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Designing new models for energy efficiency in urban freight transport for smart cities and its application to the Spanish case

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Abstract

Considering that the transport sector is responsible for 30% of the CO_2 emissions in the EU, reaching up to 40% in urban areas, the efforts for technological improvements and innovation in transportation have been increasing during the last few decades. It is evident that urban freight distribution requires innovative solutions that are capable of improving the efficiency of transport whilst promoting innovative use of renewable energy, thus reducing energy consumption and associated GHG emissions while adopting and not stifling economic development. In this context, six Mediterranean cities (Barcelona, Bologna, Piraeus, Rijeka and Valencia)) collaborated with the purpose of contributing to the improvement of energy efficiency on urban freight transport as part of the SMILE Project (2015) (SMart green Innovative urban Logistics Models for Energy efficient mediterranean cities project), funded by the MED Programme. The SMILE project aims to improve the energy efficiency of Mediterranean cities through the promotion of innovative 'green' and cost effective solutions for urban freight logistics, addressing the target of green and smart urban development. This paper shows the results of the live test of smart city urban logistics solutions in the cities of Barcelona and Valencia that consisted of combining the use of electric tricycles and Transhipment terminals (or Urban Consolidation Centres) for the last-mile delivery of parcels and small shipments. A thoughtful analysis of the quantitative outcomes of the pilot test in both cities are presented from different perspectives: economical, operational, energy efficiency, environmental and social.

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1. Introduction

Urban freight transport plays a key role towards the economic vitality of cities. Goods transport and deliveries are fundamental elements of economic activity that is increasingly dependent on the regional business network.

However, as these operations become more intensive over time, this leads to an increase in pollutant emissions and greenhouse gas (GHG) effects. Freight transport operations are mostly private, which means that they are effective from an internal cost point of view. Problematically, they are not necessarily concerned with the external costs that they often generate in urban areas such as increased traffic and negative environmental impacts. In the urban environment, goods are distributed to the local consumers in a non-optimal way, typically arriving from the producer location to major facilities in the urban areas. The high frequency and delivery time requirements, the weight of freights and the large number of shipments characterising these deliveries makes this a significant contributor for the increase in energy consumption and CO_2 emissions in urban freight transport.

In order to tackle these issues, the attention should be focused upon the energy efficient urban consolidation and distribution. Development of promising and impacts-oriented incentive measures that are able to support the effective planning, design, start-up and full implementation (including economic sustainability) facilitates interest for future actions. Promoting and facilitating the implementation of appropriate strategies and actions enables improved access and attractiveness of urban freight terminals and streamlines the urban delivery operations related to products. This could result in effective and energy efficient consolidation and distribution of products in cities, particularly in urban centres where the last-mile distribution is becoming increasingly difficult.

Urban distribution problems are more prevalent in historical city centres. The configuration of the streets is especially complex, characterised by narrow streets. These streets utilise a one-way system and some are pedestrian, which means that these streets have special conditions to navigate around, which have access restrictions and speed limitations. For instance, the city centres of Barcelona and Valencia are both prime examples of these complex systems.

This paper shows the results of the live test of smart city urban logistics solutions in the cities of Barcelona and Valencia that consisted of combining the use of electric tricycles and Transhipment terminals for the last-mile delivery of parcels and small shipments.

Several theoretical studies have been developed around the consolidation concept with terminals. Kawamura and Lu (2008) compare the situation with urban consolidation center and previous situation under given hypothesis. Later Roca-Riu et al. (2012) present a model to estimate distribution costs in an urban area, with and without distribution center. Furthermore, the concept of consolidation of urban flows was analysed by other ways, avoiding consolidation centers (Verlinde et al., 2012).

