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

Site specific improvements and goal

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1 Executive Summary

The objective of this task, and hence of this deliverable, is to describe the improvement objectives for each Key Performance Indicator (KPI) defined in Task 2.2, to evaluate the As-Is situation regarding the four construction site pilots. This task, as the first task of WP4, must lay the foundations for the scenarios and simulations defined in the following tasks of the WP. Scenarios are the combinations of the different transport and logistic solutions that aim at tackling the negative impacts of construction logistics. Two main goals make part of this task.

The first goal is to **identify the solutions that can improve the current situation**, in order to build the scenarios. Solutions to improve construction logistics have already been identified and tested in different countries and contexts (e.g. Construction Consolidation Centres (CCC), dedicated professional logistics teams, etc.). A clear understanding of their impacts is important to address the current weaknesses of the pilot sites identified in the As-Is analysis. However, building relevant scenarios for each pilot requires a good understanding of the characteristics of each solution. For example, a CCC providing just-in-time deliveries will deliver goods to the construction site only as they are needed in the production process. Minimising the quantity of materials on the site will decrease the storage area management time and therefore improve workforce productivity. Identifying and formalizing the characteristics that work in a specific situation is the first step of the construction of scenarios.

The second goal is **to check the trustworthiness / accuracy of the simulation results.** Indeed, a simulation is not the reality and a way to verify whether or not we can be confident of its results is necessary. Differences between the improvement targets identified in this task and the simulation results should be analysed to identify whether the simulation is realistic or not.

Related to this second goal, a remark must be done: it is impossible to calculate all the KPIs defined in D2.2 using a modelling & simulation approach (see Annex 1). For those KPIs that cannot be calculated using the models, a further investigation will be required, in close collaboration with the construction companies active on the sites, based on the analysis of the impacting factors provided in this deliverable. This investigation, performed in Task 4.2, will allow the consortium to evaluate the impact on all KPIs of the solution proposed (confirming or not the improvement targets hereby proposed).

To fulfil these objectives, two requirements are essential. First of all the **improvement targets should be as realistic as possible**. Second, the **solution(s) devised** to improve the as-is situation **should be detailed enough to be integrated in the scenarios**.

The adopted approach follows three steps:

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1. **Understand** the **current situation** to identify the **causes of non-performance** of each KPI**;**
2. **Identify**, among all the existing **solutions,** the characteristics that could remove the identified causes;
3. **Set improvement targets** for the KPI.

A benchmark on Construction Consolidation Centres helps identifying realistic improvement targets. Construction companies have also been consulted in this process but they can hardly quantify the potential savings associated to each of the proposed solutions. If companies are often convinced of the potential contribution of these solutions, yet they do not implement them because they are not able to assess the potential return on the investment required.

The described approach has been applied to each KPI defined in D2.2 to **emphasise the potential benefits for the different stakeholders of the supply chain** (suppliers, hauliers, sub-contractors and contractor). A cost/benefit analysis of each solution **will be provided after the simulations**, taking into account the **additional costs caused by each measure (e.g. the implementation of a CCC) and obviously the involvement of new stakeholders.**

By comparing causes of non-performance and characteristics of existing solutions we have highlighted the following potential solutions for each of the current supply chain stakeholders.

First, **for hauliers**, a CCC located outside the urban area removes the **travel time inside the city centre**. Of course, this must be coupled with an adapted organization of the last mile, including site delivery time-windows, adapted trucks, better planning and just-in-time deliveries to the site. For **travel time outside city centre for one trip**, a CCC has no major impact but a CCC could reduce the number of trips if a supplier decides to switch from several deliveries per week to only one big delivery. Travel time outside the city centre for one trip could either in fact slightly decrease or increase as a function of the specific location of the CCC. A significant reduction of the travel time outside the urban area should rather be based on routing and facility location optimization solutions and potentially on a different procurement strategy in order to select geographically closer suppliers. One other well-known advantages of a CCC for hauliers is to significantly reduce the **truck waiting time**. Indeed, the CCC plays the role of a buffer between the haulier and the construction site. A CCC reduces the need for trucks to leave earlier to avoid traffic-jams and the risk to arrive outside the time-window of the site. Moreover, thanks to a dedicated logistics team, a CCC providing logistics services could reduce the truck waiting time presently due to the unavailability of unloading resources and non-adapted handling equipment.

Secondly, **for all the contractors and subcontractors active on the construction site**, the advantages of CCCs are also abundant. CCCs positively impact

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workforce productivity, logistics management effort, costs of waste and accidents. Of course, the amount of potential savings is not the same for all the four pilot sites because it depends also on the current construction site maturity in terms of logistics processes as well as on the environment of each site. On the one hand, just-in-time deliveries allowed by the CCC can reduce the quantity of material on site and consequently **remove** an important part of non-value-added activities as "**several handlings"** and **"looking for material"** identified for some of the pilot sites. The short delay between the order and the site supply provided by a CCC increases the reactivity of the site with respect to frequent changes of the production plan; consequently, it will remove workforce **waiting times due to material issues** and some of the **rework activities** identified also due to the wrong material. On the other hand, potential savings are not only on the construction workforce. **Logistic management effort** should also be positively impacted by CCC introduction. Indeed, by delivering with adapted trucks and with ideal handling equipment, the time spent to **manage unloading activities as well as the congestion in front of the site** can be drastically reduced. Moreover, less significant quantities of materials on site reduce the time spent to **manage sites movements and storage areas**. As for workforce productivity, the potential savings depend on several features of the construction site (proximity with the road, surface available on site, etc.) So the four pilot sites cannot all expect the same gains. Finally, **the costs of treating waste** as well as **of accidents** can be reduced. The costs of treating waste can be reduced by **decreasing the number of unsorted bins** collected by the waste management sub-contractor. Indeed, a CCC could increase the turnover of bins and remove one of the main causes of unsorted bins, i.e. that bins are not available near the sub-contractor's workplace. The costs (not only financial of course!) of accidents can be reduced by **decreasing the number of accidents associated with congested storage areas.** For one of the pilot sites, accidents involving storage of material account for 20% of the total number of accidents.

Last but not least, important construction site stakeholders are **the neighbourhood and the city itself**. For the public side, the main advantages lie in the reduction of traffic congestion as well as in the potential diminution of CO_2, PM, NO_x and other noxious emissions and of the noise and vibrations associated with deliveries. The most perceptible advantage already identified is the reduction of the **congestion in front of the site** by reducing truck waiting time and loading / unloading time as well as avoiding simultaneous deliveries through a better delivery plan. Moreover, by using adapted and greener trucks, emissions could be substantially reduced. Of course, detailed simulation results are needed to estimate the potential impact on CO_2 and PM, because the number of deliveries from the CCC to the construction site will change either positively or negatively depending of the configuration of the CCC.

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2 Introduction

The objective of this deliverable is to describe the improvement objectives for each KPI (defined in Task 2.2) used to evaluate the As-Is situation regarding the four construction site pilots.

As a reminder, the goal of the KPIs is to compare the current situation to a potential future situation (with or without CCC). In order to be able to estimate the potential advantages for each stakeholder affected by the construction works.

This document is the first step of this analysis. Benchmarking on other CCC results and a first analysis of the main causes that affect the values of certain KPIs should help us provide some targets for improvements.

Targets for improvements will be associated in the following tasks of WP4 to financial values to allow the analysis of new potential business models based on the sharing of the associated gains and pains.

In terms of savings, advantages and benefits, the actors involved can be categorised into three types of actors:

- Hauliers (or material producers if they have their own transport organization) who can benefit from the presence of a CCC and better delivery management in terms of decreased travel time, waiting time, and loading and unloading time;

- Contractors and subcontractors, hereafter defined as "construction site", who can benefit from better delivery management in terms of improved workforce and management staff productivity but also reduced costs of accidents and waste treatment;

- Public administrations and neighbours (e.g. dwellers, retailers), hereafter defined as public entities, who can benefit from construction logistics optimization to decrease the negative impacts in the urban area hosting the construction site.

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Category	KPI designation	Unit	
Economic/haulier journey time	Travel time (outside and in the city centre)	h	haulieur
	Truck waiting time (outside and inside the site)	h	haulieur
	Construction site punctuality	h	haulieur
	Loading / unloading time	h	haulieur
Economic/haulier route	Number of intermediate storage	number	haulieur
	Distance from the production to the construction site	km	haulieur
Economic/material waste	Material waste	€	construction site
Economic/workforce productivity	Rework in connection with material issue	h	construction site
	Waiting time for the workforce	h	construction site
	Looking for material / equipment	h	construction site
	Several handling time	number	construction site
	Truck puntuality	h	construction site
Economic/supply chain management effort	Time dedicated to logistic activities	h	construction site
Economic/waste management costs	Costs of unsorted bins	€	construction site
Social/safety on construction site	Number of accidents and related causes	number	construction site
Environmental	CO_2 equivalent	g	public
	PM	g	public
Social/wellbeing for residents	Number of deliveries	number	public
	Congestion on construction site	m^2h	public
	Rate of obstructing vehicles	%	public

Table 1: KPI classified by beneficiaries

3 Haulier's potential benefits

In this deliverable, the objective is to define the potential savings for current partners. In this situation, on this section, we focus only on the savings for the haulier. But during the rest of the SUCCESS project, especially in the Task 4.2, it will be necessary to evaluate the additional costs caused by the involvement of new stakeholders and the impact of the CCC for the subcontractor who will be in charge of the transport of goods between the CCC and the construction sites.

Regarding the KPI previously (D2.2) defined, the potential benefits for hauliers are divided into two main items:

- Vehicle journey time
- Trips' distances

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3.1 Vehicle journey time

In the following paragraphs, we will present the definition of the Vehicle journey time, as we can analyse and calculate it within the SUCCESS project. In a second part, we will compare it with the benchmark values found in the literature. Finally, we will analyse the possible optimisations.

3.1.1 SUCCESS Haulier journey time definition

The scientific literature and the discussions with operators of the construction sites, hauliers and partners lead us to study the optimization of the vehicle journey time globally and not one aspect at a time.

It appears that this aggregation is optimal if we wish to assess the potential savings generated by the implementation of a CCC or a supply chain optimization.

In the diagram below, we describe how KPIs defined in D2.2 are integrated into the definition of the vehicle journey time of a haulier.

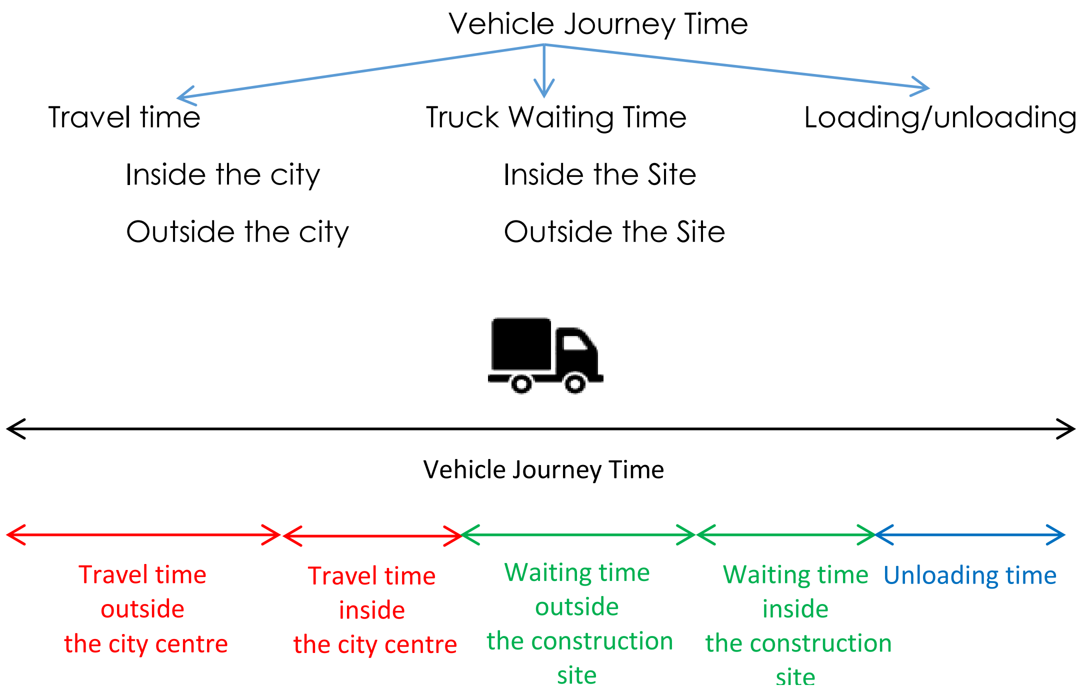

Figure 1: SUCCESS Vehicle Journey Time components

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3.1.2 Travel Time

The travel time taken into account for deliveries is the travel time of the forward path and for pick-ups is travel time of the return trip.

	Average travel time	
	Deliveries	Pickups
Luxembourg	01 :07	00 :35
Paris	02 :34	01 :14
Valencia	00 :20	00 :42
Verona	02 :32	01 :33

Table 2: Average travel times collected per pilot site

3.1.2.1 Travel Time outside the city centre

3.1.2.1.1 Main causes

In order to understand the situation and to find solutions it is necessary to perform a deeper analysis and to find the root causes of the time spent.

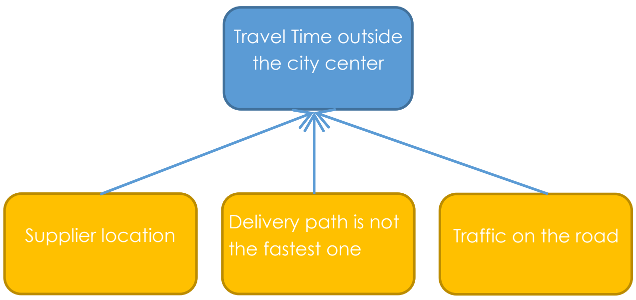

Figure 2: Travel time outside the city main causes

3.1.2.1.2 Conclusion

This time is mainly related to the supplier of the materials and its location. It will not be significantly reduced by the use of a CCC. It is depending of the distance between the supplier and the city hosting the construction site.

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	Average travel time outside the city depending on the distance between the starting point and the destination city (hh:mm)		
	0-50 km	50-100 km	> 100 km
Luxembourg	00:39	2:19:00	2:55:00
Paris	01:28	1:44:00	3:04:00
Valencia[1]	00:22		
Verona	00:40	1:28:00	3:19:00

Table 3: Average travel time outside the city centre depending on the distance (per pilot site)

In the literature, no optimisation of this time is targeted because the latter is mainly linked to the choice of the product / supplier itself and, for a given supplier, on the specific production locations.

3.1.2.2 Travel Time inside the city center

3.1.2.2.1 Main causes

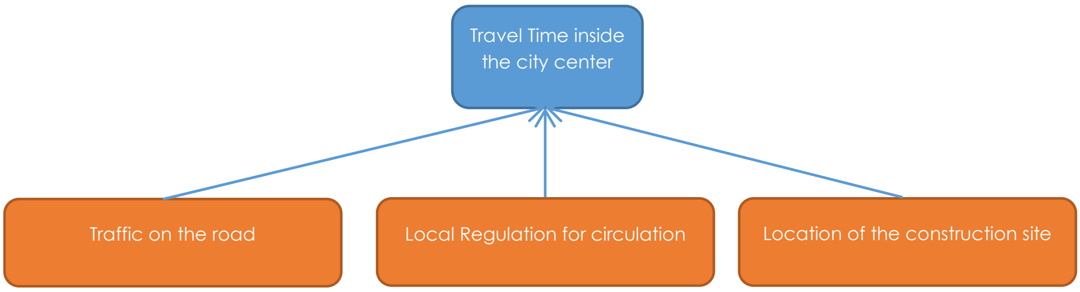

Figure 3: Travel time inside the city main causes

3.1.2.2.2 Travel Time Inside the city centre for the deliveries

[1] *For Valencia, information was not available for 50-100 km and >100km but only 5% of the deliveries are coming from more than 50 km of the construction site.*

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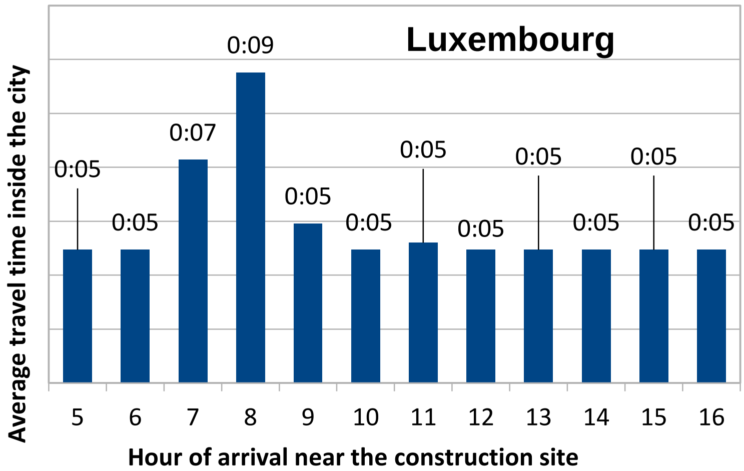

Figure 4: Distribution of travel time inside the city centre by arrival time for Luxembourg

With a CCC located at the periphery of a city, hauliers have no reason to go inside the city centre, and this average time (6 minutes) would be reduced to 0. In Luxembourg this time is not high because the construction site is close to the external border of the city and we could not gain a significant amount of time implementing a CCC.

