MICRO DISTRIBUTION IN URBAN LOGISTICS. THE PILOT CASE OF THE OLD DISTRICT OF BARCELONA

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ABSTRACT

The total amount of kilometres travelled by freight vehicles is expected to triple between 2018 and 2050. Today, 64% of all the trips happen within urban environments. There is, hence, a need for organizing the mobility and the urban freight distribution in a more sustainable way.

E-commerce has taken more relevance in the last years and an important increase of this type of consumption is expected. E-commerce has compelled to modify supply chain strategies and the management of platform distributions. Urban areas, especially old quarters and pedestrian streets are not the best scenarios for deliveries. Streets are narrow and congested, with insufficient space for loading and unloading manoeuvres. The e-commerce is worsening this situation.

One of the possible solutions that have emerged in the last years is the micro consolidation centre, a transhipment point where logistic operators store their goods and transfer them through more environmentally-friendly and smaller vehicles such as cargo bikes, for last mile distribution.

This paper presents the study case of the micro distribution in “Ciutat Vella” quarter (Barcelona) and surroundings. This micro consolidation centre, part of H2020 project, GrowSmarter, is in the oldest and most touristic part of the city, with plenty of narrow streets, and the delivery is made by cargo bikes. During the months from January 2017 to March 2019, where the study case took place, the main key performance indicators of the initiative were tracked and analysed. The results of the analysis showed a reduction of the total number of vehicle kilometres, the amount of CO_2 emissions, energy and noise levels compared to using conventional vans for the last mile distribution.

Besides these direct results, the experience of this case study allows to establish some conclusions and policy recommendations for retailers and city planners in order to implement these types of measures.

1. INTRODUCTION

By 2050, it is estimated that 68% of the world's population will live in urban areas while the global freight demand is expected to triple according to ITF (International Transport Forum) studies (Nations United, 2018).

In the context of freight transport, last mile distribution represents one of the most serious problems in urban areas of large cities. For instance, in Europe, approximately 10-15% of vehicle kilometres (CIVITAS, 2015) are travelled by urban freight vehicles. Moreover, the last mile is considered as one of the most expensive, inefficient and polluting parts of the supply chain. Freight vehicles are responsible for more than 50% of NO_x emissions of the transport sector (Dablanc, 2011). Additionally, the fact that most of the door-to-door deliveries are done by small vans implies that the carbon footprint per kg is higher than that of transport by a bigger truck. This growing number of vehicle and transport needs in urban areas is having a severe impact on cities' quality of life.

In addition to that, today the e-commerce model is fully accepted in almost all societies and is present in all sectors of the economy. The numbers prove it: according to the National Institute of Statistics (INE) and the National Centre of Markets and Competition (CNMC), in Spain the internet sales have grown by 37% from 2014 to 2017. Whereas in the city of Barcelona, in 2017, freight transport represented approximately 21% of total traffic, which in absolute values was about 430.000 daily trips per year (Pimecomerç, 2018).

However, these same figures also indicate that there is still much growth ahead, given that there are other countries that show much higher levels of penetration of e-commerce. In fact, according to Europe last mile data, issued by the European Commission, in the period between 2005 and 2050 the transport of goods will increase by 80% (Commission, 2011).

Undoubtedly, the situation is testing the limits of the infrastructures of our larger cities, which will require the drastic restriction of CO_2 emissions due to the high levels of air pollution as proposed by EEA (European Environment Agency). Consolidation schemes (Janjevic and Ndiaye, 2014) are one of the most popular measures in city logistics. The most common of them being the Urban Consolidation Centres (UCCs).

The key purpose of UCCs is avoiding the need for freight vehicles to deliver part loads into urban areas (Browne, Woodburn and Allen, 2007).

Different cities, mainly in continental Europe, have conducted studies, trials and showed the growing interest in the UCCs (for instance, the UCC case initiatives of Parma in Italy, Huddinge in Sweden and Sheffield in UK) (ProSFeT, 2018).

However, despite their popularity, many researchers have also demonstrated the limits of the Urban Consolidation Centres, the difficulty to implement them in a competitive environment and their limited benefits (Ville, Gonzalez-Feliu and Dablanc, 2013).