Previous real life experiences have been developed mainly in Europe (BESTUFS, 2007), with different attempts to implement alternative long-term systems. Urban Consolidation Centres were deeply explored. However, experiences failed mainly because the business model required direct subsidies from the public sector. Recently, in the context of the STRAIGHTSOL (2014) Project, a mobile depot was used in combination with electric tricycles that was tested in the city of Brussels. The environmental benefits were clear but the system was not efficient in terms of cost. Cargo-bikes have proven to be viable solutions in different cities. In Paris, cargo-bikes in combination with Special Delivery Areas were successful, starting with just five employees in 2011 and potentially expanding. Gnewt Cargo has been operating for more than four years in London, where cargo-bikes are used in combination with other electric vans. (SUGAR 2011). A general overview of relevant articles related with the subject can be find in (Triantafyllou, 2014)

To overcome the main drawback of financial viability (TSG, 2005), the key challenge in the solution design for last mile delivery was to adopt new cooperative models between actors with two considerations. The first consideration was to: (1) share the economical savings achieved between all the actors involved, and (2) to introduce a new actor, which does not act as direct competition with traditional logistics operators.

The solution tested in Valencia and Barcelona aimed to exploit the concept of transferring urban freight demand to smaller and greener vehicles with new modes of cooperation between the logistics operators. The pilots were focused in the last mile delivery of parcels using the support of an Urban Consolidation Centre (UCC), a transhipment terminal and electric tri-cycles for the distribution along historical city centres of Valencia and Barcelona.

This paper carries out a thorough analysis of the quantitative outcomes of the pilot test in both cities from an economical, operational, energy efficient, environmental and social perspective.

The structure of the paper is as follows: firstly, the urban context and the main problems related to urban freight distribution will be specifically described for the case of the cities of Barcelona and Valencia. Secondly, the particular solution implemented in each city will be presented and, afterwards, the evaluation framework and the main results for each city will be explained in order to compare the results of each city. Finally, the paper will conclude by presenting the key factors towards the implementation of these kinds of solutions and the main challenge faced during the live test.

2. Context and problem

As previously mentioned in the introduction, last-mile urban distribution is an essential activity that generates high costs and external impacts to the city. In particular, historical centres present a complex urban configuration that complicates the last mile deliveries. The narrowness and lack of connectivity among the streets, minimal space for loading and unloading, priority for pedestrians, traffic restricted only for neighbours and specific urban elements and road surface with high historical value and with less resistance to the use of vehicles are the main problems faced. This configuration limits the use of private vehicles, and thus most problematic for vans. For these reasons, city administrations are taking action to redirect the activity to reduce external impacts. This section presents the particular context and problems on urban freight transport in the cities of Barcelona and Valencia.

2.1. Specific case of the city of Barcelona

Freight movement is vital to the economy of Barcelona. It is a large and compact city in the Mediterranean area. Goods vehicles make up 6.6% of Barcelona’s vehicle stock, but they constitute only 15% of city traffic and 23% of connecting trips. The majority of the city’s 47,000 commercial premises have no off-street loading facilities. In 2003, it was estimated that each day, 100,000 goods deliveries were being delivered from the kerbside. Barcelona Municipality contributes to the development of the city’s logistics in four main ways; infrastructure provision, enforcement, partnerships and service integration. In terms of infrastructure, Barcelona has been active in implementing and managing on-street delivery solutions over the past decade. This includes a near two-fold increase of on-street delivery spaces from approximately 8,000 spaces in 2002 to almost 14,000 in 2009 (includes the implementation of 5.5km of multi-use lanes).

The Barcelona District of Ciutat Vella has access restrictions in several areas. The street configuration is complex and there is a high level of commercial activity across the District, which generates a lot of pedestrians and tourists in the area. The restrictions are the following; it is forbidden (except for service vehicles) to enter a limited area from 11:00 until 15:00 and from 17:00 until 20:30. This situation generates a large logistic activity in the area between 9:00 and 11:00 when most transport operators must deliver goods to shops and offices in a very limited time window.

The city council of Barcelona has recently approved the Sustainable Urban Mobility Plan (SUMP) 2013-2018, which focuses specifically on logistics activities. In particular, it contains one of the strategic objectives “to give priority to public transport and goods and to oversee the correct operation of different modes of transport, giving priority to public transport and the movement of goods” in particular, inside the optimisation of urban goods, it specifies a way: “Establish a network of multi-use vehicle parks and mini trans-shipment platforms in neighbourhoods from which goods deliveries can be realised by trolleys, electric vehicles and tricycles/cargo-bikes”.

