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Sustainable Urban Consolidation CentrES for conStruction

KPIs and methodologies for construction logistics

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Table of Contents

This project has received funding from the European Union's Horizon 2020 research and innovation

Table of Figures and Tables

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Executive summary

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

The *D2.2 KPIs and methodologies for construction logistics* is part of WP2 of the project, which maps and evaluates the current situation (As-Is) and evaluates it according to a set of common Key Performance Indicators (KPIs).

This deliverable aims to define the KPIs that are necessary to answer to the project's objectives, the methods and tools to collect the data required to compute the KPIs and a draft of the operational plan. This document is the first step of the evaluation process to quantify the potential impact in terms of cost efficiency and negative externalities of a Construction Consolidation Centre (CCC) and other improvement measures (To-Be) against the current situation (As-Is).

The report is divided into three chapters. The first chapter presents the methodology to identify the set of KPIs. The second chapter defines the KPIs following the three pillars of sustainability: economic, environmental and social categories. The last chapter proposes an initial version of the operational plan to support the data collection for the task 2.4.

This new version (v2.0) of the deliverable is needed to *formalize the modification, removal and addition done on the KPIs defined at the beginning of the project*. Several reasons justify these KPIs adjustments:

- The business relations existing on the construction site between sub-contractors and the prime contractor are sometimes sensible. Some information that the consortium expected to obtain from sub-contractors could not be retrieved.
- The firsts analysis performed on the existing KPIs have shown that the current definition of the KPIs does not enable a sufficiently relevant analysis.
- The situation on the ground makes it impossible to collect the required data for a minority of the KPIs originally identified.

These minor changes do not put in question the planned analysis of the current situation.

Moreover, in this new version we explain in Annex 2 how we have taken into account the comments of the Scientific Advisory Board on version 1.0 of the deliverable.

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1 KPIs identification methodology

To identify the list of KPIs, LIST has pre-selected a list of **47 relevant** indicators based on a literature review and partners experience in others projects focused on Urban Consolidation Centre (**UCC**) and CCC. To evaluate the opportunity of the creation of a CCC, the consortium agreed on establishing a common set of KPIs for the **four case studies**. The project partners provided their feedback on each indicator using the following criteria:

- Is the indicator understandable?
- Is the indicator relevant?
- Is the data available?
- Is there any other relevant indicator which is missing?

After the analysis of partners' feedback and the review of potential indicators for their consistency, LIST short-listed **19 indicators** and provided their definitions.

The set of KPIs refers to **the three pillars** of sustainability to assess the potential impact of a CCC as compared to the current situation:

- The **economic category** is evaluated with **13 indicators** and receives the main attention considering the project objectives. Indeed, identification of new business models aiming to ensure the financial viability of a CCC is one of the most important outcomes of SUCCESS project. This category, reflecting the potential costs savings, is an important and innovative input consequently for the following tasks
- The **environmental category** is evaluated with **2 indicators** and focuses on the emissions related to the evaluated transport system. The introduction of a CCC should contribute positively to the reduction of environmental issues
- The **social category** is evaluated with **4 indicators**. Similarly to the environmental category, it measures all obvious positive effects on congestion

The detailed schedule of data collection will be defined with each pilot leader considering the construction project phases and the start and end dates of the data collection period. Pilot leaders will collect data on the agreed plan in task 2.4. The data will be stored in a database in task 2.3.

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2 KPIs definition and data collection means

In the following section, each indicator being collected according to the task 2.4 as well as the data collection process is presented. The section includes three indicators categories described above:

- Economic category
- Environmental category
- Social category

Some preliminary definitions

Direct trip

Definition: A trip with a delivery/pick-up to one place and back again.

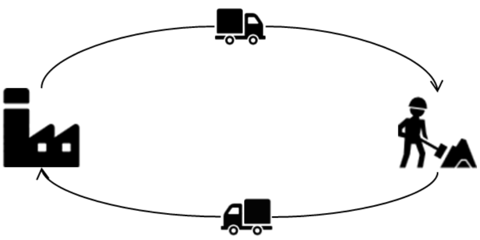

Figure 1: Direct trip

Roundtrip

Definition: A trip with deliveries/pick-ups to several places and back again.

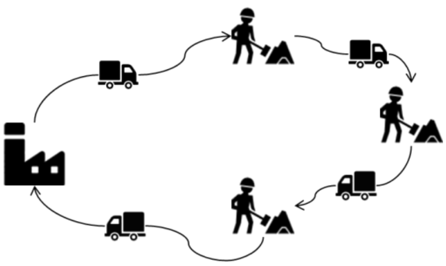

Figure 2: Roundtrip

2.1 Economic category

In the cost efficiency perspective, all KPIs aim at tracking/measuring the most relevant cost components

A valuable business model for a CCC has to comply with project objectives. Hence, economic indicators are the most important. It is important to answer the following key questions to be able to design new business models:

- Where are the saving sources? Which factors have financial consequences in the construction supply chain?
- What is the current state of these factors?
- What is the potential amount of savings based on these factors?

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- What is the impact of these savings on the construction project costs? How stakeholder benefits from this cost reduction?
- How this cost reduction could be shared?

Regarding the overall SUCCESS project structure, tasks 2.2 and 2.4 will answer the first two questions. The others items will be tackled by simulation results (WP4) and reflexion on new business models definition (WP3).

Why don't collect directly the costs?

Factors that have financial consequences, as for example transport costs, are not obvious. There are a lot of factors which influence the transport costs: distance travelled, necessary time, material damaged costs, special deliveries (night deliveries), etc.

At this stage of the project, it is difficult to identify the link between costs and their costs components. However, it is possible to identify which factors could be reduced taking into consideration the state of the art, knowledge on the construction sector, and information collected in the task 2.1.

At least, the analysis of the following potential saving sources is needed and can be split into the two main categories:

- **Material and replenishment** costs which must identify the potential saving sources in the upstream of the construction site
- **Operating costs** which must identify the potential saving sources on the construction site

Each main category is divided into subcategories that specify the potential saving source.