Danielis, Rotaris and Marcucci (2010) have demonstrated that in few cases the UCCs survived financially without public subsidies or strong political commitment. Allen (2012) confirms that the success of the UCC is greatly dependant of its type and implementation conditions. The financial considerations are often too complicated and need to be resolved with schemes requiring on-going public subsidies for UCCs that serve part or all of an urban area. UCCs are successful only in specific conditions and most often with structural public subsidies. (Janjevic and Ndiaye, 2014)

Nevertheless, many innovative experiences have been performed in the cities across the globe (for instance, Manchester in UK, Stockholm in Sweden, Helsinki in Finland), offering a large panel of alternative consolidation schemes. In particular, many experiences have focused on downscaling the consolidation effort by grouping goods much closer to the point of reception, whereas UCCs do so outside the boundaries of the urban area.

Generally, these experiences are referred to as “micro consolidation initiatives” where the scale of the consolidation is smaller, and thus the size and weight of transported goods is also smaller.

Micro consolidation initiatives usually involve the urban light freight. In fact, bundling the goods near the reception point requires the setting-up of facilities in the heart of urban areas, making these initiatives unsuitable for heavy loads.

Some of the common characteristics of these micro consolidation initiatives are:

- The aim to reduce the total vehicle trips performed in an urban area (and particularly in most dense areas) by bundling the goods close to the final destination.
- The setting-up of logistical facilities in urban areas.
- Targeting the deliveries of small and light loads (i.e., parcels as opposed to pallets) that can be grouped under the common denomination of “urban light freight”.
- The use of clean vehicles or soft transportation modes (cargo bikes) for the last leg of the delivery.

Using micro consolidation centres located closely to the final destination is a frequent solution for the improvement of last mile delivery and collection. Moreover, there are alternative consolidation schemes. Verlinde, Macharis and Witlox (2012) have provided a first classification of the alternative schemes based on the nature of the measure (behavioural or physical), and a further classification of physical measures that consist of either traditional urban consolidation centres or alternative transhipment points. Whereas, the logistic spaces are classified according to spatial dimension i.e. the size of the urban area that is served, and that can vary from one building or street to a whole city. Some of these measures focus on small urban areas: loading and unloading areas, collection points and smart points.

The objective of this paper is to show the implementation of a pilot case, present the results and draw conclusions for other similar measures. Whereas the overall objective is to demonstrate that, compared to the conventional ways and vehicles used for the distribution of goods in the urban area of the city of Barcelona, the implementation of a new business model such as the micro urban consolidation centre (mUCC) would help reduce emissions as well as vehicle kilometres.

The paper offers a comparison between the deliveries with electric cargo bikes and deliveries with standard vans in urban areas in terms of CO_2 emissions, noise, and energy consumption. Moreover, the paper also presents a description of the business model used for the implementation of the pilot case in the “Ciutat Vella” of Barcelona.

For the purpose of this article, a thorough research has been carried out in order to establish a state of the art and the different types (see Figure 1) of micro consolidation measures currently implemented in the European cities. These types are:

1. Loading and unloading areas consist in setting-up zones where carriers can load and unload the goods destined to the neighbouring receivers. In addition to reducing parking problems and better accommodating trucks, the setting-up of this type of devices also reduces the vehicles-trips to be performed in the delivery area.
2. Collection point (Click and collect) consists in setting-up an urban service where carriers can deliver their goods to a communal delivery point. This service can be used by private or business customers. In addition to providing a new service and allowing off-hours deliveries, these points also aim to reduce the total vehicles-trips in the delivery area by bundling goods at the reception point.
3. The smart points are boxes that bundle the goods at reception and enable the deliveries in the absence of the receivers by setting-up automated lockers. This typology is valid for both business and private customer are currently used in different European cities for the delivery of letters and parcels in absence of the receivers. The lockers can be installed in the streets, residential zones, office

buildings, among others to create new many-to-many hubs between the company and the customers.

4. Micro consolidation centres (platforms) adopt a similar scheme as one of the classical urban consolidation centres - bundling the goods, combined with a fleet of non-polluting vehicles making rationalized rounds. However, as opposed to UCCS, micro consolidation centres are much closer to the delivery area and have a more limited spatial range that is conditioned by the range of vehicles used for the last mile (generally clean vehicles such as such as cargo bikes or light electric vehicles). Furthermore, the bundling of goods usually takes place in a suburban depot from where a consolidated transport is performed towards the micro consolidation centre.
5. Logistic facilities bundle goods and perform consolidated transport to the city centre where a transhipment point (i.e., a loading and unloading area) is used to transfer goods to lighter and more adapted vehicles.
6. Logistic facility in a combination with a mobile micro consolidation centre that is used to perform the consolidated transport of goods towards the urban area and that contains all the necessary equipment and vehicles for the last mile of the delivery.
7. Micro consolidation centres in combination with a Smart Point can be used by different distribution companies at the same time. The purpose of the local distribution station is to reduce the number of delivery vehicles in the city centre and to support carbon neutral logistics. The service is aimed at residents and commuters. Generally, the location of this hub is strategic, in order to make it easy for public transport users and pedestrians to grab a pre-ordered shopping bag from the hub.

