Impact mitigation of urban construction: logistics solutions and strategies in Europe

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The construction sector affects urban logistics, yet its important impacts have often been neglected in urban policies. This paper discusses the need for solutions to mitigate freight urban logistics and shows the findings of the H2020 project SUCCESS with respect to the introduction of Construction Consolidation Centres (CCCs). It was found that introduction of CCCs could bring great environmental, societal and economic benefits, even though each project must be considered individually.
A model was developed to estimate the impacts of CCCs based on the input data of four construction sites in big cities in Europe. Simulations were performed to generate a number of scenarios, which were used as input to the mathematical model of the stochastic facility location problem. Information collected at the construction sites and the stochastic data generated were used to produce a series of KPIs to evaluate the opportunity of using a CCC and its sustainability.
We also investigated construction logistics in 12 European cities, analysing their approach, solutions adopted and policy frameworks in place through. Having analysed ases from large and medium-sized European cities, the paper represents a very extensive study in terms of urban logistics impacts and solutions related to the construction sector. The implications of these findings are discussed to improve policies in construction logistics.

Keywords: construction logistics, consolidation centre, simulation, construction site, city logistics

1 Introduction

Transport is responsible for 28% of all CO_2 emissions in the EU, and 84% of that is attributable to road transport [1].Urban logistics is a key issue for our urban societies as transport in the final link of the logistics chain is clearly visible to the population and it is the most costly segment for shippers: it accounts for approximately 20% of the overall cost of transport while representing 1% of distance covered [2].

Although city logistics and last mile delivery are widely studied and are at the core of policy makers' initiative, little attention was paid so far to the construction sector. Construction activity represents about 10% of Europe's GDP and directly employs 15 million people. It is a highly fragmented industry with 3 million enterprises in Europe, 95% of which are small and medium-sized enterprises [3]. In the framework of the SUCCESS H2020 project, research was conducted to evaluate the impacts of Construction Consolidation Centres (CCCs) to improve urban freight logistics.

The CCC is a logistic hub, usually located in the outskirts of a city, where the suppliers of the construction sites send the materials. The CCC aggregates the orders and optimizes the last-mile delivery to the actual construction sites with just-in-time processes. CCCs serving urban construction sites represent a promising logistics practice to optimise freight deliveries at construction sites, to reduce congestion, to reach liveable conditions for humans, an improved working environment and to reduce energy use and emissions [4].

2 Problems and solutions in freight urban logistics

2.1 Challenges of urban logistics

One of the leading sources of inefficiency for urban transport of goods is the excessive fragmentation of loads, leading to partially empty vehicles and thereby an unnecessary increase in the number of vehicles on the road.

Imbalanced transport flows are yet another challenge for urban logistics, since cities' "imports" are generally much more consequential than their "exports". This imbalance makes integrating inbound and outbound flows considerably more complex and explains in part the relatively significant proportion of empty journeys in urban areas.

Despite the negative externalities it generates - including pollution, noise and congestion - urban logistics is essential for the economic, social and cultural life of cities. The challenge is thus to find ways to improve the overall efficiency of urban logistics while minimising its negative environmental effects.

2.2 Regulations to reduce externalities

Urban logistics often constitutes a relatively new field for public authorities. One reason for this is the fact that, in general, urban goods transport provides the expected services: the freight system is extremely flexible and continuously adapts to the needs of businesses and consumers. Nonetheless, this effectiveness has a high price, particularly in terms of environmental impact and urban planning.

As such, organising logistics represents a challenge for urban planning and land management policies, at various levels. At neighbourhood level, it raises questions concerning conceptions of the road network and parking, and plays a key role in numerous conflicts regarding use of public space. At the level of metropolitan areas, the shortage of available land and the resulting land price dynamics, as well as regulatory obstacles, uncompromisingly relegate logistics functions to ever more distant peripheries, contrasting with the need for more frequent deliveries in downtown areas. This phenomenon necessarily increases the average distances travelled by vehicles.

Spontaneous movements tending to position logistics sites in distant and inexpensive areas call for corrective planning actions and integration of logistics in urban planning. Warehouses must be reintroduced to cities, as they make it possible to gather movements of goods in close proximity to recipients and thereby limit logistics sprawl. In this context, establishment of consolidation centres consists of concentrating goods flows from different carriers and intended for a given urban area, on a transhipment site where the goods can be transferred from diesel-powered vehicles to significantly cleaner and quieter modes of transport.