Even if we don't put in place a CCC, we could optimize the travel time inside the centre of Luxembourg City (by 1 minute) if we planned the deliveries outside the peak hours.

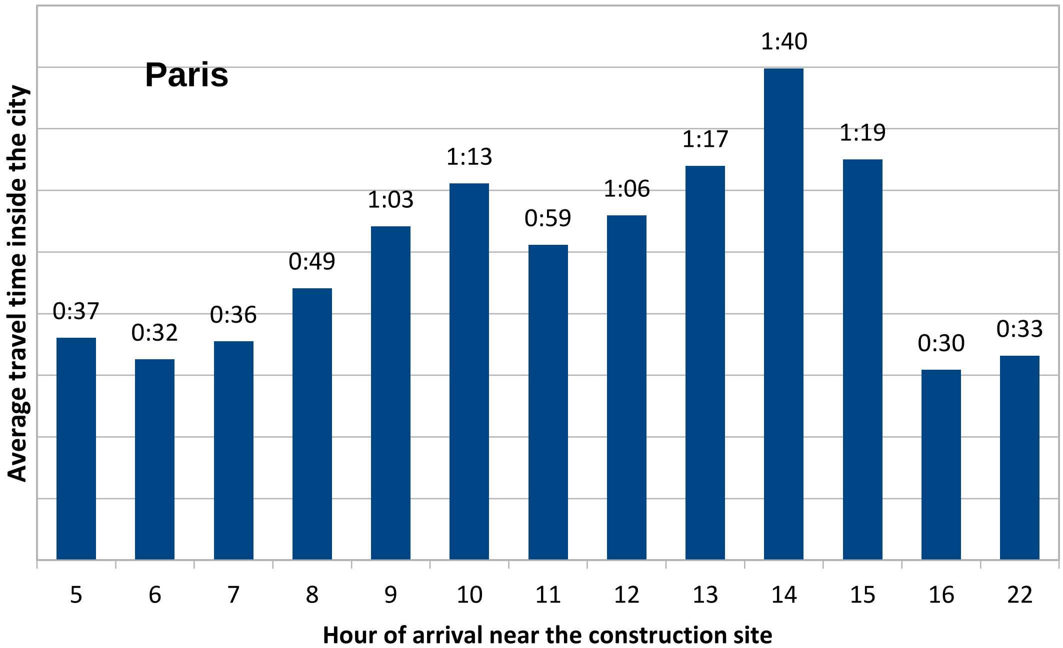

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Figure 5: Distribution of travel time inside the city centre by arrival time for Paris

The travel time inside the city centre of Paris (57 minutes on average) depends of the time at which deliveries occur. If a truck arrives at the city center at 5AM, the average travel time inside the city centre is 37 minutes, while if the same truck arrives between 7 and 10AM or between 12 and 2PM, the average time can increase to reach a peak of 1 hour and 40 minutes for the same distance and 1 hour on average. This is mainly linked to the traffic congestion in the city centre of Paris.

With a CCC, this time could be reduced to no travel time inside the city centre of Paris for hauliers, because hauliers would have no reason to enter inside the jammed city centre of Paris.

Without a CCC, in order to reduce the travel time inside Paris, it could be proposed to the haulier to deliver goods outside the traffic peak hours. In this case, hauliers could gain until 00:15 on average.

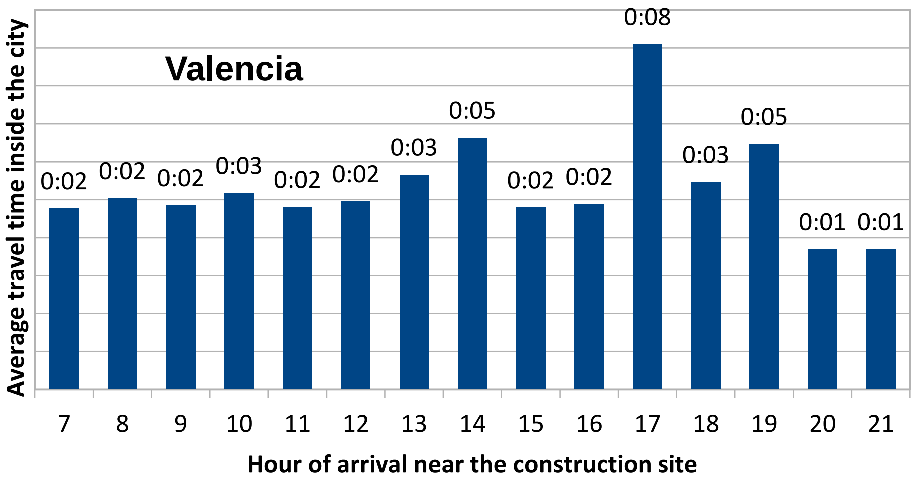

Figure 6: Distribution of travel time inside the city centre by arrival time for Valencia

For the same reasons than in Luxembourg, in Valencia a CCC could eliminate totally the actual average time (3 minutes) spent by hauliers inside the city centre and decrease it to 00:00.

In this case, a CCC would not be very relevant because the travel time is already near to 0.

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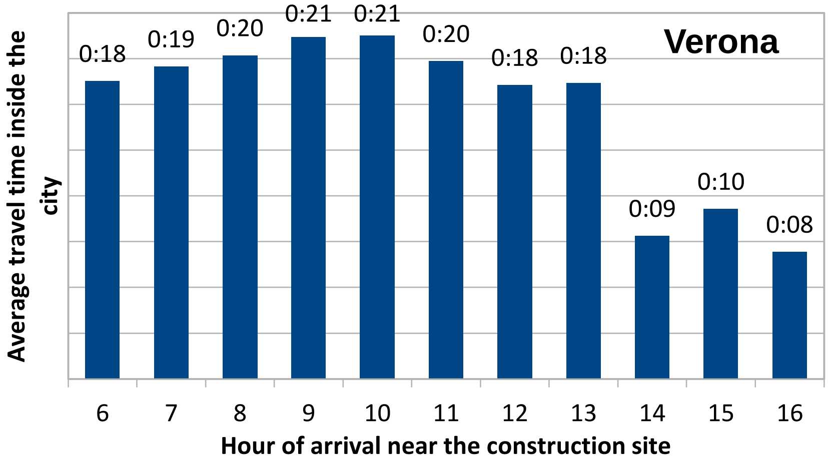

Figure 7: Distribution of travel time inside the city centre by arrival time for Verona

In Verona, a CCC could eliminate the actual time (17 minutes) spent by hauliers inside the city centre and decrease it to 0.

Without a CCC, hauliers who want to deliver outside the traffic peak hours (morning) could earn on average 7 minutes.

3.1.2.3 …Conclusion for the Travel Time

For each site, we have two ways to optimize the Travel time, i.e. with or without a CCC.

With a CCC, supposing that it is located at the border of the city, it is possible to optimize completely the travel time for the haulier by removing the travel time inside the city centre thanks to the opportunity for the haulier to leave its load at the border of the city. Obviously, it's necessary to estimate the additional cost for the CCC operator to assume the deliveries between the CCC and the construction site to check if the haulier gains allow them to participate in financing this part of the CCC costs. This economic evaluation and costs for the CCC will be simulated during the WP 3 (Business Model).

Without a CCC, if the haulier can organise its delivery when it's not a rush hour on the road, the travel times inside the city can be reduced.

With the data collected on our four pilot sites, we can identify two cases:

For the cities that have a bottlenecked city centre, a CCC will be very interesting for the hauliers. It is mainly the case for Paris, where the traffic jam inside the city has the most important impact on the travel time.

When the construction site is near the border of the city, or when the city centre is not engorged, the utility of a CCC for a haulier is not relevant. It depends on the location of the CCC, and on the location of the factory. In these cases

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sometimes, it could be more interesting for a haulier to reach directly the construction site instead of reaching a CCC located on the other side of the city for example.

Targets for deliveries travel time **outside** the city center with a CCC:

Construction site name	Average travel time outside the city centre	Target % of optimisation	Optimised Travel time outside the city centre
Neudorf Breweries Complex (Luxembourg)	01:34:39	0%	01:34:39
Îlot Fontenoy Ségur (Paris)	01:58:31	0%	01:58:31
Valencia Parque Central (Valencia)	00:29:30	0%	00:29:30
Borgo Trento Hospital (Verona Borgo Trento)	01:38:18	0%	01:38:18

Table 4: Improvements targets for travel time outside the city

It's also possible that the haulier's travel time outside the city centre increase, linked to the place of the CCC. This results can be viewed in the simulation.

Targets for deliveries travel time **inside** the city center with a CCC:

Construction site name	Average travel time inside the city centre	Target % of optimisation	Optimised Travel time inside the city centre
Neudorf Breweries Complex (Luxembourg)	00:05:37	100%	00:00:00
Îlot Fontenoy Ségur (Paris)	00:56:50	100%	00:00:00
Valencia Parque Central (Valencia)	00:03:22	100%	00:00:00
Borgo Trento Hospital (Verona Borgo Trento)	00:16:58	100%	00:00:00

Table 5: Improvements targets for travel time inside the city

Regarding the haulier time, with a CCC, it's possible to reduce this time to 00:00. In the simulation it's necessary to evaluate the impact for the construction site regarding the time needed to anticipate orders and the time needed by the CCC team provision the construction site.

Targets for pick up travel time:

Construction site name	Average travel time for pick ups	Target % of optimisation	Optimised Pick up travel times

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Neudorf Breweries Complex (Luxembourg)	00:35:16	15 %	00:30
Îlot Fontenoy Ségur (Paris)	01:14:00	25 %	00:56
Valencia Parque Central (Valencia)	00:42:16	10 %	00:38
Borgo Trento Hospital (Verona Borgo Trento)	01:33:02	20 %	01:15

Table 6: Improvements targets for pick-ups travel times

For the haulier, it's possible to pick up directly the bins at the CCC in a large quantity, in this case they can optimise the frequency of their circuit, they also optimize the distance, because the CCC can be located at the city centre, and they win all the time and distance in the city centre.

The pick up between the Construction site and the CCC can be done by the vehicle who delivers the site.

3.1.3 Waiting time

3.1.3.1 *Causes*

The analysis made in deliverable 2.4 lead to the following truck waiting time causes:

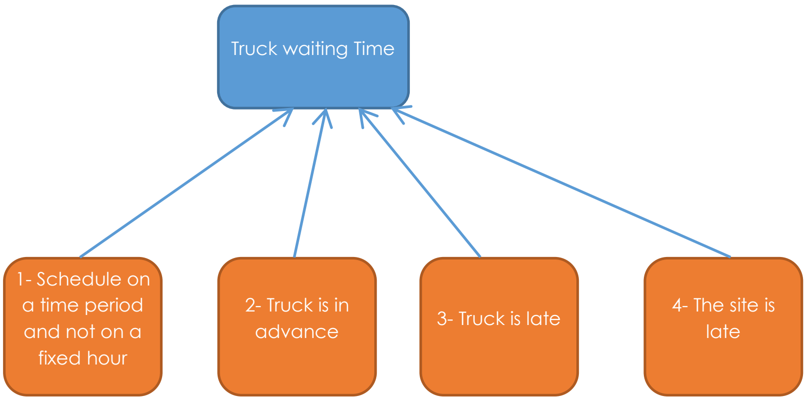

Figure 8: Causes of truck waiting time

1- In Luxembourg and Valencia deliveries are planned on a time period. This generates that sometimes both the truck and the site are on time but trucks wait.

2- The truck is in advance, so unloading resources are not necessarily available but it is not the site responsibility. So in this case the truck waiting time is due to truck difficulties to be on time and improvement should come from transport side.

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3- The truck is late, so unloading resources are not available but it is not the site responsibility. As for the previous case, reducing truck waiting time goes through transport improvement.

4- Trucks are on time but the site is not ready to unload. In this case improvement goes through a better schedule of unloading resources on the construction site

We go further in our analysis in this deliverable by analysing the truck waiting time causes by making the distinction between waiting time inside and outside the site for each pilot site.

3.1.3.2 *Waiting Time outside the construction site*

3.1.3.2.1 Luxembourg

Average time for the waiting time outside the site is 11 minutes. In most cases, this indicator is related to the fact that trucks either arrive earlier than planned to avoid traffic jam or wait because they arrived late and unloading areas are already occupied.

In a case of a CCC, this time can be significantly reduced (approximately 80%), because haulier have no reason to arrive earlier in order to avoid traffic jam in the city, the CCC will be located outside the city and ready at each time. But it's not 100% because in order to go to the CCC, in Luxembourg, it's necessary to pass through potential traffic jam areas and sometimes hauliers wants to arrive earlier at the CCC and can wait outside it.
The simulation made in task 4.2 can demonstrate the impact of the location of the CCC on this indicator.

3.1.3.2.2 Paris

56 % of the trucks wait outside the site. Average time for the waiting time outside the site is 36 minutes. The main reason is that, in order to avoid traffic jams in the city centre, trucks prefer to arrive earlier and wait outside the site for unloading at the scheduled hour.

This situation can be avoided with a CCC who can plan the deliveries during a traffic jam free period.

3.1.3.2.3 Valencia

Average time for the waiting time outside the site is 4 minutes. The specificity of this site is that they have enough space in order to park trucks when they arrive. For this reason, few trucks wait outside the site. Trucks are waiting only if the

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entrance of the site is already occupied by another truck, or if they need to use the second access of the site in order to unload their goods.

This time is not significant and either with or without a CCC, it cannot be further reduced.

3.1.3.2.4 Verona

Average time for the waiting time outside the site is 13 minutes. In Verona, the entry of the site allowed only 1 truck before the access gate. If more than one truck arrive at the same time, the first one enters inside the site whereas the remaining trucks wait on the road outside the site.

The entry gate was put in place in order to control and check by a guard, the data's of the delivery, the quantity of goods and to regulate the flow of trucks inside the site. Indeed due to site configuration, only 2 trucks are allowed inside the site at a same time: 1 in the delivery area and 1 waiting on the access slope.

3.1.3.2.5 Conclusion for waiting time outside the site

With a CCC, it is possible to optimise the waiting time outside the site and thus the impact on the street congestion. If the CCC sends a smallest truck but more frequently, up to 3 or 4 trucks inside could be accepted inside the site. and with a CCC the deliveries can be scheduled in order to avoid this congestion. With a CCC, the impact of this waiting time can reduce it to reach 0 minutes.

Without a CCC, the best practice used on Paris pilot site, can be generalized in order to reduce the waiting time outside the site. With a schedule program, it is possible to authorize only 2 trucks in the same time on site (one in the unloading location and 1 in the entry slope). In this case, the location in front of the access gate is free and only used as a spare truck storage park. If they use this type of solution, it is possible to reduce the impact on the street outside as well.

3.1.3.3 Waiting Time inside the site

3.1.3.3.1 Luxembourg

Average time for the waiting time inside the site is 13 minutes. The waiting time inside the site is mainly affected by the unavailability of handling equipment's or site organisation problem. It appears that some trucks were refused because it was impossible to unload them due to their specificities.

In the case of a CCC, this time can be reduced by more than 80%. In a CCC, it's a dedicated place for supply chain activities and the numbers of equipment are dimensioned for this activity. In a second side, the CCC is

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always ready for supply chain activity (loading/unloading) because it's not a production site but rather a supply chain site.

Without a CCC, it's difficult to optimize the waiting time inside the site, except if the site decides to use an ICT Tool, like in Paris, where the haulier or the subcontractor can indicate the type of truck scheduled and the type of handling equipment needed for the unloading.

3.1.3.3.2 Paris

Average time for the waiting time inside the site is 0 minutes. Out of 1695 deliveries recorded, no truck waits inside the site.

It's the effect of a dedicated logistic team using a scheduling tool. When a truck is allowed inside the site, the team is ready to unload it. Handling equipment's and team members are ready at truck arrival and the team knows where the goods are going, their type and which unloading equipment is required.

Due to the logistical solutions already in place on Paris site, a CCC will not impact the truck waiting time inside the site, which is already not significant for the site.