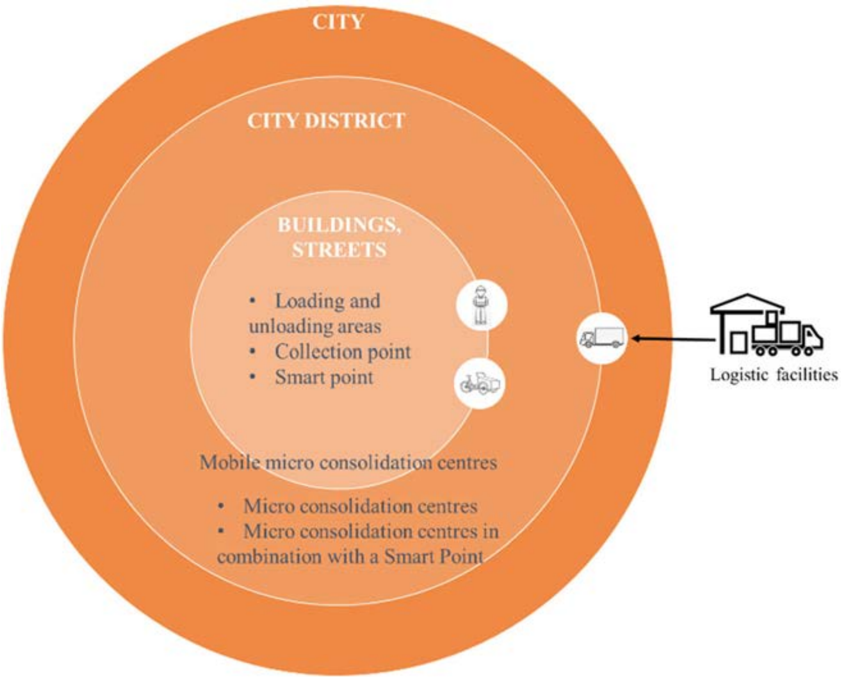

Figure 1: Urban logistic spaces within the city

This paper is based on a study case that analysed a micro urban consolidation centre (mUCC) where transport operators could store their products and transfer them to electric cargo bikes for the last mile urban distribution, covering a high-density area in the old town of Barcelona (narrow streets and stores). The project database was built with data from January 2017 to March 2019.

The remainder of the paper is organized as follows. The second section provides a brief review of the state of the art, giving context to the micro urban consolidation centres. The second section describes the study case in Barcelona. This is followed by the calculations of the key performance indicators, in the fourth section. The fourth section is an assessment of the environmental impacts. Then, the fifth section explains the business model in this study case. The following section offers a discussion of the results and policy recommendations.

2. THE DESCRIPTION OF THE STUDY CASE

Barcelona has opted for micro consolidation centre of goods to incentivize the use of friendlier transport. A consolidation centre was installed next to the “Estació de França” to serve the old town (
Figure **2**). It is an area of 4,49 km2 characterized by narrow streets, high density and an import commercial activity (the majority are small stores and restaurants) with high demand. Moreover, the area is characterized by a lack of parking space. Thus, freight delivery in this area can be critical if carried out by vans. The implementation of the solution was part of the Growsmarter project that ended in 2019.

However, the consolidation centre is still active and running.

The micro consolidation centre operates in the following way:

- The services of the last mile operator (independent operator) can be contracted by any logistics operator.
- The micro consolidation centre, owned by an independent operator, is the place of transhipment of all packages from vans to sustainable vehicles and is also used as a small storage place.
- The last mile distribution is carried out by electric cargo bikes.

