D2: REPORT ON LAST-Mile PARCEL DELIVERY BASED ON REAL-ROAD DATA

– Data collection and results analysis

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*The data collection was carried out with 13 drivers from CORREOS under the supervision of two directors. 6 drivers are from urban distribution center-USE7 and 7 drivers are from the suburban distribution centre-URP2, who attended an eco-driving course in their depot and facilitated the data collection and evaluation.

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Executive Summary

The current work documents the procedure and outcomes of a logistic experiment conducted under the national project "**Eco-Traffic**" (TRA2016-76485-R) which belongs to the Plan Estatal I+D+i in the context of challenge number 4-Intelligent, sustainable and integrated transport.

With the aim of analysing the potential reduction of energy consumption and emissions (both GHGs and pollutants) from an efficient way of driving (eco-driving), our research group have conducted two field trials: one with passenger cars and another one with light-duty vehicles (LDV).

Urban freight accounts for 21 per cent of CO_2 emissions, but this field is usually less studied by researchers. This report focus on the issues of Last-Mile Delivery (LMD), along with two specific aspects that may contribute to overcome the recent problems in urban freight:

- to collect real data within last-mile delivery routes of local logistic company, to characterize the pattern of current distribution operations, and to present the extent to which distribution operations vary for the same company in two different areas studied (urban and suburban).
- to develop a sequential method to study on the collected data;
- to compare energy efficiency between electric and diesel vans under same road and operating conditions;
- to study the efficiency of eco-driving for professional logistic drivers, distinguishing between combustion and electric vehicles;
- to present a holistic view of the problem and provide useful information to analyse the impacts of the use of distribution vans, comparing the energy consumption along different roads with different traffic and slope conditions.

The details of the report consist of the **Data collection campaign** of LMD that is conducted in Madrid cooperating with local logistic company (CORREOS), and the **Data analysis developed** by the TRANSyT group, to further understanding trip characteristics of LMD as well as the efficiency of eco-driving.

The results analysed regards to three aspects: **Characterization of last-mile delivery**, **energy efficiency comparison between EVs and DVs** and **analysis on eco-driving impacts**. Within a number of findings achieved via the systematic analysis method, a simple theoretical class of eco-driving could contribute to reduce energy consumption both in urban and suburban area regardless the vehicle type. However, an optimized fleet may dramatically reduce emissions and air pollutants, as well as diminish operating cost of the logistic company.

1. Introduction

1.1. Posing the problem

The OECD (2003) defines **urban freight transport (UFT)** as follow: '*The delivery of consumer goods (not only by retail, but also by other sectors such as manufacturing) in city and suburban areas, including the reverse flow of goods in terms of clean waste*'. UFT becomes an indispensable part of people's lives, supporting industry and trading activities. Meanwhile, it produces considerable negative impacts at the three dimensions of sustainability, such as air pollution, less accessibility of passenger, traffic safety, etc. The previous research shows that **UFT also accounts for 20 to 30 percent (depending on the local context) of total traffic emissions** (Macharis and Melo, 2011). In larger European urban areas, freight vehicles are responsible for 21 percent of CO_2 emissions, half of particulate matter (PM) and a third of transport-related NO_X emissions (Dablanc and Rodrigue, 2009).

