

**FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO**



# **Environmental assessment of parcel delivery: from data sources to data analysis**

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# Abstract

Recently, online purchases and parcels delivery have increased as a consequence of COVID-19 pandemic, leading to new environmental sustainability challenges for last mile operations planning. Despite last mile data being gathered and treated by companies, accessibility to certain data for investigation and control purposes is very limited.

In order to demonstrate variety in types of sources for data that, directly or indirectly, is related to last mile logistics operations impact on the environment, a three-stage methodology is considered: (i) Characterization of last mile data, (ii) Data categories and exploration of visualizations and (iii) Environmental logistics planning. This analysis was focused on the development of Sustainable Urban Logistic Plan (SULP).

In the first stage, the state-of-art review of data collection within parcel delivery sector was conducted, whose analysis topics are result of thematic clustering of most used terms in those documents. In the second stage, websites oriented to statistical analysis and spatial representation were explored. Statistical last mile data types are considered and how data is represented and analysed was investigated. At last, in Environmental planning stage, reports and articles of environmental logistics were considered. Different implementations areas were compared in a benchmark analysis on which data facilitates a sustainable planning.

Data collection procedures such as online surveys to customers and interviews to parcel delivery workers/managers are the most performed, in order to gather feedback from different interested parts. Certain cases perform both procedures, while others conduct analysis on documents which make reference to primary or secondary data collection.

Within the datasets considered, weight measurements are most common, for emissions and parcels delivered assessments. Relevant dimensions of analysis also consider the parcel delivered and its type, as well as particularities of freight vehicles. NUTS and GIS application are recognized as spatial representations for data in maps, for possible identification of local logistics associated with environmental problems, in which annual or quarterly granularities are consensual.

Previous analysis to operational data are required for logistics planning. To highlight the utility of mapping, movement sensors or mobility questionnaires to recognize last mile limitations. Also surveys and interviews to stakeholders to assess further adherence to environmental logistics. Within others, legislation, reports of electrical distribution, vehicles mechanics or results from computational tools also contribute to a contextualized environmental plan for the region in question.

**KEYWORDS:** delivery, logistics, last mile, environmental sustainability, data collection, representation, analysis



# Resumo

Recentemente, as compras online e entrega de encomendas têm aumentado como consequência da pandemia COVID-19, levando a novas necessidades de planeamento da sustentabilidade das operações de última milha. Apesar dos dados operacionais de distribuição serem recolhidos e tratados pelas empresas, a acessibilidade a estes dados para fins de investigação ou controlo é muito limitada.

Com este trabalho, pretende-se identificar fontes de dados que, direta ou indiretamente, estão relacionados com as operações logísticas de última milha. Assim, tendo em conta a necessidade de um planeamento de uma logística ambientalmente mais sustentável definiu-se uma metodologia de três fases: (i) Caracterização de dados de última milha, (ii) Definição de categorias de dados e exploração de visualizações e (iii) Planeamento ambientalmente sustentável da logísticas.

Na primeira fase, foi realizada a revisão do estado de arte da recolha de dados nos serviços de entrega de encomendas, cujos tópicos de análise são resultado de agrupamentos temáticos de termos mais frequentes nesses documentos. Na segunda fase, foram explorados websites com orientação à análise estatística e representação espacial. Tipos de dados estatísticos de última milha foram considerados e foram investigados como é que os dados são representados e analisados. Por último, na fase de Planeamento ambiental foram tidos em conta relatórios e artigos de intervenções logísticas. Foi realizada uma análise conjunta de áreas de implementação e sobre que dados facilitam um planeamento sustentável.

Métodos de recolha de dados como inquéritos online a clientes e entrevistas a trabalhadores/gestores de entregas são os mais realizados, para recolher opiniões de diferentes partes interessadas. Alguns casos realizam os dois procedimentos, enquanto outros analisam documentos que usam dados primários ou secundários.

Entre os exemplos considerados, aferições às encomendas e emissões são efetuadas considerando medidas de peso. Dimensões de análise relevantes têm em conta as particularidades da encomenda ou do veículo da frota. As representações espaciais de mapas NUTS ou do aplicativo GIS são reconhecidas para possível identificação das logísticas associadas a problemas ambientais, nas quais as granularidades anual e trimestre são consensuais.

Análises prévias de dados operacionais facilitam o planeamento de logísticas. Denota-se a utilidade de mapas, sensores de movimento e questionários de mobilidade para reconhecer limitações de última milha. Também inquéritos ou entrevistas para avaliar a futura adesão a novas logísticas ambientais. Entre outros, para além de regulamentos, relatórios de distribuição elétrica e mecânicas de veículos contribuem também para um planeamento contextualizado à região em causa.

**PALAVRAS-CHAVE:** entrega, logísticas, última milha, sustentabilidade ambiental, recolha de dados, representação, análise



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Diogo Filipe Miguel



*” There is nothing permanent except change. ”*

Heraclitus



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# Abbreviations and Symbols

|                 |                                 |
|-----------------|---------------------------------|
| ADV             | Autonomous Delivery Vehicle     |
| AI              | Artificial Intelligence         |
| CO <sub>2</sub> | Carbon dioxide                  |
| EV              | Electric Vehicle                |
| GHG             | Greenhouse gases                |
| IF              | Impact Factor                   |
| KPIs            | Key Performance Indicators      |
| LEZ             | Low Emission Zone               |
| PDS             | Parcel Delivery Services        |
| SDGs            | Sustainable Development Goals   |
| SULP            | Sustainable Urban Logistic Plan |
| ZEZ             | Zero Emission Zone              |



# Chapter 1

## Introduction

In a competitive and constantly increasing market such as e-commerce, keeping abreast of technological development is imperative. This can be useful not only to implement changes in last mile services, but also on data analysis systems. In this way, is important to understand how e-commerce relates to environmental problems and how this knowledge can contribute to fix that. This topic is briefly approached next, with a prior assessment on motives for this study and the definition of each chapter purpose through this dissertation. Then, sources and their data are evaluated for assisting the implementation of environmental logistics.

### 1.1 Context and problem

E-commerce sector consolidation in economy is undeniable, largely due to the greater coverage communication systems. Thanks to COVID-19 settlement all around the world, home deliveries have grown exponentially, as people find this way of purchasing goods a much more efficient alternative, either in safety or practicality [8]. In 2020, 72% of people that use Internet bought goods online (Eurostat,2021).

On e-commerce, orders tend to be scheduled just-in-time. As result, lead time became a dictating factor of delivery workers efficiency. This issue is a delicate and complex engineering topic as at this level many aspects have to be taken into consideration [9], namely: (i) whether it is cost effective while delivering urgent deliveries; (ii) if it can simultaneously process various goods and provide more personalized service; and (iii) if it can reduce environmental pollution caused by vehicles and traffic congestion. When facing multiple influencing factors on scheduling, prioritize each one helps setting better routes.

Due to traffic congestion, cities usually experience high levels of air pollution and noise. As result, last decades Europe has turned their attentions to the overall awareness on climate action. Until 2030, a set of 17 Sustainable Development Goals (SDGs) has been implemented as a mean to reach the goal of reducing the entire European Union (EU) carbon dioxide ( $CO_2$ ) emissions by, at least, 20% [10], in comparison to 2020.

In the scope of logistics, the main SDGs that can impact last mile logistics are the *Industry, Innovation, and Infrastructure* (SDG 9) and *Sustainable Cities and Communities* (SDG 11). Goal 9 aims to promote new technologies, facilitate international trade and enable the efficient use of resources while goal 11 aims to make urban spaces more sustainable. The growing population discrepancy between rural and urban areas generates a larger population aggregate. Provide urban data, evidence-based mapping and knowledge for informed decision are seen as solutions for a better land management and the impact of everyday activities.

To address the environmental issues and meet the responsiveness required, as logistic providers want to prevail, operational strategies need to be planned properly. For example unnecessary dislocations during deliveries are one of the biggest cause of expenses. In this way, the low percentage of cargo load, the crossed route selection, the distribution during busiest road hours requires to be tacked into account.

In order to improve logistics, year after year new technologies emerge [11]. Many of those solutions are based on the use of data analytic to optimize pricing, supply chain movement or improve customer loyalty. With the growing use of technologies, the problem is not any more the lack of data but its accessibility to any user. Without a clear notion of the primary origin of the data, their interconnection becomes more complex. Therefore, to get close to sustainable targets, changes on data association must take place.

The range of solutions, from digital maps to path planning using heuristics and optimization algorithms, among others, gives people who manage shipping the possibility to create different effective alternatives, obviously with access to correct information. However, in a era o big data, the combination of different data sources to create more robust decision methods/tools is not an easy task. There is much uncertainty when dealing with so many information from different stages of the delivery chain, causing parcel delivery misalignment when unexpected requests appear. Adding to that, the scenario gets worse when returns exist [12], which provokes additional costs and emissions.

Gathering varied and significant information will grant enough background to draw assumptions on what provokes more pollutant emissions, why is that and where and when it is most frequent. Collecting the most recent information possible has the advantages of already taking into account current technological development and the aftermath of a society affected by a global pandemic.

These issues can be overcome by taking advantage of land use, transport legislation and sustainable plans. To achieve such strategies, policy makers need information about mobility patterns, demography and cartography in those same areas and take into account each local logistic.

In order to define robust decision support systems, it is important to identify not only the data sources, their access and utility, but also the treatment and analysis that they may be subject to. This choice impacts the results obtained and these will allow the implementation of models and decision tools for sustainable PDS, while helping delivery firms to increase their operational efficiency. Therefore, e-commerce sector future is dependant on Artificial Intelligence capability of dealing with big data and blockchain.

This work is part of e-LOG project, which is led by researchers from INESC TEC. The e-LOG aims to understand how different delivery models impact the environment and what measures can be implemented to mitigate those models.

## 1.2 Environmental impact of logistics

As mentioned, different sources are categorized in the next chapters, seeking an understanding on what type of data can be found. With Table 1.1, examples of future revised data contexts are presented. Although data relating to emissions and environments are intended, temporal, geographic, analytical and parcel delivery services (PDS) contexts are addressed.

Brick-and-mortar deliveries are the most common PDS. Weideli [13] conducted a research to compare this traditional model environmental impact to retailing. According to this author, the brick-and-mortar model only turns out to be more environmentally advantageous than retailing when facing short distance deliveries [14]. A set of other studies ([15, 16, 17]) that focused on last mile deliveries, particularly at air emission level, are presented during state-of-art review in third chapter. In this analysis, the location and the company details as the product market, services offered, types of deliveries, the number of orders and what vehicles used are identified. A temporal analysis with two metrics is also revealed.

Postal deliveries, food market and shipping of electronic equipment, are the top three products delivered in the e-commerce (Eurostat, 2022). Several studies have been measured the impact on CO<sub>2</sub> emissions in some of these products, particularly express postal [18, 19] and food delivery [20].