3.1.3.3.3 Valencia

Average time for the waiting time inside the site is 14 minutes. The site has enough space available and trucks have the possibility to wait inside the site instead of outside the site. As seen before in 3.1.3.2.3, the time for a truck outside the site is relatively low and most of the truck waiting time is inside the site. Due to space available inside the site the trucks waiting inside do not generate congestion on site as opposed to other pilot sites.

However, In the case of a CCC, the waiting time can be decreased by using a dedicated team and spaces dedicated to logistic activities.

3.1.3.3.4 Verona

Average time for the waiting time inside the site is 22 minutes. The waiting time inside the site is the result of the organisation of the site. Due to the topography of the site, the site can only organise one area for unloading. As a consequence if a truck is unloading, others trucks have to wait inside the site (on the slope to go to the unloading location or just after the access gate).

3.1.3.3.5 Conclusion for truck waiting time inside

With a CCC this situation can be optimized linked to the schedule of the trucks sent by it to the site. For the haulier, it's a time saved because he doesn't enter to the site for unload.

Without a CCC, the best solution is to put in place an ICT scheduling tool in order to affect to each truck a time slot who take in account the time for each

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unloading and to allow a schedule slot when the previous trucks is at the end of his unloading activity.

3.1.3.4 Conclusion for the Waiting Time

The waiting time for a haulier can be decrease significantly either by using a CCC or by putting in place a dedicated logistic team.

With the CCC, hauliers can expect a reduction of their waiting time by 80%. Indeed, a CCC by nature is a site with unloading spaces dedicated to this activity, with the suited unloading equipment and with a specific trained team. However, the haulier can still lose time in the front of the CCC if it is not open 24H/24H.

Without a CCC, construction sites can offer an option for the hauliers to reduce their waiting time if they put in place some best practices like in Paris site such as an ICT scheduling tool for hauliers and a dedicated logistic team.

Without a CCC, it is possible to optimize the waiting time inside the construction site by setting up delivery slots where logistic team will be available to unload the truck soon as he arrived.

Target for the waiting time outside the construction site

Construction site name	Average waiting time outside the site	Target: % of optimisation	Optimised waiting time outside the site
Neudorf Breweries Complex (Luxembourg)	00:11:33	80 %	00:02
Îlot Fontenoy Ségur (Paris)	00:42:42	80 %	00:09
Valencia Parque Central (Valencia)	00:03:45	80 %	00:01
Borgo Trento Hospital (Verona Borgo Trento)	00:13:44	80 %	00:03

Table 7: Targets for waiting time outside the site

Target for the waiting time inside the construction site

Construction site name	Average waiting time inside the site	Target: % of optimisation	Optimised waiting time inside the site
Neudorf Breweries Complex (Luxembourg)	00:15:13	80 %	00:03
Îlot Fontenoy Ségur (Paris)	00:00:00	/	00:00
Valencia Parque Central (Valencia)	00:14:15	80 %	00:03
Borgo Trento Hospital (Verona Borgo Trento)	00:22:42	80 %	00:04

Table 8: Targets for waiting time inside the site

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3.1.4 Loading / Unloading time

3.1.4.1 Causes

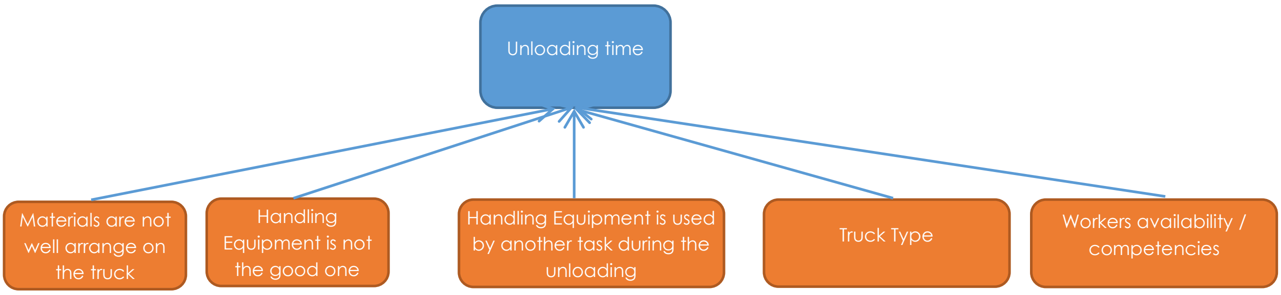

Figure 9: causes of important loading / unloading time

Based on the data collected, we are not able to identify for each delivery which cause, among the causes presented on the figure 2, is the source of the non-efficiency.

However we have, for Paris and Luxembourg (table 7), the average unloading time requested to unload a truck with handling equipment and human resources provided by the construction team and the average unloading time requested to unload a truck with its own handling equipment (called "self-discharged").

By considering that **a "self-discharged" unloading is impacted neither by handling equipment or workers unavailability nor by truck and handling characteristic**, we can use the "self-discharged" unloading time as improvement target.

	Average unloading time	Average unloading time per equipment			
		Crane	Forklift	Pump	Self-discharged

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Luxembourg	00:58	00:51	01:10	04 :21[2]	00 :29
Paris	00:45	00:51	00:53	-	00 :33
Valencia	00:46	00:56	00:44	-	00 :46
Verona	00:34	00:54	00:28	00 :30	-

Table 9: Average unloading time by handling equipment

3.1.4.2 Luxembourg target

As explained just before, the average "self-discharged" unloading time is around 30 minutes. The average unloading time with handling equipment provided by the site is around 1 hour.

The target for Luxembourg, by eliminating all the sources of variability thanks to a CCC and more specifically a dedicated and professional logistic team in charge of unloading materials at the site, is 50% of unloading time reduction.

3.1.4.3 Paris target

In the way, in Paris, the average "self-discharged" unloading time is also around 30 minutes. In Paris the average unloading time is already not impacted by handling equipment and resource unavailability and is around 45 minutes.

So the improvement for Paris is less than in Luxembourg because it already deals with a dedicated logistic team. Improvement can only come from removing truck characteristics issues.

The target for Paris, by ensuring the best truck characteristics to unload on site, is 33% of unloading time reduction.

[2] *In Luxembourg, "average unloading time depending on pump" needs to be put into perspective. This equipment is used to unload and at the same time put in place concrete, it is not possible to separate these two tasks. Then the recorded unloading time is time of unloading + time of application. For average unloading time calculation, deliveries using pump were moved aside.*

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3.1.4.4 Valencia target

For Valencia we cannot use the "self-discharged" unloading time because it is not the same materials (concrete and aggregate) and compare unloading times for such different materials is not serious.

3.1.4.5 Verona target

The average unloading time is already close to the time measured in Luxembourg and Paris during "self-discharged" deliveries. The few unloading performed with the crane slightly increase the average unloading time. By removing all the unloading activities performed with the crane the unloading time could be reduced to around 30 minutes.

The target for Verona, by ensuring the best truck characteristics and the best handling equipment to unload on site, is 12% of unloading time reduction.

3.1.4.6 Conclusion on unloading time

Target for the unloading time:

Construction site name	Average unloading time	Target: % of optimisation	Optimised waiting time inside the site
Neudorf Breweries Complex (Luxembourg)	00:58:00	50 %	00:30
Îlot Fontenoy Ségur (Paris)	00:00:00	33%	00:00
Valencia Parque Central (Valencia)	00:46:00	0 %	00:46
Borgo Trento Hospital (Verona Borgo Trento)	00:34:00	12 %	00:30

Table 10: Targets for unloading time

3.1.5 Haulier Journey Time Benchmarking

For the Vehicle Journey Time it is possible to compare and analyse SUCCESS pilots results to what is achieved in the London Construction Consolidation Centre (LCCC) reported by Transport for London .

The KPI 'travel time' was not defined in the LCCC report , but they did intend to target the average 'journey time' by going direct to the CCC rather than driving into the city centre (including loading / unloading time). The following

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results come from LCCC feedback (Information collected through interviews with drivers):

- *An average of 45 minutes saved in the time to unload a large goods vehicle at the LCCC compared with at a central London construction site;*

- *An average of 45 minutes saved in the time to reach the LCCC compared to a central London construction site;*

- *An average of 45 minutes saved when leaving the LCCC compared with departing from the centre of London.*

A saving of approximately two hours in a driver's typical 10-hour day implies a potential saving of 20 per cent in a driver's working day as a result of using the LCCC. This time saving can be used to carry out other productive freight transport work, thereby increasing the efficiency of the freight transport operation.'

Our understanding of LCCC's Vehicle Journey time decomposition is described below:

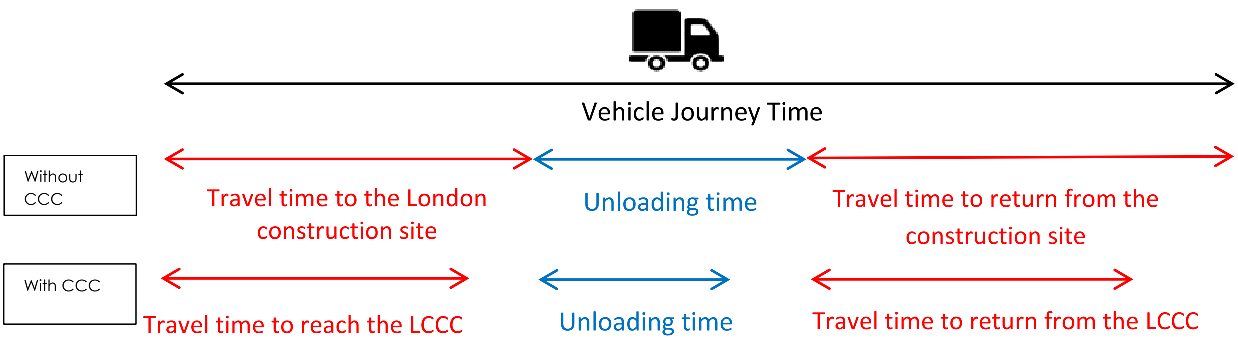

Figure 10: LCCC Vehicle Journey Time components

As we can see, for each of the 3 parts described in the LCCC analyse, drivers win 45 minutes if they use the CCC.

Haulier Journey Time improving targets (from the hauliers point of view)

3.1.5.1 Luxembourg

➢ Case with CCC

	Current	Target	Expected

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	data		results
Travel time outside the city centre	01:34	0 %	01:34
Waiting time outside the construction site	00:11	80 %	00:02
Travel time inside the city centre	00:05	100 %	00:00
Waiting time inside the construction site	00:15	100 %	00:03
Loading / unloading time	00:58	50 %	00:30
Haulier journey time	**03:03**	**30 %**	**02:08**

Table 11: Targets for Haulier journey for Luxembourg

In the Luxembourg pilot site case, we can estimate the potential improvement for the Haulier's journey time to: **30 %** that represents a gain of **55 minutes**.

3.1.5.2 Paris

- Case with CCC

	Current data	Target	Expected results
Travel time outside the city centre	01:58	0 %	01:58
Waiting time outside the construction site	00:43	80 %	00:09
Travel time inside the city centre	00:57	100 %	00:00
Waiting time inside the construction site	00:00	/	00:00
Loading / unloading time	00:45	33 %	00:30
Haulier journey time	**4:23**	**40 %**	**2:37**

Table 12: Targets for Haulier journey for Paris

In the Paris pilot site case, we can estimate the potential improvement for the Haulier's Journey Time to: **40 %** that represents a gain of **1 hour 46**.

3.1.5.3 Valencia

- Case with CCC

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	Current data	Target	Expected results
Travel time outside the city centre	00:29	0 %	00:29
Waiting time outside the construction site	00:04	80 %	00:01
Travel time inside the city centre	00:03	100 %	00:00
Waiting time inside the construction site	00:14	80 %	00:03
Loading / unloading time	00:46	0 %	00:46
Haulier journey time	**01:36**	**18 %**	**1:19**

Table 13: Targets for Haulier journey for Valencia

In the Valencia pilot site case, we can estimate the potential improvement for the Haulier's Journey Time to: **18 %** who that represents a gain of **17 minutes**.

3.1.5.4 Verona

- Case with CCC

	Current data	Target	Expected results
Travel time outside the city centre	01:38	0 %	01:38
Waiting time outside the construction site	00:14	80 %	00:03
Travel time inside the city centre	00:17	100 %	00:00
Waiting time inside the construction site	00:23	80 %	00:04
Loading / unloading time	00:34	12 %	00:30
Haulier journey time	**3:06**	**27 %**	**2:15**

Table 14: Targets for Haulier journey for Verona

In the Verona pilot site case, we can estimate the potential improvement for the Haulier Journey Time to: **27 %** that represents a gain of **51 minutes**.

3.1.6 Haulier Journey Time Conclusion

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	Current data	Target	Expected results
Neudorf Breweries Complex (Luxembourg)	03:03	30 %	02:08
Îlot Fontenoy Ségur (Paris)	4:23	40 %	2:37
Valencia Parque Central (Valencia)	01:36	18 %	1:19
Borgo Trento Hospital (Verona Borgo Trento)	3:06	27 %	2:15

Table 15: Summary of tagets hauliers journey per site

For a haulier, in average, it's possible to win **29 %** of their journey time in the case of a CCC. However, these results **emphasize that site specificities must be considered to draw conclusion on the relevancy of a CCC**:

- Luxembourg is the most constrained site in terms of surface available for waiting, unloading and store material and the less constrained in terms of site location. Improvement target is in the average for all sites.
- Paris is the most congested city but the most efficient site with regards to logistics. Logistic efficiency on site does not offer advantages to the haulier and consequently a CCC is very relevant for the haulier in this case.
- Valencia pilot has the least constraints in terms of surface and location; Moreover Valencia is not as congested as Paris. So CCC' advantages for hauliers are the less significant.
- Verona has the same result as Luxembourg. The city is slightly more congested but the site is larger and is more effective in terms of logistic without being at the level of Paris.

Without CCC: (just Supply chain Optimization)

To reduce the travel time outside the city we should consider:

- Choosing suppliers with a smaller km ratio. By example, putting a maximum threshold for the travel distance a supplier could do to deliver the materials; (Could this material be delivered by another supplier, nearer?)

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- Route optimisation. Choosing highways rather than routes (Faster deliveries).
- Ask suppliers to deliver outside the peak periods (Peak periods 7.30-9.30 and 16.30-18.30). … savings are also possible but we currently are not table to fix accurate targets …

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3.2 Construction site punctuality

3.2.1 Definition and explanation

Site punctuality is the time between the planned unloading time (scheduled delivery time) and the real unloading starting time.

Construction site punctuality = Scheduled delivery time - unloading starting time

If site punctuality is positive it means that unloading starts earlier than planned. If site punctuality is negative it means that unloading starts later than planned.

In the case where punctuality is negative we cannot conclude directly that the truck waiting time is caused by construction site delay (negative construction site punctuality). Indeed if the truck arrives late at the construction site and if the handling equipment required for unloading are not available we cannot consider that the construction site is responsible for the delay.

We identified the following causes of negative construction site punctuality:

- Human resource unavailability
- Handling equipment unavailability
- Loading area unavailability

Indeed, except for the Paris pilot who has a dedicated logistic team, the 3 others pilots sites share their resources between production and delivery management. So impact of **production schedule variability** on unloading resources is one of the root causes of negative construction site punctuality.

However, unloading resources unavailability is also generated by a negative truck punctuality that disrupts the **unloading activities schedule** and impact unloading resources availability for others deliveries.

We have actually no data that allow us to pinpoint what cause between production schedule variability and truck punctuality is the most important factor of negative construction site punctuality.

We can just infer that CCC implementation impacts the supply chain processes mainly by forcing a delivery schedule. This delivery schedule should allow the construction site to better plan the shared resources used to unload trucks. So **to fix a target on construction site punctuality the main idea is to compare LCCC feedbacks in terms of the capacity of the construction site to unload a delivery on time**.

3.2.2 Benchmarking (projects using the CCC)

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Taking into account LCCC feedback (table below), the construction sites supplied by a CCC are reliable in 99% of cases. That is to say, the construction site cannot unload on time a material, due to site unavailability, only 61 times on 5393 deliveries (1% of deliveries). Explanation may be found in the fact that being supplied by a CCC force sites to better schedule the replenishments and the associated resources.

Site	No. of Call-Offs	Failed Call-Offs	Late Deliveries	Equipment Failed	Site Rejection	Crane Called Off	Percentage of Successful Call-Offs
Unilever	4266	197	138	22	23	12	95%
Basinghall St.	730	27	23	4	0	0	96%
Coleman St.	305	2	1	0	0	0	99%
Bow Bells House	92	0	0	0	0	0	100%
Total	**5393**	**226**	**162**	**26**	**23**	**12**	**96%**

(Data: January 2006 – April 2007)

Table 16: 2007. London Construction Consolidation Centre: Case of study. Freight Best Practice, Transport for London (TfL)

3.2.3 Sites Analysis

3.2.3.1 *Luxembourg*

3.2.3.1.1 Data

On Luxembourg's site, 209 trucks arrived on time, 34 of these 209 trucks were unloaded after the planned time due to construction site issues.