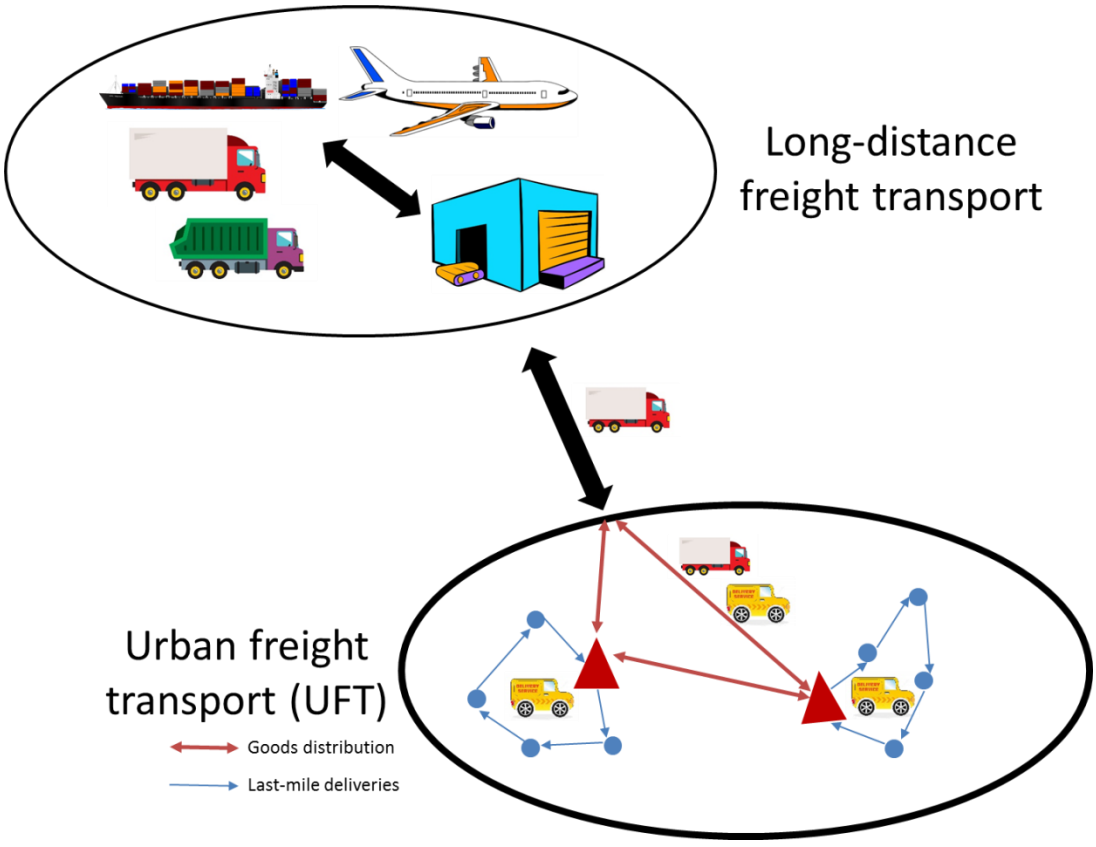

Figure 1 Long-distance and Urban Freight Transport

UFT is more pollutant than long distance freight transport owing to its older vehicle fleets and the frequency of short trips and stops, **resulting local emissions and directly affects the health of citizens** (Dablanc and Rodrigue, 2009).

With the rise of e-commerce activities, the demand for urban freight and parcel delivery services is soaring, particularly for **last-mile delivery**. The last-mile

delivery is the end of the logistics chain directly to consumers, and it is usually one of the **more expensive, least efficient and most polluting** chapters (Gevaers, et al., 2011). Problems of Last-mile delivery costs possibly an amount between 13 per cent and 75 per cent of the total logistics cost (Onghena, 2008).

To increase energy efficiency and mitigate its negative impacts, several strategies and initiatives are promoted to meet the challenges on last-mile delivery, like vehicle-routing improvements, green and clean logistic fleets, technological vehicle innovations and competitors' cooperation.

However, those initiatives in practice encounter various difficulties to implement, such as real-time information is missing to provide dynamic vehicle route service; the investment costs are very high for carriers; freight competitors are not willing to share valuable information to cooperate. It requires more feasible and cost-effective strategies or solutions to aid the implementation in urban freight delivery. Certain strategies ought to support mitigating negative impacts on urban congestion, noise disturbance and air pollutions.

Last-mile delivery has distinct characteristics to long distance freight transport, containing shorter trip distance and frequent stops. Previous work reveals that fuel consumption may increase 140 percent if a vehicle stops frequently: with five stops in 10 kilometres (Martensson, 2005). In order to discover effective measure for urban freight (especially last-mile delivery), it is essential to characterize on urban freight trips both in urban and suburban where have higher demand on goods movements. Through a review on the literature of urban transport, the authors found neither urban studies nor transport research has neglected to this subject until recently. It still lacks a full understanding of urban freight distribution and last-mile deliveries.

Another critical reason resulting the lack of studies on UFT is **unavailable of real logistic data**. Most of the mentioned initiatives have not been tested in practice, but only by simulation. Previous studies are mostly qualitative rather than quantitative. To assess the impacts of sustainable solutions in urban freight is still a challenge.

Besides, traditional logistic fleets that usually diesel vans are either replaced by electric vans (such as Renault Kangoo Z.E. and Nissan E-NV 200) or EVS are added to the last-mile operations (Quak et al., 2017). The operating experiences and energy efficiency from using **electric vans in real-life city logistics are not yet studied** enough, either the total cost of ownership comparisons between conventional and electric freight vehicles, as well as the barriers to switch from the conventional vans to electric vans based on the logistic operators´ value network.

What is more, **logistic drivers as the key actor involved in urban freight, have been usually neglected in the evaluation of impacts of sustainable measures**.

Neither survey method nor participating surveillance method was used to capture the difference between before and after a measure is applied.

One of sustainable measure that may contribute on GHG emission reduction on urban freight is eco-driving technique. Despite few studies on bus driver or professional truck drivers (Kircher et al., 2014; Sullman et al., 2015), **there is not a single study in relation to eco-driving with urban logistic drivers**.