Zhong et al. [18], in a study which took place in China, referred socioeconomic and demographic status of the delivery area as influential for emission decrease. On the other side, Dobrodolac et al. [19] compared, for Belgrade's, the emissions from traditional parcel delivery with the ones from a new post express nonstop system working 24 hours per day. The results show that the better solution is reached by combining both systems. Following the innovative way with better time service availability, emissions could potentially decrease by approximately 25%. Additionally, Crawford et al. [20] conducts a study in Australia, evaluating emissions in food packaging and how to reduce them. Recyclable materials are seen with great potential.

The majority of the studies are conducted for urban areas [21, 22, 23], particularly at intracity level [18, 19, 24]. Rural areas, for their small population and little diversity of services available, are the areas less studied [25]. Also, as expected, most of the deliveries are done with grounded vehicles. Many possibilities were attempted, so there is not a clear preference on which carrier to use between vans, bikes, motorcycles or trucks.

Implementing delivery systems in urban areas during hours with less traffic, can decrease by high amounts the quantity of greenhouse gases (GHG) emissions [21]. Thanks to data collected by GPS trackers on vehicle freight, the authors observed that through off-hours there are periods which lead to less emissions. As example, reductions in the range 45-67% were detected in the best scenario (deliveries during night time) and about 13% for parcel deliveries for early off-hours.

Koiwanit [25] concluded that drones can be used to perform small distance deliveries for everyday products. Making use of technology advance and collect data from them was seen as a trial for future tests in urban areas. By using drones, traffic congestion and pollutant emissions are mitigated, with fibers releasing and energy consumption, despite in small quantities, the only pollution factors. In a simulation study, Macrina et al. [26] take into consideration congestion, emissions and associated costs of different vessels. At the end, a delivery system combining both trucks and drones was proposed, avoiding inefficiencies in each one. Deliveries using air locomotion can be done not only by drones, as some companies possess airfreight [13].

Shipping the product obviously generates pollution proportional to the distance travelled. To minimize this impact several authors used multiple distinct types of vehicles (cars, bikes, walking) during the same shipping [27, 28]. Complementary, many last mile logistic companies have been adopt the use of electric vehicles to minimize the environmental problems of cities. However, the mechanical aspects of this transportation type requires extra planning due to their recharge need [29]. Intermediate parcel storage helps reducing long trips and is commonly based on final destination, spreading several storing facilities all over the area. Sun et al. [30] defends exactly the opposite, arguing the advantages of strategically placing clustered facilities, serving as central point to orders inside that specific area. The difficult in this strategy is where to place the clusters, what size should they have and how many should they be. Miranda et al. [31] analysed those questions.

Another last mile solution is known as Crowd-shipping [32]. In this solution companies make use of their vehicle freight, as well as contracting third party occasional drivers who, during their trips and, are passing through delivery routes and make small deviations to pick up the product and hand it in to the final client. In spite of the payment to this drivers, this ends up to be eco-friendly as less dislocations are needed.

Previous studies shows the potential in adding restrictions on the mechanics in the vehicle used for the delivery, as well as low-emission zones, where vehicles that release more that a certain quantity of a compound, cannot go through that same zone [33]. Spijkerman [34] suggests an extra proposal of a method creation which could make costumers avoid going to shops just for seeing the product in first person. If consumers change their shopping preferences they reduce emission, which can be obtained online by offering a variety much bigger than in physical stores. It will enable the PDSs managers to optimize their delivery operations.

Table 1.1 outlines some studies that addressed vehicle freight emissions. As can be observed in this table, companies involved in parcel delivery tend to concentrate their efforts in this activity alone and when other services are offered, only consensus on their application in urban areas is detected. Postal services stand out in environmental awareness, but there is considerable variety of markets attained for the amount on articles reviewed. Between these, postal services may also deal with more deliveries than others, but dispatched quantities are not collected with regularity. As intended, in all cases, GHG are measured, with clear preference on  $CO_2$  and some cases with combined estimations for a specific GHG, without dismissing the rest. When applied, annual granularity is most detected, with cases that refer the analysis to the product or the displacement.

Table 1.1: Introductory assay on emission analysis on last mile logistics.

| Ref  | Location          |         | Company                    |                           |                                   |                       |               | Emissions                      | Temporal analysis |                                |
|------|-------------------|---------|----------------------------|---------------------------|-----------------------------------|-----------------------|---------------|--------------------------------|-------------------|--------------------------------|
|      | Region            | Context | Market services            | Business model            | Type of delivery                  | Dispatched quantities | Vehicles      | Gases                          | Period            | Granularity/Analysis dimension |
| [21] | Brazil, USA       | U       | Several                    | Production & Delivery     | Off- hour vs Regular deliveries   | -                     | T             | $CO_2$ , $CO$ , $NO_X$ , VOC   | 2014-2016         | 2-4 weeks each tracker         |
| [18] | China             | U       | Postal                     | Delivery                  | Intracity express deliveries      | 10 million units      | Land vehicles | $CO_2$                         | 2017              | Annual (2017)                  |
| [20] | Australia         | SU      | Food                       | Delivery                  | Instant deliveries                | -                     | C, M          | $CO_2$ , other GHG             | 2018              | Annual (2018)                  |
| [13] | USA               | U       | Electronics, clothes, toys | Store and Delivery        | Brick-and-mortar/Online retailer  | 10000 units           | A, T          | $CO_2$                         | -                 | -                              |
| [35] | Several countries |         | Several                    | Delivery                  | Online retail                     | -                     | Several       | $CO_2$ , other GHG             | 2005-2020         | -                              |
| [22] | USA               | U       | Several                    | Delivery                  | Single/Omni-channel               | -                     | Land vehicles | $CO_2$ , $CO$ , $NO_X$ , GHG   | 2016-2018         | Per tour                       |
| [25] | Thailand          | R       | Several                    | Delivery                  | Short deliveries                  | -                     | D             | $CO_2$ , $SO_2$ , $NO_X$ , GHG | 5000 hours        | Per km travelled               |
| [19] | Belgrade          | U       | Postal                     | Delivery                  | Intracity express                 | -                     | V, T          | $CO_2$                         | 2020-2025         | Annual                         |
| [24] | Europe            | U       | Several                    | Delivery                  | Intracity last mile               | -                     | B, V          | $CO_2$                         | 2019              | Annual (2019)                  |
| [23] | New York          | U       | -                          | Delivery                  | Parcel lockers vs Home deliveries | 200 daily deliveries  | V             | $CO_2$ , other GHG             | 365 days          | Daily                          |
| [26] | -                 | U       | -                          | Delivery                  | Home deliveries                   | -                     | T, D          | $CO_2$                         | 2019              | Per delivery                   |
| [14] | -                 | U       | Clothes                    | Supply, store and deliver | Brick-and-mortar/Multi-channel    | 3K - 40k parcels      | C, M          | $CO_2$                         | -                 | Per travel/Per item            |

<sup>1</sup>: *Location Context*: U: Urban, R: rural, S: sub-urban.

<sup>2</sup>: *Vehicles*: A: airfreight, B: bikes, C: cars, D: drones, L: land vehicles, M: motorcycles, T: trucks, V: vans.

<sup>3</sup>: *Gases*: CO: carbon monoxide,  $CO_2$ : carbon dioxide, GHG: Grenhouse gases,  $NO_X$ : oxides of nitrogen, VOC: Volatile organic compound.

### 1.3 Objectives

Researchers attempt to understand which factors from freight vehicles usage cause more pollution and emissions, but privatization of data limits exterior analysis to companies operational information, including data collection from workers and their services. With the recent e-commerce and transportation sectors consolidation, it is uncertain if existent sources translate modifications inherent to COVID-19 since it became a deterrent factor in society daily activities [36]. Consequently, in this work is intended to perform a review of last mile data treatment and available sources, from its collection and processing to several further applications in the industry. Findings are intended to support researchers in assessing the environmental impact of last mile deliveries.

The study intends to answer to the following research question:

- What data sources provide e-commerce/deliveries information?
- Which types of data and representation facilitate last mile assessments?
- How does data from different sources help planning sustainable last mile logistics?

In order to address these goals, a systematic literature review is conducted on various sources as articles, statistical websites and reports. Analytical metrics and visualisations are recognized by characterizing examples within these sources and categorizing their data. Their use is considered for sustainable logistics planning, whose implementation process is conceptually established.

### 1.4 Document structure

This chapter intends to contextualize the online commerce sector and introduce how the environmental impact of last mile operations have been addressed. The environmental goals of the work and the research questions to be answered are presented.

The second chapter summarises the proceeding which was performed in the following chapters. A three stages methodology explains what data assessments and sources are considered, the intended conclusions and what activities are worth highlighting for their consolidation.

On third chapter, a systematic literature review focused on last mile documents with data extraction is conducted. First, a bibliometric analysis is presented and then, the filtered documents are characterized according to last mile topics prominence.

Chapter four presents statistical data sources, giving last mile numerical context (for European Union and Portugal). There is the identification of variables, granularities, analysis dimensions and visualizations most employed, which can help setting environmental objectives for new logistics.

In the following chapter, environmental idealization of logistics is performed. They require a previous analysis to find limitations in urban mobility or last mile issues as in chapter four. Areas of environmental intervention are also highlighted, as well as examples of tools to plan logistics.

Finally, conclusions on how data from PDS is collected and analysed are led, in order to facilitate last mile sustainability. Noteworthy environmental logistics are mentioned and what future work can complement this research is stated.

## Chapter 2

# Methodology

The nature of PDS data, including variables and their treatment, fluctuates according to each source. While other investigations try to study a phenomenon or situation in detail, this research approach is intended to make standardised and systematic comparisons of data analysis within representative examples. In order to characterize these metrics and last mile data, an empirical investigation is performed to identify types of data sources and understand how data has been analysed and integrated in logistics. Sources of distinct nature are separately reviewed, so a three stages (one per chapter) methodology was implemented, as Figure 2.1 illustrates.

- Characterization Stage: Characterization of last mile data based on state-of-art review;  
Identification of last mile data analysis and PDS trends by characterizing e-commerce/ deliveries sectors and how its consequent data is treated in scientific publications;
- Categorization Stage: Data categories and exploration of visualizations for placing last mile objectives;  
Assessment on data representation and analytical metrics by exploring technological sources, whose last mile data types are defined.
- Benchmark Stage: Environmental logistics planning for PDS sustainable implementation;  
Idealization of environmentally sustainable strategies by looking at veracious reports or real case articles and their causes, which helps emphasizing last mile implementation areas.

All stages have in common the classification of data within each source. Data collection in PDS articles is thematically assessed, types of statistical last mile data from datasets and areas for last mile intervention from reports and articles. However, to recognize variety in sources, distinct approaches are led for each stage (Figure 2.1).

Companies may impose restrictions on access to its operational data and academic literature can have limited access, and for that reason, sources without those limitation will be reviewed. Therefore, the ideology of *Open Access* is embraced, which promotes the principle of data openness, an essential element of progress. Investigation resources have specifically been made available online to use for free, aspect that influences other investigations in the existence of budgets.