So for 16% of deliveries arriving on time at the construction site, the site working team was unable to unload whether it is due to unavailability of unloading area or resource. **Luxembourg's construction site punctuality is then 84%.**

3.2.3.1.2 Improvements targets

If we consider that with a CCC, the service target achieved by the construction site can be the same as demonstrated through LCCC experimentation, the construction site punctuality **could be improved from 84% to 99%** in the Luxembourg case.

For Luxembourg pilot this construction site punctuality service level would have generated a delay only for 2 trucks instead of the 34 identified on the data collection period and a total delivery delay of around 1 hour instead of a total delay of 20 hours.

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3.2.3.2 *Paris*

3.2.3.2.1 Data

On Paris' site, 535 trucks arrived on time, 167 of these 535 trucks were unloaded after the planned time due to construction site issue.

3.2.3.2.2 Improvements targets

So, for 31% of deliveries arriving on time at the construction, the site working team was unable to unload whether it is due to unavailability of unloading area or resource. **Paris' construction site punctuality is then 69%**.Targeting Improvements

If we consider that with a CCC, the service target achieved by the construction site can be the same as demonstrated through LCCC experimentation, the construction site punctuality **could be improved from 69% to 99%** in the Paris case.

For Paris pilot this construction site punctuality service level would have generated a delay only for 5 trucks instead of the 167 identified on the data collection period and a total delivery delay of around 3 hours instead of a total delay of 90 hours.

3.2.3.3 *Valencia*

3.2.3.3.1 Data

On Valencia's site, 732 trucks arrived on time, 167 of these 732 trucks were unloaded after the planned time due to construction site issue.

3.2.3.3.2 Improvements targets

So for 23% of deliveries arriving on time at the construction, the site working team was unable to unload whether it is due to unavailability of unloading area or resource. **Valencia's construction site punctuality is then 77%**. Targeting Improvements

If we consider that with a CCC, the service target achieved by the construction site can be the same as demonstrated through LCCC experimentation, the construction site punctuality **could be improved from 77% to 99%** in the Valencia case.

For Valencia pilot this construction site punctuality service level would have generated a delay only for 7 trucks instead of the 167 identified on the data collection period and a total delivery delay of around 3 hours instead of a total delay of 67 hours.

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3.2.3.4 *Verona*

3.2.3.4.1 Data

On Verona's site, 11 trucks arrived on time or ahead, 9 of these 11 trucks were unloaded after the planned time due to construction site issue.

So for 82% of deliveries arriving on time at the construction, the site working team was unable to unload whether it is due to unavailability of unloading area or resource. **Verona's construction site punctuality is then 18%.**

3.2.3.4.2 Targeting Improvements

If we consider that with a CCC, the service target achieved by the construction site can be the same demonstrated through LCCC experimentation, construction site punctuality **could be improved from 18% to 99%** in the Verona case.

For Verona pilot this construction site punctuality service level would have generated a delay only for 1 truck instead of the 9 identified on the data collection period and a total delivery delay of around 1 minute instead of a total delay of 2 hours.

3.2.4 Construction site punctuality conclusion

The main impact of construction site punctuality improvement should be on truck waiting time and consequently on traffic jam in front of the construction site which is one on the major negative impact with the noise and the pollutant emissions.

We have to be sensible with these conclusions because improving construction site punctuality could reduce the potential reactivity of the construction site to unload overdue and ahead trucks.

	Current service level	Expected results
Neudorf Breweries Complex (Luxembourg)	84%	99%
Îlot Fontenoy Ségur (Paris)	69%	99%
Valencia Parque Central (Valencia)	77%	99%
Borgo Trento Hospital (Verona Borgo Trento)	18%	99%

Table 17: Targets for construction site punctuality per pilot site

3.3 Haulier route

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The Haulier route is mainly defined by the distance between the factory and the construction site, but is also linked to the number of intermediate storage and the distance between each of these intermediate storages.

With this category of KPI's we can understand and analyse the possible optimisation linked to a potential CCC location. Reduction comes from intermediate storage removing by introduction of the CCC (the haulier can unload directly in large quantity in the CCC instead of an intermediate storage). But it is not a savings for all hauliers, it depends on mini factors like contractual arrangement between producers and distributors, business model of hauliers, distributors and producers ….

The size and location of a CCC can impact negatively or positively both the number the number of intermediate storage and the distance travelled from production to construction.

3.3.1 Benchmarking

We report conclusions of two examples of CCCs.

*"*The SHCC (Stockholm Hammarby Consolidation Centre) 'was located adjacent to the construction site, acting as a focal point for all delivery vehicles coming to the site. If flows had not been coordinated, 700 tonnes of materials would have been delivered into the site by 400 vehicles each day, with an average consignment size of 1.75 tonnes'.

The SHCC accomplish a reduction in vehicle distances from 64 kilometres a day to 26 kilometres a day per vehicle."

Wilston Ltd, S., 2010. Freight Consolidation Centre Study-Final Report. South East Scotland Transport Partnership.

"At Hammarby (SHCC) 'The vehicles in the project drove approximately 26 kilometres per day. The number of vehicle kilometres was reduced by 38 kilometres per day with the LC compared to a situation without the LC (Logistic Centre*)*"'.

Trendsetter - Evaluation Report (2006). CIVITAS. Stockholm, Sweden.

"The CCC used in North Kent encourage up to 20% reduction in haulier costs when delivering to congested area".

Blumenthal, A., Young, A., 2007. Construction Consolidation Centres in North Kent: Needs analysis and feasibility study. Construction Excellence.

"Average distance from CCC to *the construction site:* This parameter was set at no more than 30 minutes drive time from the CCC to the construction site and

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as a result the distance between construction site and CCC is no more than 3 miles in any strategy'.

These are quite short distances in this study, because most of the construction sites are located in central London. However, it is expected that these distances would be further if CCCs were located to serve construction taking place in the suburban areas - e.g. 5 to 7 miles.

In the Heathrow consolidation centre it was reached an estimated saving of 144,000 vehicle kilometres in 2004 that resulted in a reduction in CO2 emissions of 3,100kg per week."

> ***2007. London Construction Consolidation Centre: Case of study. Freight Best Practice, Transport for London (TfL).***

3.3.2 Number of intermediate storage

Number of intermediate storages is the number of times the material is unloaded and stored between the finish product manufacture and the construction site.

Unit: Expressed as a positive integer.

Our assumption is that a CCC can replace all the intermediate storage between the producer and the construction site. In this case, you can optimize also the risk of damages on goods if you manipulate them only one time.

And after, you win time with a direct trip between factory and CCC, instead of multiple loadings/unloading and consequently, waiting time for goods in different warehouses.

However this assumption is very strong and highly depending on the various relationships between manufacturers, hauliers and contractors.

3.3.2.1 Luxembourg

In Luxembourg, only 4 intermediate storages are recorded during the data collection period. All those products have a production site located more than 300 km.

The remaining majority of materials are produced near the construction site. In this case, a CCC will not be relevant for the haulier route optimisation, except if it's possible to provide hauliers an interesting added value like space well organised to unload, time savings during haulier route or unloading, or if the haulier can improve the loading of his truck.

With a CCC, haulier can optimise the number of intermediate storage for material who come from far away, but for materials that come from a

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production closed to Luxembourg city, the CCC deteriorate this indicator by adding an additional intermediate storage.

In order to understand the interest of a CCC, during the simulations on the next WP 4.2 it will be necessary to analyse and simulate the impact generated by the CCC regarding indicators other than haulier route, like time, price, etc.. .

3.3.2.2 Paris

Like in Luxembourg, only few numbers of intermediate storages (3) were recorded during the data collection. Intermediates storages are mainly used for materials produced more than 350 km far from Paris.

With a CCC, like in Luxembourg, haulier can optimise the number of intermediate storage for material who come from far away, but for materials that come from a production closed to Paris, the CCC deteriorate this indicator by adding an additional intermediate storage.

In order to understand the interest of a CCC, during the simulations on the next WP 4.2 it will be necessary to analyse and simulate the impact generated by the CCC regarding indicators other than haulier route, like time, price, etc...

3.3.2.3 Valencia

In Valencia, no intermediate storage was recorded.

With a CCC, like in Luxembourg and Paris, the CCC deteriorates this indicator by adding an additional intermediate storage.

In order to understand the interest of a CCC, during the simulations on the next WP 4.2 it will be necessary to analyse and simulate the impact generated by the CCC regarding indicators other than haulier route, like time, price, etc...

3.3.2.4 Verona

In Verona, no intermediate storage was recorded.

With a CCC, like in Luxembourg, Paris and Valencia, the CCC deteriorates this indicator by adding an additional intermediate storage.

In order to understand the interest of a CCC, during the simulations on the next WP 4.2 it will be necessary to analyse and simulate the impact regarding time, price, etc.. occurred by the CCC.

3.3.3 Distance from the production site to construction site

It's defined by the real distance between the finished product manufacture and the construction site. This distance includes the potential detour related to the design of the distribution network (intermediate storage location).

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Unit: Expressed in km.

If suppliers are not far from the construction site, a CCC will not be relevant as it will probably add extra distance on the route from production to construction. On the other side, if suppliers are far from the construction site a CCC will be interesting for hauliers in order to deliver goods in advance to the CCC who is in charge to deliver just in time the site. The CCC would then allow distant suppliers to be as flexible as closer suppliers.

Distance from producer to construction site depends on the number of intermediate storage. It seems that even if intermediate storage exist there are not used for every material delivery. We have not enough data to determine the frequency of use of intermediate storage for each material and each site. So our targets would not be representative enough for each site and material. We need to perform further data collection and analysis during simulation step.

During the data collection it was not possible to find a correlation between the distance and the type of material. In this situation, the situation of the factory of the producer cannot be optimized.

4 Construction site potential benefits (contractor and subcontractors)

Potential benefits for construction site actors can be divided into four types of savings:

- On **workforce time** generated by reducing waiting time and unproductive activities
- On **management staff time** by reducing time dedicated to material handling
- On **safety topics** generated by **accident reduction**
- On **material waste** which represents all the materials ordered and delivered on site but not used.

In this chapter we will analyse all the potential benefits per construction site.

4.1 Workforce time

As mentioned, workforce productivity can be analysed on two axes: the loss of time during the production, the loss of time linked to the logistic activities performed by the workforce.

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4.1.1 Production time loss

4.1.1.1 Cause analysis and solutions

The working time per day is divided into two main parts:

- o Efficient work
- o Unproductive works.

By analysing collected KPI's, we can identify that during production activities, workforce can lose time for 4 reasons (unproductive work):

- The time dedicated to the **rework activities due to a logistic issue**,
- The **waiting time related to material unavailability** at the point of use during material installation,
- Some of the **material looking and transport times** could be reduced by modifying the way of provide material to the site (frequencies, quantities),
- **Setups times** required to performed tasks that could be avoided or performed externally.

4.1.1.1.1 Looking and transport causes and solutions

The following activities make part of the looking and transport times:

- Looking for material
  - o Find the good material on site

- Handling materials:
  - o Move material from storage area to point of use
  - o Re distribution of materials

Causes:

We perform a causes/consequences analysis in order to identify the main root causes of those problems.

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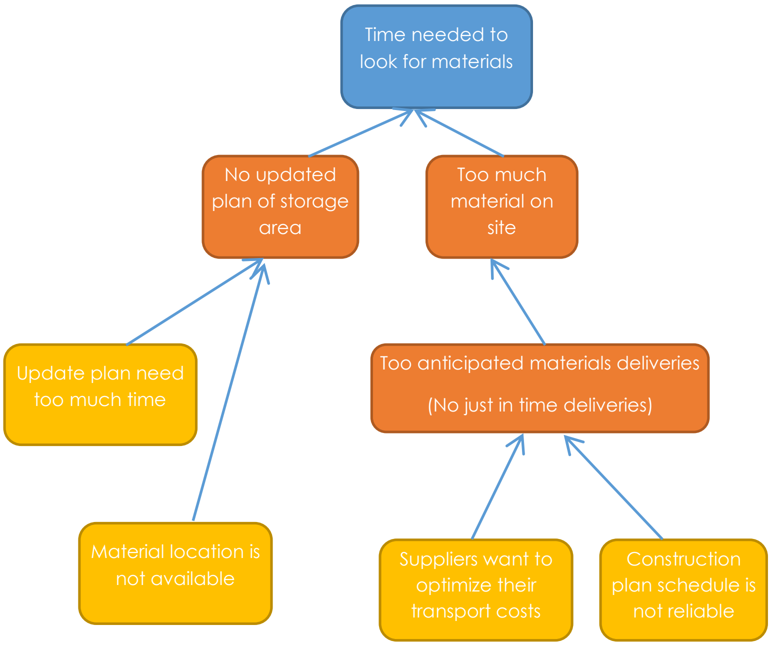

Figure 11: Causes of loss times needed to look for materials

Regarding the time needed to find the good material to perform a task, we can consider 4 main causes related to the logistic activities. Some others causes can be identified, but not linked to the logistic or are not significant.

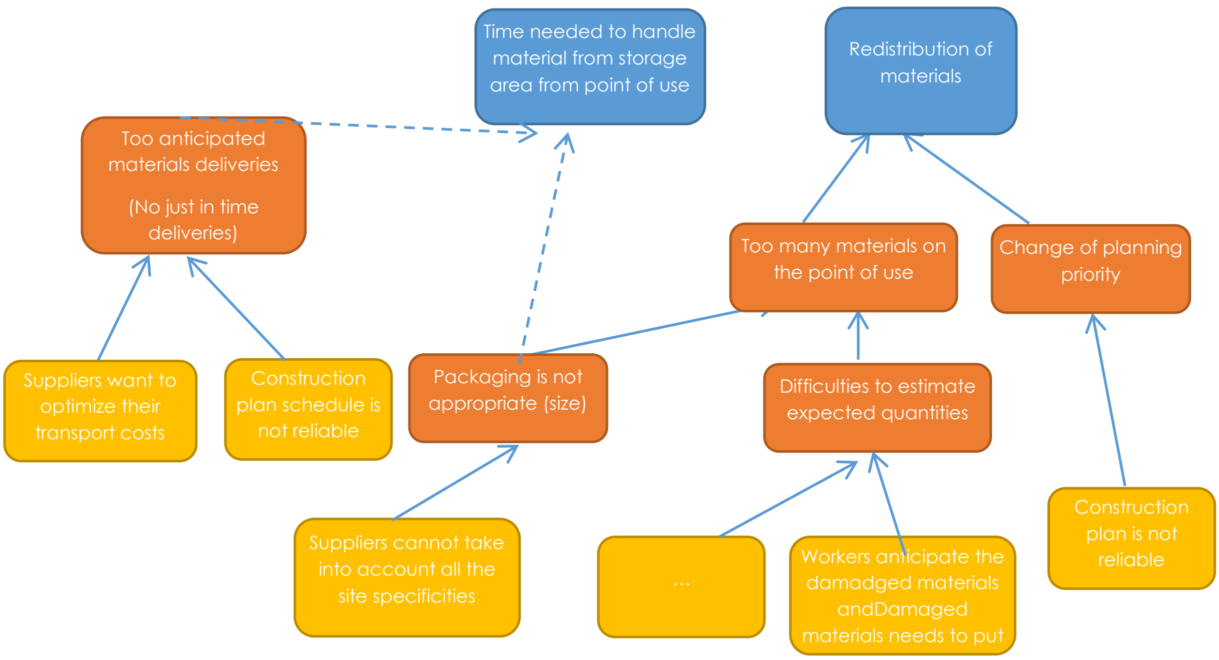

Figure 12: Causes of loss times needed to transport materials

The time spent to handle materials to the point of use is mainly the consequence of i) changes in the scheduling of the site linked to the customer needs and changes, and ii) the schedule is not performed with the entire

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workforce. A second reason is that hauliers want to optimize their trucks' volume and use a standard packaging for all customers. In this case, the haulier delivers too much materials and a non-adequate packaging size for the site.