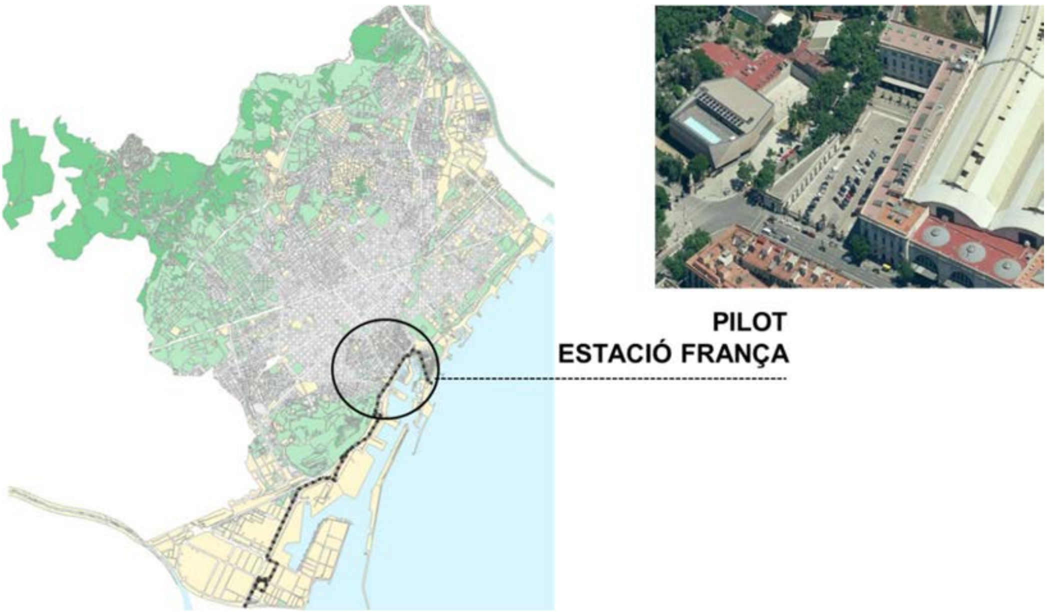

Figure 2: Area of delivery

Carriers bring their packages to the consolidation centre and the last-mile operator handles the delivery of goods to their final destination using electric cargo bikes, thus reducing congestion, diminishing emissions, and lowering delivery times in the highly populated areas as well as reducing costs for conventional carriers. During the implementation of the measure there was an increase in the use of electric cargo bikes, from 3 to 15 vehicles, and a modal shift from vans to electric cargo bikes.

3. CALCULATIONS OF THE KEY PERFORMANCE INDICATORS

The data was collected for a period of 26 months (from January 2017 to March 2019) as part of the Growsmarter project where the last mile deliveries were carried out through the usage of electric cargo bikes.

3.1 Vehicle kilometre reduction

The vehicle-km reduction was calculated as follows:

- It was assumed that, without this last mile delivery service, the deliveries were performed by regular vans. With the new service, last mile delivery was carried out by using cargo bikes, allowing the shortening of the routes, since cargo bikes can run through narrow streets (which do not allow access to regular vehicles).
- From the data collected from the trips, which were provided by the logistic operator involved in the study case, the difference in vehicle-kilometres between the two types of delivery was calculated.
- In Figure 3, it is possible to observe an example of a route in the studied area. As observed, the difference between the two routes (with vans and with cargo bikes) is 1,5 km.

Figure 3: Example route: the route of the van is blue, and the cargo bike route is orange

3.2 CO_2 reduction

An interview with the last mile operator was carried out as part of the study and the information provided by the interviewee was used for the calculations. The interview provided data and information about the number of cargo bikes, number of packages per cargo bikes and type of contract for each logistics company, among others.

In order to calculate the reduction of emissions obtained, a comparison was carried out between the emissions of the electric cargo bikes and the standard delivery vans. These steps were followed:

- The first step consisted of the calculation of the total number of kilometres travelled during the evaluation period (26 months) by cargo bikes taking into account all deliveries. The data on kilometres was provided by the logistic service provider that used GPS to track it. For example, during the Growsmarter project the cargo bikes travelled an amount of 72.183 km.
- The second step consisted in the conversion of the kilometres travelled by electric cargo bikes (calculated in step 1) to the equivalent kilometres that would have been carried out by standard courier services for the same deliveries. The conversion was implemented taking into account the route differences between the vehicles as shown in the example of Figure 3.
- During the third step, the calculation of the energy required by the cargo bikes was carried out. The energy required by the vehicles was represented by the capacity of the electric battery. To carry out the calculations of the energy that the standard services. would have consumed, the Catalan energy mix (Climàtic, 2020) was used.

This mix represents the average value of kg CO_2 emissions that 1kwh of produced energy generates. Two conditions were taken into account for the calculations:

1. The standard courier services (by truck/van) used for distribution produce local emissions.
2. The production of electricity (for cargo bikes) does not generate local emissions (only at the energy production site, if any).

- Finally, the amount of CO_2 emissions by the standard courier services was calculated considering the kilometres travelled as obtained in step 1 and the reference value in kg CO_2/km obtained from EEA (European Environment Agency, 2019) for standard delivery vans.