At operating level, eco-driving is cost-effective measure based on follow some easy eco-tips like accelerating and braking smoothly, shifting gears at low RPM, maintaining a constant speed and anticipating traffic to avoid stopping as much as possible (Barkenbus, 2010). The advantages of eco-driving, go beyond CO_2 reductions, also help to reduce operation cost to individual and producing tangible and well-known safety benefits (with fewer accidents and traffic fatalities).

To overcome the mentioned research gaps in urban freight and last-mile delivery, it encourages researchers to collect real data to know the detailed characteristics of urban fleet and their trips, as well as the potential impacts by applying certain measures in urban and suburban areas.

Under this consideration, ECO-TRAFFIC Project is a national R+D project of Spain, aiming to analyse the potential reduction of fuel consumption and emissions (both GHGs and pollutants) by adopting eco-driving technique both for private car users and logistic drivers. The project is supported by several entities including CORREOS the national postal service of Spain (100% state owned) with 51,000 employees, which distribute more than 2,500 million shipments per year.

With the great support of CORREOS, the data collection of last-mile delivery was carried out with 13 drivers from two distribution depots in Madrid. This report documents all details of the data collection, includes route choice, driving pattern and road conditions, etc., both in urban and suburban area. The results obtained facilitate the study on urban freight as well as fills the research gaps of the field.

1.2. Research Objectives and Methodology

The current work continuous achieving the objectives of the project, but focus on several specific aspects that may contribute to overcome the recent research gaps in last-mile delivery:

- to collect real data within last-mile delivery routes of local logistic company, to characterize the pattern of current distribution operations, and to present the extent to which distribution operations vary for the same company in two different areas studied (urban and suburban).
- to develop a sequential method to study on the collected data;
- to compare energy efficiency between electric and diesel vans under same road and operating conditions;

- to study the efficiency of eco-driving for professional logistic drivers, distinguishing between combustion and electric vehicles;
- to present a holistic view of the problem and provide useful information to analyse the impacts of the use of distribution vans, comparing the energy consumption along different roads with different traffic and slope conditions.

The present study aims to achieve its objective by defining the following research questions:

1. How last-mile delivery perform in urban or suburban area? What are the main differences between the two geographic service areas?
2. Which type of van (electric or diesel) would be more economic efficiency in different delivery areas?
3. What are the potential effects of eco-driving on emissions reduction and fuel consumption in last-mile delivery? Is that different among fuel type or serving area? Is the effect homogenous among drivers?
4. Is that beneficial to train professional drivers with eco-driving technique for logistic company?

In order to answer the questions, a systematic methodology is developed for this work. It is described in the following graph (Figure 1) and explained more in details in the following parts of the report.

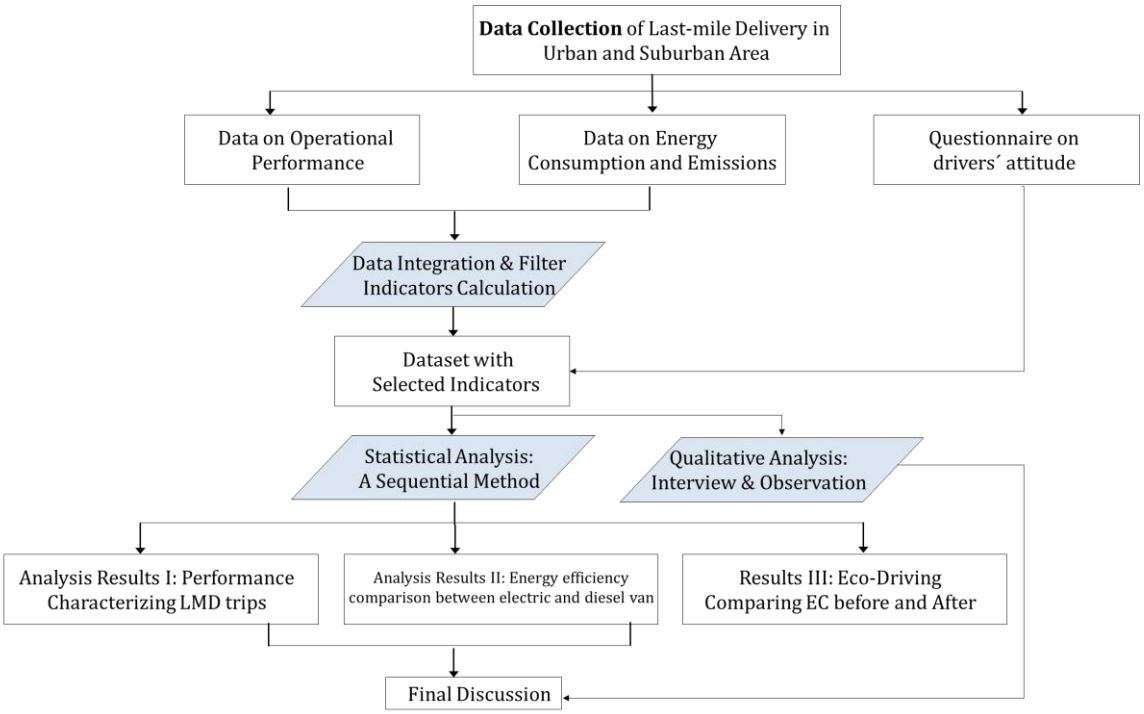

Figure 2 Methodology Framework

After having carried out a deep and comprehensive literature review of previous researches and articles, the state of the art has been defined. It helps to target on the most urgent research gaps in urban freight. Several research topics are found that may contribute to develop sustainable urban freight, which are logistics distribution, operation performance, energy consumption of electric vehicles and eco-driving.