Given the opportunity when the project SMILE was conceded, the city council decided to perform a pilot test to improve last-mile deliveries in the Ciutat Vella district with two main aims.Design and implement an alternative system and all its related activities to operate it successfully.

- Design and implement an alternative system and all its related activities to operate it successfully
- Boost the participation of private companies, so the business model could be financially viable

The idea was to obtain a fully working system that should, simultaneously save costs for transport operators and reduce energy consumption, emissions and noise in the city centre.

2.2. Specific case of the city of Valencia

Currently, in the city of Valencia there are 15,083 commercial establishments with 2,428 being located in the city centre, representing 16.1% of the total number of city premises. Most of them are small establishments whereby the average number of weekly freight deliveries range between 5 and 25 depending on the commercial activity. 80% of the freight deliveries are performed by vans or light commercial vehicles during the peak hours in the morning, which means that between 9 and 12 the average duration of the delivery stops is just 13 minutes. Specifically, the historical centre of the city of Valencia is characterised by pedestrian zones and narrow streets. The majority of these streets are one-way and access control measures are applied. Access is only allowed for loading and unloading operations from 7 to 11 with a speed limit is really low (speed of human). The urban freight distribution causes severe traffic problems, especially during peak hours, were the congestion and the lack of space for loading/unloading activities leads to unauthorised areas for parking being used and vehicles may pass via pedestrian roads to deliver goods.

In order to manage urban freight logistics, there are 1,463 areas for loading and unloading operations in the city of Valencia and 24.3% of them are located in the city centre. At present, the ratio between areas for loading and unloading operations and commercial premises is 1:10 but the city authority aims to improve the urban freight logistics in order to achieve an efficient and environmentally friendly urban distribution system. According to this objective, the city hall of Valencia follows two strategic lines: (1) increase the number of reserved places for loading and unloading operations in order to reduce the ratio between loading and unloading areas and commercial premises from 1:10 to 1:8 and (2) to promote new distribution schemes by using eco-friendly delivery vehicles to reduce the impact of congestion and contamination in the city centre.

In 2011, the regional government of Valencia approved the law 6/2011 "*Mobilidad en la Comunidad Valenciana*" (In English, Mobility in the Region of Valencia). The new regulation establish a framework aims to improve the mobility of the citizens of Valencia as well as their quality of life by promoting sustainable urban mobility planning and management. With regard to urban freight logistics, the new legislation and urban mobility plan was implemented in December of 2013 to try to boost the use of efficient transport vehicles, to promote renewable energy sources and to reduce the energy consumptions. However, one of the most important objectives is to reduce the traffic congestion in the city centre, especially in the early hours of the morning when the commercial premises open.

Even though the implementation of the new urban mobility plan of Valencia has improved the previous situation, the problems of urban freight logistics in the city of Valencia still need to be solved in order to increase the quality of life of the citizens and reduce the negative impact on the urban environment. The historical centre of Valencia is one of the most important areas to focus on in terms of congestion due to the density of commercial units and the physical configuration of the streets. For this reason, the City Hall of Valencia found in SMILE project the opportunity to test new urban distribution models addressing the target of green and smart urban development.

3. Proposed solution and implementation

One of the ideas developed inside the SMILE project to tackle the problems mentioned previously was to build an alternative system for last-mile distribution of parcels in urban areas adapted to the context. For example, promote a system that could use a smaller vehicle, which is more agile and more sustainable. The whole system works by simply combining the use of e-tricycles with the installation of transhipment points. Electric tri-cycles do not have limitations for accessing the restricted area, since they are a different class of vehicle. In addition, they are agile and do not pollute the air. On the other hand, the transhipment terminal is a new facility that can boost the participation of more transport operators. The transhipment terminal offers shelter and security for the transhipment, which also facilitates the work for the company managing the last mile delivery from the terminal. The new process for the pilot test consists of the use of a support terminal that will be able to accommodate more transport operators in the initiative, and promotes the use of this alternative in the area. One of the main differences with previous approaches is that different transport operators transferring their goods in the terminal could share the same vehicle in the last mile delivery. Another main difference is that the transfer always takes place in the terminal, providing advantages for both the transport and terminal operator.