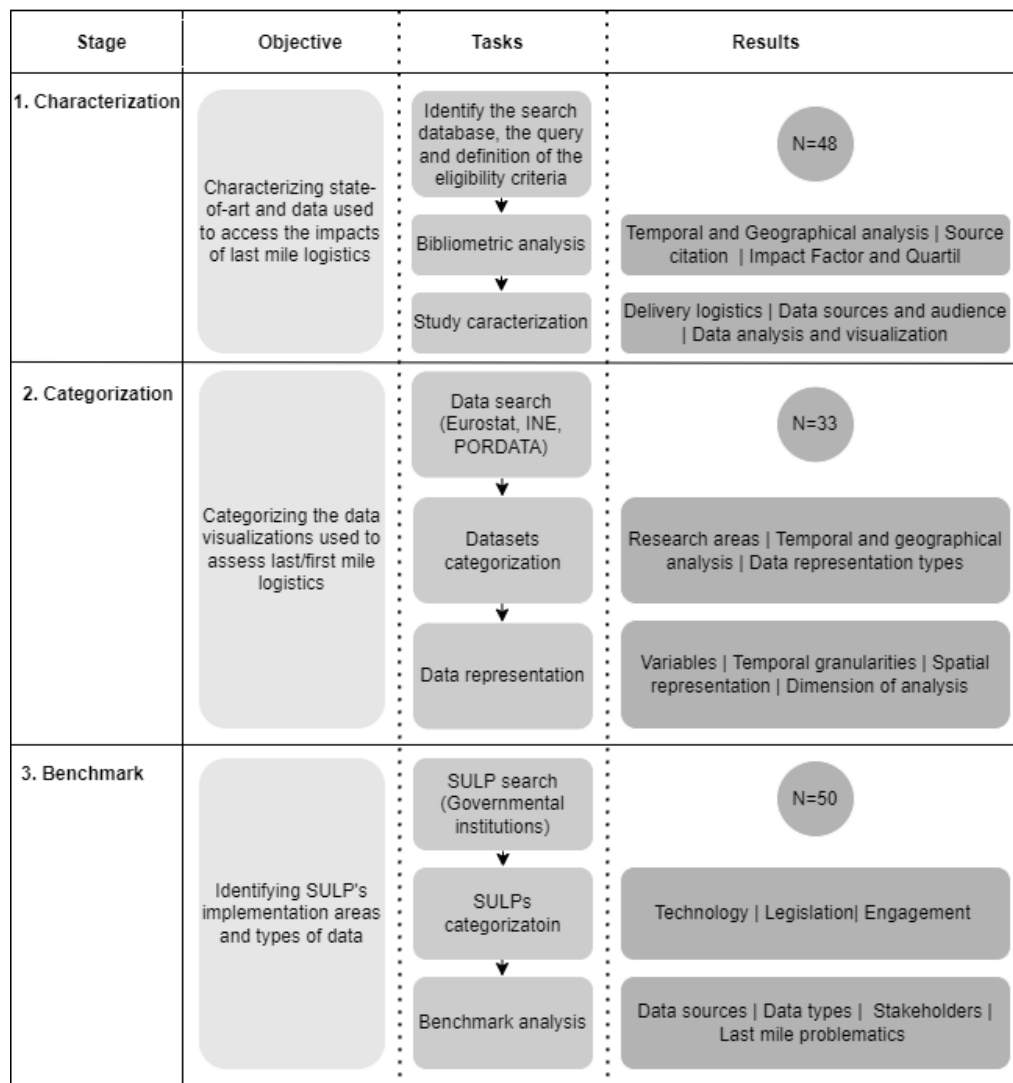


Figure 2.1: Methodology for last mile data review (own figure).

Information processed within these stages may come from various data collection methods. Beside interviews or surveys, which implementation procedure can be diversified [37], other data collection methods are implemented. If data was collected, those same sources must be identified. Considering their source, data can be divided into two sets, primary and secondary.

- Primary data is generated by the researcher, surveys, interviews, experiments, specially designed for the research problem
- Secondary data is generated by large government institutions, healthcare facilities

All in all, secondary data is certified by institutions, becoming a viable source. Nevertheless, articles acting as primary source of data are evaluated in Characterization stage. Despite primary data being most commonly reviewed, secondary data will be pursued in Categorization and Benchmark stages from the methodology in Figure 2.1.

To simultaneously conduct an environmental assessment, an implementation plan (Reis et al. [1]) for sustainable logistics is also taken into consideration during Categorization and Benchmark stages. Data analysis in these two stages are examples of last mile issues identification and further comparison of logistics plans, respectively in each stage. All three are going to be described.

## 2.1 Characterization of last mile data

For Characterization stage, a systematic literature review was carried out, which differs from a classic narrative-based review because it follows a guideline based on a replicable and transparent process [38]. The literature review presented in this article was based on the guideline proposed by Denyer & Tranfield [39]. The five phases approach followed is illustrated in Figure 2.2.

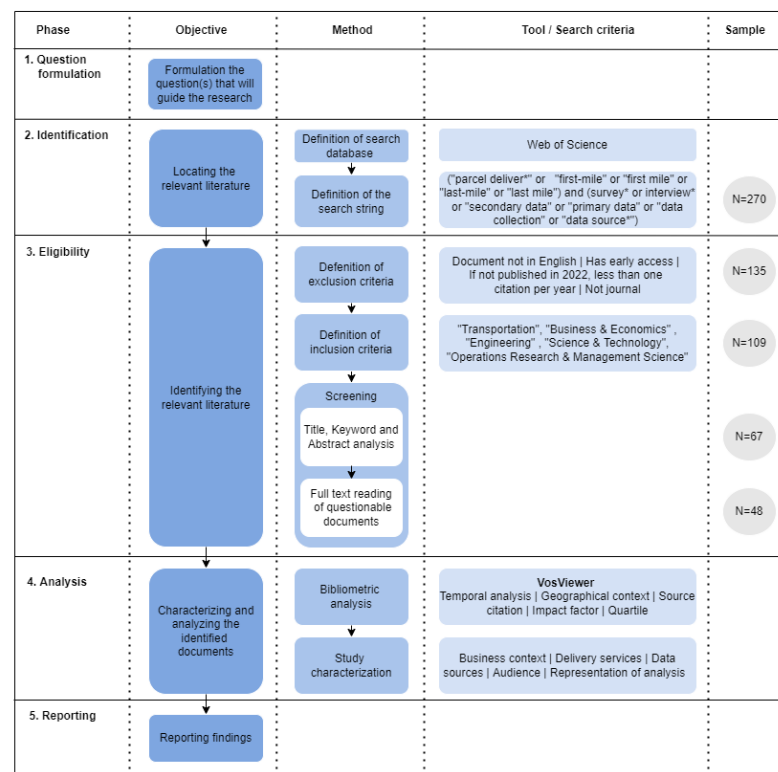


Figure 2.2: Methodology for scientific publications review (own figure).

The method in Figure 2.2 begins with question formulation by defining the scope of the literature review. Focusing on articles, first two research questions from the objectives in first chapter that highlight which data collection methods are conducted and how data assessments can be facilitated are addressed.

Acknowledge distinct data sources for last mile data collection is a research question for this study and therefore, articles in which data was collected and treated are sought. Is intended to define what standard vocabulary can be used to categorize the data. For this, an auxiliary tool was used to evaluate the frequency of mutual appearance in the selected articles. Final question aims at the collection of preferred analysis and treatment methods for the collected data.

Identification phase objective is on searching and creating a comprehensive list of documents aligned with the review purposes [39]. Web of Science was used to this end as it contains a vast collection of academic publications and most of the journals are peer-reviewed. The search query used in Web of Science and already mentioned in previous chapter was:

- ("parcel deliver\*" or "first-mile" or "first mile" or "last-mile" or "last mile") and (survey\* or interview\* or "secondary data" or "primary data" or "data collection" or "data source\*")

This search query was directed to the publications' title, keywords and abstract. The search was conducted in June 2022, and resulted in a preliminary sample of 270 publications that study the subject of last mile parcel deliveries.

In Eligibility phase, documents' context was reviewed in order to only select scientifically and thematically relevant studies. Four exclusion criteria and a inclusion one regarding the research area were considered. Regarding the exclusion, the following criteria were considered: (i) articles not in English, (ii) early access publications, (iii) from sources other than journals; and (iv) publications with less than one citation per year (if published before 2022). The inclusion criteria included only articles from the areas of *Transportation, Business Economics, Engineering, Science Technology and Operations Research Management Science*. The screening resulted in a sample with 109 publications.

Third phase continues with speed reading every keywords, title and abstract to access each circumstance and if it fits the parcel delivery topic. Although some were highlighted for future analysis, only 67 out of 109 documents were selected for potential careful reading, 10 of those still to be confirmed. As mentioned, there was uncertainty about some of the articles in these sample. Taking a closer look to them, only 3 met the requirements, resulting in sample size of 60. While performing a first reading of the introductory and final chapters, other 12 were removed from the list, reaching final 48 articles mentioned in both Figures 2.1 and Figure 2.2.

After electing the final set of documents, a two step analysis of the documents was done. First, a bibliometric analysis was developed to quantitatively evaluate the reviewed publications, as well as data inherent to the publication journal. Their background check on last mile data allowed a thematic analysis based on clusters of themes coming from the words that appear most regularly in the title and abstract of the final articles. This thematic assay on information most debated within the articles was conducted using the VOSviewer tool. Then, considering last mile topics, relevant publications were review according to the clusters obtained from terms prominence.

- Context on e-commerce services
- Stakeholders profile for data collection
- Delivery logistics and emissions
- Type of data analysis and accessibility

## 2.2 Data categories and exploration of visualizations

To idealize environmental last mile interventions, different analysis must be previously considered. At first, finding performance problems helps identifying sustainable goals. Then, possibilities to achieve them must be enumerated to detect the most feasible alternative. Knowing what it will be, a detailed plan considering policies must be led and cautioning further performance tracking.

Adapted from Reis et al. [1], Figure 2.3 illustrates the implementation procedure of an environmental SLP, whose phases of causes/objectives identification and logistic plan development are attained for environmental sustainability in PDS and looked at in Categorization and Benchmark stages, respectively. Last mile deficits can be identified from statistical datasets, while options to mitigate most relevant urban issues are compared from reports and articles.

|        |                                                                                                                                                                                                      |
|--------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Phase1 | <ul style="list-style-type: none"> <li>• Identify causes</li> <li>• Set objectives and KPIs</li> </ul>                                                                                               |
| Phase2 | <ul style="list-style-type: none"> <li>• List possible logistics</li> <li>• Assay each logistic feasibility</li> <li>• Search related policies</li> <li>• Develop implementation strategy</li> </ul> |
| Phase3 | <ul style="list-style-type: none"> <li>• Implement strategy</li> <li>• Monitor evolution and track KPIs</li> </ul>                                                                                   |

Figure 2.3: SULPs implementation procedure (Adapted from [1]).

Pointing out inappropriate last mile values for future intervention is the outcome of the first phase. The second phase helps to determine which strategy will be most appropriate and what data its planning requires. Performing the first phase consistently helps to conceive the third phase, involving its implementation. By enumerating deficits, performance control variables can be identified. Their monitoring requires the collection of inherent information and this must be previously considered. Surveys can be used to assess the impact and SULPs success. This is the focus of third phase, as well as constant monitoring of defined performance elements.