Material and replenishment costs:

- On the **haulier journey** time and indirectly on transport costs
- On the **haulier route and** path (including warehousing costs) and indirectly on transport costs
- On the **material waste** and indirectly on material costs

Operating costs:

- For the prime contractor/trade contractors: on **workforce productivity** and indirectly on operating costs
- For the prime contractor: on **supply chain management effort** and indirectly on operating costs
- On **waste management costs**

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2.1.1 Potential saving sources on material and replenishment costs

2.1.1.1 KPIs on the haulier journey time

Haulier journey time is divided in travel time, potential waiting time and loading and unloading time (**Figure 3**). Each part of their journey time must be analysed and could potentially be reduced through supply chain optimization. Indeed, CCC or supply chain optimization could reduce the travel time because the CCC is outside the city and the carrier travel time is not impacted by city traffic jam.

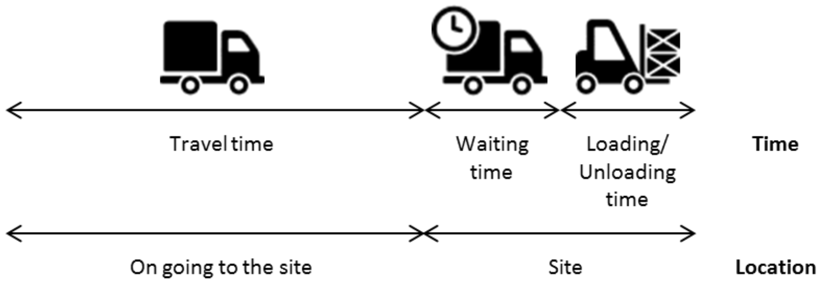

Figure 3: KPIs on the haulier journey time

NB: The gain in hours (travel time, waiting time or unloading time) has to be transformed into euros for the business model.

<u>Travel time</u>

<u>Definition:</u> The time travelled describes the driving time per trip (the waiting and loading/unloading time are not included).

On the one hand, by considering a CCC outside the urban centre area, one can hypothesize that the haulier travel time could be reduced by the time spent in the city centre. On the other hand, the supply chain optimization solution that will be proposed could reduce the travel time outside the city centre too. Consequently, travel time can be divided into travel time outside the city centre and in the city centre (**Figure 4**).

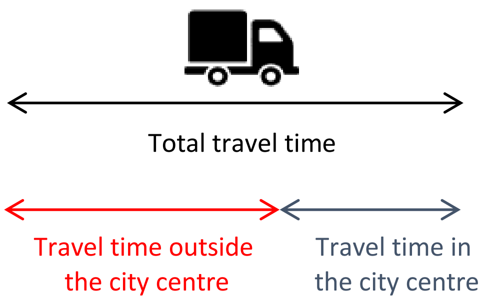

Figure 4: Travel time components

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These two types of travel time will be calculated according to the following formula:

Travel time outside the city centre	=	Arrival time in the city – Starting time
Travel time inside the city centre	=	Arrival time to the construction site – Arrival time in the city

Pick-up travel time

Distinction between travel time outside and inside the city cannot be done for the pick-up trip. Indeed, data required to make this distinction is the arrival time in the city for the deliveries and the exit hour of the city for the pick-ups. However, for pick-up trips when the driver is interviewed he doesn't yet know this information. So for pick-ups we have calculated the total pick-ups travel time calculated as follows:

Pick-up travel time = Arrival time in unloading location – Loading ending time on site

Unit: Expressed in h.

How to collect: Fulfil a **delivery tracking board** by asking the delivery driver the following information:

- Starting time from the "last storage location"
- Arrival time in the city (urban area)
- Arrival time at the construction site or at least near the construction site

To check the information consistency, the time should be calculated on the basis of an average speed outside and inside the city centre multiplied by the distance.

Truck Waiting time

Definition: The truck waiting time is the period during which the driver waits his truck unloading since his arrival time on the site **or near** the site for each delivery (the loading/unloading time is not included). Through supply chain optimization including CCC set up, the waiting time could be reduced for several reasons. There are two types of waiting time:

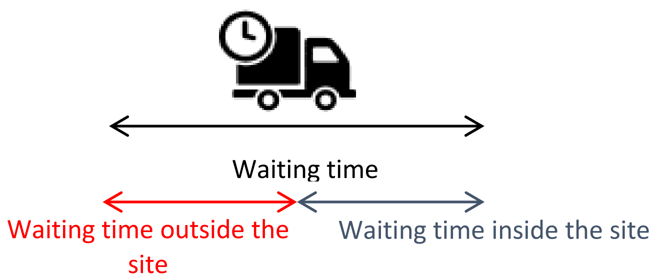

Figure 5: Waiting time components

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- Truck waiting time outside the construction site considering the fact that the delivery driver arrives early or the delivery area on the construction site is not available.

Truck waiting time outside = Arrival time at the const. site - arrival time near the const. site

- Truck waiting time in the construction site due to the fact that handling resources are not available. When the truck is on time it is a construction site issue (i.e. handling material not available, receiver unavailability, administrative issues, etc.). However when the truck is late we cannot consider that it is a construction fault.

Truck waiting time inside = Arrival time at the const. Site - unloading starting time

These two types of waiting time can be reduced through supply chain optimization. **Additional KPIs are necessary to understand the waiting time causes** and consequently the innovative solutions that could help to reduce these two truck waiting time. These additional KPIs are the following:

- Truck punctuality (considering that truck punctuality has a negative impact on the construction site workforce productivity, this KPI is described in the 2.1.2.1 part of this document page 14)
- Construction site punctuality (considering that construction site punctuality has an impact on the haulier journey time, this KPI is described in this part of the document - next KPI described)

Unit: Expressed in h.

How to collect: Fulfil a **delivery tracking board** by asking the delivery driver or measuring the following information:

- Arrival time at and near the construction site
- Unloading starting time

Construction site punctuality

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 to unload are not available we cannot consider that the construction site is responsible.