Both pilots have used the same kind of vehicle, two electrically assisted pedal tricycles that carry parcels in a closed container located on the back with a loading capacity of 1.5 m^3 and dimensions measuring 2.78 m long, 1.03 m wide and 1.95 m high. This vehicle can transport a maximum load of 280kg, although the average weight of transport is 180kg (approximately 40 parcels).

In order to successfully implement the pilot, the first step was to build a consortium counting on all actors involved in urban freight transport, including public and private stakeholders. In both the Barcelona and Valencia case studies, the city´s Municipality was directly involved since it is the Public body responsible for the development and implementation of strategic lines related to urban mobility and transport infrastructures. In order to provide technical support, two research centres with great expertise in transport participated in the pilot (CENIT and Fundacion Valenciaport). From the business point of view, four transport operators, specialised in parcel and express post delivery, participated in the pilot delivering parcels in the urban consolidation centre to be distributed to the final consignee among the historic centre. Electric tricycles were used for the last-mile distribution and an eco-logistic company was contracted for the management of the urban consolidation centre. In addition, the company that owns and manages the public and private car parks supported the initiatives making space available for the transhipment terminal base. Finally, the pilot required the involvement of the retail trade association of the historical centre in order to take into consideration the market requirements.

The particular solution implemented in each city is presented in the following sections.

3.1. Implementation in Barcelona

The pilot was designed to provide some space to operate a transhipment center with e-tricycles covering the Ciutat Vella district. The transhipment point was designed to be dynamic and flexible to accommodate future services and changes. Mainly, the service was orientated towards parcel services and similar shipments (i.e. fashion shops), the size and the weight of the packages are limited by the total capacity of the tricycles.

Differently from previous experiences, the transhipment centre was oriented to transport operators that cover last-mile deliveries inside the area. They were offered to use the services of the transhipment centre, with a limited number of packages. Transport carriers visited the transhipment point at an agreed time and shipments were transferred to electric tricycles, which delivered the shipments to their final destinations.

In Barcelona, the transhipment terminal is composed of two different modules, the closed one and a porch. The covered module occupies around 33m^2, and the porch around 40m^2. Inside the module, there are three different spaces. There is a small office where cargobike drivers can process the information. Inside, there is a dressing room for drivers and some shelves for temporary storage of the parcels if necessary and also a meeting room that might have multiple uses if needed. The transhipment terminal is located just above a public car park managed by a private company who manage some public parking space in Barcelona. This company supports the initiative by allowing some of the activities to happen on their premises: night parking of the tricycles and re-charging, toilet facilities for workers, and storage of tricycle batteries and other supplies.

For several years now, there has been an eco-logistic company operating in Barcelona. Its activities are focused on urban distribution with electric tricycles. As a support to other transport companies, they offered a service consisting of the transhipment of some packages with destination to Ciutat Vella. This eco-logistics company won the public tender in Barcelona for managing the transhipment terminal during the pilot. Their expertise and experience with the tricycles was essential for developing the pilot.

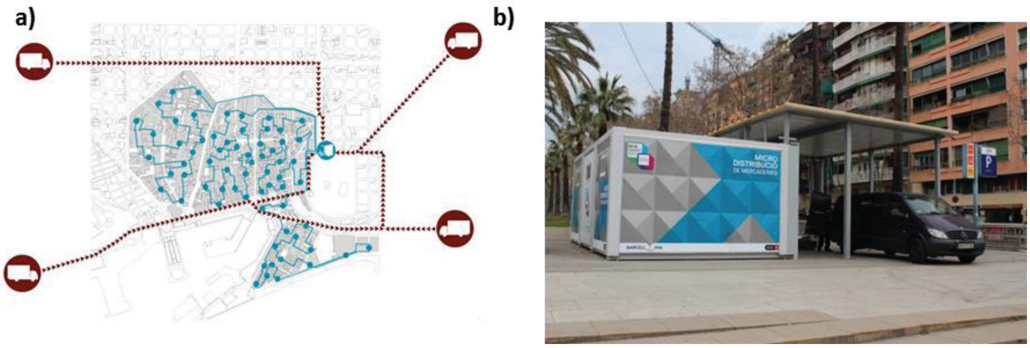

Fig. 1. (a) Schematic of the last mile distribution system followed in Barcelona´s pilot; (b) Barcelona´s transhipment terminal.