3.3 Energy saving

To calculate the savings in energy, a comparison between the energy needed for the cargo bikes and the energy needed for standard delivery vans, was carried out.

The energy of the cargo bikes is represented by their capacity. Thus, the total energy needed by the cargo bikes during the evaluation period was obtained by multiplying the capacity by the number of cargo bikes available and the number of working days.

To calculate the energy consumed by standard delivery vans, the total number of kilometres was multiplied by the amount of fuel per km.

Finally, the comparison between the values obtained was carried out. To carry out the calculations, get real values, better understand the practices carried out by logistic operators and cope with the reality of the sector, the interview with the last mile operator was of utmost importance.

3.4 Noise reduction

To calculate noise reduction in the pilot area, a comparison was carried out between the noises emitted by cargo bikes and noise emitted by standard delivery vans.

The number of cargo bikes available for the pilot was 15. Taking into account that approximately 1,5 cargo bikes were needed for each van (information obtained from the interview), the number of vans necessary for the same deliveries would have been 10.

The noise reduction was calculated assessing and comparing the noise a standard van generates in average for each operation (approx. 80 dB) with the noise generated by a cargo bike (approx. 45 dB). Since, decibels are a logarithmic scale, an increase of 10 decibels (dB) is perceived as a doubling of noise volume. The number of decibels from multiple sources cannot simply be added to get the total number of decibels.

If two trucks that produce 80 dB of noise each are passing the same location at the same time, they will produce a total of 83 dB. Table 1shows an approximate scheme for the calculation of the noise from overlapping of multiple sources. The table is accurate within 1 dB of the exact value.

Adding Decibel Amount differ by:	Add this amount to the higher value	Example
0 or 1 dB	3 dB	70 dB + 69 dB = 73 dB
2 or 3 dB	2 dB	74 dB + 71 dB = 76 dB
4 to 9 dB	1 dB	66 dB + 60 dB = 67 dB
10 dB	0 dB	65 dB + 55 dB = 65 dB

Table 1: Example of noise calculation (Rudy Hendriks, Bruce Rymer, David Buehler, 2013)

4. ASSESSMENT OF THE ENVIRONMENTAL IMPACTS

During the study period of 26 months when the data was collected (with the exception of June 2018, because there were contractual changes between the micro consolidation centre company and the different logistics companies), the number of deliveries has undergone large variations as can be observed in Figure 4. Despite the increase experienced during the first 6 months of the year 2017, the summer represented a difficult time for the company.

However, the difficulties encountered were due to the fact that one of the main logistic companies stopped using the micro consolidation centre. This fall was observed only for a few months, and as of October 2017, the number of deliveries carried out raised up again. From this point of inflection, they remained constant for a year. From October 2018 until March 2019, a new company joined and helped double the number of deliveries. During the study period, a total number of 207.000 deliveries was carried out.

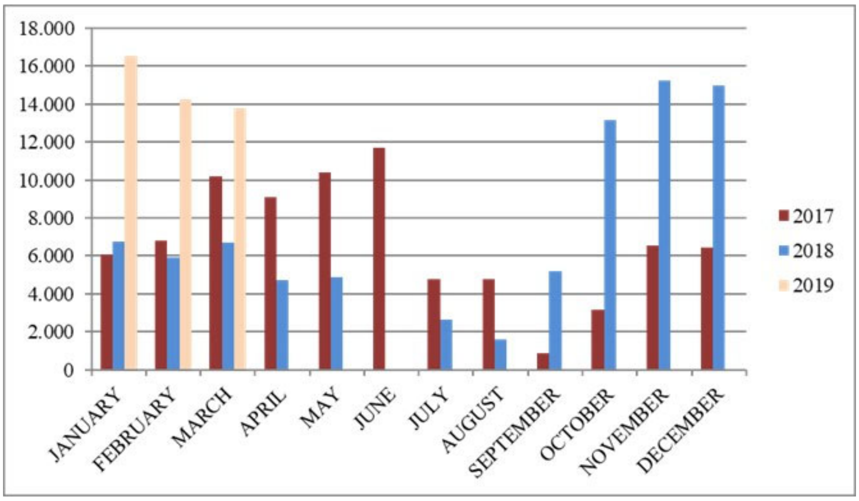

Figure 4: Number of monthly deliveries

Looking the data at a more disaggregated level, the distance between two delivery points is displayed in Figure 5. It can be noted, that with the increase of the number of cargo bikes available, the distance between delivery points decreases. The lower the distance between two delivery points, the more optimized and efficient are the routes, therefore a higher number of packages arrive on the micro consolidation centre for delivery because a higher number of logistic operators employ the service.