2.3 Specific challenges in construction logistics

The construction industry is not only one of the biggest "consumers" of freight transport in urban centres, but also one of the biggest "producers": construction, despite the recent industry crisis, still represents an economic backbone sector for all EU cities. The construction supply chain (CSC) is often fragmented, with many suppliers delivering materials to many different trade contractors on the same site in a given urban area. A multitude of suppliers and lack of coordination regarding delivery windows lead to a large number of deliveries and long waiting times. The consequence is an increase in external costs such as pollution, congestion, noise, accidents, degradation of infrastructure and quality of life, and a rise in transport and production costs. In addition, downtown construction projects also generate significant logistics activities, fuelling demand for land and buildings.

Many initiatives are under development to reduce the costs and negative impacts of freight and service journeys in urban areas. Some concern supply chain improvements and more specifically consolidation centre projects. Few case studies are dedicated to the construction industry.

Experiences of CCCs are few and far between. Among these initiatives [5], four are construction-site specific (Stockholm, Utrecht, Berlin, London Heathrow) and only one is dedicated to several construction projects (London). These pilot studies have demonstrated reduced transportation impacts, positive effects on transportation efficiency and construction site productivity. Several limitations to the transferability of this concept are identified though: on the one hand, the demonstrators were implemented in specific contexts (regulatory incentives, cities' investment contribution, and specific transport and logistics infrastructure issues) which are not the same in France, Spain, Italy and Luxembourg. On the other hand, long-term economic viability has not been demonstrated.

3 Construction Consolidation Centres as solution for construction logistics: modelling and simulation

For citizens, there may be three main advantages in CCC introduction: improvement of congestion problems, safety improvements and decrease of air pollutants.

To quantify the above advantages we considered several KPIs to measure them directly or indirectly: number of trips (KPI1), total distance travelled (KPI2), time spent travelling (KPI3), load factor (KPI4) and emitted pollutants (KPI5). Simulations were performed to produce a quantitative evaluation of these KPIs based on six different scenarios (**Table *1***). In addition, a Cost-Benefit Analysis (CBA) was employed to assess the possible economic sustainability of the CCC, without intervention of public funds.

The data of the single pilot sites were directly collected during the project. To define multiple sites to be simulated both the real licenses issued for the next years and information from the construction companies were considered. We defined a set of sites that represent the main construction activities that will be performed in the next three years in the four cities (Luxembourg, Paris, Valencia and Verona). To generate the hypothetical demand of materials by the new sites we considered the real material flows that we recorded from the four pilot sites during the SUCCESS project. Using these flows, we generated an estimate of the demand of the other construction sites by considering it proportional to the budget and the time. These databases were successively randomized to derive stochastic scenarios (with increased and decreased demand). We have thus obtained a set of possible demands that can be used within a stochastic optimization framework to derive the expected optimal location of a CCC, in order to minimize the weighted flows (km·m^3 transported). The main elements of the case studies are as follows: Luxembourg: 16 construction sites, 6 potential CCCs, total budget € 714,350,000, Paris: 11 construction sites, 10 potential CCCs, total budget € 1,569,000,000, Valencia: 23 construction sites, 4 potential CCCs, total budget € 535,814,000, Verona: 49 construction sites, 5 potential CCCs, total budget € 219,948,000.

Table 1 Description of simulated scenarios

n.	Description of scenario
1	One construction site and no CCC. This is the baseline for comparisons.
2	Introduction of a CCC & optimization in the second echelon of the pilot site (from the CCC to the inner city).
3	Introduction of a CCC serving the pilot site, optimization of both echelons (suppliers to CCC and CCC to pilot site).
4	Introduction of a set of possible construction sites, but no optimization. This is the baseline for multiple sites computations
5	Multiple construction sites, introduction of a CCC serving them and optimization of the second echelon
6	Multiple construction sites, introduction of a CCC and optimization of both echelons

The simulation process uses a set of quantitative tools:

- C++ programs to define the stochastic demand, based on the real data from the pilot sites;
- Mathematical models to implement the stochastic optimization;
- XPRESS© tool to solve the stochastic optimization (XPRESS is a commercial software by FICO to solve generic Mixed Integer Programming problems);
- C++ programs to simulate the trips in the optimized scenarios;
- COPERT© to compute the emissions in the pilot cities (developed as a European tool for the calculation of emissions from the road transport sector).