Knowing that variables from data collected can be categorised as either quantitative or qualitative [40], each analytical purpose requires a specific approach. On one hand, qualitative variables are made up of a group with concrete characteristics. On the other hand, numerical variables are countable and usually reflect proportions, measures or duration, which can be used to contextualize European e-commerce and transportation status and assist environmental assessments.

Analysis on last mile numerical variables induces the representation in graphics or tables, illustrated in statistical websites, whose raw information can come from various collection methods. Their data collection methods and sample selection can be found in each online page published reports on data extraction methodology.

Renowned examples were collected to assess which offer more diversified analysis [41]. Websites classification is performed according to indicators from users satisfaction on online pages front end, research procedures and representation types on last mile data. In this work, three online pages are chosen to extract datasets: *Eurostat*, *INE*, *PORDATA*. Within these websites, five categories of last mile data are recognized, for which variables and dimension of analysis vary.

- Demographics
- Sales
- Technology
- Environment
- Transport

Categorization stage contextualizes 33 datasets according to data thematic classification within the selected websites. Variables, analysis dimensions and visualization types are identified. All relevant quantitative sets were gathered in a table, where information about their representation, as time window, region, graphics portrayed and variables were compared. Some cases from data categorization groups on sets are presented to numerically contextualize relevant sectors.

To find outcast values and design robust decision support systems, the ease of data understanding should not be overlooked. How last mile data is exhibited and which visualization methods are employed is also pursued in this stage. Measurement variables will be analysed to understand what last mile metrics bring most insights to researchers, analysts and decision-makers. Spatial and temporal granularities influence visualisations, so their scope will also be studied.

## 2.3 Environmental logistics planning

During the COVID-19 pandemic, PDS increased, as costumers were forced to rely on couriers [42]. This forced change in buying behaviour became recurrent and it implies that if parcel delivery firms want to remain competitive in post-COVID era, these have to match their customers expectations on last mile PDS.

As the sector needs to be re-considered to respond to higher demands caused by population lockdown, a guide on useful data to structure different logistics is carried out. In order to have a well-established SULP, prior analysis to operational data and feedback from interested parts help performing a robust plan. Comparing options to select the best strategy is necessary, procedure suggested in phase 2 of SULP implementation plan in Figure 2.3 and explored in this stage. Having that in mind, interventions that minimize environmental impact are sought.

More than ever, companies want new logistics to increase productivity while keeping environmental impact in mind. To understand the scope of last mile logistics, Plazier et al. [43] define three SULPs fundamentals.

- Cooperation
- Authority
- Technology

Cooperation sets importance on data sharing and stakeholder engagement, while Authority with respect to laws that reinforce compliance. Technology highlights the advantages from technological development. Cooperation and Authority are two separate areas, but this fact is not associated with both being simultaneous principles for other logistics [44].

Besides datasets, other sources (reports) with data collection procedures are considered for finding problems on urban mobility and accessibility. 10 SULPs led in Portuguese soil are identified by Seabra [45], which were further collected from respective municipal and parish councils. Which data collection procedures were conducted are mentioned, as well as limitations detected from their analysis.

Considering most recurrent issues in these examples and previous fundamentals, implementation areas were defined. Figure 2.4 shows the division into five logistics areas for further last mile implementations.

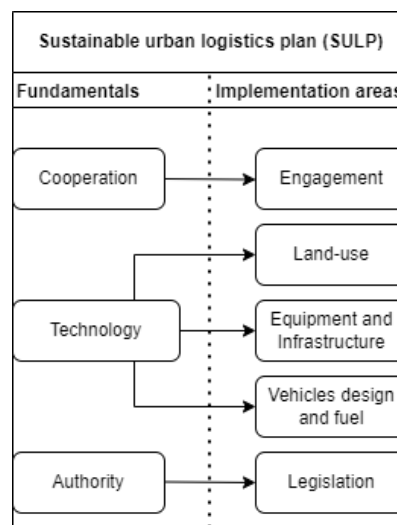


Figure 2.4: Last mile interventions areas (own figure).

Technology presents wider horizons, leading to its' subdivision into three areas: (i) Equipment and Infrastructure, seeking automation in first/last mile parcel delivery, (ii) Land-use covers issues associated with intensive vehicle circulation and cities layout, having consequences on parking and intracity mobility and (iii) Vehicles design and fuel because of their permanent role as source of polluting gases and particles, considering that freight management is not being environmentally maximized.

40 strategies are divided according to SULPs fundamentals, seeking what data and legislation are considered to place new sustainable logistics. Which stakeholders can get involved and how data visualizations are employed in urban implementations planning will be also investigated.



## Chapter 3

# Characterization of last mile data

The understanding of how emissions have been studied in the last mile logistics is one of the objectives of this study. What information is extracted, from what sources and how it is treated are previous steps to arrange new logistic models. Therefore, to answer to this questions, a systematic literature review was conducted, being also the state-of-art review on last mile analysis and PDS.

Bearing in mind the purpose to assess the extent to which emissions are analysed, the journals and articles collected will be characterized. In literature review, types of data collection and audience, analytical procedures and representations are assessed. Analytical metrics come from thematic groups resulting from a clustering of most common terms in the elected articles.

### 3.1 Bibliometric analysis

Filtering eligible documents allowed to identify 48 research articles related with parcel delivery (Eligibility phase from Articles review [2.2](#)). Identifying their journal geographic and temporal context, quartil, impact factor as key performance indicator (KPI) and most regular ones allows a further assumption on which journals are closely involved in the study of last mile activities, without dismissing their environmental impact.

The articles' characterization is result of an analysis tool ability (VOSviewer) to detect which terminologies are most used and how they bond by their simultaneous presence in documents. Those with the greatest connection belong to one of the characterization groups, for as each one receives a title that contextualizes.

#### 3.1.1 Documents' context

Figure [3.1](#) shows the publication years of the articles identified, with the aim of showing the trend how current the addressed topics are. As for the year of publication, there is a stagnation of one article per year until 2016, with years in between without any article. From 2017 onwards, there is already a greater number of articles published, oscillating year after year, until 2022. Having into consideration that this articles were gathered in April of this same year, only publications until that month in 2022 are considered.

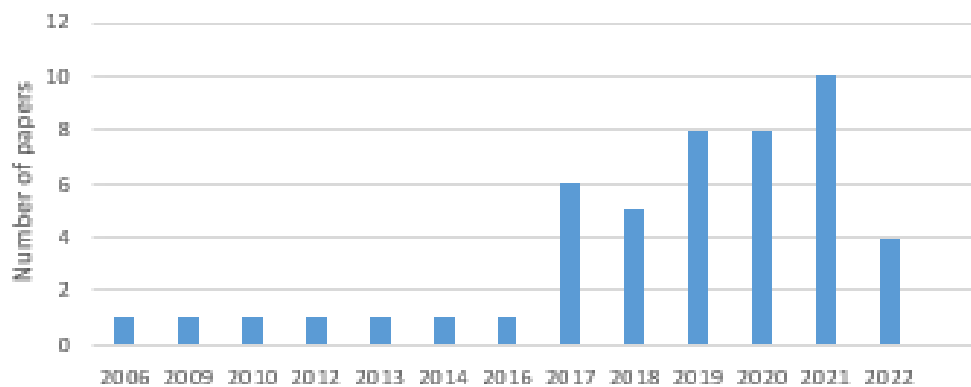


Figure 3.1: Publication years of reviewed documents (until April 2022) (own figure).

The most active countries in this type of publications are proportionally colored in Figure 3.2. The geographical dispersion of the articles highlights countries such as United Kingdom with 11 references, USA with seven and both Sweden and Italy with six articles. However, the diverse variety of countries means that there are articles from all continents.

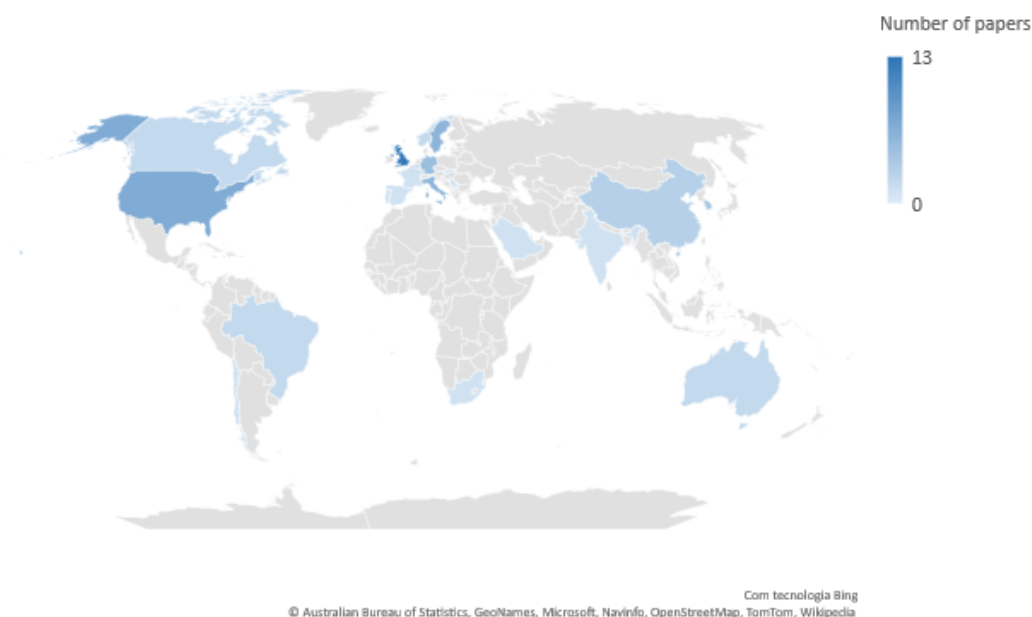


Figure 3.2: Publication country of reviewed documents (own figure).

A scientific journal is associated with each publication, whose information illustrating its relevance can be found at orange in Figure 3.3, while at blue are displayed the number of documents they are responsible from the 48 reviewed. Of the 28 different journals, 20 referenced only one article. *Sustainability-Basel* stands out with 8 articles from it, followed by *Int J Phys Distr Log* with 4 references. The remaining ones allowed to analyze either 1, 2 or 3 articles.