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Loading/Unloading time

Definition: The loading/unloading time per delivery is the period during which the goods are loaded or unloaded.

Unit: Expressed in h.

How to collect: Fulfil a **delivery tracking board** by measuring starting and ending loading/unloading time.

2.1.1.2 KPIs on the haulier route

Client constraints (e.g. time, number of deliveries, etc.) and/or supplier distribution network can generate some non-optimised routes. For example, a plasterboard supplier which needs to store in an intermediate warehouse to deliver the construction site in relative bulk results in extra distribution cost and longer distance.

So, supply chain optimization including CCC implementation could reduce the costs related to this kind of issue. Based on the information already collected in task 2.1 on material route, a deeper analysis will be done to understand better the role of each link of the supply chain.

Number of intermediate storages

Definition: Number of intermediate storages is the number of times the material is unloading and storing between the finish product manufacture and the construction site.

Unit: Expressed in number of times.

How to collect: Ask directly to the material suppliers.

Distance from the production plant to the construction site

Definition: 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).

Unit: Expressed in km.

How to collect: Ask directly to the material supplier all the intermediate storage location and estimate the distances based on a distance calculator.

NB: this analysis cannot be performed on all materials because suppliers are not involved in SUCCESS project. This deeper analysis could be based on a qualitative survey which could be achieved for a short list of suppliers. An interview of the selected suppliers will be carrying out to understand their logistical process.

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2.1.2 Potential saving sources on construction site operating costs

2.1.2.1 KPIs on the workforce productivity

Through CCCs implementation and supply chain optimization, better material flow synchronisation between the distribution network and the construction plan requirement should make easier Just-in-Time deliveries.

Many studies demonstrate that this better synchronisation should have an impact on workforce productivity. The main idea of these KPIs is to evaluate the effects of just-in-time deliveries on workforce productivity and consequently on operating costs.

Remark on the collection methodologies for KPIs on the workforce productivity

Based on construction companies' feedback on data collection feasibility, all these data are complicated to collect for all materials and during all the data collection phase. However these data are essentials to design new business models based on win-win relationships and gain sharing.

That is why instead of tracking/collecting each indicator independently for all materials a list of representative materials is preferred during all the data collection period. For each representative material it will be necessary to make three types of monitoring to be able to collect all the data mentioned above concerning workforce productivity.

Reduced productivity causes

Productivity could be affected by some reworks, lack of material and non-value added activities. These different causes affect productivity reducing the working time of the workforce which is carrying out a task and by occupying the workforce to non-value added activities. The KPIs on the workforce productivity are categorised to with these two types of causes.

A) *Causes for reducing the working time*

There are multiple causes that can reduce the working time. The observation will only focus on the causes linked to the material flow.

Rework in connection with material issues

Definition: The time spent to carry out a material installation already performed due to several moving in order to maintain free area for storage. It includes the required time for uninstalling the defective material.

Unit: Expressed in h.

How to collect: Monitor the material installation and identify on a limited period and task the difference between an optimized daily productivity and a real day to day productivity. By tracking the causes of the reduced productivity, the expected indicator (rework) can be measured.

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Waiting time for the workforce performing a task

Definition: Mean time (and variations) of the workforce waiting time due to a lack of material, a defect on uncontrolled delivered material. Not to be confused with others waiting time for the workforce and more specifically with a waiting time generated by deliveries delay for example.

Unit: Expressed in h.

How to collect: Monitor the material installation and identify on a limited period and task the difference between an optimized daily productivity and a real day to day productivity. By tracking the causes of the reduced productivity, the expected indicator (waiting time) can be measured.

Looking for material/equipment

Definition: Mean time (and variations) when the workforce are looking for material (some other waste related to this activity such as walking around the site to go to the storage, checking plans, requesting information, reading plans will be included).

Unit: Expressed in h.

How to collect: Monitor the material installation and identify on a limited period and task the difference between an optimized daily productivity and a real day to day productivity. By tracking the causes of the reduced productivity the expected indicator will be measured (looking for material).

B) *Causes for occupying the workforce to non-value added activities*

As specified in previous indicators, there are multiple non-value added activities that occupy the workforce and consequently reduce the workforce productivity. The non-value added activities related to logistics will be tracked.

Waiting time for material

Definition: The time spent by material on storage zone before being used. This time of storage gives an overview of stock turnover and highlights the incapacity to deliver goods in just in time. This KPI is not a direct non-value added activity but an important material waiting time in a constrained environment potentially generate non-value activities as for example unnecessary several handlings.

Unit: Expressed in quantity of materials (depends on material unit).

How to collect: Monitor the existing storage area on the site and save regularly the number of material existing in these areas.

Several handling time

Definition: Even if it is necessary, handling time is a non-valued added activity. Ideally materials should be handled directly from the truck to the point of use. Below, the unnecessary handling time to track:

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- 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.

How to collect: **Monitor the material location of the representative materials**. For the issues which occupy human resources with non-value added activities, the materials location in storage area will be trucked. On a daily basis a site tour can be done in order to localize the selected materials. For each new material location, one unnecessary handling will be counted.

Truck punctuality (Waiting time of the workforce due to truck delay)

Definition: The punctuality of deliveries and pick-up is defined as the time 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.

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

Unit: Expressed in h.

How to collect: A **delivery tracking board** must be established to collect the real delivery time in order to be able to compare with the forecasted delivery time. This delivery tracking board will not be used only for this data. This data will be included in a more global delivery tracking board.

2.1.2.2 KPIs on supply chain management effort

Time spent to logistic activities (material flow management, delivery management, etc.) by contractor staff could be reduced through the solutions proposed. Indeed these logistic activities could take advantages of the CCC by using more efficient handling means, improving delivery reliability and consequently the need for delivery issues management, etc.

