the urban environment (pollution, congestion, noise…) and by increasing the productivity and the sustainability of the construction activities on site (less wastage, better materials consumption, safer conditions of work…). The CCC must be the main component of a new construction Supply Chain. This new Supply Chain involves deep changes in the current construction value chain: refocus the construction companies on their core activities ("build"), consider the logistics activities as a full and essential support service that requires new

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skills and the development of new partnerships and create a new scheme in the contractual relationship between all actors of the construction sector to improve the collaboration. Public authorities will have a key role to play to implement the incentives and regulations that will help to accelerate those changes.

The scenario 6, that is to say a CCC serving multiple sites and optimizing the upstream and downstream flows, is considered as the best configuration to implement. A CCC must be seen as a long-term business that will need a sufficient and permanent activity to be sustainable. The CCC scheme we propose is the following:

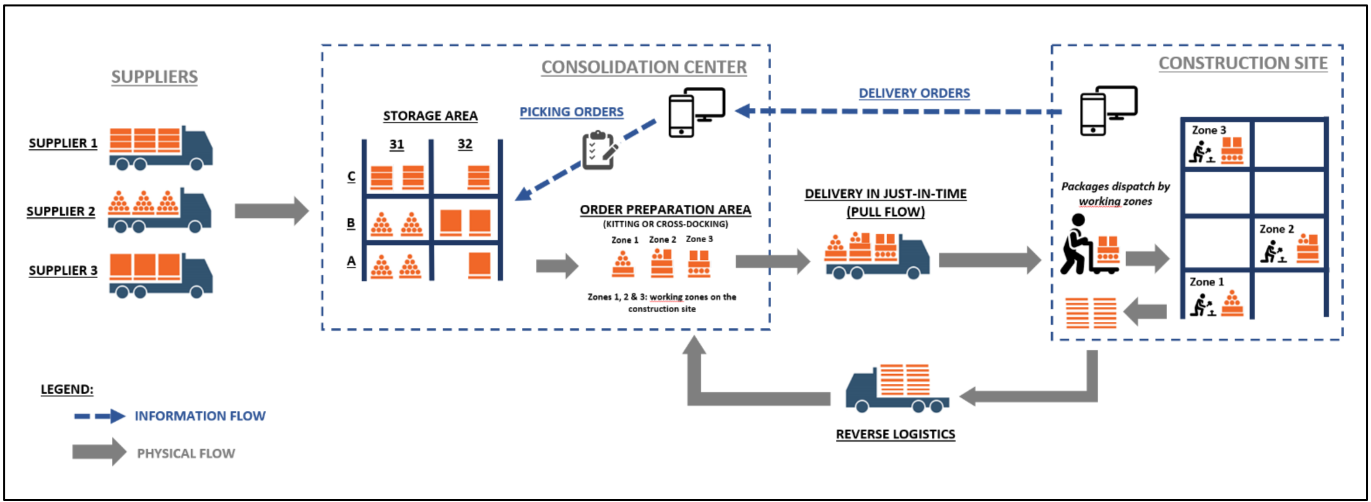

Figure 20: CCC scheme

As an interface between the suppliers and the construction sites, the CCC aims at consolidating the materials upstream and downstream flows and delivering the sites in just-in-time to ensure construction activities as productive as possible on site by minimizing the wastage and risks we currently face in the construction sector: low manpower productivity, high materials wastage, accidents… CCC offers also the possibility to maximize the use of the reverse logistics by managing globally the sites outgoing flows. It might be a key change to develop the circular economy in the construction sector and make the building process more environmental friendly.

This Supply Chain model implies a new scheme in the relationships between the different actors of the construction field: collaboration and transparency instead of tension and suspicion. Collaboration is essential because the implementation of a CCC needs the implementation of a collaborative planning process on site in order that the construction companies work all together and commit on the tasks that they will execute. Those commitments will initiate the delivery orders that the site will send to the CCC. Transparency is also very important as this new Supply Chain scheme will lead to a new allocation of the logistics costs. Today each actor of a construction project has

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a part of his budget dedicated to some logistics activities: transport costs from the suppliers to the site, movement of materials on the construction site, time spent by the management in some logistics tasks (order passing…) … The objective is to allocate most of those costs to a common budget dedicated to the Supply Chain activities that will support the construction activities of all companies during the life of the project: logistics team on site, CCC, … The pooling of the logistics resources will deeply improve the performance of the logistics activities and make them less expensive at the end. In parallel the construction companies can focus on their core activities and improve their productivity and on the long term their competitivity.

The introduction of CCCs will also require the development of new skills in terms of Supply Chain Management. New information flows will appear with the CCCs:

- flows between the sites and the CCCs (materials forecast (to plan the CCC resources), delivery planning (1-week look ahead) or electronic kanban …),
- flows between the CCC and the suppliers (we recommend that the CCC is in direct relationship with the suppliers to manage the orders/reorders according to rules that must be clearly defined for each material passing by the CCC like the stock levels: minimum level, maximum level, re-ordering level… to ensure the best service possible to the sites),
- accurate bills of materials for a good materials requirement planning

New IS systems will be needed to manage all those information flows.

We also recommend to consider the purchasing activities as a component of the Supply Chain. By consolidating the materials and information flows, the CCC scheme can provide essential data to the purchasing department to optimize the procurement process: better materials forecast, better negotiation by consolidating the volumes among multiple sites…

We are convinced that without a strong involvement of the public authorities those changes might take time. Municipalities should study all the solutions they have in hand to encourage the actors of the construction sectors to implement new logistics skills. The non-partners cities that participated to the Joint Transfer Exercises underlined two roles they could have in the promotion of the CCC model: including CCC's use in procuring public works and planning areas for CCC(s) in the cities area. We consider this point very essential as the CCC cannot be a sustainable model if it is not taken into account in the urban policies: a city cannot be "smart" by omitting the construction freight as an essential element of cities mobility. Regulatory initiatives fostering use of CCCs like urban access regulations (urban road tolls, low-emission zones…) or subsidies to support the investments in low-emission vehicles are also advised.

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The non-partners cities do not perceive their role in funding CCCs. We agree with this point. We believe that the CCC model can and must be sustainable without public funds and is a complete part of private companies' business.

On the model of what has been done in London city, we are confident that some proofs of concept will be quickly launched in other European cities by the actors of the construction sector in close collaboration with public authorities. Private and public actors show a growing interest in facing the construction logistics issues.

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