Fig. 2. Electric Tricycle used in Barcelona´s pilot

3.2. Implementation in Valencia

The pilot study on innovative technologies in Valencia was focused on the last mile delivery of parcels using electric tricycles in the city centre of Valencia and supported by the use of a micro-distribution platform where the interchange of goods takes place. The scheme covers the postal codes 46001, 46002 and 46003, all of which correspond to the historical centre of Valencia.

Logistics operators deliver goods and parcels first thing during the morning to the micro-distribution platform (UCC). And the company managing the last-mile delivery handles their transfer to the tricycles for delivery to their final destinations. At the end of the day, the parcels that have not been able to be delivered to the final address are returned to the initial logistic operator. The operation of the pilot is presented in Fig. 3.

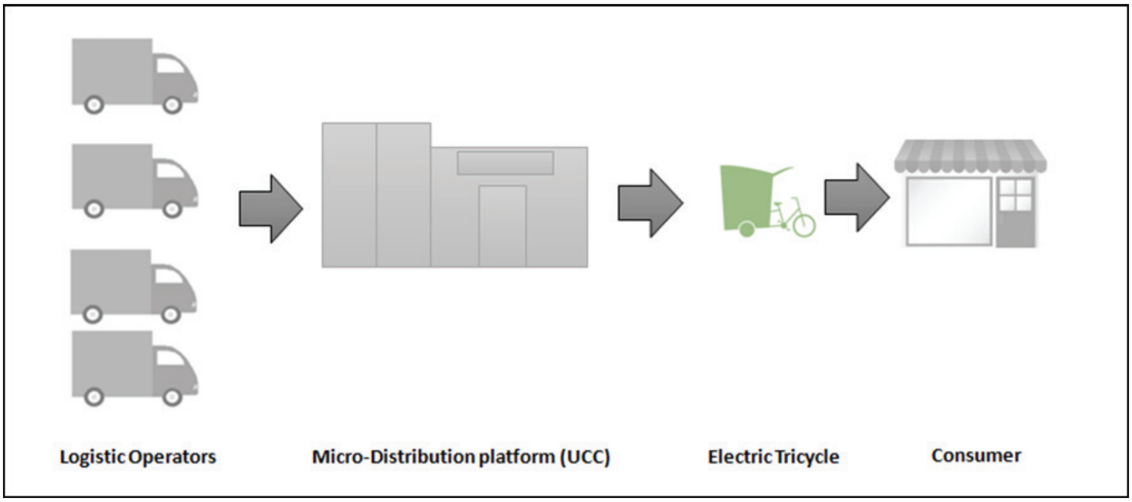

Fig. 3. Schematic of the last mile distribution system followed in Valencia´s pilot

The micro-distribution platform is composed of two different spaces, one module of 15.15 m2 and a twenty-foot equivalent container. The module is divided into two zones: an office and a temporary warehouse for parcels. The container is used as overnight parking for tricycles. This platform is located in the parking of the Railway Station of Valencia thanks to the collaboration of the company managing this parking. This location of the micro-platform, at the edge of the access belt of the historical centre of Valencia, helps to reduce the number of vehicles that enter in the city centre of Valencia to deliver goods. Electric tricycles are used to deliver goods (Fig. 4) to reduce the traffic and congestion in this area whilst minimising negative environmental effects such as noise and pollution resulting from urban freight distribution.