Time dedicated to logistic activities

Definition: A list of logistic activities will be defined in order to evaluate the hours could be saved with a CCC. An evaluation of the time dedicated to all the logistic activities will be performed. The time dedicated to logistic activities is the time spent

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on each of the defined activities. This list of activities is formalized in the part "operational plan" at the end of this document.

Unit: Expressed in h.

How to collect: The main idea is to identify all the activities considered as logistic activities and the assigned resources for each activity. Then each resource who manages these activities will receive a data collection sheet.

Each resource should complete this data collection sheet on a short period (ideally one week per project phase). This will allow analysing which project phase is time consuming in terms of logistic management.

2.1.2.3 KPIs on waste management costs

This indicator is directly linked to the unsorted waste due to the lack of space to have enough bins. Indeed, sometimes the construction site does not provide free space to put enough bins to sort all the waste as required by the country legislation. Evaluate the costs of unsorted bins will allow to identify the potential direct saving source.

Costs of unsorted bins

Definition: In some cases different wastes must be put in a single bin. So the waste will be sorted by the subcontractor that collects the waste. This sort is a cost that could be avoided. The cost of unsorted bins is the price invoiced by the subcontractor.

Unit: Expressed in €.

How to collect: Posteriori processing of waste management bills.

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2.2 Environmental category

This category aims at proving that CCC and supply chain optimization reduce transport related pollutant emissions.

A lot of analyses could be relevant in terms of transport related pollutant emission analysis. You can find several examples below:

- An estimation of transport related pollutant emission **per type of material** could help to focus on some specific construction supply chain which has a significant negative impact.
- An estimation of transport related pollutant emission **per project phase** could help to understand which project phase has the more significant negative impact and to guide the solution design to some specific project phases.

There are a lot of others ratios that could be relevant depending of our objectives. Our objectives will be clarified depending on the optimized solution. So it is necessary to estimate the negative impact of each delivery in order to be more adaptable for the rest of the project. This level of detail in term of gas emission estimation is mandatory in order to be able to propose thereafter some relevant analysis. Gas emission will be evaluated according the two main indicators defined below:

CO_2 equivalent

Definition: 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**) ad 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.

How to collect: Setup a **delivery tracking board** for collecting all the parameters required to run COPERT (tool used to estimate gas emission). The list of parameters is the same for the following indicator.

PM

Definition: PM is defined as the total PM emissions emitted by the vehicles during the evaluation period.

Unit: Expressed in g.

How to collect: Setup a **delivery tracking board** for collecting all the parameters required to run COPERT (tool used to estimate gas emission). The list of parameters is the same for the following indicator.

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List of required data

At least, **vehicles and trip characteristics for each delivery** (described below) and for **each truck departure** (waste, material return, etc.) should be collected:

- Vehicles characteristics
  - Gross vehicle weight rating (GVWR) = Gross vehicle mass (GVM) (PTAC in French)
  - Euro class (Euro IV, Euro V, etc.)
  - Fuel type (Gasoline/Diesel/CNG, etc.)
  - Vehicle load
- Trip characteristic
  - Country: It is the county in which the trip takes place
  - Driving share between Urban/Rural/Highway
  - Mileage -> based on the distance to construction site defined in the task 2.1

These data reflect the minimum information required **to obtain an estimation of CO_2 equivalent emission per delivery**. However the estimation could be more accurate by taking into account other factors as for example mileage degradation factor which take into account the truck age.

Among these data, some of them (essentially trip characteristics) will be already calculable based on the Excel file used for the task 2.1: country, driving share between urban/rural/highway, mileage (distance to construction site x 2).

NB: It is worth asking the driver his starting point to confirm the data collected in task 2.1. It could be one action that aims at ensuring the quality of data.

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2.3 Social category

Regarding CCC literature and feedbacks, in a social perspective the following potential benefits should be at least analysed:

- On safety on the construction site
- On wellbeing for the townspeople

2.3.1 KPIs on safety on the construction site

Number of accidents

Safety is a primary concern in construction sector. Focus on accidents linked to logistics can highlight the importance of professionalization of logistics on site.

Definition: 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.

Several causes are at the origin of these incidents but the following issues will be focused:

- **Handling equipment:** Inadequate handling equipment may cause incidents or muscular and skeletal disorders. The risk of incident increases with the weight of the load. The injuries can happen during deliveries or transit between storage areas
- **Paths for moving material and equipment and storage areas:** Undefined and non-secured paths as well as numerous storage areas may cause incidents. The implementation of a CCC would here reduce the risk of incidence in reducing stock on site and make the working conditions cleaner
- **Packaging:** Inappropriate packaging may cause incidents. The risk of incident increases with the overload of pallets. Inadequate packaging identification should help to assess risk of accident

Unit: Expressed in number of accidents per cause.

How to collect: Fill an accident register describing the circumstance for each construction company involved in the pilot projects.

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2.3.2 KPIs on wellbeing for residents

Noise and congestion nuisances are difficult to quantify. Impact on wellbeing seems to be complicated. So a quantitative impact assessment of CCC will not be possible in this project which is mainly focused on costs efficiency and viable business model for CCC. However it is possible to define a tendency even if the social impact can't be quantified. The positive or negative impact will be estimated in terms of:

- Traffic jam based on the number of deliveries
- Congestion around the construction site

Number of deliveries

Each delivery and pick up at the construction site generates a truck in the urban area by reducing the number of deliveries and pick up the proposed solution.

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

Unit: Expressed in number.

How to collect: The real number of deliveries will be extracted from data collected for other KPIs.

Congestion is divided into two main KPIs: Congestion on construction site and rate of obstructing vehicles described below.

Congestion on construction site

Definition: The congestion on construction site is defined as the space used by vehicles at the construction site as soon as it enters on the site and until it leaves the site. 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 / 15 minutes. To be able to have a relevant analysis of this indicator we add the time parameter in the KPI calculation to get the total surface occupied on site by the trucks per 15 minutes time slot

How to collect: Based on others indicators described above, congestion can be estimated with the number of deliveries and the time spent by the vehicle on site. The surface will be estimated with the type of vehicle.