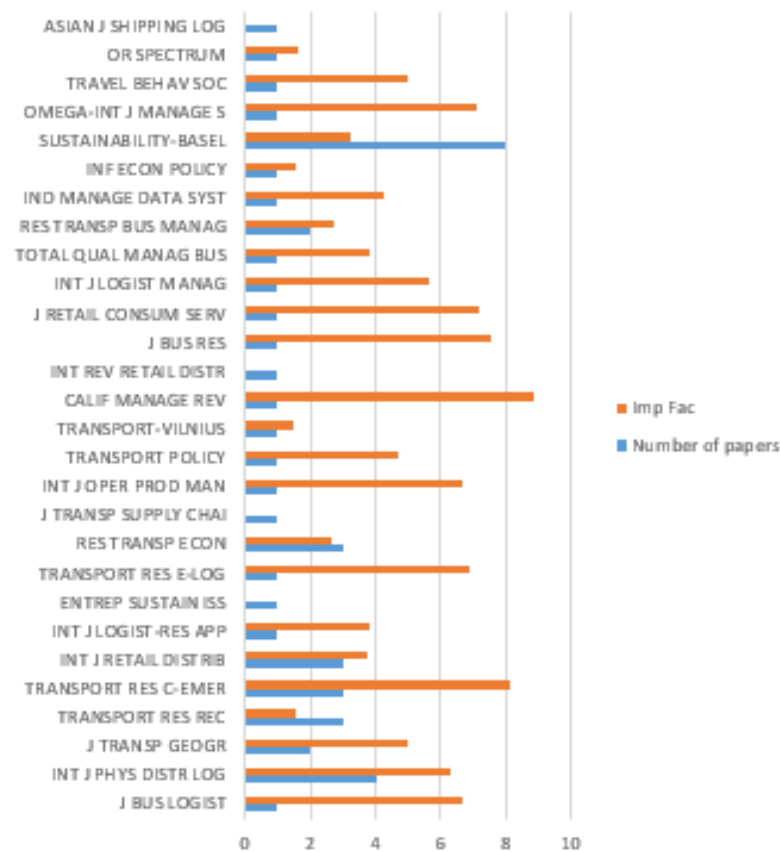


Figure 3.3: Journals incidence and Impact Factor of reviewed documents (own figure).

Screening had an exclusion criteria which eliminated articles extracted from sources rather than journals. One of the reasons was to allow a quantitative assessment on their relevance. In VOSviewer, each publication referenced where it was published, as well as two of its characteristics: impact factor (IF) and quartile. On one hand, the IF allows to acknowledge the importance of scientific journals in their respective investigation areas. It is a measure that reflects the average number of citations of scientific articles published in the same journal. Usually, higher IF means they are considered more relevant in their research area. On the other hand, quartile is a value that arises after dividing an ordered set of journals into four equal parts based on the IF and research fields. The same journal may be in different quartiles depending on the areas to which it relates.

Figure 3.4 exhibits the distribution of the identified documents IFs per defined intervals and Figure 3.5 evidences the breakdown of quartiles. As there is no regularity regarding the dispersion of articles by the IF, a higher number is highlighted between IF 3 and 4, but this is justified by the existence of a journal with 8 selected articles (*Sustainability-Basel*), with IF 3.251. As second most common, there is the range between 6 and 7. In addition, the number of articles with an IF between 1 and 2 is greater than desired, with the third interval having the highest quantity and the one with articles that come from less prominent journals.

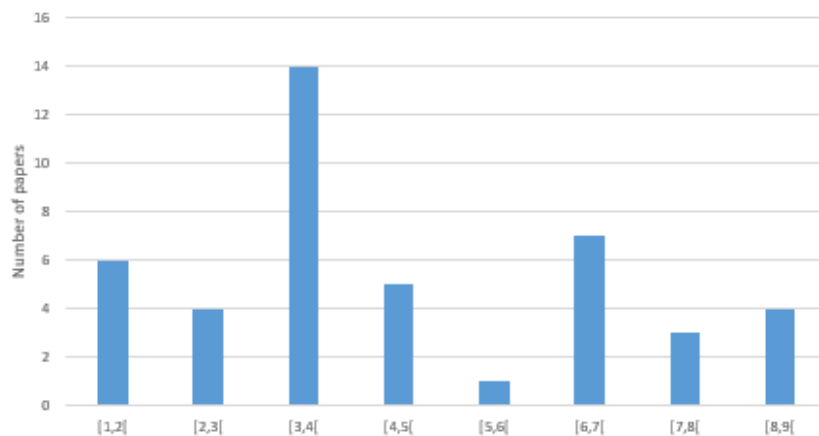


Figure 3.4: Impact Factors distribution of reviewed documents (own figure).

Exactly one third of the documents is in the 1st quartile, which reflects the relevance of a significant part of the articles. Although only one is between quartiles 1 and 2, there are 3 others in quartile 2. Another significant portion of the documents, in this case almost a quarter, belong to quartile 3, with another nine between this quartile and 2. Four belong to the last quartile, coming from less scientifically relevant journals.

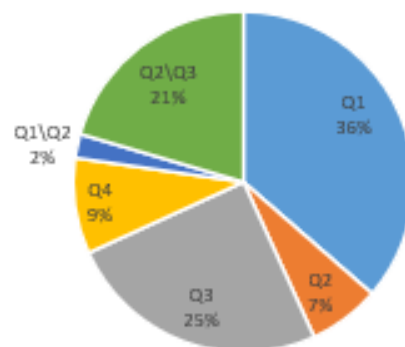


Figure 3.5: Quartiles ratio of reviewed documents (own figure).

## 3.2 Cluster labeling

Upon reaching Analysis phase from articles review method shown in Figure 2.2, a second query was set containing only the selected documents, with Pinetools assistance. Web of Science provides a functionality that creates a RIS format file, which would be used in VOSviewer software, based on text data from this reference manager file. Both title and abstract were targeted during several trials, always with a binary counting method. Within VOSviewer features, 3 occurrences would result in approximately 100 terms and with 5 occurrences, clusters would not be descriptive

Upon identifying those words, thesaurus was set on a text file, as some existing terms are synonyms or very similar. In order to replace repeated ones, VOSviewer presents the functionality of inserting a text file that explains the terms to be removed or which to replace. After removing the outcast terms, the previous occurrences attempt was repeated with 0.9 resolution and without the last three words because they are ordered by relevance and these had a relatively low one.

The result gathered the following three different coloured clusters Figure 3.6 and to overcome the poor legibility due overlap, the terms were grouped in Table 3.1. Even though each group may have some outcast terms compared to the rest, it was possible to contextualize each one to parcel delivery vocabulary. At first, coloured red and labeled as Cluster 1, *industry*, *policy*, *implementation*, *stakeholder* imply *E-commerce/Business* semantics. Cluster 2 at green, blends *Stakeholders*, as *consumer* and *retailer*. At last, in blue, Cluster 3 is *Deliver* related, as *supply chain*, *home delivery* and *order* suggest. *Sustainability*, *environmental impact* and *cost* can also be analysed as consequences from vehicle freight delivery. In addition, all data source types were accounted apart from these three clusters, so that a more detailed analysis could be carried out on interviews, surveys, among others.

Table 3.1: Clusters terms.

| Cluster 1: E-commerce (18 items) | Cluster 2: Stakeholders (13 items) | Cluster 3: Deliver (10 items) |
|----------------------------------|------------------------------------|-------------------------------|
| activity                         | challenge                          | analysis                      |
| addition                         | china                              | cost                          |
| area                             | consumer                           | delivery                      |
| city                             | context                            | environmental impact          |
| e-commerce                       | data                               | good                          |
| factor                           | design methodology approach        | home delivery                 |
| implementation                   | grocery                            | order                         |
| industry                         | growth                             | supply chain                  |
| number                           | interview                          | sustainability                |
| parcel delivery                  | logistics service provider         | use                           |
| perspective                      | model                              |                               |
| policy                           | practice                           |                               |
| problem                          | retailer                           |                               |
| recent year                      |                                    |                               |
| stakeholder                      |                                    |                               |
| survey                           |                                    |                               |
| willingness                      |                                    |                               |
| work                             |                                    |                               |

From e-commerce cluster, *activity* and *industry* suggest that deliveries of different items are studied and that they can belong to businesses with functions beyond just *parcel delivery* to the recipient, as production and/or storage. *Area* and *city* lead to the superiorization of urban over rural areas. Surveys should be the main data collection method, in order to assess *stakeholders willingness* to accept new parcel delivery strategies.

From the second cluster, may be noticed that *interview* is a common data collection from *logistics service providers*, including *retailer*. *China* is the only country mentioned, studying what others appear can give geographical *context*. All investigations deal with a specific *problem*, which requires an adequate *practice/design methodology approach*.

Deliver associated cluster reveals that in fact the *environmental impact* and *sustainability* are considered for *analysis* in the articles, as well as resulting *costs* for financial efficiency.

### 3.2.1 State-of-art review

To assess how data collection is carried out in the delivery sector and subsequent steps, articles in which that occurs are analysed. Categories were defined for data characterization, including the title of each cluster from last section (e-commerce, stakeholders and deliver), which is present in the category that results from that cluster, except for last category, as necessity to specifically assay last mile data, how it is treated and if the case, the mention to the original untreated data.

- Context on e-commerce services
- Stakeholders profile for data collection
- Delivery logistics and emissions
- Type of data analysis and accessibility

All this categories are result of their prominence in the clusters obtained in Table 3.1 resulting from their representation in Figure 3.6. Each obtained cluster was associated into a category, considering which last mile themes they make reference to. Category *Type of data analysis and accessibility* was placed apart from the rest to separately evaluate how data is treated.

Although not verified in the established query, a major objective of this study is to detect how emissions have been studied. Therefore, not all articles analyze them, but Alfaro et al. [16] predicted the possibility of reducing total  $CO_2$  emissions by 53 million grams per km travelled, which corresponds to 1103 annual hours saved. McKinnon et al. [15] estimates that it is possible to reduce the total distance traveled by between 20 and 40%, depending on the number of deliveries along the route (10 to 15). Bourlakis et al. [46] also includes vehicle capacity as a reduction factor and states that it is still possible to reduce distances traveled between 15% and 40% depending on the number of deliveries on a route and between 22% and 26% for a vehicle capable of making 10 to 15 deliveries on one route.

Something commonly mentioned refers to data sharing and transparency being highly valued by consumers. Despite the fact that almost all customers choose the most ecological means of delivery, given the existence of several last mile delivery methods, in the presence of details regarding the environmental and social impact of each one, the trend towards sustainable deliveries is greater [47, 48]. Preference is given to free deliveries to an address of your choice, during day-time hours [49]. In the inclusion of the return, also for free, consumers accept to wait longer or even to collect the delivery in a designated place, with preference for stores of retailers [50].

Parcel delivery workers willingness to embrace new strategies is evaluated in most articles. Their punctuality and flexibility are what retailers prioritize the most, as it allows for better inventory management, allowing to reduce stocks [51]. Online retailing customers, on the other hand, value the shopping experience from the moment they interact with the website [52]. To improve the delivery experience, the existence of different delivery methods would cause a greater sense of security [48]. There is a distinction between food and non-food retailing, especially in logistics organization and outsourcing strategies. Food retailers are inclined to organize fulfillment and last mile activities in-house, while non-food retailers partner closely with logistics service providers [53].

To assay trends and treatment on last mile data in 48 different investigations, a table was formulated to be filled in by the particularities of each article 3.2. At the same time, attention was paid to relevant metrics for their prominence previously exposed in the bibliometric analysis clusters from Table 3.1. Local and temporal context is given, as well as on firms services. On *Data*, target population mentions to who data was collected from, while domain concerns who the data collected was about. Type of illustration is also present, as well as details on sample dimension, how long did the data collection took and the dimension of analysis to track how units of measurement may be employed. The analysis performed are textually resumed and if present, which cases refer the previous data to that same analytical procedure.