Those ineffective times could be reduced / optimized through the resolution or the decrease of the following root causes:

- **Update plan of the storage area**. If construction sites have a storage plan updated on a regular basis, they can put directly near the point of use the required material and avoid time spent for searching or moving this material. Two types of solutions can be implemented on the Luxembourg site:
  - Collaborative planning: It's necessary to know witch task the workers will performed in order to define the type and the quantities of material needed. The best tool in order to fix the schedule and to know the % of achieving is to realise on a daily basis an update of the collaborative planning, based for example on the Last Planner System ® methodology.
  - **Technological tools as for example BIM**, dynamic storage map: it's important to have a schedule up to date but in the same way, it's important to have also an up to date map of the storage areas with a precise view of the type and material quantities that will be present in this area. Currently the best tool to update those areas is a BIM solution (Building information model). After a first parameter session in order to define all logistic surfaces, the scheme can be updated every week to have a precise view of the storage situation.

- **Improve reliability of the construction plan: as explained before, the reliability of the construction schedule is important in order to prepare and anticipate the tasks to be performed.**
  - Collaborative planning: a collaborative planning is the best way to understand all the tasks currently performed and the % of achievement. As we explained before, the Last Planner System ® can be a good solution.
  - Client involvement: one major risk is also the client who wants to change some parts of the project. In this case, the site needs to change his schedule.

- **Provide synchronizing tools between suppliers constraints and sites requirements**
  - CCC can improve the interface between the suppliers and the site. With a CCC it is possible to offer services to the site in order to

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optimize the discussion between stakeholders. Two important services that can support the site are:

- Repackaging taking into account construction plan: each day, the exact quantities of material needed by the site can be sent by the CCC. For this activity, the CCC can offer a service of storage and kitting.
- Just in time deliveries: with a CCC the hauliers can deliver a large quantity, in order to increase ratio volume/trip, while the CCC can store the material to deliver the site just in time.

The CCC can be justified by the lack of space on construction site. If a CCC is used, it is easier to manage the site storage map if all materials are directly unloaded on the point of use thus limiting the number of storage areas on site.

4.1.1.1.2 Rework causes and solutions

The **rework** time is not important.

This rework time is divided in 4 main activities:

- The dismantling of the task already done
- The cleaning time
- The working time to realise the new task
- Time to find and handle the required equipment and material

The non-ended task time have an impact principally on set up time in order to finish task (handling of the required equipment, cleaning the place, time for studying the tasks non finished, etc.…)

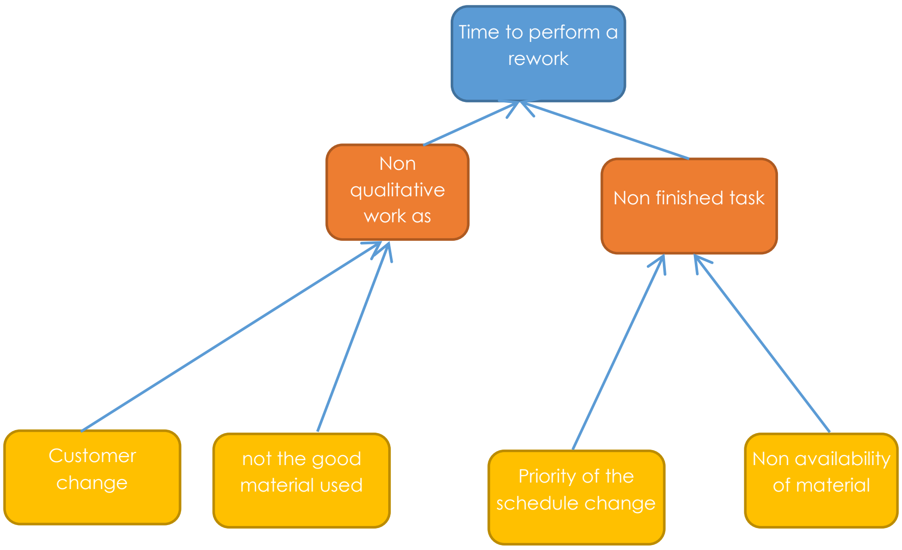

Figure 13: Causes of loss times needed to perform reworks

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The main reason for rework due to logistic issues is delivery reliability. All the CCC feedbacks demonstrate that CCC highly increases delivery reliability so CCC is a solution in this case. Without CCC the solution is to perform quality control for each delivery.

4.1.1.1.3 Setup time causes and solutions

Setup on construction site is time dedicated to prepare and clean the working area, prepare tools and equipment. It's a necessary time in order to perform a good job. It's not an optimisation who can be achieved by a CCC. We can put in place some others methodologies like (lean manufacturing, SMED) if we want to reduce it. It's around 1 hour per person and per day .

Regarding the **set up on material**, it's mainly (for the materials that allow prefabrication) time dedicated to pre assemble some building components. In general this activity takes too much time and can be subcontracted in order to win time .A CCC could bring some savings by performing the prefabrication under better working conditions.

Causes :

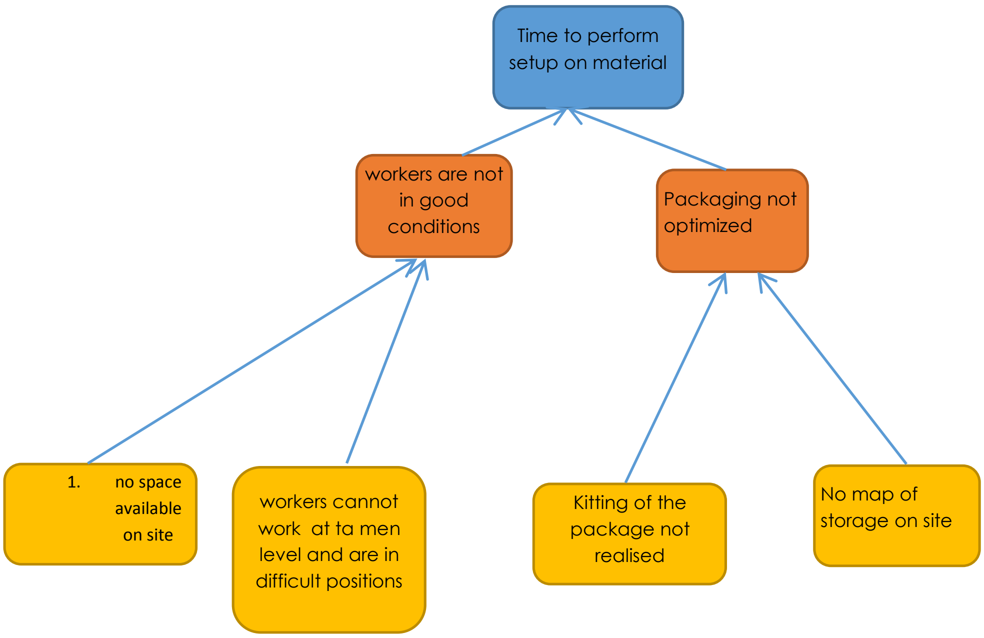

Figure 14: Causes of loss times needed to setup activities

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4.1.1.2 *Sites analysis*

4.1.1.2.1 Luxembourg

	Efficient work	Setup on construction site	Setup on material	Rework	Waiting	Looking and transport
Average h/Day	4,51	0,93	1,05	0,75	0,21	0,54
%	56	12	13	9	3	7

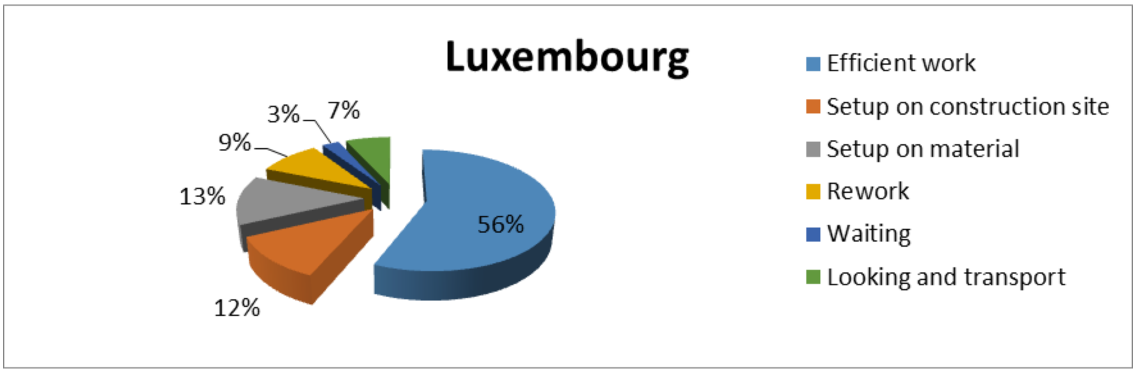

Figure 15: Distribution between time losses and efficient work per day for Luxembourg

The effective working time is significant (56%). Unproductive working (44%) time could be reduced by optimizing of non-essential time component. We study in the following paragraph each unproductive time component to look for saving sources opportunities.

In average, each worker spent around 0h30 in **looking and transport** of the material.

In average, each worker spent around 0h10 in **waiting time** for the following activities

- Work area to be cleared
- Machine failure
- Test of material handling
- Waiting for material (due to not appropriate handling
- Waiting for material (urgent order)
- Waiting for the crane

For some material, the most important waiting time value is related to the required time to catch a time slot of the crane in order to perform the transportation of the material.

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Regarding all this times, in Luxembourg we can find some solutions in order to reduce the non-productive time

In order to reduce **unproductive time on construction site a CCC**could perform::

- § just in time delivery
- § kitting
- § prefabrication

In addition the construction site should implement:

- A site storage map
- A construction site planning
- A dedicated team to perform logistic activities

Luxembourg targets:

Setup on site: with lean (5S, SMED) methodology, we think we can win 50% (0,50 h)

Setup on material: with a ccc and a prefabricated bench, or a kitting optimization, we can win 50% (0,50 h)

Rework: with a CCC (good material, sufficient material) and a planning, we can win 75% (0,56h)

Waiting: with a CCC (smaller trucks, adapted handling equipements) and a logistic planning and site planning (right time of the delivery): 50% (0,1)

Looking and transport : with a CCC (just in time, good material at the right place, etc…): 50% (0,25)

4.1.1.2.2 Paris

	Efficient work	Setup on construction site	Setup on material	Rework	Waiting	Looking and transport
Average h/day	6,02	0,43	0,27	0,01	0,03	1,24
%	75%	5%	3%	0%	1%	16%

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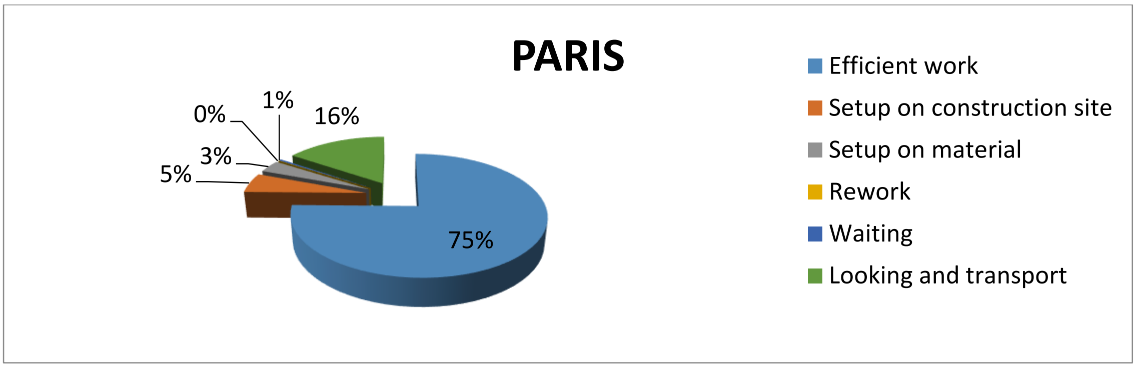
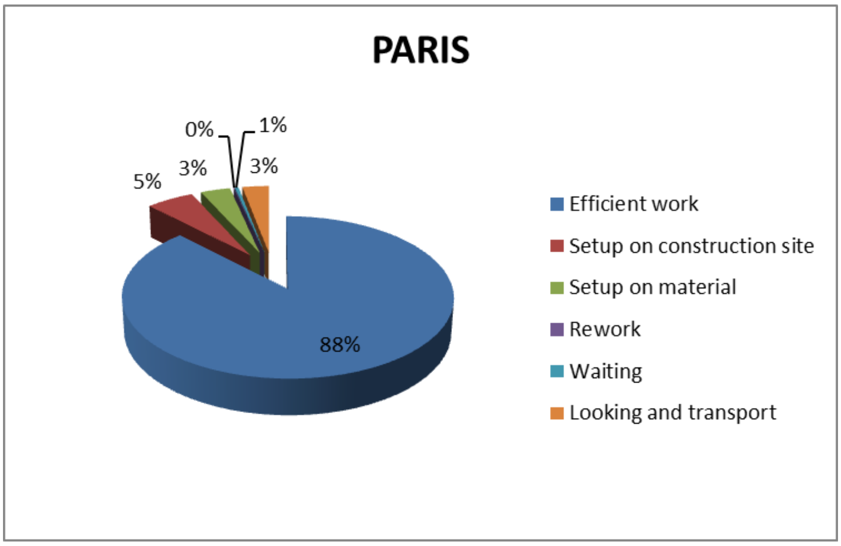


Figure 16: Distribution between time losses and efficient work per day for Paris

The effective working average time for each worker is important (75%). Only 25% of their time could be considered by a non-productive work.

In average, each worker spent 1H10 in **looking and transport**. In fact this time is not really relevant, only one material (Rockwool), impact this activity by approximately 13%. If we don't take into account this material, the new values are more representative with only 0H15 in **looking and transport**.



00H15 for looking and transport seems to be a time more relevant to the observed situations on Paris site. On the site a dedicated logistic team is responsible to unload trucks and to transfer goods from the unloading area to a storage area close to the utilisation point. In this case, workers have just a time to go to this storage area and to find their material in a small warehouse instead of finding it on the entire site.

Reasons:

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- Paris has a dedicated team for logistic who can unload trucks, and carried the products to the good warehouse located at each floor and at each strategic place.
- The logistic team have an updated map of the storage areas in order to know the available quantity of space on each floors warehouse.
- The logistic team have a specific tool in order to schedule and to organise the arrival of the truck on site. This solution helps the logistic team to have a constant work and not a heavy work only at some times during the day.

The workers spent around 0H05 in **waiting time.** For the same reasons as ahead, they have only few times dedicated for the following activities:

- Machine failure
- Work area to be cleared

Regarding the average waiting time in Paris, it seems to be efficient enough and it's difficult to get a more optimal time.

The **rework** is close to 0. During the data collection and on the material studied, workers performed only some limited rework on the material already installed.

However our study has been performed only on a limited set of material.

Regarding the **setup time on material and the set up on construction site**, it's about 0H35 It's difficult to improve it. This is partially linked with the fact that it's a refurbishment of a building and they don't construct a new one.

Paris targets

Regarding times in Paris, if we remove the Rockwool from the study, because it's not representative of the material analysed, they work more than 7H00 per day.

Working time is already well optimized thanks to the dedicated logistic team. The expected optimization on Paris site is marginal between 0 and 5 %.

4.1.1.2.3 Valencia

	Efficient work	Setup on construction site	Setup on material	Rework	Waiting	Looking and transport
average H / day	05 h 35	00 h 29	00 h 25	00 h 04	00 h 30	00 h 55
%	70%	6%	5%	1%	6%	12%

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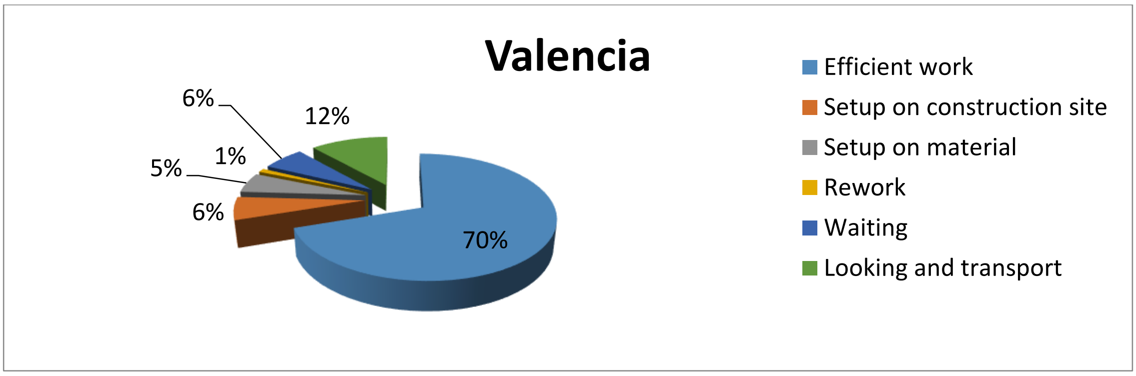

Figure 17: Distribution between time losses and efficient work per day for Valencia

The effective working time in Valencia is approximately 5H30 by day (representing 70% of the workers time). The **looking and transport time**, is mainly due to the size of the site. Indeed, if the site has no space problem in order to unload trucks, the consequence is that the storage area is often far from the point of use.