The interested reader can found details on the mathematical formulations of the problem, variables, functions, etc. in [6], while the complete description of the simulation process and its assumptions can be found in [7].

The overall simulation process starts from the input data described above, then we apply a C++ program which generates the stochastic scenarios. The generated scenarios are used as input of a mathematical model of the stochastic facility location problem, which gives the optimal choice for the location and selection of CCCs. Using this information and the stochastic data generated, a set of C++ programs execute the simulation for distances and times of the flows in the different scenarios. The results of this evaluation are next used both by COPERT and by our CBA models to evaluate, respectively, the pollutant emissions and the economic sustainability and opportunity of using the CCCs.

The main results of the simulation are presented in Table 2 and Table 3 and are available in [7]. Different behaviours are present in the four simulated cities, but there is a clear common factor: the use of a CCC to aggregate materials and to perform efficient transports from the suppliers and to the construction sites has a direct positive impact by reducing trips, distance travelled, travel time and pollutants. The implementation of a CCC can highly help to reduce negative impacts by reducing the number of deliveries to the construction site and the total distance travelled in the urban area.

Table 2 KPI improvement between scenario 4 and 6 in the urban area of the four pilot cities

KPI n.	KPI	Improvement
1	number of trips	-60%
2	distance travelled	-44%
3	time spent traveling	-36%
4	load factor	+166%

Table 3 Average emission improvements in the four pilot cities

KPI n.	KPI	Inside city	Outside city	Total
5	CO	-19%	-16%	-15%
5	$PM_{2.5}$	-23%	-14%	-15%
5	PM_{10}	-23%	+5%	-14%

5	NO_x	-11%	-22%	-20%
5	CO_2	-26%	-16%	-16%

Our simulation suggests very clear and important environmental and social advantages in the implementation of a CCC. Nevertheless, economic impacts must be considered to define the viability of the CCC approach. To consider them, a cost-benefit analysis was run, which showed a positive return over the total budget of the construction sites.

4 Characteristics of urban freight distribution in the construction sector in Europe

Based on the results of the simulations we performed, CCC implementation show many operational, environmental and social advantages. Some of the key points to be addressed for its setup are the agreements between the companies and the cooperation public authorities. The implementation of a CCC will request a new type of collaboration between all the partners of a construction project and a new way to manage contracts between stakeholders. Authorities are naturally part of the cooperation that must support the introduction of new measures.

The SUCCESS Enlarged Transfer Programme (ETP) engaged twelve non-partner cities in three international workshops to discuss the project tools and results and contribute to road mapping construction logistics actions in the involved cities.

Cities presented different levels of experience and maturity in construction logistics. We note that the involved northern EU cities have more experience both in terms of construction logistics practices which are in place, and in terms of inclusion of construction logistics in mobility planning. However, construction logistics appears to be a niche topic.

We can group cities based on our understanding of the reasons underlying their participation to the ETP [8]:

1) Cities delivering or committed to deliver construction logistics actions, which had interest in engaging in dialogue with other cities to better shape future actions: Antwerp, Brussels, London. These cities had many construction logistics measures in place, and were eager to discuss other possibilities (deliveries by night and by river) and whether these initiatives should be mandatory to ensure a level-playing field for businesses.
2) Cities engaged in urban freight projects or in logistics planning initiatives, which consider construction logistics as a potential topic in their future plans: Turin, Rijeka, Trieste, and Rome.
3) Cities starting to be engaged in urban freight initiatives but for which construction logistics is not a priority even if several construction projects are in place or planned and they are aware of construction works logistics impacts: Genoa / Liguria, Durres, Koper, Graz, and Limassol.