Table 3.2: Overview of the literature review.

| Ref  | Company         |                |                    |          |                   | Data     |       |               |         |          |             |             |       |               |            |           |          |       |         |           |       | Open access | Methods of analysis |                       |           |                                                                                                  |
|------|-----------------|----------------|--------------------|----------|-------------------|----------|-------|---------------|---------|----------|-------------|-------------|-------|---------------|------------|-----------|----------|-------|---------|-----------|-------|-------------|---------------------|-----------------------|-----------|--------------------------------------------------------------------------------------------------|
|      | Area of service | Business model | Quantity of orders | Vehicles | Target population |          |       | Target region |         | Domain   |             |             |       | Support       |            |           |          |       | Type    |           |       |             |                     | Other                 |           |                                                                                                  |
|      |                 |                |                    |          | Company           | Consumer | Other | Region        | Context | Business | Consumption | Environment | Other | Questionnaire | Interviews | Documents | Websites | Other | Textual | Numerical | Image |             |                     | N                     | Dimension | Period                                                                                           |
| [54] | E               | A, B           | -                  | adv      |                   | X        |       | Brazil        | U       |          | X           |             |       |               | X          |           |          |       | X       |           |       | 534         | A                   | 2015 (1 month)        | -         | Statistical analysis and Electronic spreadsheets                                                 |
| [55] | F               | C              | -                  | S        | X                 | X        |       | South Africa  | SU      |          |             |             |       | X             |            |           | X        |       | X       |           |       | 3           | -                   | -                     | -         | Statistical analysis for later code creation                                                     |
| [56] | F               | A              | -                  | L        |                   | X        |       | China         | U       |          | X           |             |       | X             | X          |           |          | X     | X       |           |       | 299         | B                   | 2019 (-)              | X         | Multinomial logit model                                                                          |
| [57] | F               | A              | -                  | C        |                   | X        |       | Sweden        | U       | X        | X           |             |       |               | X          |           |          | X     |         |           |       | 19          | -                   | 2017 (1 month)        | X         | Statistical analysis                                                                             |
| [51] | F               | A              | -                  | L        |                   | X        |       | China         | U       | X        | X           |             |       | X             |            |           |          | X     |         |           |       | 273         | B                   | 2020 (2 months)       | -         | Structural equation modeling, hierarchical regressions analysis, importance-performance analysis |
| [46] | F               | A              | 346 745            | L        | X                 |          |       | UK            | U       |          |             |             |       | X             |            |           | X        |       | X       |           |       | 533         | C                   | 2014-2015 (11 months) | X         | Monte Carlo simulation                                                                           |
| [58] | F               | A              | -                  | L        | X                 |          |       | Italy         | U       | X        |             |             | X     | X             | X          |           |          | X     | X       |           |       | 127         | D                   | 2015 (2 months)       | -         | Multiple Correspondence and Cluster analysis                                                     |
| [59] | F               | D              | -                  | L        | X                 |          |       | Europe        | SU      |          |             |             | X     |               | X          | X         |          | X     |         |           |       | 8           | A                   | -                     | -         | Text analysis software and content analysis techniques with increasing sample size               |
| [60] | F               | A              | -                  | L        |                   | X        |       | USA           | U       |          | X           |             |       | X             |            |           |          |       | X       |           |       | 3301        | E                   | 2018 (-)              | X         | Trends analysis through data comparison                                                          |
| [61] | F               | D              | -                  | L        | X                 |          |       | 6 countries   | U       | X        |             |             |       |               | X          |           |          |       | X       |           |       | 755         | -                   | 6 months              | X         | Data triangulation                                                                               |
| [62] | F               | A              | -                  | L        |                   | X        |       | Sweden        | SU      |          | X           |             |       | X             |            |           |          |       | X       |           |       | 1694        | E                   | 2014 (2 months)       | -         | Descriptive analysis, bivariate correlations and stepwise multiple linear regression             |
| [53] | S               | C              | -                  | L        | X                 |          |       | Belgium       | U       |          |             |             |       | X             |            |           |          | X     | X       |           |       | 30          | -                   | 2017 (6 months)       | -         | Computer- assisted qualitative data analysis software                                            |
| [15] | S               | S              | -                  | L        | X                 |          | X     | UK            | U       |          |             | X           |       |               | X          |           |          |       | X       |           |       | -           | F                   | -                     | -         | Sensitivity analysis                                                                             |
| [63] | S               | A              | -                  | L        |                   |          | X     | North America | U       |          |             |             | X     |               |            |           | X        |       | X       |           |       | 261         | -                   | -                     | -         | Cluster and Statistical analysis                                                                 |
| [16] | S               | A              | 468                | L        |                   |          | X     | Chile         | R       |          |             | X           | X     |               |            |           | X        |       |         |           |       | -           | E                   | -                     | X         | Analytic hierarchy process                                                                       |
| [64] | S               | E              | -                  | L        | X                 |          |       | Australia     | U       | X        |             |             |       | X             |            |           |          |       |         | X         |       | 255         | G                   | 2017 (4 months)       | -         | Statistical analysis                                                                             |
| [65] | S               | A              | -                  | adv      |                   | X        |       | Germany       | U       |          | X           |             |       | X             |            |           |          |       | X       |           |       | 501         | B                   | 2018-2019 (2 months)  | X         | Structural equation modeling                                                                     |
| [66] | S               | C              | 150 000            | L        |                   | X        |       | Belgium       | SU      |          | X           |             |       | X             |            |           |          | X     |         |           |       | 1000        | A                   | 2017 (11 days)        | -         | Statistical analysis (descriptive statistics), Cluster analysis (two-step)                       |
| [67] | S               | B              | -                  | L        |                   | X        |       | USA           | U       |          | X           |             |       |               |            |           | X        |       |         | X         |       | -           | H                   | 2019 (3 months)       | -         | Accessibility and equity metrics                                                                 |
| [47] | S               | B              | -                  | L        | X                 |          |       | China         | U       |          | X           |             |       | X             |            |           |          |       | X       |           |       | 230         | B                   | 2018 (4 months)       | -         | Structural equation modeling                                                                     |
| [48] | S               | E              | -                  | L        |                   | X        |       | Sweden        | SU      |          | X           |             |       |               | X          |           |          | X     |         |           |       | 26          | -                   | 2016 (1 month)        | -         | Two-staged and axial codings based on theory                                                     |
| [68] | S               | A              | -                  | B, L     |                   | X        |       | Germany       | U       |          | X           |             |       | X             |            |           |          |       | X       | X         |       | 2017        | I                   | 2019 (1 month)        | X         | Statistical analysis                                                                             |
| [69] | S               | F              | -                  | L        |                   |          | X     | Canada        | SU      |          |             |             | X     |               |            |           | X        |       | X       | X         |       | -           | -                   | -                     | -         | Statistical analysis, Taxonomy                                                                   |
| [70] | S               | A              | -                  | L        |                   | X        |       | USA           | SU      |          | X           |             |       | X             |            |           |          |       | X       |           |       | 181         | J                   | -                     | X         | Statistical analysis (t-test)                                                                    |
| [71] | S               | A, B           | -                  | L        |                   | X        |       | Singapore     | SU      |          | X           |             |       | X             |            |           |          | X     |         |           |       | 209         | L                   | -                     | X         | Structural equation modeling                                                                     |

|      |   |        |            |      |   |   |   |               |    |   |   |   |   |   |   |     |   |                        |   |                                                                                                             |
|------|---|--------|------------|------|---|---|---|---------------|----|---|---|---|---|---|---|-----|---|------------------------|---|-------------------------------------------------------------------------------------------------------------|
| [72] | S | A      | -          | L    | X |   |   | USA           | SU | X |   |   | X |   | X | 500 | R | 2009 (-)               | - | Software using vehicle routing                                                                              |
| [49] | S | S      | -          | V    |   | X |   | UK            | U  |   |   | X | X |   | X | 30  | H | -                      | - | Statistical analysis                                                                                        |
| [17] | S | A      | -          | L    |   |   | X | 18 coun-tries | U  | X | X |   | X |   | X | 248 | J | -                      | X | McNemar tests                                                                                               |
| [52] | S | A,E    | -          | L    |   |   |   | UK            | U  |   |   | X |   | X | X |     |   | 2015-2016 (23 months)  | - | Data triangulation/ Within- and Cross-case analysis                                                         |
| [73] | S | A      | -          | L    | X |   |   | Sweden, India | U  |   | X | X |   | X | X |     |   | 2017 (-)               | - | Statistical analysis                                                                                        |
| [74] | S | B, F   | 35 000     | L    |   | X |   | Italy         | U  |   | X |   | X |   |   |     |   | 2017 (1 month)         | - | Discrete choice modelling                                                                                   |
| [75] | S | S      | -          | V    | X |   | X | France/UK     | U  |   |   | X |   | X | X |     | X | 2014-2015 (11 months)  | X | Statistical analysis                                                                                        |
| [76] | S | A      | -          | D, V | X |   |   | Germany       | U  |   |   | X |   |   |   | X   | X | -                      | - | Literature review (Snowball approach)                                                                       |
| [77] | S | A, G   | -          | S    |   | X |   | EU            | SU |   | X | X | X |   |   |     | X | 2011 (-)               | - | 27x27 trade matrix for online and of-line purchases                                                         |
| [50] | S | C      | -          | L    |   | X |   | Belgium       | U  |   | X |   |   | X | X |     |   | 2017 (11 days)         | X | Choice-based conjoint analysis                                                                              |
| [78] | S | A, F   | -          | L    |   | X |   | USA           | U  |   |   | X | X |   |   | X   | X | 2015 (-)               | X | Statistical and descriptive analysis for later code creation                                                |
| [79] | S | A      | 80 000 000 | S    |   |   | X | Austria       | U  |   | X |   |   | X |   | X   | X | 2016 (2 weeks)         | - | Statistical analysis and 4-point Likert-type                                                                |
| [80] | S | S      | -          | L    |   | X | X | China         | U  | X |   | X | X | X |   | X   | X | -                      | - | Fuzzy hierarchy analysis                                                                                    |
| [81] | S | E      | -          | L    | X |   |   | Italy         | U  | X |   |   | X |   |   | X   |   | 2018 (2 weeks)         | - | Factor and correlation analysis                                                                             |
| [82] | S | E      | -          | D    | X |   |   | Canada        | SU |   |   | X |   |   |   | X   |   | 2015-2020 ( 50 months) | - | Trends analysis and Mathematical model                                                                      |
| [83] | S | A,H, I | -          | L    | X | X | X | Saudi Ara-bia | SU | X |   | X |   | X |   | X   |   | 2018 ( 5 months)       | - | Thematical analysis                                                                                         |
| [84] | S | A, G   | -          | S    | X |   |   | Brazil        | SU | X |   | X |   | X | X | X   |   | -                      | - | Comparison with theory from documents and field notes                                                       |
| [85] | S | B      | -          | L    |   | X |   | China         | R  |   | X | X | X | X |   | X   |   | 2021 ( 6 days)         | X | Structural equation modeling                                                                                |
| [86] | S | S      | 5900       | V/T  |   |   | X | Serbia        | SU |   |   | X | X |   |   | X   | X | -                      | - | IMPACT methodology                                                                                          |
| [87] | S | E      | -          | L    |   | X |   | Sweden        | U  |   | X |   | X |   |   | X   | X | -                      | - | Partial Least Squares Structural Equation Modelling                                                         |
| [88] | S | C      | -          | L    | X |   | X | UK            | U  | X |   |   | X | X | X | X   | X | 2015-2016 (18 months)  | - | Verbatim transcription and Memo/Field note writing                                                          |
| [89] | S | F      | -          | L    | X |   |   | China         | U  | X |   | X | X |   |   | X   |   | 2019 (6 months)        | X | SmartPLS3.0 Software (based on structural equation modelling and Push–Pull–Mooring theory), Hypothesis test |
| [90] | L | A      | 350 000    | D, L |   | X |   | Italy         | U  |   | X |   | X |   |   | X   |   | -                      | - | Multinomial logit model from Weibull-Gumbel law                                                             |