The **waiting time**, approximately 0H30, is mainly impacted by the waiting time of the workers related to the transport of the products between the storage and the point of use. During this transport time, workers wait for the material.

In order to reduce the waiting time, it is possible to use a dedicated team in order to make the transport a hidden time (during the working time of the workers).

The **rework** time is quite near 0, and works perform more readjustment than real rework.

The **setup on construction site** is mainly used to clean the material stocked outdoor during a long time. Indeed for these materials, a cleaning period of 0H30 seems to be necessary before the working time. This period can be optimized by a dedicated team who perform this task in hidden time.

The **setup on material** is mainly dedicated to provide a material with the right measures. This time can be optimized by a prefabricated activity. If a team is dedicated to move the goods and to prepare the material, workers can optimise the working time and can stay concentrated on their main work instead of losing time to stop their work, go to the warehouse, transport material and cut it at the good size.

In order to reduce the time loss, the main option is to perform some tasks in hidden time. If you specify a dedicated team in order to perform the transport and the setup on material, you can delete those loosing times but you can also reduce significantly the waiting time.

With a dedicated team, you can win 20/25% of efficient work.

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4.1.1.2.4 Verona

	Efficient work	Setup on construction site	Setup on material	Rework	Waiting	Looking and transport
Average h / day	6,25	1,10	0,52	0,01	0,08	0,04
%	78%	14%	6%	0%	1%	1%

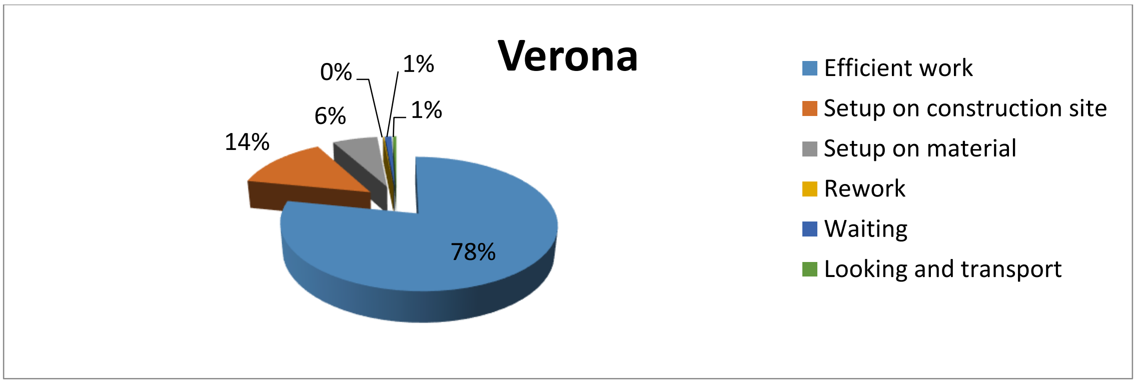

Figure 18: Distribution between time losses and efficient work per day for Verona

In Verona, the efficient working time is high, more than 6H15 on a day representing 78% of workers time.

In average, each worker spent only 0H04 in **looking and transport**. This time is spent essentially to find the material in the storage area. This time cannot be improved.

The **waiting** time, 0H08, is principally due to a non-availability of material on site. This time can be completely removed in a case of CCC. With the CCC it's possible to deliver on site the right quantity and to avoid the lack of material on site.

Only few **rework** activities on the site (2) with a relatively low impact and mainly due to a wall out of square

Regarding the **setup on material**, it's mainly a time dedicated to unpack the material. This type of time can be reduced by using a CCC, with a person who unpacks materials and preconditions in an easier manner for the site. With this solution, you cannot eliminate totally this time on site because it's always necessary to unpack materials.

Setup on construction site time with 1:05 is the most important time loss in Verona. This time is mainly dedicated to cleaning the workplace. It's a necessary time at the end of a production day. But it can be reduced by some

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lean methodologies, or by using a dedicated team in order to perform the cleaning.

With the data collected on Verona site, we can reduce the setup on material with a CCC and optimize the setup on construction site with lean or others solutions. In this case, the range of optimization can be defined between 5 and 10 % of the efficient work time.

4.1.2 Several handling time

Although necessary and non-avoidable, handling time is a non-value added activity. Ideally materials should be handled directly from the truck to the point of use. Below, the unnecessary handling time track:

- Count of the number of times when a selected material is moved within storage areas before its final installation
- Measure the time spent by the workforce for the several handling times

Unit: Expressed in number.

Closely related to the previous KPI, if the workforce spends lot of time in order to find goods it's because those goods are moved to another place and this for different reasons (they are located at a workplace, they are in advance and it's necessary to protect them from rain or heat, etc…).

The several handling is a non-productivity activity and has an impact more important than just the time of the moving. Indeed, in lot of case, before moving the materials, it is necessary to find a tool to perform the moving. If the site is important, this activity can be time consuming.

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4.1.2.1 Main Causes

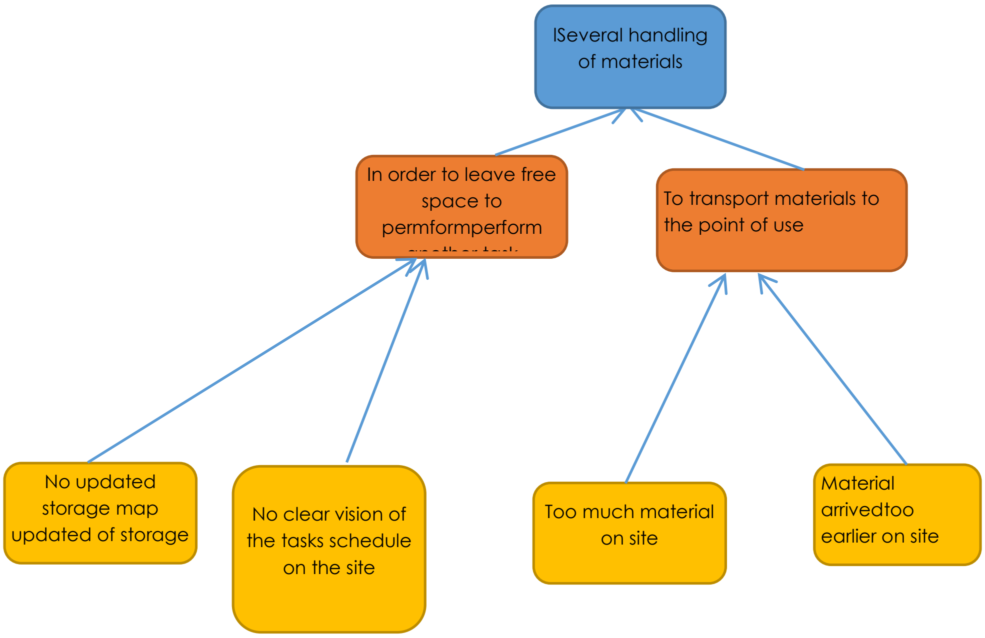

Figure 19: Causes of loss times needed to perform several handlings

4.1.2.2 Benchmarking

As for example, on the LCCC, the "Delivery reliability" (rework in connection with material issue + waiting time for the workforce + looking for material / equipment + several handling time) increased productivity of the labour force on the construction sites by up to 25 minutes per person day.

2008. London Construction Consolidation Centre - Final Report. Transport for London (TfL), UK.

And besides another positive outcome was the Increased productivity of the site labour force by up to 30 minutes per day. On a site employing 500, this is up to 250 hours per day saved, equating to 30 workers if working an eight-hour shift.

Lundesjo, G., 2011. Using Construction Consolidation Centres to reduce construction waste and carbon emissions. Wrap. The Logistics Business.

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4.1.2.3 Sites Analysis

4.1.2.3.1 Luxembourg

	Number of moving detected	Total duration of several handling	Average duration of one handling
Luxembourg	227	14:16	00:29

Table 18: Several handlings identified during data collection in Luxembourg

In Luxembourg, they moved regularly materials for two main reasons:

- Materials delivered too early on site or in too big quantity than necessary for the week job activities.
- Storage place must be recovered in order to perform a production task.

With a CCC it's possible to reduce in Luxembourg this important time. If we put in place a CCC, materials can be delivered the good day and are stored in a dedicated place, with only one moving.

In addition, the time used by the workforce to perform this activity is very high and have an important impact on the productive day

4.1.2.3.2 Paris

	Number of moving detected	Total duration of several handling	Average duration of one handling
Paris	24	8:05	0:20

Table 19: Several handlings identified during data collection in Paris

It's not relevant to fix an improving target in Paris. The number of several moving is not important linked to the dedicated logistic team who performs the moving to a storage area near the point of use.

4.1.2.3.3 Valencia

	Number of moving detected	Total duration of several handling	Average duration of one handling
Valencia	0	-	-

Table 20: Several handlings identified during data collection in Valencia

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Due to available storage area on the site, workers can put material where it's necessary. In this situation the site does not record any several handling.

In this case the advantage of a CCC is not relevant.

4.1.2.3.4 Verona

	Number of moving detected	Total duration of several handling	Average duration of one handling
Verona	22	34:00	01:32

Table 21: Several handlings identified during data collection in Verona

In Verona they don't have lot of moving, but they take long time due to the limited availability of the handling equipment. In this situation, a CCC can improve this time, because only few materials are on site and hauliers can unload only when the workers and the handling equipment are available.

4.1.2.4 Conclusion

Based on the collected data except in Luxembourg where potential savings seem to be important, potential savings on this indicator is null on the others sites:

- For Valencia pilot site it is mainly due to the site configuration,
- For Paris pilot site it is due to the logistic organization implemented: a dedicated logistic team and a specific organization of the storage area
- For Verona, there is no obvious explanation so far. Further analysis would be necessary to identify precisely the lack of losses time due to several handlings.

4.2 Truck punctuality

4.2.1 Definition and explanation

The punctuality of deliveries and pick-up is defined as the difference between the planned delivery time and the truck arrival time near the construction site.

Truck punctuality = planned (scheduled) delivery time – Arrival time near the construction site

If truck punctuality Is positive it means that truck arrives before the planned delivery time. If truck punctuality is negative it means that truck is late.

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Obviously, when the delivery time is not defined, the indicator is not calculated. In this specific case, the time loss is not estimated.

Unit: Expressed in h.

Identified potential causes of negative truck punctuality are the followings:

- Traffic jam
- Carriers schedule changes
- Suppliers out of stock
- Delays in the production of materials
- Others carriers or suppliers issues …

We have actually no data that allow us to pinpoint what cause between traffic jam and others carrier's issues are the most important factor of negative truck punctuality. What we can just say is CCC implementation impact on the supply chain processes is mainly in favour of truck punctuality.

So **to fix a first target on truck punctuality the main idea is** to compare LCCC feedbacks in terms of the capacity of the construction site to unload a delivery on time.

4.2.2 Benchmarking

At the LCCC, in South Bermondsey, 5,393 deliveries made, of which around one-sixth required 'just-in-time' delivery (i.e. less than 24 hours), which would have been more difficult to achieve with normal delivery arrangements.

Also it was possible to improve the overall reliability of the supply chain, as the 97% on-time delivery from the LCCC to site was almost four times greater than the 24% on-time delivery achieved by suppliers into the LCCC.

2008. Thames Gateway FQP (Construction Sector Scoping study). Intermodality LLP, UK.

At the LCCC it was a reached an 'achievement of delivery performance of 97% of goods delivered right first time.'

Lundesjo, G., 2011. Using Construction Consolidation Centres to reduce construction waste and carbon emissions. Wrap. The Logistics Business.

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In *the* One Hyde Park *project:*

93 % of materials arrive at the Construction Consolidation Centre on time, 100 % of materials arrive at *the construction site on time ("on time"* being defined as a delivery being made within 15 minutes of its allotted delivery slot), 100 % of materials arrive in the right quant*ity and in the right condition*

Using Construction Consolidation Centres to reduce deliveries and waste at One Hyde Park. Wrap.

Taking into account LCCC feedback (table below), trucks are late in 3% of cases (162 late deliveries on 5393 deliveries). Explanation may be found in the fact that deliveries can be performed outside peak periods, that they are less impacted by carriers planning variability or another carrier cause.

Site	No. of Call-Offs	Failed Call-Offs	Late Deliveries	Equipment Failed	Site Rejection	Crane Called Off	Percentage of Successful Call-Offs
Unilever	4266	197	138	22	23	12	95%
Basinghall St.	730	27	23	4	0	0	96%
Coleman St.	305	2	1	0	0	0	99%
Bow Bells House	92	0	0	0	0	0	100%
Total	**5393**	**226**	**162**	**26**	**23**	**12**	**96%**

(Data: January 2006 – April 2007)

Table 22: 2007. London Construction Consolidation Centre: Case of study. Freight Best Practice, Transport for London (TfL).

4.2.3 Sites Analysis

4.2.3.1 Luxembourg

4.2.3.1.1 Data

On Luxembourg's site, 35 out of 244 scheduled deliveries arrived after the planned delivery time and were unloaded after the planned time due to truck delay.

So 14% of trucks arrived late at the construction site. Truck punctuality for Luxembourg construction site is then 86%.

4.2.3.1.2 Targeting Improvements

If we consider that with a CCC, the service target achieved by the truck in a punctuality perspective can be the same as demonstrated through LCCC experimentation, the percentage of truck arriving to late could drop from 14% to 3% in the Luxembourg case.

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For Luxembourg pilot this improvement of the truck punctuality would have generated a delay for only 8 trucks instead of 35 as identified during the data collection period

4.2.3.2 Paris

4.2.3.2.1 Data

On Paris' site, 231 out of 766 scheduled deliveries arrived after the planned delivery time and were unloaded after the planned time due to truck delay.

So 30% of trucks arrived late at the construction site. Truck punctuality for Paris construction site is then 70%.

4.2.3.2.2 Targeting Improvements

If we consider that with a CCC, the service target achieved by the truck in a punctuality perspective can be the same as demonstrated through LCCC experimentation, the percentage of truck arriving to late could drop from 30% to 3% in the Paris case.

For Paris pilot this improvement of the truck punctuality would have generated a delay for only 23 trucks instead of 231 as identified during the data collection period.

4.2.3.3 Valencia

4.2.3.3.1 Data

On Valencia's site, 11 of 743 scheduled deliveries arrived after the planned delivery time and were unloaded after the planned time due to truck delay.

- So 1% of trucks arrived late at the construction site. Truck punctuality for Valencia is then 99%.

4.2.3.3.2 Targeting Improvements

If we consider that with a CCC, the service target achieves by the truck in a punctuality perspective can be the same as demonstrated through LCCC experimentation, the percentage of truck arriving to late could not be reduced. Indeed, for Valencia pilot truck punctuality results is already better than those observed during LCCC implementation.

Potential explanations:

- the specificity of the type of deliveries (74% of deliveries are concrete deliveries) that is less subject to the potential causes exposed before
- the location of the construction site that is not enough in a congested urban area which could justify CCC advantages with regards to truck punctuality

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4.2.3.4 Verona

4.2.3.4.1 Data

On Verona's site, 11 out of 22 scheduled deliveries arrived after the planned delivery time and were unloaded after the planned time due to truck delay

- So 50% of trucks arrived late at the construction site. Truck punctuality for Verona is then 50%.

4.2.3.4.2 Targeting Improvements

If we consider that with a CCC, the service target achieve by the truck in a punctuality perspective can be the same as demonstrated through LCCC experimentation, the percentage of truck arriving to late could be reduced from 50% to 3% in the Verona case.

For Verona pilot this improvement of the truck punctuality would have generated a delay for only 1 truck instead of 11 as identified during the data collection period.

However for Verona the number scheduled deliveries (22) is quite low with regards to the total number of deliveries, so conclusions have to be taken carefully and more data would be needed in order to generalise the site conclusions.

4.2.4 Conclusion

	Current trucks late	Excepted results
Neudorf Breweries Complex (Luxembourg)	14%	3%
Îlot Fontenoy Ségur (Paris)	30%	3%
Valencia Parque Central (Valencia)	1%	1%
Borgo Trento Hospital (Verona Borgo Trento)	50%	3%

Table 23: Targets for truck punctuality per pilot site

Based on the figures analysed for Paris and Luxembourg, potential gains are more important in big cities with a construction not located near the border of the urban area. Indeed in Luxembourg the site is located near the border of the urban and the potential improvements are potentially based on the possibility to avoid carriers or suppliers issues.

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In Verona the number of planned deliveries is not enough to be able to draw representative conclusions and in Valencia the deliveries characteristics do not allow improvement on this indicator.