The overall average distance between two delivery points during the study period was 427 m.

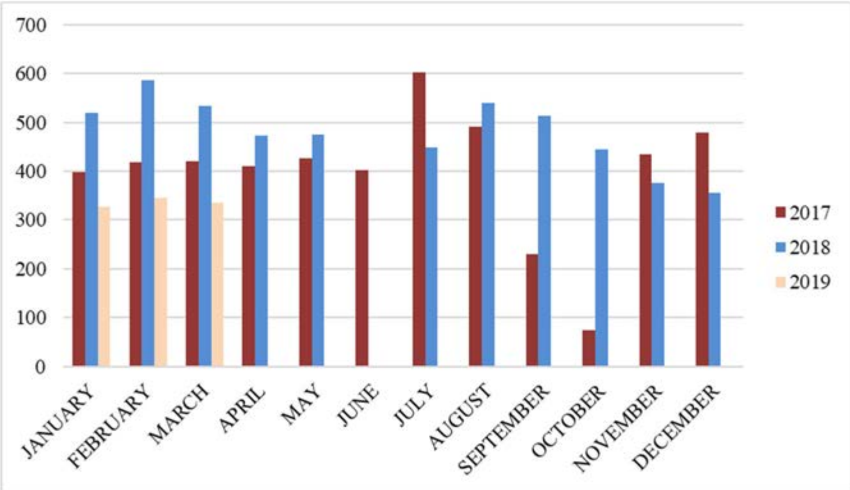

Figure 5: Distance between two delivery points (m)

More in detail, the number of expeditions carried out per hour is plotted in Figure 6. The expected number of hours corresponds to the time needed for the trip, excluding the time required for loading the cargo bicycle, for example, at the beginning of the route or the time used for lunch stops. On average, during the study period, 7,12 deliveries per hour were carried out.

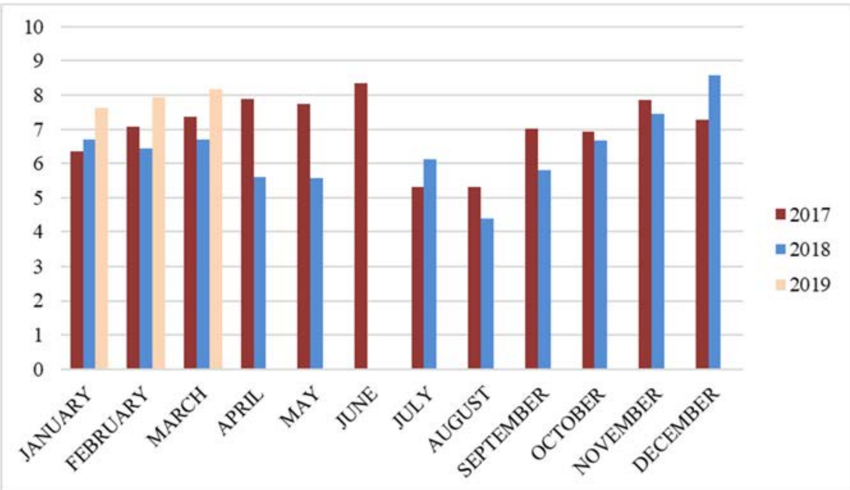

Figure 6: Expedition per hour

Moreover, the number of kilometres travelled by each cargo bike per day is shown in Figure 7, with an average of 19.3km per day. The figure indicates the variations that have occurred over the study period. The variations are lower during the end of the pilot (2019), because the micro consolidation centre has been used by more logistic companies than the ones operating in the study zone.