The CCC raised particular interest among the participants. Authorities indicated that their role in CCC practices should mainly be that of fostering CCCs use when procuring public works, as leverage to foster sustainable practices in the construction sector, in terms of requirements for contractors and bidding criteria. Authorities may also secure logistics areas for CCCs, as a medium and long-term perspective. Moreover, authorities can also develop rules and standards which can create a market for CCCs, similarly to the cases of Urban Consolidation Centres for other supply chains (e.g. retail, food). This indicates that authorities do not necessarily think that they should fund CCCs; one reason is the lack of public funding, but our understanding is that cities consider CCCs as a business activity which is in private companies' domain. Moreover, in case authorities would operate CCCs this may bring market distortion issues.

ETP stakeholders emphasised that financial sustainability is indeed a core issue in the implementation of CCC practices. The dimension of the construction sites served by the CCC will drive the expected CCCs' transport demand / market. Participants noted how a permanent CCC business may rely on a variable demand compared to other types of consolidation platforms. Moreover, the presence of major construction sites will ease CCC sustainability, by ensuring demand for its services and the possibility to develop economies of scale and related business sustainability. In this sense the dimension of the construction sector in a city and the presence of specific big construction projects are facilitating factors.

Another important element contributing to the CCC financial sustainability, further than an issue of driving time - distance (and related transport costs) from CCC to construction sites, is the price of land where it will be located. In particular, if the CCC area is in the city centre and if this is sold at market prices for commercial activities (which are higher than those for areas normally dedicated to logistics activities), this may make the CCC initiative not profitable. In this sense, authorities may act to secure acceptable land prices (for example with financial support for their acquisition) or to make land available to CCC initiatives.

5 Conclusions and implications for EU policies

Our review of the state of the art of urban logistics showed that many European cities are witnessing a growing demand for goods and warehouse facilities. Despite this growing phenomenon, urban freight transport is not sufficiently integrated in urban planning. In particular, the excessive fragmentation of the supply chain for many sectors and the imbalance between inbound and outbound flows in cities (which are consumers rather than producers of goods) create an important inefficiency in urban freight transport, with a significant proportion of empty journeys and suboptimal load factors.

Guerlain et al. [9] showed the specificities of the chain that supplies urban construction sites in urban areas as compared to other, well studied, supply chains such as retail, Ho.Re.Ca and home deliveries. They revealed how few researches are carried on construction logistics and supply chain, which translates in a low awareness of ways to optimize it among the professionals of the sector. This is even more worrying in a sector, that, as shown by The Economist [10] suffers from very poor productivity performance.

These observations combined show a huge potential for optimization of the construction supply chain in urban areas, and especially through the consolidation of deliveries by means of CCCs.

The simulations performed in the framework of the SUCCESS project with the help of a set of numerical tools confirmed that the introduction of CCCs to aggregate materials and to perform efficient transports from the suppliers to the construction sites and back can have a huge positive impact by reducing the number of trips, the distance travelled, the time spent travelling and the noxious emissions produced by those trips.

Having said that, the discussion with the stakeholders of the ETP confirmed that a number of key factors impact the viability of a CCC in a specific urban environment and for a specific set of construction projects. These are related to the financial sustainability of the CCC, its location and the impact of its introduction on the supply chain.

The ETP conducted within the SUCCESS project showed indeed that many cities across the EU are engaging in the challenges related to the transport impacts of the construction sector. Currently their perspective is more targeted to traffic management than to supply chain management, in line with local authorities' statutory competences, but promising developments are emerging, especially in the promotion of specific construction logistics practices and in terms of the inclusion of the construction logistics topic within the mobility and logistics planning tools of these cities.

Local authorities can have an important role in fostering the use of a CCC, for instance through the way they procure public construction works, by ensuring land for CCCs at a reasonable price and by developing rules and standards that can ensure the market viability of a CCC.

The desirable introduction of CCCs must face a number of constraints. It is a naïve utopia to believe that the savings brought about by CCCs alone can be the driver for cooperation between actors (both on the demand side and on the offer side) to optimize the supply chain. From our findings, CCCs have positive impacts but require the regulator's action. This is not necessarily in contrast with the fact that public actors consider the topic as an exclusive matter of private actors. Merging logistics in public planning, strict access rules, availability of areas close to the city at a control price: they are all examples of policies that can stimulate optimization of the supply chain without imposing a re-organisation of the supply chains themselves in a "collaborative" frame.

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