And it provides information about the impacts of current used strategies and assessing methods.

The current work is to collect real data on parcel delivery along the daily routes from logistic company's vehicle fleet, as well as to obtain the effects that a short-term eco-driving course on fuel consumption in suburban or urban contexts.

To this end, a field trial is critical to collect necessary data and observe the changes on driving patterns before and after the eco-driving is received. With the collaboration of the CORREOS, we enabled to conducted data collection campaign in Madrid, the capital of Spain. The campaign is divided into two periods: normal driving at the first driving period and eco-driving for the second period. By that way, it enables us to compare the difference on fuel consumption and emissions between the two periods, meaning before and after drivers were enrolled in an efficient driving course. Moreover, to better understand eco-driving efficiency in urban and suburban parcel delivery, the data collection campaign uses two types of vans (diesel or electric) in two delivery areas.

The collected data contains various formats resulted from different devices were used in the trial. A systematic approach to integrate, filter, and process the raw data is imperative. We used R programming which is a free software environment for statistical computing and graphics, to integrate and filter the collected data. In addition, a geographic information system (GIS) application (ArcGIS) is used to obtain street names through longitude/latitude coordinates of each register data.

Two types of data are stored in the dataset: trip related data and driving pattern related data. Trip data consists of trip time, distance and GPS locations, and data of driving pattern includes instant speed and RPM. The fuel consumption is recorded and used to calibrate estimated value.

Additional variables regarding on driving pattern are calculated based on the previous researches (Ericsson, 2001; Smit et al., 2007; Greenwood et al., 2007; Beusen et al., 2009). Vehicle Specific Power (VSP) model is adopted to calculate instant fuel consumption for deiseal vans (Palacio, 1999), meanwhile micro energy consumption model is applied to evaluate the instantaneous energy consumption for electric fleets (Zhang and Yao, 2015).

Through the data process, a dataset is finally created and validated. Once the data have been obtained and analysed, an estimation of the average impact that an eco-driving course can produce on the expenses and consumption of the Company will be made. Through the experiment and subsequent analysis, we can provide results in terms of annual expenditure and environmental impact (CO_2 emissions) according to fleet type, delivery route, delivery context and driving style.

In addition, through a daily survey, we will know the level of driver's satisfaction and comfort in the different situations analysed. Finally, results should be projected to the goods distribution companies, to improve their environmental and economic impact.

The last step of the methodology is data analysis. The analysis has two aims: one is to characterize last-mile delivery in terms of distance, speed, stop time, etc., at different geographic context; another aim then is to compare fuel consumption between the two period distinct fuel types. Statistical tools like explanatory analysis, cluster analysis and regression analysis are used to obtain the results regarding the two aims.

1.3. Structure of the report

This report is structured in six chapters, following the consecutive steps of the research methodology defined in part 1.2.

In the current chapter one, the general and specific objectives are presented. It poses the problem of urban logistic impact over environmental quality, focusing on the impact that an efficient driving course or the change of vehicle (diesel to electric) can have over the environmental and economical quality. The general methodology and the data process followed in the research is presented and developed in the next chapters.

In chapter two, a literature review of the main aspects considered in the research is presented. Firstly, we present the state of art of the scientific researches in urban logistics, including the main challenges and solutions for urban goods delivery, and freight fleets in the recent years by this sector considering the urban environmental quality and focusing afterwards on research gaps of urban freight regarding reduction of GHG and pollutants emissions produced.

In the third chapter of the report, the main data collection campaign is presented describing the experiment design and the study case. Here, each part involved in the experiment, data source of the investigation, is described in details.

The data analysis part, consisting of data cleaning, data processing, dataset creation and energy consumption estimation models, is described in the chapter four.

Results regarding the characterization of last-mile delivery trips, energy consumption comparison and eco-driving impacts are given in chapter 5 respectively.

Conclusions are presented in the last chapter with the main findings, policy recommendations, research limitations and future researches.

Thus, in the following chapters, the research is presented, aiming to understand how influence an eco-driving course over driving behaviour in delivery spots. Moreover,

the difference between the energy consumption produced by diesel or electric delivery duty vehicles.