<sup>1</sup>: *Area of services*: E: Eletronics; F:Food; S:Several; L:small/light deliveries <sup>2</sup>: *Business model*: A: B2C; B: Self pick-up; C: Omnichannel/Multichannel; D: Brick-and-mortar; E: Retailing; F: Crowdsourcing; G: Cross-border; H: B2B; I: C2C; S:Several <sup>3</sup>: *Vehicles*: A: airfreight, B: bikes; C: Cars; D: drones; L: land vehicles M: motorcycles; T: trucks; V: vans; adv: autonomous delivery vehicle; S:several <sup>4</sup>: *Context*: U: Urban, R: rural, S: sub-urban <sup>5</sup>: *Dimensions of analysis*: A: Per delivery method; B: Per delivery attribute; C: Per vehicle capacity; D: Per type of good; E: Per type of trip; F: g of CO2 per item; G: Per sub-industry; H: Per metropolitan area; I: Per age; J: Per company; L: Per factor selected ; M: Per schedule, N: Per pollution scenario; O: Per purchase mode; P: Per article; Q: Per business model; R: Stops per route/ Miles per route

### 3.2.1.1 Context on e-commerce services

There is a clear dominance of urban areas in e-commerce activities, having been considered a suburban area in the absence of information on the exact location of the study (despite having knowledge of the country). 14 articles either complied with this rule or have different locations, simultaneously considering urban and rural areas. Only two present a clearly rural context [16, 85].

There are trends in online ordering, because people find assisted deliveries convenient for a few type of goods. Most of the articles do not specify the product, having that it was considered *Several* in these cases. Online meals and grocery delivery market were the most investigated e-commerce product. On the contrary, Cullinane et al. [15] looks at causes of emissions and how to mitigate them in scenarios of delivery of any goods, with the exception of food. Other very common goods, but not so present in these samples, are electronic equipment, visible only in Dablanc et al. [54], using autonomous delivery vehicles (ADV). In opposition, without being integrated into a single market, Borghetti et al. [90] focuses on working only with deliveries of reduced dimensions and weight. The same case study presented a significant amount of 350 thousand daily deliveries, comparing land and drone means, to test the feasibility of the second method.

### 3.2.1.2 Stakeholders profile for data collection

Data from consumers had slightly more interest than firm's information. This audience was selected upon research on the business model while attempting to acknowledge what can increase its efficiency. There appears to be no relationship between the audience from which the data was collected and the stakeholder group to which data makes reference, as consumers are surveyed to assess e-commerce/transportation workers, or vice-versa. It mainly depends on the investigation purpose, but there are few cases where data from companies did not rely on their business. Also, few were the insights from consumers other than consumption related, either about their preferences, willingness to accept new delivery approaches, or shopping routines. Information on external factors, such as logistic issues and impediments on delivery success, comes mostly from companies' data. In general, gathering intel from consumers allowed to extract a bigger sample than other stakeholders.

While the year when the information from stakeholders was collected is close to the publication one, how long it took is a consequence of its objective and complexity. One-third of the documents do not mention when the data collection took place and consequently, its duration. From the ones who mention the year, only 26 references while it lasted. Except for some studies [46, 52, 75, 82, 88], which information gathering method took nearly one year, or longer, all others did not exceed half a year. Some cases performed their data collection within days, which is remarkable in comparison to longer examples[66, 50, 85].

Before performing data collection methods, they have to be planned according to the industrial context. If a specific audience/sample is targeted, key questions and how to process the responses

are carefully chosen [37]. Companies maintain regular surveys of their employees, as a performance tracking system. Its filling also allows insights from workers, which is very much taken into consideration by some firms.

A survey is carried out in a large portion of the studies. Interviews are the most immediate method of data collection, either for direct contact with stakeholders or less complex data, while a survey involves the organization and interpretation of data. There are examples in which more than one of these typologies is used. This occurs when it is intended to complement the previous work or in situations where one method of collection is used in a target audience and the second method in another audience.

Transportation and e-commerce are constantly changing due to high competitiveness, so logistic workers and upper managers find useful collecting field workers' points of view so that they can keep up fulfilling their services needs. *Other* means that unusual methods are required for the specific purpose of the article are exceptionally used: group discussions, field notes and data from microhubs and smart lockers.

Two studies approach certain websites, with *EuroStat* being a site used worldwide for statistical purposes. In Turlea et al. [77] the amounts spent on home deliveries from the national territory and abroad, including non-European Union countries, were researched. Another website analyzed is called *ComExt*, which has similar purposes and complemented the values obtained. In Lim & Srai [88], gas measurements are mathematically estimated. To this end, the *National Atmospheric Emissions Inventory* provides emission factors by vehicle type and the *Freight Transport Association* with details of distribution costs, associated with fuel consumption.

### 3.2.1.3 Delivery logistics and emissions

Certain products require a particular type of delivery or when urgency exists. B2C appears more regularly, and in most cases it is intended to acquire information associated with the consumer's experience. Retailing also being studied, but with a view more oriented to the potential of the business and analyzing the style of delivery and what factors can maximize its efficiency. Also noteworthy are innovative attempts such as Crowdsourcing/Crowdshipping and the use of Parcel Lockers. This last one grants own and temporally unlimited collection, whose acceptance by consumers [47] was studied and potential factors that make it possible [85]. Crowdsourcing is investigated as an alternative that may allow cost reduction, despite the payments inherent to the population that participates in deliveries [89]. Shorter delivery times and distances [77] are also advantages that consequently lead to lower emissions [78, 74].

The use of land vehicles is the type of locomotion most implemented for deliveries, appearing in 41 examples of the reviewed documents. However, this is the result of the lack of identification of grounded vehicles, in which cases a generalization into *Land vehicles* is done. Within these 41 cases, when the vehicle is identified, vans are more used. Hagen & Scheel-Kopeinig [68] also consider the use of bicycles, aiming for more ecological deliveries and the predisposition of customers to pay for a personalized delivery service to achieve this. Some cases embrace delivery approaches that are more technologically developed with drones [90, 76, 82] or automatic delivery

vehicles [54, 65]. However, these cases are about primitive approaches on how to implement such delivery methods, while trying to understand the acceptance rates by consumers.

Only two out of 48 analyze and aim to measure emissions, which is a relatively low proportion [66, 88]. However, both aimed at  $CO_2$  gas and measured it using mathematical models based on the previously collected information.

#### 3.2.1.4 Type of data analysis and accessibility

Each investigation has a specific data analytical purpose, which influences how data is treated. Most common data analysis procedures comprehend statistical reviews on responses and audience social status. Structural equation modeling, which shows how theoretical phenomena are structurally related to another, is also frequent [51, 65, 47, 71, 85]. This procedure is based on statistical models, to appear in a pair of tests, with a specificity in Hjort et al. [87] involving Partial Least Squares.

Data triangulation is verified for cases with different sources, when consensus on harming factors are sought. In two cases, data triangulation becomes practical to assess different sets of collected data. In the first one, Lim & Winkenbach [52] presents information from both the consumer and the client, from interviews and document content. In the second one, Trautrim et al. [61] has six countries into consideration and the technique allows distinguishing each one.

Some data representation types are more accurate than others, but applying more than one typology can result in a better understanding from the reader, which was conducted by 11 articles of the analysed sample [56, 58, 53, 68, 69, 17, 78, 79, 80, 87, 88]. Textual representation was applied when no other typology was identified, mostly to detect dictating factors on a PDS problem. When a single representation is carried, information in text form is mostly used, followed by numerical type and images. Quantitative data is portrayed when graphics are designed, as images are used for thematic illustrations. However, certain details can only be exhibited in a certain form, strongly dependent on the type of data collected. Fifteen cases effectively display the information gathered only in graphics.

When applied in the reviewed articles, 17 different granularities were detected, as it depends on the graphics visualization purpose. Despite the numerous dimensions of analysis used, the ones most detected are associated to the type of product or delivery logistics much as the vehicle and trip. This concern to firms' services is used when trying to understand which are the delivery logistics factors with most impact. There are 12 that do not display any granularity [55, 57, 61, 53, 63, 48, 69, 52, 76, 78, 87, 90]. Consequently, it appears that in these cases, the results/information were exposed in text format.

18 of the 48 articles analysed either mention the data on which they based during the course of the article or explain how they carried out the questionnaires or interviews and also provide the data derived from them [56, 57, 46, 60, 61, 63, 16, 65, 68, 70, 71, 17, 75, 76, 50, 78, 85, 89]. Among these, 9 indicate an outside data source with the last mile information they analysed, while the rest are cases in which demographics are statistically analyzed or the content of the sources is summarized in the publication itself [56, 57, 60, 61, 63, 70, 71, 75, 85].

### 3.3 Summary

To find trends in last mile data treatment, the analysis of documents that collect data from a certain audience is advisable. With the help of VOSviewer tool, most regular topics are detected, which can be confirmed with a further literature review of the elected articles.

In general, when searching for customer information, surveys are carried out on online platforms. However, online interviews are also used for less quantifiable information, such as reaction to innovative measures or personal shopping habits. Interviewing is the most adopted method to collect the perception of companies, where more formal questions extract information about the strengths or weaknesses of each business, as well as receptivity to progressive policies. Most of the cases in which a survey is implemented, it is singly led but there are spontaneous situations of adding interviews. When surveys are carried out, sometimes there is still an analysis of other publications. The use of tools on websites is practically non-existent or not even mentioned. Regardless, it is anticipated that several were consulted, if only for thematic contextualization.

The detection of causes for impediments on firms logistics is what researchers try to identify. A problem that was not really addressed is data accessibility, which, due to the small number of articles that directly reference the information on which they were based, is seen as inefficiency in last mile data analysis. Although environmental consequences are taken into consideration, data on emissions is rarely gathered, which also constitutes as a problem for this study.

The most noticeable variations are in analytical procedures when using computational tools for mathematical modeling, but this is justified in the current technological growth in diversity. A statistical analysis of engaged audience (demographics) is done regularly, directed to age and economical context. Other models resulting from a statistical and mathematical combination are also detected, but as already mentioned, the purpose of the data and its representation influences how the procedure is led. Such a choice affects the results and likewise the representation for them. Great incidence in numerical visualization of data shows how common is the collection of quantifiable variables, which are easily displayed with graphics.