Rate of obstructing vehicles

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

Unit: Expressed in %.

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How to collect: Data will be collected on a daily basis with visual observation around the construction site considering the relative importance of this indicator. In this case a visual observation is adequate because precise value is not required.

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2.4 Summary table of KPIs

Category	KPI designation	Unit
Economic/haulier journey time	Travel time (outside and in the city centre) / Total travel time for pick-ups **-> modified**	h
	Truck waiting time (outside and inside the site) **-> modified**	h
	Construction site punctuality **-> added**	h
	Loading / unloading time	h
Economic/haulier route	Number of intermediate storage	number
	Distance from the production to the construction site	km
Economic/material waste	~~Material waste~~ **-> removed**	€
Economic/workforce productivity	Rework in connection with material issue	h
	Waiting time for the workforce	h
	Looking for material / equipment	h
	Several handling time	number
	Waiting time for material **-> added**	
	Truck punctuality **–> modified**	h
Economic/supply chain management effort	Time dedicated to logistic activities	h
Economic/waste management costs	Costs of unsorted bins	€
Environmental	CO_2 equivalent	g
	PM	g
Social/safety on construction site	Number of accidents and related causes	number
Social/wellbeing for residents	Number of deliveries	number
	Congestion on construction site **-> modified**	m^2 / 15min
	Rate of obstructing vehicles	%

Table 1: Summary table of the KPIs

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3 Operational plan for data collection

In this chapter, a **summary of all the individual methodologies** is proposed with an operational perspective in order to propose coherent and efficient collection tools:

- Coherent because all the several KPIs cannot be collected all in parallel due to the limited resources which will make the collection
- Efficient because one method can collect several KPI and if it's not organized wasted time will be generated by repeating the same type of collect

3.1 Summary table of data collection tools

To collect data, 3 types of data collection tools are needed:

- One delivery **tracking board**
- Four **specific data collection tools** on several limited period
- Four tools based on **posteriori processing** of existing information

The following tables summarises the required data collection tools with for each tool the related KPI. Each tool is explained in the following chapters of this document.

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Type of tool	Tool designation	Duration of use	Frequency of use	Related KPI
Tacking board tool	Delivery tracking board	Data collection period	Every days	• Travel time • Truck waiting time • Construction site punctuality • Loading/unloading time • Truck punctuality • CO2 equivalent • PM • Number of deliveries • Congestion on construction site
Specific data collection tools	Material installation monitoring	Two weeks	6 times distributed on each project phase	• Rework • Waiting time of the workforce • Looking for material equipment • Waiting time for material
	Material location monitoring	Two weeks		• Several handling times
	Logistics activities monitoring	One week		• Time dedicated to logistic activities
	Congestion monitoring	One week		• Rate of obstructing vehicles
Posteriori processing tools	Distribution network analysis			• Number of intermediate storage • Distance from the production plant to the construction site
	Site supervisor interview	One hour	Biweekly	• removed
	Waste management bills analysis		At the end of the data collection	• Costs of unsorted bins
	Accident register analysis		At the end of the data collection	• Number of accident related to logistic issues

Table 2: Summary of data collection tools

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3.2 Delivery tracking board

This tool aims at collecting information to calculate the following KPIs:

- Haulier journey time
- Air pollutant emission
- Congestion on construction site

This delivery tracking board must be fulfilled every day in order to record all the deliveries and pickup. **So it will be used for deliveries as well as for waste or material pickup.**

The requested information for each delivery is divided into four main categories:

- General information
- Trip characteristics
- Truck characteristics
- Loading / unloading characteristics

General information:

General information							
Round trip or Direct trip	Date	Material name	Supplier name	Number of product	Number of items to manipulate	Item packaging	Material weight

Figure 6: Delivery tracking board/General Information categories

- On delivery: some general information aiming at characterizing the delivery
- On material carried: some information on the material carried are necessary to be able to draw some conclusions
- On haulier: in the same idea this kind of information should help to draw some conclusion

Expected information for KPI measurement regarding **trip characteristics**:

All these data aims at defining the KPI on the haulier journey time.

Trip characteristics												
Haulier name	Address of the loading location	Address of the previous delivery 1	Address of the previous delivery 2	Starting time from the loading location	Arrival time in urban area	Arrival time near the construction site	Arrival time at construction site	Planed delivery time	Come back empty or loaded	Address of next delivery 1	Address of next delivery 2	Adress of final come back

Figure 7: Delivery tracking board/Trip characteristics categories

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Expected information for KPIs measurement regarding **truck characteristics**:

All these data aims at defining the KPI on environmental impact (air pollutant emission) and social impact (congestion).

Truck characteristics							
Vehicle type	Euroclass	Fuel type	Net weight	Gross vehicle weight rating (GVWR)	Surface vehicule	Vehicle load rate in terms of volume	Handling equipment inside the truck

Figure 8: Delivery tracking board/Truck characteristics categories

Expected information for KPIs measurement regarding **loading / unloading characteristics**

Loading / unloading characteristics				
Handling equipment	**Number of people**	**Starting time of loading / unloading**	**Ending time of loading / unloading**	**Location**

Figure 9: Delivery tracking board/Loading Unloading categories

Depending on the pilot project own organization it could be the watchman at the site entrance, the unloading team or a dedicated person who will collect this information.

3.3 Specific data collection tools

Taking into account construction companies' feedback some KPIs cannot be measured for all materials on all the data collection period. These KPIs concern:

- Workforce productivity assessment with "material installation monitoring" and "material location monitoring"
- Supply chain management effort with "logistic activities monitoring"
- Rate of obstructing vehicle with "visual observation"

3.3.1 Material installation monitoring

This tools aims at measuring the following KPIs:

- Rework due to material issue
- Waiting time of the workforce linked to material issue
- Time dedicated to look for materials

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Below an example of a graph representing the daily productivity of an item: in blue the optimized productivity and in red the real daily productivity in items per day. For each day with a lower productivity than the optimized productivity the lower productivity causes have to be identified.