Fig. 4. Schematic of the last mile distribution system followed in Valencia´s pilot

4. Evaluation of results and comparison

4.1. Evaluation framework

In order to perform a deep evaluation of the pilot activities, we used an extensive evaluation framework adapted from STRAIGHTSOL (2014). During the pilot, all activity was monitored so that most of the indicators were measured directly. At times were this was not possible, alternative approximation methods were used. The set of indicators are grouped by the following areas that can be impacted upon: economy, transport operations, transport energy, environment and society.

In the economy impact area, the most relevant indicators are: operating costs and investment costs. These are the most important costs that define the cost structure of the transhipment operators. Investment costs are the total capital cost spent for setting up the initiative, which in this case include: tricycles costs and the infrastructure. In the case of operating costs, we consider the costs incurred due to the operation of the terminal.

In the operations impact area, the original framework proposes many indicators, which in our case we classified to the following: vehicles used, shipments, vehicles km, shipments/km, weight, tour-driving time. We propose to study average monthly values, and its projection to annual values.

In the transport energy area, only two indicators are considered, the fuel consumption and energy consumption (kWh). In our case, the pilot does not generate fuel consumption.

In the environment impact area, we mainly consider three indicators: emissions of CO_2, emissions of local pollutants (PM, SO_2.NO_x, VOC and CO) and noise nuisance.

Finally, we consider the set of indicators related to society, which are more subjective. In a way, they capture the reactions of society with the pilot. However, they are difficult to quantify objectively. For instance, we consider: acceptance level of the measure, employee satisfaction of the workers in the transhipment terminal, green concern, public welfare, space occupancy, business attractive and visual nuisance.

4.2. Evaluation in Barcelona and Valencia

In this section, we will present the evaluation framework applied to both cities, this way we will compare their individual performances. The values are detailed in Table 1, where costs in Barcelona and Valencia are presented monthly and annually.

Table 1. An example of a table Evaluation of Barcelona and Valencia Pilots

Indicator	Monthly		Annually	
	Barcelona	Valencia	Barcelona	Valencia
Economy				
Investment costs	€6,878	€3,409	€82,542	€40,800
Operating costs	€8,743	€4,885	€104,929	€57,600
Transport Operations				
Shipments	740	1,194	8,880	14,328
Vehicles (tricycles)	2	2	2	2
Vehicle km (tricycles)	26.9 km	20.1km		
Vehicle km saved (vans)	64 km	41 km	16,000 km	10,250 km
Shipments/km	1.38	1.40		
% Weight	64%	59.88%		
Tour driving time	5h 24min	5h 30min		
Transport Energy				
Fuel consumption (tricycles)	0	0	0	0
Fuel consumption (vans) saved	- 400.3 L	-256.25 L	- 4,804 L	-3,075 L
Energy consumption (tricycles)	32.3 kWh	21.6 kWh	387.2 kWh	259.2 kWh
Environment				
CO2 Emissions (vans) saved	-0.15 Tn	- 0.172 Tn	-1.9 Tn	-2.064 Tn
Local Emissions (monetized)	-182.81 €	N/A	-2,193.75 €	
Noise (monetised)	-412. 5 €	N/A	-4,950 €	
Accidents (monetised)	-28.2 €	N/A	-338 €	
Society				
Acceptance level	High	High		
Employee Satisfaction	-	-		
Green Concern	Low	High		
Noise nuisance	Low	High		
Public welfare	High	Medium		
Space Occupancy (m^2)	70	35		
Business attractive	Medium	Medium		
Visual nuisance	Medium	Low		

4.3. Analysis

The costs in the economy section reflect the costs of the pilot, which are a little higher than a future viable implementation. These costs also include the branding of the pilot, a consultancy work or other supports that might not be necessary for a stable implementation, or at least they will be recovered for longer periods. Implementation in Barcelona was carried out previously and it is more expensive to operate than in Valencia. This is especially true for the cost of the module and also the previous works are higher. The experience in Barcelona allowed the Valencia pilot to better predict the costs incurred

Regarding the operations indicators, shipments are also higher in Valencia. Monthly values are averages of the whole period of operation. In the case of Barcelona, the shipments were increasingly progressively and in the last month, the number of shipments was more than 1,000. In both cases, however, there is still free capacity from the tricycles that should be exploited.