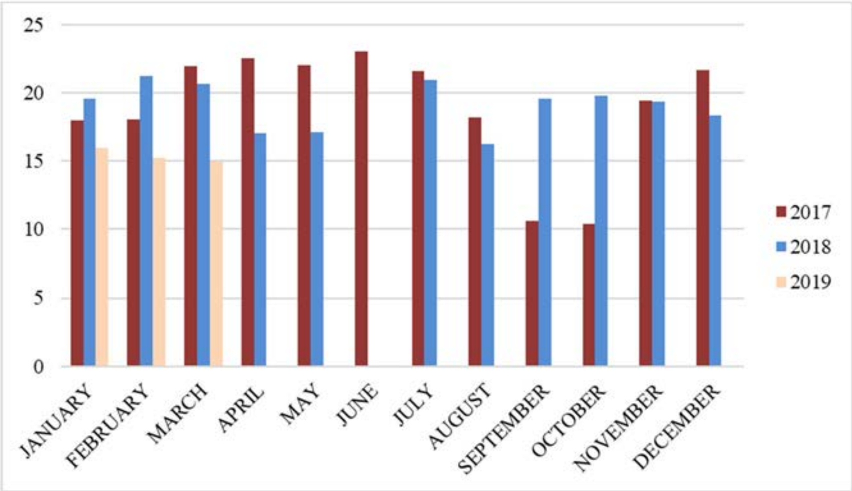

Figure 7: Number of daily kilometres covered per cargo bike

The number of kilometres covered by the cargo bikes during this time period is shown in Figure 8. It can be noted that it follows a similar shape to the curve of the number of deliveries (see Figure 4). Moreover, as can be seen from the figure, October 2018 was the month in which the highest number of kilometres was covered, more than 5.000 km.

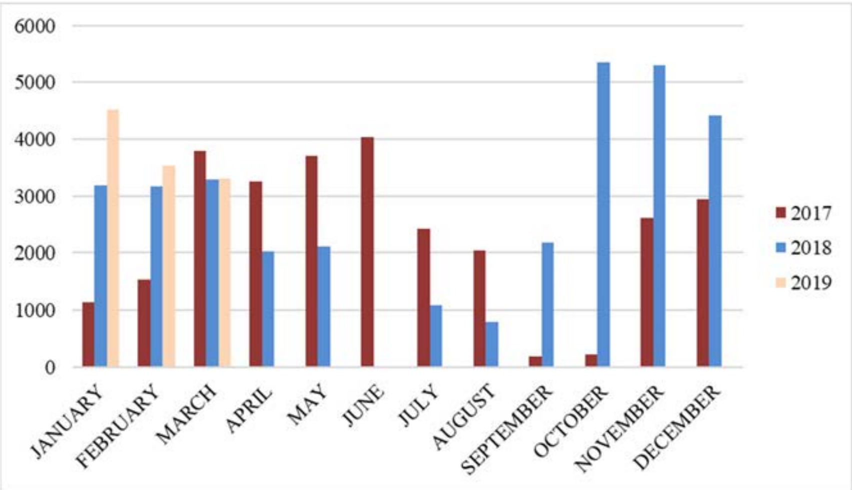

Figure 8: Total distance covered by all vehicles monthly (km)

Table 2 presents the main indicators calculated to check if the modal change in last mile distributions in the old part of Barcelona has helped reducing pollution, energy and noise.

	Average emissions per heavy vehicle kilometre (kg CO_2/km)	Average energy use per heavy vehicle kilometre in the site (kWh/km)	Number of heavy vehicle kilometres shifting to renewable fuels (km)	Number of bicycle/tricycle kilometres needed to perform the same deliveries (km)
Key indicators baseline	0,26	0,79 kwh/km	101.778 km	0
Key indicators 26 months	-	-	0	72.183 km
	Total estimated reduction of emissions (kg CO_2) based on indicators	Total estimated reduction of energy use (% kwh) based on indicators	Total estimated reduction of emissions (% CO_2) compared to baseline	Total estimated reduction of noise (dB) based on indicators
Key indicators baseline	27.084 kg CO_2	80.970 kwh	-	115 dB
Key indicators 26 months	1.085 kg CO_2	97,55% kWh	95,99% CO_2	90 dB

Table 2: KPIs evaluated

The reduction in terms of emissions generated in kg of CO_2 using electric cargo bikes instead of heavy vehicles is 95,9%. Similarly, the energy reduction between these two types of vehicles is about 97,5% and the noise reduction is about 22%.

Finally, the data gathered during the pilot study indicates that the implementation of the micro consolidation centre helped reduce the number of vans circulating in the area as well as pollution, congestion and noise.

5. BUSINESS MODEL

The current study takes into account the business model based on the micro urban consolidation centres. Through the business model, the municipality aimed at making these services economically autonomous with no need for monetary subsidies.

