The urban distribution of freight is a challenge that is gaining more and more momentum over the years because of a skyrocketing use of e-commerce. Even if market places could almost fully rely on TIC platforms in future years, physical networks for the distribution will be always needed. In this supply chain, the last mile represents on average 29% of the total delivery costs (Lopez, 2017). To make these operations more efficient and reduce their economic weight, new types of robotic technologies – mainly Ground Autonomous Delivery Devices (GADD) and drones – are emerging. Unfortunately, the research in this field is nowadays essentially oriented towards operations and focused on finding new algorithms to optimize the distance travelled by different combinations of these vehicles when they operate in the city. More strategic insight is needed to help cities define adequate frameworks. The main objective of the thesis is to gain knowledge about the economic potentialities of drones and GADDs as well as their future impacts on cities in the context of the urban last-mile freight distribution. Viable Business Models for these brand new logistics services will be defined, resulting in an improvement of business opportunities for carriers and more sustainable operations from the city perspective.

Methodology

Considering available data related to the current distribution patterns in the metropolitan area of Barcelona, different demand models will be assessed and calibrated. The idea is to use machine learning and neural networks techniques to highlight the delivery routes of carriers depending on several relevant parameters such as the time of the day, the type of the neighbourhood (residential, CBD…), the economic activity (population density, number of supermarkets, number of shops…) and so on.

Then, considering the previously calibrated demands, Continuous Approximation (CA) models (Daganzo, 2005) will be developed to compute some of the carriers’ Key Performance Indicators (KPI) – the total distance travelled by its fleet, the total time spent in operations, the overall energy consumption of the fleet… – in different scenarios. These KPIs will enable us to compute the carriers’ operative costs as well as the externalities induced in the city by the operations of the robots. CA models are highly valuable because the equations are easy to interpret and the most relevant decision variables can be rapidly identified (Campbell, 2017).

A strategic in-depth study of GADDs to evaluate their economic competitiveness is to be done. The optimal design of GADDs seems to be driven a priori by some trade-offs on the speed and size of the robots. If GADDs travel at a high speed, the different delivery routines take less time (because the robots travel very fast between 2 customers) but the energy consumption per unit distance is much higher, which increases the total operative costs of the carriers. On the contrary, if GADDs travel at a low speed, the energy consumption decreases (low operative costs per unit distance) but the routes would take a very long time, affecting the carrier’s economic profitability. If the GADD is very big, it can deliver lots of parcels in one route (increasing its efficiency) but its travel speed on the sidewalks or the bike lanes would be very limited because of safety issues. If the GADD is small, it can deliver less parcels per route (which limits its economic competitiveness) but it may be allowed to travel faster.

As for drones, also known as Unmanned Air Vehicles (UAV), the challenges that are raised are quite different because 1. Considering the current technology, drones are only able to deliver one parcel at a time, which means they need local consolidation hubs and 2. Regulation may play a much more important role. Drones’ operative protocols need to be clearly defined. The total number of drones that will potentially fly in the sky of our cities (a key data for future regulations) should be quantified considering their actual (and future) technical characteristics. Even if the potentialities of drones in very specific markets such as the food

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delivery are quite clear, many other options are to be explored. An innovative concept that may be used for a further drone regulation will be introduced. Let us imagine that there is a huge demand for drone operations and that a given city implements some vertiports (landing and take-off infrastructure) to control these drone activities. For safety reasons, drones (used for parcel delivery for instance) would have to land or take-off at one of these points; no ground operation would be allowed out of these vertiports. Considering these assumptions, a system of slots would be needed (such as in airports for landing tracks) because there will be a high demand for drone operations and limited infrastructures. In this drone slots management system, one of the main decision variable is the duration of each slot. If the slot is very short, many operations can be executed in a given time. However, some failures can occur. If the drone is a bit late, it cannot catch its slot and the management system needs to reallocate a new one later on, which decreases the overall efficiency of the system. If the slot is very long, the system deals very well with uncertainty. If the drone is a bit late, this is not a problem because the slot is very long and there is some time margin. However, the number of operations done per unit of time decreases, which limits the economic competitiveness of the system. A Proof-of-Concept of this drone slots management will be proposed considering different relevant variables, among others:

- The density of drones (number of drones per square kilometre) operating in a given service region.
- The vertiports density
- The operative characteristics of the drone: speed, range…
- The uncertainty of drones operations.
- …

Finally, all these findings about GADDs and drones will be gathered and compared to provide city representatives with some guidelines and recommendations concerning the last mile GADD and drone operations in urban environments. Depending on the city characteristics (demand density, size of the service region, urban planning of the neighbourhoods…), one of the two technologies may present more potentialities in terms of economic competitiveness and/or induced externalities. GADDs and drones will surely emerge in future years because the e-commerce market is attracting more and more money and very powerful private companies are doing really huge investments in this field. If not monitored and regulated, the deployment of these new vehicles may result in a worse situation than the Business-as-Usual delivery strategies.

**First results**

Some preliminary results have already been obtained. In very dense urban environments (with a total parcel demand density over 100 parcels/km²) GADDs appear as the most economically profitable. If there is a cooperation between all the carriers operating in the service region and an Urban Consolidation Center (UCC) is implemented, costs savings could reach 30% using GADDs for the last mile delivery (Lemardelé et al., 2020) when compared with the Business-as-Usual delivery patterns. Truck-launched delivery drones seem to show much more potentialities in less dense urban environments like suburban areas. For medium demand densities (around 25 parcels/km²), the costs savings could be of 60% with truck-launched UAVs when compared to the Business-as-Usual last-mile delivery operations (Lemardelé & Estrada, 2020).

**References**


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