4.3 Time dedicated to logistic activities

A list of logistic activities has been defined in order to evaluate the hours that could be saved with a CCC. An evaluation of the time dedicated to all the logistic activities has been performed. The time dedicated to logistic activities is the time spent on each of the defined activities

Without CCC feedbacks on this indicator, qualitative analysis is performed with regards to standards CCC processes and expectations. The qualitative analyse provide hereafter some trends for each type of logistic activities identified.

We don't put in this deliverable all the quantitative results of the as-is situation per pilot site because no quantitative targets are defined here. All these data are available in deliverable 2.4

Regarding the part of **order management**, the time spent on this activity going overall increase because of the increased interactions with the CCC. So as to be delivered daily construction sites, will need to place orders every day.

For **material validation time**, the discussion was only between the customer and the site team. The introduction of a CCC or other logistic optimization means will not change significantly the time spent on this activity

Regarding the **deliveries issues**, it is possible to drastically reduce the problems generated by deliveries. With a CCC, the trucks will be adapted and more easily manoeuvrable. Moreover, simultaneous deliveries should be avoided. Therefore deliveries issues should be reduced.

Regarding the **management of the site requirements**, with a CCC, sites will have to spend more time to identify, track and establish the schedule of activities. This task will require a greater involvement of supporting teams, and their activities will increase when compared to the current situation.

For the **storage area management**, it is possible to reduce the surface occupied by materials with the introduction of the CCC and by reducing the amount of materials on site.

For the **reverse logistic management** time, it's possible to optimize the time dedicated to this activity by using a CCC. The number of order may increase related to the fact that the number of bins will increase. In order to optimize this time, it's possible to set up a contract with the subcontractor in order to bring in a systematic way the bins.

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	Qualitative targets
Order management:	Increase
Material validation:	No impact
Deliveries issues:	Decrease
Management of the site requirements:	Increase
Manage the site movements and storage area:	Decrease
Reverse logistic management:	Decrease

Table 24: Qualitative targets for logistics activities

4.4 Costs of unsorted bins

In some cases different wastes could be put in a single bin. So the waste will be sorted by the subcontractor that collects the waste. This additional sorting activity is a cost that could be avoided. The cost of unsorted bins is the price invoiced by the subcontractor expressed in €.

4.4.1 Causes

It's not possible to find a benchmark on this subject; however by analysing the causes of unsorted bins, two main reasons appear:

- Lack of discipline
- Not enough available bins on site for each type of waste
- Bins not close enough to the working places and require too much time for the subcontractors

4.4.2 Solutions

With a CCC, it's possible to reduce the costs of the unsorted bins in two ways:

- Sorting of the bins can be performed by the CCC resources in order to be sure to send to the subcontractor properly sorted bins.

- CCC introduction can allow increasing the bins rotation with smaller bins. This solution could remove the two lasts causes identified before: Use smallest bins can allow to put more bins on the site and to locate ideally the bins close to the working places to reduce the subcontractor time to put the waste in the correct bin.
  This solution could reduce drastically the number of unsorted bins provided by the sites without avoiding lack of subcontractor's discipline.

With this solution all the unsorted bins costs invoiced by the waste management company are removed for the construction companies. However all the

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activities transfer to the CCC (sort bins, consolidate small bins in bigger bins used by the waste manager, supply small and adapted bins …) have a cost.

The global return on investment of this solution **will be quantified after the simulation and integrated in the following tasks of the SUCCESS project**, taking into account the **additional costs.**

4.4.3 Targets

By implementing the solution proposed a reduction of 80% seems to be achievable and provide the following savings on each pilot site for the construction companies:

Pilot Site	Current costs per month	Target improvement	Expected costs per month
Luxembourg	770€	80%	154€
Paris	7131€	80%	1426€
Valencia	690€	80%	138€
Verona	1468€	80%	294€

Table 25: Targets improvement for costs of unsorted bins

4.5 Number of accidents

4.5.1 Definition and explanation

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

4.5.2 Benchmarking (projects using the CCC)

"In Wilson James (at Silvertown) the operator and owner of a Consolidation centre, claims that by it a 25% reduction in accidents/injuries is achievable."

http://www.wilsonjames.co.uk/case-study-6-construction-consolidation-centre-.html

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4.5.3 Sites Analysis

4.5.3.1 Luxembourg

	Number of accidents due to logistic	Number of global accident	Reasons
Luxembourg	2	10	No appropriate handling mean Confined and no adapted storage area

Table 26: Number of accidents due to logistic for Luxembourg

4.5.3.2 Paris

	Number of accidents due to logistic	Number of global accident	Reasons
Paris	2	11	Wastes handling

Table 27: Number of accidents due to logistic for Paris

4.5.3.3 Valencia

	Number of accidents due to logistic	Number of global accident	Reasons
Valencia	1	-	In the refurbished building manipulating materials

Table 28: Number of accidents due to logistic for Valencia

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4.5.3.4 *Verona*

	Number of accidents due to logistic	Number of global accident	Reasons
Verona	0	-	

Table 29: Number of accidents due to logistic for Verona

4.5.4 Targets

It's possible to reduce by 100 % the number of accidents linked to logistic activities on all sites. Given that in average for the observed sites, accidents due to logistics issues represent 20% of the number of accidents, one can expect an improvement of 20% of the number of accidents, which is in line with the benchmark. An economic analysis can find a financial return of investment on this matter.

Pilot Site	Current number of accidents	Target improvement	Expected number of accidents
Luxembourg	10	20%	8
Paris	11	20%	9
Valencia	N/A		
Verona	N/A		

Table 30: Target improvements on the number of accidents

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4.6 Congestion on construction site

4.6.1 Definition and explanation

The congestion on construction site is defined as the space used by vehicles at the construction site during the loading/unloading activities, which includes also the waiting time. This indicator reflects the inconvenience related to deliveries. The implementation of a CCC and a supply chain optimisation should reduce congestion on and around the site in optimising deliveries and reduce the nuisance for the neighbourhood.

Unit: Expressed in m^2h.

This indicator is interesting in order to reschedule the deliveries. It's possible to limit the congestion on construction site, if trucks arrives more linearly.

4.6.2 Benchmarking (projects using the CCC)

- *Consolidating goods at the LCCC eliminated the use of articulated goods vehicles for site delivery, and significantly reduced the use of vans.*

- *Unilever House, of all deliveries made from the LCCC, 98 per cent were made by rigid goods vehicle and 2 per cent by van. By comparison, of the direct deliveries to the site by suppliers (i.e. not using the LCCC), 13 per cent were made by articulated goods vehicles, 49 per cent by rigid goods vehicles and 39 per cent by vans'. (***congestion on construction site***)*
  2016. The Directory of London Construction Consolidation Centre. Transport from London (TfL), UK.

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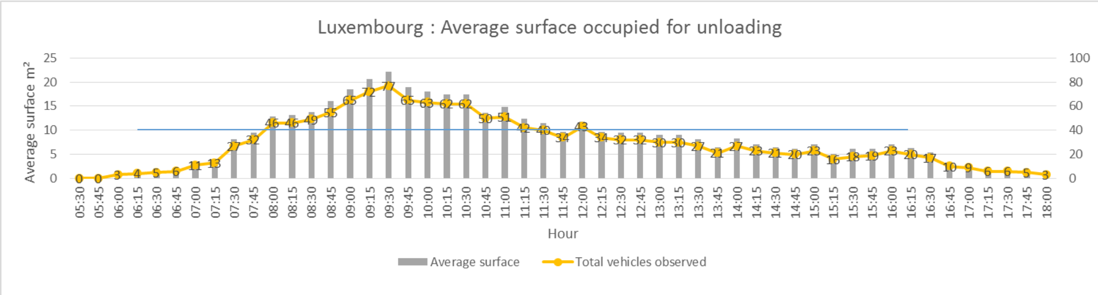
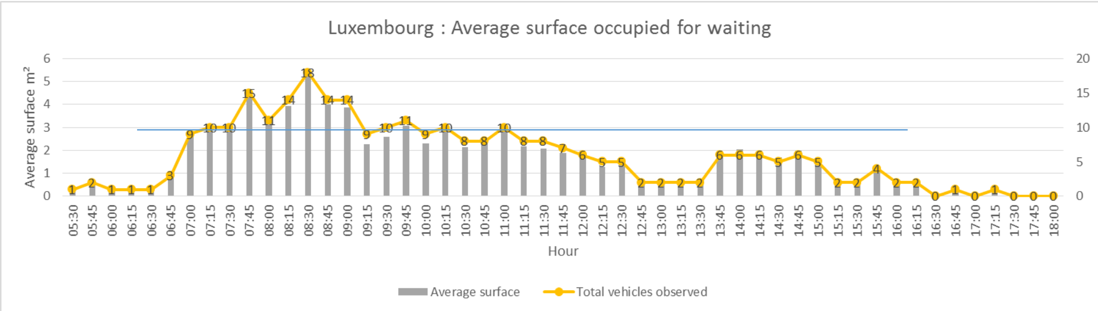
4.6.3 Sites Analysis

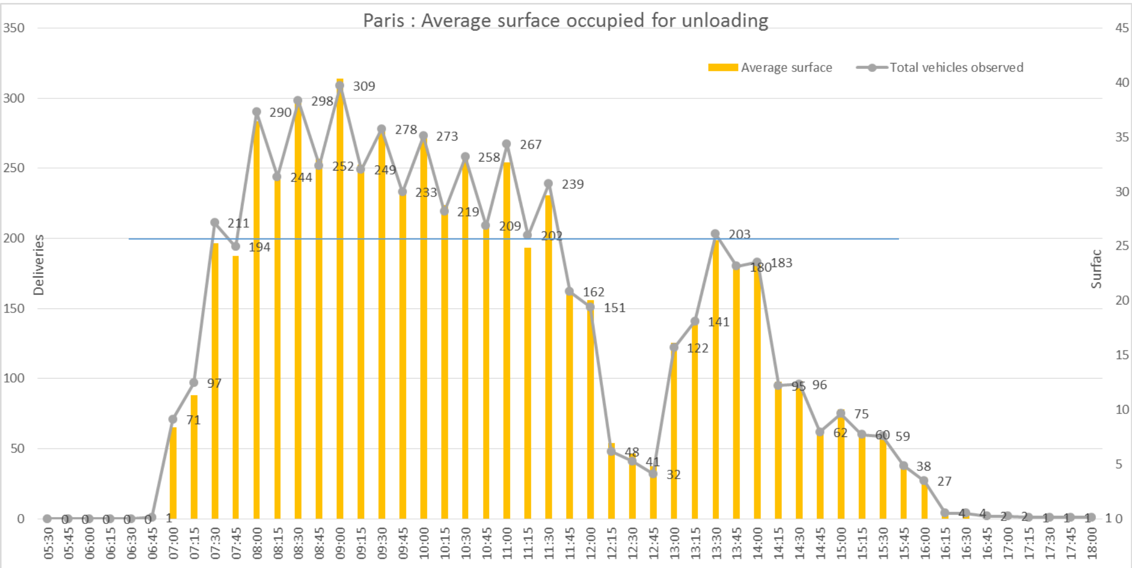
4.6.3.1 Luxembourg



The peak of deliveries is in the morning. If more hauliers arrive in the afternoon and less in the morning, it's possible to optimize the waiting time and consequently the congested surface on the construction site.



4.6.3.2 Paris



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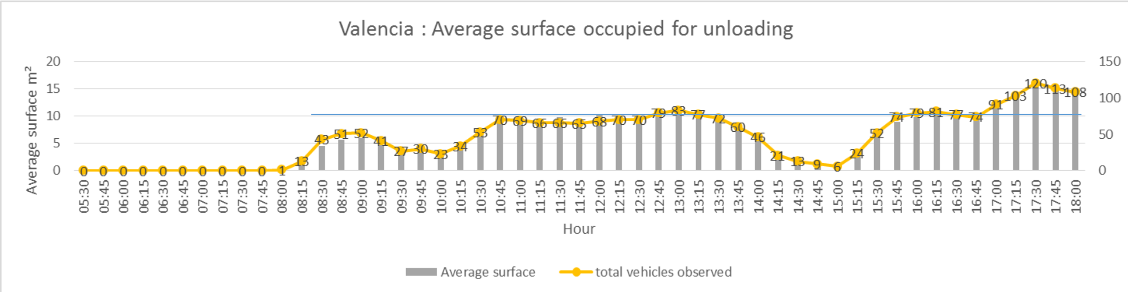
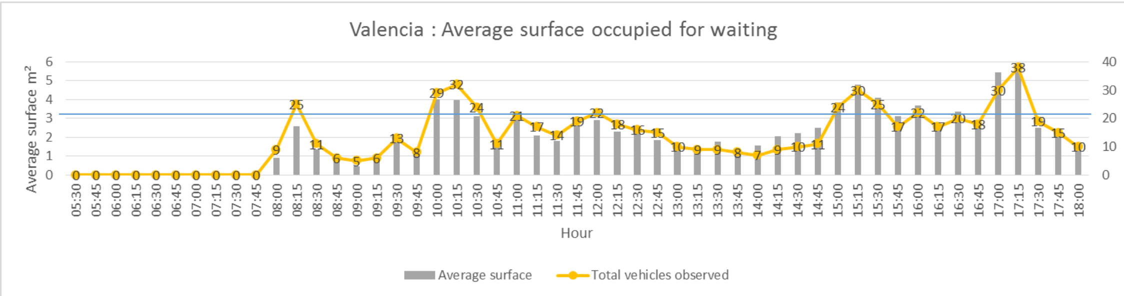
The same analysis than in Luxembourg can be made for Paris. The peak of deliveries is in the morning. If more hauliers arrive in the afternoon and less in the morning, it's possible to optimize the waiting time and consequently the congested surface on the construction site.

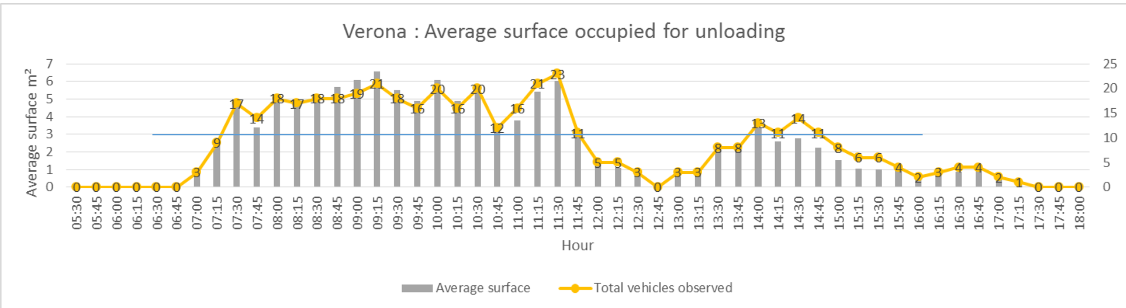
4.6.3.3 *Valencia*



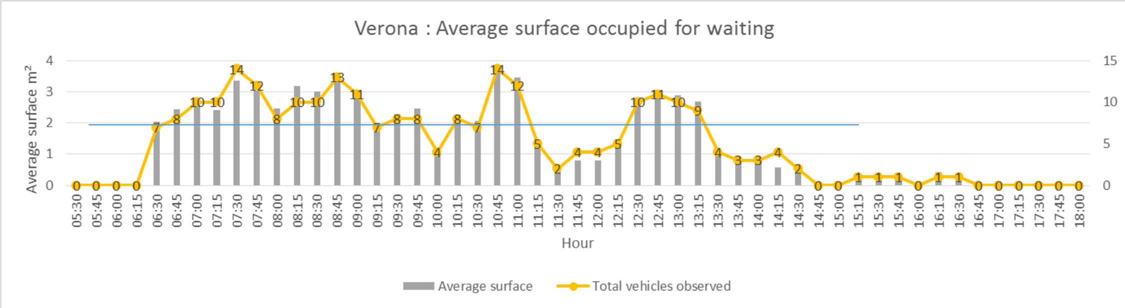


The same analysis can be made although the peak in mainly in the afternoon. If more hauliers arrive in the morning and less in the afternoon, it's possible to optimize the waiting time and consequently the congested surface on the construction site.

4.6.3.4 *Verona*



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



The same analysis than in Luxembourg and Paris can be made for Verona. The peak of deliveries is mainly in the morning. If more hauliers arrive in the afternoon and less in the morning, it's possible to optimize the waiting time and consequently the congested surface on the construction site.

4.6.4 Targets

Either with a CCC or with a supply chain optimisation, it is possible to smooth and limit the number of deliveries on the construction sites all the day long. By doing so, one can assume that only one delivery truck at a time would be allowed on the construction site. Given that in average a delivery truck has a surface around 20m², the **congestion** target would be a **maximum congested area of 20 m² per time unit** (in our case the time unit is 15 minutes).