The business model was created following the canvas methodology. The following table summarizes it:

<table>
<tr><th>Key Partners</th><th>Key Activities</th><th>Value Propositions</th><th>Customer relationships</th><th>Customer Segments</th></tr>
<tr><td rowspan="3">1) Carriers / Transportation companies
2) City council / local governments</td><td>1) Reception and consolidation of goods into the consolidation centre
2) Operating the micro distribution centre
3) Delivery to their final destination using cargo bikes
4) The Workshop</td><td rowspan="3">1) Customers / citizen: increased time frame to perform deliveries and extended delivery coverage
2) Traditional carriers: they avoid entering the limited access and pedestrianized areas of the city centre and costs saving. The sensors in the cargo bikes can help optimizing delivery routes, and to make it more competitive for the last mile operator
3) Community: reduced environmental and noise impact
4) City Council: to monitor the noise and pollution levels in that area</td><td>1) Customer support
2) Personal assistance</td><td rowspan="3">1) Users / customers
2) Carriers / Transportation
3) City Councils / Municipalities</td></tr>
<tr><td>Key Resources</td><td>Channels</td></tr>
<tr><td>1) Physical assets (UCC construction and maintenance, electric cargo bikes)
2) Human resources (Delivery staff, operation staff at the consolidation centre)
3) Technology
4) Public Financing</td><td>1) With users/consumers: website and mobile phone apps
2) With City Councils: WLAN communications
3) With carriers: sales force and web sales</td></tr>
<tr><td colspan="2">Cost Structure</td><td colspan="3">Revenue Streams</td></tr>
<tr><td colspan="2">1) Fixed costs (Running costs, Salaries, Cargo bikes)
2) Variable costs (Costs of operating the micro distribution centre)</td><td colspan="3">1) Fee charged from carriers
2) Delivery fee charged from customer</td></tr>
</table>

Table 3: Business model canvas

With regards to Table 3, three main considerations are taken into account: (1) the main revenues are dedicated to delivery parcel (which is very scarce). Additional revenues are provided through maintenance/repairs to other cycle companies or electric cycle owners and by pick-up points (storage services); (2) the rent of offices of the logistics company in this case, is responsibility of the City Council; (3) the more efficiently parcels are delivered, the more profitable can the company be.

The micro consolidation centre is managed by a company which negotiates different conditions with each logistics company. These conditions might include different benefits per package delivered, advertising of the logistics company on the cargo bikes, uniform for distributors etc. The procedure followed for the delivery consists in each logistic company sending their packages to the micro consolidation centre (early in the morning) which are then delivered by the cargo bike operators to their end customer. Nevertheless, the details of the agreement between the last mile company and the logistics companies are confidential and cannot be presented.

During the current study, all logistic companies used a micro consolidation centre which was managed by a company that offered last mile solutions. However, there is a risk that partners (logistics companies) may build their own micro consolidation centres of a high enough parcel delivery density to be profitable. If such thing happened, we would increase the number of micro consolidation centres and thus the number of cargo bikes moving through the city as well as the number of vehicles that distribute parcels in the different micro consolidation centres.

Thus, the best solution would be to use shared micro consolidation centres, in order to reduce the risks and optimize the routes and last mile deliveries. Moreover, a neutral stakeholder/company should operate the micro consolidation centre, otherwise, it would be unlikely to be accepted by all the logistic operators, who should be ensured that they will not lose clients as there is tough competition between them. The city – or another public authority – should take care that the neutral operator stays neutral.

6. CONCLUSIONS

This paper describes the pilot case of a micro consolidation centre located in the oldest part of Barcelona. On-bike sensors were installed to assist with routing and to monitor the service and environmental conditions for research purposes along the routes. Over 207.000 journeys were made by the e-cargo bikes over a 26-month period, reducing CO_2 emissions by approximately 96% compared to delivery by trucks, and also cutting noise and pollution.

The results indicated that the reduction of vehicle kilometres, emissions, energy and noise could be achieved by using micro consolidation centres with cargo bikes for urban last mile distribution.

Last mile delivery is an emerging market segment, and creative support from city administrations is needed to accelerate a transition to sustainable delivery systems. Such support could be given in terms of e.g., designating a zone for deliveries with a dense population and high turnover of parcels; mandating actors to deliver within the zone and monitoring non-compliance; and – in this case – identifying premises and agreeing a tenancy arrangement to enable implementation. Identifying a suitable location for the service, agreeing the terms of operation, and ensuring a suitable installation of the sensor units on the bikes were the main challenges and achievements. It is important to reach a trade-off between robustness, safety and functionality.

The urban freight transport possibilities are generally determined by policies of public authorities, such as the local government, the national government, and for some issues even the European Commission (e.g., setting EURO-standards for truck engines).

However, lessons learned from past experiences in European projects show that success in implementing urban freight logistics measures such as the micro consolidation centres, requires the involvement of multiple stakeholders. Private, public and community stakeholders are all impacted by last mile issues and/or could potentially play a role in developing their solutions.

ACKNOWLEDGEMENTS

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