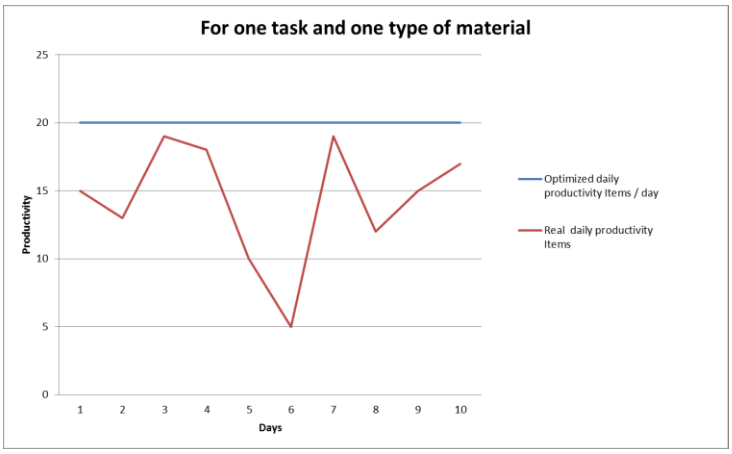

Figure 10: Example of "material installation monitoring"

Instructions:
Two solutions to measure the loosing time related to rework and waiting time due to material issues are presented below.

First solution:

- Provide a time tracking sheet to the workforce
- Analyse at the end of each day to identify the loosing time related to rework, waiting time and time dedicated to look for material

Second solution:

- Measure the number of items installed during the working day
- Calculate the time lost with reference to the optimised daily productivity
- Identify the lost time due to rework, waiting time and time dedicated to look for material

Duration of use: 2 weeks.

Frequency of use: Ideally one time for each project phase (structural work, technical trades, Roof and casing, finishing).

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3.3.2 Material monitoring

This tool aims at measuring time dedicated to "several handling".

Instructions:

- Identify the location of the selected materials on a construction engineering plan
- Make two construction site tour per day: one in the morning and one in the afternoon
- Identify after each tour the selected material location
- Count the number of each new material location and consider it as a material handling
- Affect an average time to a material handling to calculate the time required for the several handling times

Duration of use: 2 weeks.

Frequency of use: Ideally one time for each project phase (structural work, technical trades, Roof and casing, finishing).

3.3.3 Logistic activities monitoring

This tool aims at measuring the time dedicated to supply chain management by prime contractor staff or workforce depending on the contractor organization. This tool is mainly based on the table below which will give to all the resources.

	WEEK 1	Day 1	Day 2	Day 3	Day 4	Day 5
-	Order management:					
	Place an order					
	Confirm an order,					
	Modify an order,					
	Check an order status					
-	Material validation					
	Ask technical data sheet to the supplier,					
	Technical data sheet diffusion,					
	Ensure the validation by all stakeholders					
-	Deliveries issues:					
	Delivery schedule management,					
	Take information on delivery progress,					
	Check the compliance with the order,					
	Manage the offloading activities,					
	Manage the congestion in front of the site					
-	Management of the site requirements:					
	Send consumption forecast for suppliers,					
	Formalize and send production schedule to suppliers,					
	Manage urgent replenishment,					
-	Manage the site movements and storage area:					
	Storage area management					
	Material andling management					
-	Reverse logistic management:					
	Manage return material (find a transport)					
	Loading management					

Figure 11: Tool for logistic activities effort monitoring

Instructions: Each day when performing an activity identified in the list (first column) fulfil the duration of this activity.

Duration of use: 2 weeks.

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Frequency of use: Ideally one time for each project phase (structural work, technical trades, Roof and casing, finishing).

3.3.4 Congestion monitoring

This tool aims at measuring rate of obstructing vehicles KPI. It is based on a visual observation all around the construction site to count the number of vehicle

Instructions: Two time per days at the most critical.

Each pilot project must define the two most relevant periods during the working day. For example at Luxemburg pilot this visual observation can be made between 07:00 and 09:00 and between 11:00 and 14:00.

Duration of use: 2 weeks.

Frequency of use: Ideally one time for each project phase (structural work, technical trades, Roof and casing, finishing).

3.4 Posteriori processing of existing information

Posteriori processing concerns two KPIs:

- Distribution network analysis
- Accident register analysis
- Site supervisor interview
- Waste management bills analysis

3.5 Proposal on data collection plan

Based on the Luxembourgish pilot production plan and the tools utilization parameters, can find below a plan for the data collection.

As described, the four "specific data collection tools" used on a limited period will be carried out on each project phase and the delivery tracking board is fulfilled regularly during all the data collection period.

For "posteriori processing tools" site supervisor interview are planned on a bi weekly basis on all the data collection period and the three others tools will be performed during the last month of the data collection period. Of course this analysis could be started earlier.