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5 Savings for public

5.1 Pollutant emissions (CO_2 equivalent, PM)

5.1.1 Definition and explanation

CO_2 emission is defined as the total CO_2 emissions emitted by the vehicles during the evaluation period. Other gases will be added in the calculation as CO_2 equivalent: methane (**CH_4**) and nitrous oxide (**N_2O**). These two gases are also emitted from fossil fuels combustion and have a high greenhouse gas effect potential.

Unit: Expressed in g.

PM is defined as the total Particulate Matter emissions (PM2.5, PM10) emitted by the vehicles during the evaluation period.

Unit: Expressed in g.

We group CO2 and PM emissions because they are highly correlated when considering transport as the source of pollutants emissions.

5.1.2 Benchmarking (projects using the CCC)

- *Estimated 70-80 per cent reduction of CO2 emissions as a result of the reduction in vehicle movements compared with if all deliveries had been made direct to the construction sites (however, this only refers to the relatively short journey from the consolidation centre to the construction sites)'. (**CO2 equivalent**)*

  2008. London Construction Consolidation Centre - Final Report. Transport for London (TfL), UK.

- *According to the LCCC in South Bermondsey, 'an estimated 74% saving in CO2 emissions across the three delivery sites for which data was available'. (**CO2 equivalent**)*

  2008. Thames Gateway FQP (Construction Sector Scoping study). Intermodality LLP, UK.

*It was also recognised a 30 percent reduction in local **atmospheric pollution**, as part of the results of the MoCC.*

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Wilston Ltd, S., 2010. Freight Consolidation Centre Study-Final Report. South East Scotland Transport Partnership.

Reduction for deliveries from consolidation centre of 90% in PM. (***PM***)

Case of study - An international vision of success: The Hammarby Construction Consolidation Centre (TfL)

- *The LAMILO project has analysed that, among the 3 CC pilots' experiments, the CO2 emissions have been reduced between 7% for one pilot to more than 80% for another pilot.*

2015. Last Mile LOgistics project

5.1.3 Sites Analysis

5.1.3.1 Luxembourg

Indicator	Luxembourg
CO2/delivery (kg/delivery)	32
CO2/km (kg/km)	0,26
PM/ delivery (g/delivery)	8,5
PM/km (g/km)	0,07

5.1.3.2 Paris

Indicator	Paris
CO2/delivery (kg/delivery)	27
CO2/km (kg/km)	0,34
PM/ delivery (g/delivery)	5,7
PM/km (g/km)	0,07

5.1.3.3 Valencia

Indicator	Valencia
CO2/delivery (kg/delivery)	20
CO2/km (kg/km)	0,41
PM/ delivery (g/delivery)	3,0
PM/km (g/km)	0,06

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5.1.3.4 Verona

Indicator	Verona
CO2/delivery (kg/delivery)	79
CO2/km (kg/km)	0,30
PM/ delivery (g/delivery)	16,1
PM/km (g/km)	0,06

5.1.4 Targets

With a CCC, pollutant emissions savings can be due to multiples factors depending on the CCC configuration. Among others: cleaner and/or smaller vehicles used by the CCC, increased vehicles loaded, decreased number of deliveries, trips during off-peak hours …

We understand from the LCC example that the important emissions saving were estimated by comparing the ex-ante trips performed by suppliers from their last storage location to the construction site with the ex-post trips from the CCC to the construction site. By doing so in the ex-post analysis, the trips from the suppliers' last storage location to the CCC are excluded from the pollutants emissions analysis. This explains the important savings mentioned (around 80%).

In our case we propose targets that would be measured taking into account the whole travel from the last storage location to the construction site (and not limiting the analysis to the urban part of each trip). Therefore our improvement targets would be more limited, around 15% of pollutant emissions saved by using CCC. This 15% target is defined by comparing benchmarks and due to the limited benchmarks details and parameters, the figure remains hypothetic and will need to be further explored by the simulation tasks of the project.

Last, for comparison purpose, it seems more relevant to defined targets on pollutant emission per delivery rather than on the absolute value.

Site	Indicator	Value from the As-Is analysis	Target	Valued target
Luxembourg	CO_2	32 (g)/ delivery	15%	27,2 (g)/ delivery
Luxembourg	PM	8,5 (g) / delivery	15%	7.2 g/delivery
Paris	CO_2	27 (g)/ delivery	15%	23 g/delivery

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Site	Indicator	Value from the As-Is analysis	Target	Valued target
Paris	PM	5,7 (g) / delivery	15%	4.8 g/delivery
Valencia	CO_2	20 (g)/ delivery	15%	17 g/delivery
Valencia	PM	3,0 (g) / delivery	15%	2,5 g/delivery
Verona	CO_2	79 (g)/ delivery	15%	67 g/delivery
Verona	PM	16,1 (g) / delivery	15%	13,7 g/delivery

5.2 Number of deliveries

5.2.1 Definition and explanation

The number of deliveries is the number of truck arriving at the construction site to load/unload materials.

Unit: Expressed in number.

5.2.2 Benchmarking (projects using the CCC)

For those materials delivered via the LCCC, it is estimated that there was a 60-70 per cent reduction in the number of vehicles delivering to the four sites being served.

When taking account of all deliveries from suppliers, there was a reduction of approximately 40 per cent in total vehicle deliveries in the case of Unilever House (which was the best managed site in that it had the lowest proportion of deliveries direct).
Approximately 3000 goods vehicles did not enter the London Congestion Charging Zone over the two-year pilot as a result of the LCCC.

2008. London Construction Consolidation Centre - Final Report. Transport for London (TfL), UK.

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5.2.3 Sites Analysis

5.2.3.1 *Luxembourg*

5.2.3.1.1 Data

	Building Gross floor area	Number of deliveries
Luxembourg	11.400 m²	343

Table 31: Number of deliveries for Luxembourg

5.2.3.1.2 Targeting Improvements

According to the benchmarking, it's possible to estimate to reduce the number of vehicle deliveries which will reach the construction site (-40%). In the case of Luxembourg, the number of deliveries received by the construction site would be 251 deliveries instead of 343.

5.2.3.2 *Paris*

5.2.3.2.1 Data

	Building Gross floor area	Number of deliveries
Paris	55.475 m²	1695

Table 32: Number of deliveries for Paris

5.2.3.2.2 Targeting Improvements

According to the benchmarking, it's possible to estimate to reduce the number of vehicle deliveries which will reach the construction site (-40%). In the case of Paris, the number of deliveries received by the construction site would be 1 017 deliveries instead of 1 695.

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5.2.3.3 Valencia

5.2.3.3.1 Data

	Building Gross floor area	Number of deliveries
Valencia	7.772 m²	756

Table 33: Number of deliveries for Valencia

5.2.3.3.2 Targeting Improvements

According to the benchmarking, it's possible to estimate to reduce the number of vehicle deliveries which will reach the construction site (-40%). In the case of Paris, the number of deliveries received by the construction site would be 454 deliveries instead of 756.

5.2.3.4 Verona

5.2.3.4.1 Data

	Building Gross floor area	Number of deliveries
Verona	44.034 m²	171

Table 34: Number of deliveries for Verona

5.2.3.4.2 Targeting Improvements

According to the benchmarking, it's possible to estimate to reduce the number of vehicle deliveries which will reach the construction site (-40%). In the case of Paris, the number of deliveries received by the construction site was: 103 deliveries instead of 171.

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5.2.4 Conclusion

	Number of deliveries received by the site before CCC	Number of deliveries with a CCC
Luxembourg	**343**	**251**
Paris	**1695**	**1017**
Valencia	**756**	**454**
Verona	**171**	**103**

Table 35: Targets for the number of deliveries per site

With this analyse, it's possible to see that the number of trucks and of deliveries arriving directly to the site can be reduced thanks to a better use of trucks' capacity.

It's also possible to reduce the number of deliveries before the CCC if it's possible for the haulier to optimize the rate of loading of the truck. This deeper analyse could be done in Luxembourg for 105 deliveries and can be interesting for the haulier route and for the business model of the CCC.

By limiting the number of deliveries, the number of vehicles circulating in the city will decrease, and thus city congestion will be limited. Moreover LCCC benchmark showed that articulated truck can be avoided in the city centres.

5.3 Rate of obstructing vehicles

5.3.1 Definition and explanation

The rate of obstructing vehicles is the number of vehicles parked illegally in the streets nearby the construction site over the number of total deliveries for the site.

5.3.2 Benchmarking (projects using the CCC)

- *Bart and Central St Giles case of study, show significant reductions (c.75%) in vehicle traffic to site.*

- *Environmental: if 75% of material were delivered via the CCC there would be a 50% reduction in local traffic and emissions.*

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Lundesjo, G., 2011. Using Construction Consolidation Centres to reduce construction waste and carbon emissions. Wrap. The Logistics Business.

❖ *The MoCC achieved a 38 percent reduction in traffic congestion.*

Wilston Ltd, S., 2010. Freight Consolidation Centre Study-Final Report. South East Scotland Transport Partnership.

By analysing the benchmarks we note that no other CCC experiment has used the precise concept of rate of obstructing vehicles. Instead CCCs report a reduction in traffic congestion which is more generic. Therefore we cannot use benchmark comparison to set our targets.

5.3.3 Sites Analysis

Pilot site	Rate of obstructing vehicles
Luxembourg	33,3%[3]
Paris	57,5% [4]
Valencia	0,0%
Verona	11,6%[1]

Table 36 : Rate of obstructing vehicles per pilot site

Most of the obstructing vehicles are due to vehicles arriving early or site being late, and the driver has to park his vehicle in order to ask for the unloading location of the site.

5.3.4 Targets

With a CCC, a large majority of the deliveries would be performed by the CCC vehicles (shuttle service). Then the drivers would know the unloading location and the delivery slots schedule would not overlap. As a consequence, the vehicle would not have to park illegally nearby the site and the **rate of obstructing vehicles** would **drop to 0%.**

[3] *Ratio to the number of deliveries*

[4] *Ratio to the number of visual checks*

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With a supply chain optimization, the deliveries would be scheduled with enough buffers to limit the vehicles overlapping. However we cannot totally avoid trucks arriving early and possibly congesting the surrounding streets. A buffer area could be put in place to allow truck waiting outside the site but not being illegally parked. Again the **rate of obstructing vehicles** would **drop to 0%.**

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6 CONCLUSION

To conclude, this deliverable proposes a target improvement for the indicators defined in D2.2. These targets are in some cases (when a benchmark is not available) based on a problem analysis and in other cases on a benchmark on the experience of existing CCCs. For each possible improvement identified we propose, per main beneficiary, the summary of the advantages emphasized in this deliverable.

6.1 Hauliers

Potential improvements for hauliers have been highlighted on two aspects: first on the haulier journey time and secondly on the haulier route.

6.1.1 Vehicle journey time

The improvement targets proposed on the vehicle journey time are quite different for the 4 pilot sites: 2 hours 8 minutes for Luxembourg, 2 hours 37 minutes for Paris, 1 hour 19 minutes for Valencia and 2 hours 15 minutes for Verona. On the one hand, this proposition is aligned with one of the conclusions of D2.4 that emphasizes that being located in an urban area is not enough to ensure that a CCC is relevant. Indeed, some specific characteristics were defined in D2.4 and are confirmed by these targets. On the other hand, regarding existing CCCs, our analysis confirms the results reported by the London Consolidation Centre: all the pilot sites could gain around 2 hours. For KPIs that increase haulier journey time, only travel time will be calculated with a simulation. For the others KPIs, an evaluation with the main stakeholders of the problem analysis performed in this task will allow to adjust the improvement targets if needed.

6.1.2 Haulier route

From a haulier route perspective, at this stage of the project, providing a precise target for each construction site is not possible without simulation results. However, by assuming that all deliveries coming from an intermediate storage location will come, thanks to the implementation of a CCC, directly from the producer, an important saving can be forecasted for this KPI. Secondly, construction site potential improvements have been identified on the construction operating costs, but also on safety issues, logistic management activities and costs of waste management.

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6.2 Construction sites

6.2.1 Impact on the operating costs

In terms of impact on the operating costs of the **construction sites**, the introduction of a CCC should reduce the causes of losses of time for the workers and consequently improve significantly the productivity of the construction site (reducing the time needed for unnecessary handling, optimising the material availability, etc.).

However, the improvement targets proposed point to the fact that productivity improvements depend also of the contractor's maturity level in terms of logistics processes and tools: that is to say that the investment already done by the contractors in the improvement of their logistics processes and tools (e.g. with a delivery management system, dedicated logistic team, systematic storage drawings, etc.) has a major impact on the potential savings that could be gained thanks to a CCC. In Paris the potential saving identified is only 5% while in Luxembourg it is almost 20%.

6.2.2 Safety on construction sites

Assuming that a CCC drastically reduces the amount of material on the construction site and offers adequate handling means, the experience of existing CCC shows that around 20% of accidents are avoided. The data collected on the Paris and Luxembourg sites confirms this ratio. Indeed, around 20% of the existing accidents are caused by a logistic issue (no use of appropriate handling mean, congested storage area) that could have been avoided with a CCC.

6.2.3 Other impacts on construction sites

The introduction of a CCC has an obvious impact on productivity and safety. However, this deliverable shows that it can have a positive impact on logistic management activities and on the costs of waste management, too.

Even if it could slightly increase the material ordering process, it is demonstrated that the management of both the deliveries and the storage area in the same site is also a source of significant gains.

Moreover, with the present way of managing bins on the sites, all the pilots have a significant cost of unsorted bins. By introducing a CCC and more specifically using it to improve waste management, new ways of working could also reduce these costs.

6.3 Cities

Thirdly, a potential reduction of the negative impact of construction logistic on cities has also been identified. By demonstrating that a CCC can bring major improvements on both truck and construction site punctuality, reduction of the

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negative externalities of construction logistic is confirmed. Furthermore, the potential reduction of the travelled distance will also confirm the reduction of transport related pollution.

6.3.1 Service level improvement and rate of obstructing vehicles

By using feedbacks from existing CCCs completed with a problem analysis we identified that punctuality (either truck's and site's) is considerably improved (up to 30%) thanks to avoiding trucks arrival time variability due to traffic jams, carriers' schedule changes and other carriers' or suppliers' issues and ensuring handling resources availability thanks to a better delivery schedule and potentially to the use of handling equipment on the truck ("CCC shuttle").
As for some of the KPIs included in the haulier journey time, an evaluation of the problem analysis performed in this task will allow to adjust the improvement targets because these KPIs cannot be calculated by using models.

However, these major improvements contribute to the high expectations on the rate of obstructing vehicles (up to 30% of reduction). This indicator was used to put in evidence the negative impact of deliveries on traffic jam and urban congestion.

6.3.2 Number of deliveries and reduction of transport related pollutant emissions

We propose some targets significantly smaller than those based on the feedback from existing CCCs because, in our opinion, the analysis they performed was not totally consistent and secondly, because the results of the LaMiLo project[5] showed also less important improvements in terms of transport related pollutant emissions. Our proposition is aligned with the proposition already made in the SUCCESS project proposal. These targets will be compared to simulation results thanks to a more precise calculation of the number of deliveries by taking into account the potential location of the CCC for each pilot site and the hypothesis on type of trucks and the improved organisational processes.

In conclusion, this deliverable, as the corner stone between the As-Is analysis and the design of new solutions, confirms that CCCs can give some advantages and savings to all the construction stakeholders. Furthermore, it identifies the main components of the solutions that could bring these savings. This will provide good inputs for the following tasks of the project and more specifically those dedicated to scenarios design.

[5] See http://www.lamiloproject.eu

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Annex 1: List of KPI that can / cannot be calculated by using modelling

Category	KPI designation	Unit	Can it be calculated using models?
Economic / haulier journey time	Travel time (outside and in the city centre)	hours	YES
	Waiting time (due to early arrival and to construction site)	hours	NO
	Loading / unloading time	hours	NO
Economic / haulier route	Number of intermediate storage	Number	YES
	Distance from the production to the construction site	Km	YES
Economic / workforce productivity	Rework in connection with material issue	Hours	NO
	Waiting time for the workforce	Hours	NO
	Looking for material / equipment	Hours	NO
	Several handling time	Number	NO
	Punctuality of deliveries and pickup	Hours	YES
Economic / supply chain management effort	Time dedicated to logistic activities	Hours	NO
Economic / waste management costs	Costs of unsorted bins	Euros	NO
Environmental	CO_2 equivalent	gram	YES
	PPM	gram	YES
Social / safety on site	Number of accidents and related causes	Number	NO
Social / wellbeing for residents	Number of deliveries	Number	YES
	Congestion on construction site	m^2.h	NO
	Rate of obstructing vehicles	%	NO

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