As previously stated, the vehicles that were used consisted of just two tricycles in each city with the same features. On average, the total distance the vehicles travelled in Barcelona and Valencia was 26.9 km and 20.1 km respectively. We estimate that this operation can save 32 km per each tricycle in vans in Barcelona and 20.5 km in Valencia. We consider that savings are both due to distance from distribution centre to the delivery area and inside the delivery area. Savings in the delivery area are due to car restrictions in the area, which tricycles do not have. Then, vans have to detour when tricycles can drive more directly.

Savings in energy are minimal from an urban perspective because the whole system is small. However, if the system could be scaled, then potential benefits are higher. Similar things happen with external savings of approximately 2 tons of CO_2 per year could be saved using this solution. The values are discrete, but the measure has a clear potential in reduction impacts to citizens.

Finally, indicators regarding society are presented. However it is more difficult to capture them objectively but we can confirm that there is a positive feedback regarding society impacts as the survey with final shipper showed the high acceptance level of this kind of solutions.

5. Conclusions

5.1. Key ideas

From the experience of the pilot, several elements can be classified as key factors. It is highly important to consider the features of the area where the measure is being implemented: the density of commercial activity in the area, the control of access for vehicles depending on a time plan and the licences that vehicles need to circulate and delivery in this area. Also, there is the role of the different stakeholders involved. There is an essential need to perform an active search to involve transport operators in the system, to use a neutral carrier for last-mile deliveries and also have a true support from the city council.

The type of service offered is limited, in this case shipments have a limited size and warehouse services are not considered. The limitation of the number of packages was only for a pilot free service, but it should not be applied to a future long-term implementation.

The organisation of the routes is also a key point for making the system efficient. It is important that drivers get to know the area and organise the trips.

The economic equilibrium is not easy to reach. Before any implementation, the forecast for potential transport operators joining and the total number of shipments is important. The business model studied for both cities needs to incorporate publicity in the vehicles to cover part of the costs.

5.2. Challenges for implementation

The measure presents potential benefits that have been previously discussed. However, there are some challenges when implementing these kind of solutions. With the experience in the city of Barcelona and Valencia, and previous experiences, the main challenge is to reach agreements with transport operators. Transport operators are reluctant to collaborate for different reasons. But the following considerations have become essential for the implementation in Barcelona:

- The manager of the transhipment terminal should be a neutral company that does not compete with the other operators.
- The support of the city council is also crucial to obtain positive feedback.
- The delivery strategy of the companies is also important. Companies with a franchise structure have difficulties adapting to the system.

The second main challenge is the location of the transhipment terminal. Again, it is a key factor. From the experience of the Barcelona and Valencia pilots, we consider that the location has to fulfil the following requirements:

- It has to be connected to the main access roads for accessing the delivery area.

- It has to be close to the destination.
- The visual perception of the transhipment terminal should be as hidden from the general public as possible, since neighbours perceived it as a nuisance.

On the other hand, the implementation of this solution has a clear risk. From previous experiences as well as the Barcelona example, the financial model has to be clear for a long-term implementation. The business model has to be defined in order for it to be viable as a long-term solution on its own. It is not recommendable to plan the business as a subsidised system. If there is no previous viable plan, it is possible that the initiative will fail after the first few months.

Finally, some barriers might exist when implementing this plan in other locations. The Barcelona and Valencia pilot have been developed in an historic centre with access restrictions. The conditions of the area are local and are important for reproducing the same business. Thus, the conditions of the context where applied can be a barrier if the system does not fit exactly. The conditions should be previously studied for exploiting in other contexts.

The live test shows that new city freight distribution systems combining shared micro urban consolidation centres and electric assisted tricycles have a significant potential for decarbonisation of urban transport and climate change mitigation. However, whilst environmental benefits and the reduction of transport externalities are obvious, the widespread implementation of these innovative solutions faces a significant number of barriers. For this reason, the aforementioned key challenges for implementation should be taken into consideration for future implementation.

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