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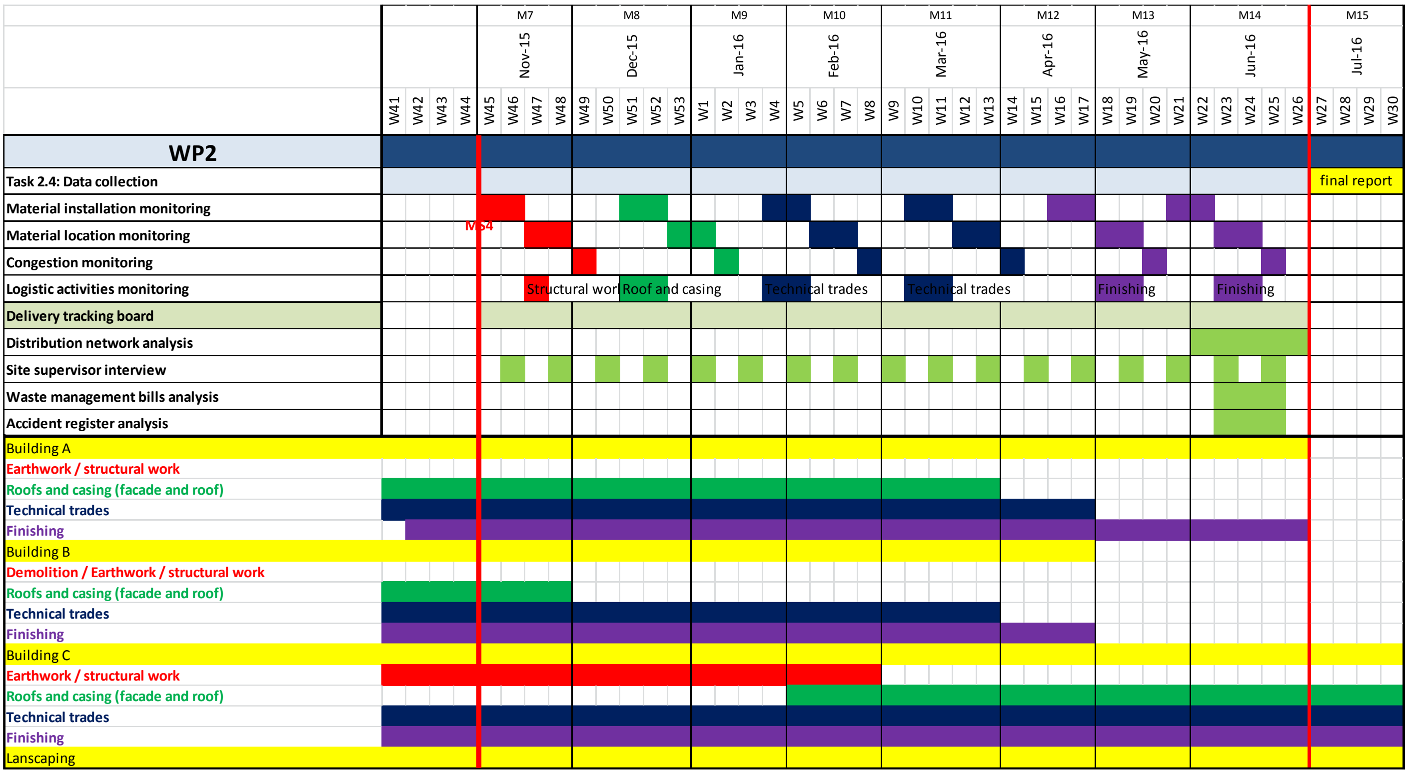

Figure 12: Proposal of data collection plan

Conclusion

The literature review and partners' experience in other projects on city logistics and specifically on urban consolidation centres allow the identification of the main objectives and indicators to answer project objectives. Discussions within the consortium enable to short-list **19 KPIs considered** as the most relevant for the project. Clear definitions and data collection methods should give enough guidance for next steps of the evaluation. The list of KPIs and data collection methods has changed all along the evaluation process. During data collection and data analysis (task 2.4), some KPIs have been removed considering they are not any more relevant, changed due to analysis difficulties.

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4 Annexes

4.1 Annex 1: Rationale for the requested changes to the KPIs after the data collection and the first analyses

The following modification has been performed on the KPIs defined in the version 1.0 of the deliverable D2.2. For each modification, a rationale is provided. The modifications are divided in three categories:

- Removed: the KPI is removed for all the sites or at least one site
- Modified: the KPI is modified for all the sites or at least one site
- Added: the KPI is added for all sites or at least one site

Removed KPIs:

Material waste

Rationale:
It is impossible to get this information because sub-contractors consider this to be a sensitive information (in financial terms) that they don't want to provide. Sub-contractors don't belong to the consortium and won't cooperate.

Modified KPIs:

Truck waiting time and truck punctuality

Rationale:
With the first definition of "truck waiting time" we were not able to identify who is responsible for the actual waiting time. By redefining these indicators we emphasize when a truck waits within the site and / or when trucks are late. This could allow us to better understand the issues causing these delays. Moreover, the first definition of these KPIs could not ensure the consistency of the calculated indicators.

Travel time

Rationale:
The travel time should have been calculated for the trip inside and outside the urban area. This is the case for the deliveries but not for the pick-up.

Indeed for pick-up trips, the urban area exit time cannot be known. The human resources in charge of the data collection can interview the truck drivers to collect some data (e.g. truck characteristics) but it is impossible to know the urban area exit time. So for the pick-up the distinction between travel time inside and outside the city is impossible.

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Congestion on construction site

The KPI as originally defined gave us the information of the congestion per delivery. This KPI does not allow drawing some relevant conclusion on the impact of the truck size and unloading time on the construction site. To be able to have a relevant analysis of this indicator we add the time parameter in the KPI calculation. So for this KPI we now calculate the total surface occupied on site by the trucks per 15 minutes time slot.

Rework in connection with material issues, waiting time of the workforce, looking for material and equipment

- Some changes to the indicators that assess the construction site workforce productivity. This concerns the following indicators:

    - "Rework in connection with material issues"
    - "Waiting time of the workforce"
    - "Looking for material and equipment"

  These three indicators are replaced (only for the sites of Paris and Valencia) by an aggregated indicator called **"waiting time for material"** which highlights the time spent by the material on site between its delivery and its use.
  It will highlight the incapacity to deliver goods "just in time" and consequently the impact on the requested inventory surface with the following risks:

    - Material damaged
    - Workforce accident
    - Waste of time for the workforce to handle several times the material because the surface is needed for future works

  Rationale:
  Paris provided first results in April but the original methodology revealed to not be adapted to the site. When they follow a team, there is no big time of "waiting time due to logistic" and "transport of materials" because materials are already provided in the work station by a dedicated logistic team before operators start to work. So the data collected was not relevant due to a specific organization of the works.

  In Valencia, they provided first results in April but material selected are specific to the construction site (Ribloc tubes, pavement, etc.) and they have lot of space available on site (no issues in looking for material).

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Added KPIs:

Construction site punctuality

Rationale:

Following the modification of truck waiting time and truck punctuality performed to be able to have a better analysis of truck waiting time causes, the addition of construction site punctuality is essential to complete the analysis.

Waiting time for material

Rationale:

As described above some KPIs (rework / waiting time / looking) that measure the workforce potential waiting times during production are not relevant in both the Paris and Valencia pilots. So to give an idea of the potential workforce loosing times related to the lack of space and the material replenishment policy for these two pilots, this new indicator was setup.

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4.2 Annex 2: Answers to Scientific Advisory Board comments

We received comments from:

- Martin Savelsbergh
- Natashia Boland

In this annex we explain how we have taken into account these feedbacks in both the KPI definition and the data collection phase.

4.2.1 Martin Savelsbergh's comments

Comment 1:

Even though "trip" is used in the document it is not clearly defined. Is a trip equivalent to a delivery? Is every trip always from a single origin to the construction site? Are there multi-stop trip? For example, does it ever happen that items are picked up at multiple locations before delivering at the construction site? Multi-stop trips may improve efficiency, so if they are happening, or if we anticipate that they may happen in the future, it would be good to have an appropriate indicator.

Answer 1:

We totally agree with this comment. These kind of information is not directly included in the formalized indicators. However, it makes part of the information gathered in the "Delivery Tracking Board" tool used to collect data on deliveries and pick-ups.

There are currently some partial answers to these questions:

- *Does every trip always come from a single origin to the construction site?* With the information gathered we can answer yes so far.
- *Are there multi-stop trip?* Yes, although not for picking-up materials but for delivering to several construction sites in the same trip. It is what we call "round trips".
- *Does it ever happen that items are picked up at multiple locations before delivering at the construction site?* No, we have no information in this direction so far.

Comment 2:

Load factor is an important indicator, but the current one may not capture all the information of interest. It is often the case that vehicle capacity is measured by both volume and weight. As such, it is important to measure both. Furthermore, the "lost volume per item" is an interesting one, but there may also be "lost volume because of non-optimal loading/packing". Vehicle load optimization may be another opportunity for efficiency improvement.

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Answer 2:

We agree with this comment, we planned to collect not only the data to calculate the load factor but also the load rate in terms of volume.
However the number of data collected is really important and some information on the way of loading / packing material on the trucks is too much detailed to be able to collect it with enough quality and to be able to make relevant use of it.

Comment 3:

Related to load factor is the equipment used. Are large trucks used? Are small trucks used? Efficiency improvements may result from using different equipment.

Answer 3:

We have collected data related to the truck used (size, capacity) and to the unloading equipment used. So we will be able to perform some analysis on these issues for the four pilot sites considered.

Comment 4:

Punctuality of deliveries is important, but it may not be sufficient to only count on-time deliveries. It may be equally important to capture how late or how early deliveries are that are not on-time.

Answer 4:

We have adjusted the punctuality indicator in this way.

Comment 5:

Is there a need to capture driver utilization? That is hours worked as a percentage of hours available?

Answer 5:

In our context getting information on driver utilization should be really relevant to better assess the impact of a CCC on the haulier journey time and confirm the potential savings identified. However, this information is difficult to obtain from drivers themselves.

Comment 6:

An indicator related to reducing congestion is the "number of vehicles on the site". If this refers to vehicle making deliveries and pickups, it is probably also important to capture timing information. Five vehicles visiting the site on one day may not be a problem, but five vehicles visiting the site all at once may be an issue.

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Answer 6:

We have planned to collect all the data to perform these kind of analysis.

4.2.2 Natashia Boland's comments

As for M. Savelsbergh's comments we split the original comment of Mrs Boland into several sub-comments in order to give a coherent answer to each of them.

Comment 1:

From that experience, I feel it is very important to collect as much information as possible about:
- The types of vehicles that are used, individually or in combination, to deliver building construction materials,
- And their capabilities, in terms of capacity, handling equipment needed for loading/unloading,
- Any coordinating vehicle types,
- And rules for site compatibility.

Answer 1:

We planned to collect the Gross Vehicle Weight, the net weigh, the type of truck (chassis-cab, semi-trailer, etc.) as well as the handling equipment used to unload depending of the type of material packaging. For the pilot sites observed no coordinating vehicles are needed.

Regarding rules for site compatibility, they were not yet collected but it is the kind of data we can obtain a posteriori by interviewing the construction workforce.
We of course agree that this kind of information is important to develop a coherent CCC but the amount of data to be collected is so important and we have to set priorities to ensure data quality.
We can already say that rules for site computability can be very specific depending of the site environment. However some classical rules can also be generic, as for example the truck characteristic that make easier the unloading activities with the crane.

Comment 2:

Understanding what kinds of time windows might apply to deliveries, and what the motivating reason for the time windows are, could also be critical. Since distributors usually service multiple customers at multiple sites, it is important to understand the interactions to be able to know how efficiency can be improved in the distribution of materials.

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Answer 2:

As for some other information, it is the kind of data we can obtain a posteriori by interviewing the suppliers. We have partial information on the motivating reasons for time windows from the construction site point of view. For example during the phase of structural works, the crane is often used in the afternoon for productions so unloading activities using the crane are planned in the morning. Distributors have adapted their construction delivery schedule to this kind of constraints.

Comment 3:

Rules for what materials can be loaded, how they can be loaded (as in sequenced/packed within the vehicle space) would be important to understand, as well as how many workers of what types need to either accompany certain loads, or be present for loading/unloading.

Answer 3:

The number of workers required to unload materials have been collected but what we emphasise until now is that some factors are not only based on materials or packaging characteristics but also on human resources' experience. Moreover, on one pilot site a dedicated professional logistic team helps to be efficient for unloading activities.
However, the firsts results show that the main potential savings are not really on unloading activities but more on trucks and workforce waiting times due to lack of planning robustness.

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