Most articles do not specify which type of ground vehicle is used, despite acknowledging that the product is delivered by land. Small and light packages can be more successfully delivered using drones, which require few logistics and carry minimal pollution, not only environmental, but also noise. They are one of the delivery methods with the highest profit margin for the courier. However, for the high price of a drone, this same profit would not be immediate, but after purchasing the drone, it only requires maintenance. In times of a pandemic, it also allows deliveries without human interaction and possible exposure. ADVs are similar-purpose vehicles, but a consensus was not reached about the feasibility. In general, the more daily deliveries and companies involved, the less interest there is in implementation. Electric vans' potential is well acknowledged for running without any type of burning fuel. However, their upfront prices make companies take a step back. To contradict it, government incentive schemes and charging infrastructure subsidies might encourage this implementation.

No details are given on the transported products, as only grocery deliveries were presented in significant amount, in which carrier interaction and empathy is crucial to customer satisfaction. It is an industry where delivery duration is not seen as a primary factor and cost in relation to delivery quality is what customers give most importance. The integration of multiple channels is not advisable for most products, unlike non-food industries. When crossing channels, the lack, and mismanagement of information is considered to be the most harmful, as well as in the general experience of customers, with regard to product information, their variety, and delivery status.

Numerical variables can be expressed in plain text. However, all information is more transparent and easily interpreted in a graphical format that contains the different values measured. For their potential, they will be further assessed in sources that can clarify when collecting data, whether there is objectivity in relation to the products delivered and used vehicles.

## Chapter 4

# Data categories and exploration of visualizations

Statistical information, in the absence of access to operational surveys, is seen as an adequate alternative. Besides representing a data source for numerical variables, last mile statistical data analysis, combined with geographical information, is considered an efficient data assessment [91].

Non-numerical variables can be plain text displayed, while focusing on numerical ones allows graphical visualizations that facilitate users comprehension, most valued by researchers for data analysis [92]. Data illustration is the most intuitive representation for a thematic spatial contextualization, so the diversity of visualizations is investigated, specifically on websites with information oriented to geographic dispersion of statistics for local last mile contextualization. Analytical metrics as dimension of analysis, variables and granularities are also pursued.

The definition of last mile deficits, as Sulp implementation procedure in Figure 2.3 suggests, is the first activity required for planning sustainable logistics. This assessment can be conducted from sets of data on five investigation areas, regarding e-commerce/delivery sectors.

### 4.1 Source identification

Three main data sources associated with the environmental impacts of the last mile were identified: *Eurostat* for already providing last mile data in first chapter of this document, *Kaggle* for thematic versatility except on environmental data, theme that *UNESCO* website pursues.

In Table 4.1, renowned examples of websites for statistical data are presented [41], including information on the number of visitors by July 2022, to gauge the popularity so far, which serves as an illustrative factor of the viability and general acceptance of their content. In addition, rejection percentages are stated which reflects the portion of users who left the website after entering the first page. Both these indicators are obtained for all websites by the online tool *SimilarWeb* ([93]), dating July 2022. Searching features available influence the final sample, which can be limited if filters on documents context are suggested. Beside this, investigation areas covered may be

presented, which have necessarily to concern last mile information. The presence of different methods for illustrating data is assessed.

Table 4.1: Websites for statistical information.

| Website      | Access details |             | Data search |            | Data visualization |          |      |        |         |
|--------------|----------------|-------------|-------------|------------|--------------------|----------|------|--------|---------|
|              | No. Visits     | Rejection % | Filter      | Categories | Tables             | Graphics | Maps | Images | Textual |
| Eurostat     | 19,5 M         | 51,84%      | X           | X          | X                  | X        | X    | X      | X       |
| Statista     | 20,9 M         | 72,18%      |             | X          |                    | X        |      |        | X       |
| Kaggle       | 8,1 M          | 35,31%      | X           |            | X                  | X        |      |        | X       |
| UNESCO       | 3,7 M          | 68,07%      | X           | X          |                    |          | X    | X      | X       |
| NationMaster | 506 K          | 68,91%      |             | X          | X                  |          |      |        | X       |
| INE          | 247 K          | 40,4%       |             | X          | X                  | X        |      | X      | X       |
| PORDATA      | 148 K          | 57,4 %      |             | X          | X                  | X        |      |        |         |

External perception on online pages is important to instill confidence in future users. There is a clear dominance from Statista and Eurostat with nearly 20 million visits by July 2022, while the rest do not reach 10 million. Nevertheless, Kaggle, which is the third most visited, has a very low rejection percentage. Its datasets are extensive, but not updated with much regularity as other websites. Considering their investigation areas, the remaining websites can be used to execute a similar assay as this chapter and compare results, as other specific graphical visualizations and map designs can be detected.

Despite being the most visited, *Statista* presents a higher rejection percentage. Fulfilling both Research features and Data representation also influences the source selection. Searching per spatial level of representation is applied in *INE* online page on Database. It immediately reveals how detailed the analysis is, as datasets are divided into national level or even municipality or parish. Providing search filters according to the existing granularities or dimensions of analysis allows representation-based results, a typology that facilitates e-commerce and transportation sector contextualization in each region.

Each source implements different visualizations, but *Eurostat* stands out for representing numerical data by *Several* visual methods, specially graphics and spatial representations. From European perspective, this website exhibits news, datasets, and publications. Its free access, as well as reckoning most of European countries, makes it a wide source. On *Eurostat* Database, most of datasets were presented in dynamic tables, which could be customized in distinct pages according to year (granularity).

*Eurostat* is elected as a secondary data source to be analysed as it also is an international governmental website, the European Union. *INE* and *PORDATA* were also used with the purpose of inserting examples of sources and analysis managed in the Portuguese territory, as *INE* (National Statistical Institute) is also governed by an institution supported by the national government, while *PORDATA* is managed by *Fundação Francisco Manuel dos Santos*

How data is represented is further investigated. Numerical tables exhibit the values measured, while graphics lead to a visual interpretation of data. Linear regressions for temporal observations, numerical bars with ordination, or geographical illustration of maps. That is also the case with images, but with less information complexity. Having into consideration that this document will

serve to assist in the study of last mile environmental impact, the analysis of such a topic by a given region on maps helps the local contextualization and granularities induce chronological circumstances.

## 4.2 Dataset visualization

Each website embraces different themes, making it more or less suitable for the e-commerce and transportation sectors. To understand which sources present last mile data, the existence of data categories facilitates the identification of sources within the topic. Statistical analysis on audience social status, or demographics, was usual in last chapter to characterize the surveyed audience. To separate e-commerce activity in first mile at beginning of the delivery chain from the actual delivery of goods in last mile, *Sales* and *Transport* were respectively defined. To assay if technological development is investigated, *Technology* is set. At last, if environmental data is collected, they correspond to *Environment* area.

- Demographics
- Technology
- Environment
- Sales
- Transport

Websites present a vast amount of research areas, so it was restricted in a smaller group on PDS/ e-commerce related. In this section, several visualization methods are illustrated, while exploring what sort of information can be extracted within each data type. To conclude what measurement variables, dimension of analysis and visualisation methods are most used, Table 4.2 groups some sets. They are divided according to source website and five last mile data categories. Illustration methods shown per category are not representative of their prominence in that theme.

Each set title is presented because they reveal what variables are quantified and in almost half of the cases, the specific dimension of analysis they base the representation on. For each dataset, how each variable is measured and granularity applied are assessed. The area represented and time span are set for geographical and temporal context of data, but possible territorial representations within the selected websites are investigated.

Table 4.2: Relevant datasets from elected websites.

| Category    | Title                                                                                                                               | Source   | Unit of measurement           | Area     | Years      | Data visualization                |
|-------------|-------------------------------------------------------------------------------------------------------------------------------------|----------|-------------------------------|----------|------------|-----------------------------------|
| Sales       | People ordering goods or services online                                                                                            | Eurostat | Percentage                    | EU       | 2020       | Geographic dispersion (NUTS II)   |
|             | E-commerce sales                                                                                                                    | Eurostat | Percentage                    | EU       | 2012-2021  | Several                           |
|             | Internet purchases - perceived barriers (2021 onwards)                                                                              | Eurostat | Percentage                    | EU       | Since 2021 | Several                           |
|             | Internet purchases - problems encountered (2021 onwards)                                                                            | Eurostat | Percentage                    | EU       | Since 2021 | Several                           |
|             | Internet purchases - goods or services (2020 onwards)                                                                               | Eurostat | Percentage                    | EU       | 2020-2021  | Several                           |
| Transport   | International annual road freight transport - goods unloaded in reporting country, by type of transport (Mio Tkm)                   | Eurostat | Million tonne-kilometre (TKM) | EU       | 2011-2019  | Several                           |
|             | International quarterly road freight transport - goods loaded in reporting country, by type of transport (1 000 t, Mio Tkm)         | Eurostat | Million tonne-kilometre (TKM) | EU       | 2019-2021  | Several                           |
|             | Transport of dangerous goods                                                                                                        | Eurostat | Thousand tonnes               | EU       | 2012-2021  | Several                           |
|             | Sea transport of goods                                                                                                              | Eurostat | Thousand tonnes               | EU       | 2010-2021  | Several                           |
|             | Goods transport by rail                                                                                                             | Eurostat | Thousand tonnes               | EU       | 2007-2016  | Several                           |
|             | Goods transport by road                                                                                                             | Eurostat | Thousand tonnes               | EU       | 2010-2020  | Several                           |
|             | Air transport of goods by country (yearly data)                                                                                     | Eurostat | Tonnes                        | EU       | 2010-2021  | Several                           |
|             | Transport by type of vessel                                                                                                         | Eurostat | Thousand tonnes               | EU       | 2012-2021  | Several                           |
|             | National annual road freight transport by distance class, type of transport and group of goods, from 2008 onwards                   | Eurostat | Thousand tonnes               | EU       | 2008-2020  | Several                           |
|             | Gross weight of goods transported to/from main ports - Portugal - quarterly data                                                    | Eurostat | Thousand tonnes               | Portugal | 2019-2021  | Several                           |
|             | Annual road freight transport, by type of goods and type of transport , from 2008 onwards                                           | Eurostat | Thousand tonnes               | EU       | 2008-2020  | Several                           |
|             | Goods transported by type of transport (detailed reporting only )                                                                   | Eurostat | Thousand tonnes               | EU       | 2012-2021  | Several                           |
|             | Gross weight of goods transported to/from main ports by direction and type of traffic (national and international) - quarterly data | Eurostat | Thousand tonnes               | EU       | 2019-2022  | Several                           |
|             | Annual road freight transport, by load capacity of vehicle                                                                          | Eurostat | Million tonne-kilometre (TKM) | EU       | 2011-2020  | Several                           |
|             | Annual road freight transport vehicle transit movements, by transit country                                                         | Eurostat | Thousand tonnes               | EU       | 2011-2020  | Several                           |
| Environment | Pollutant emissions from transport                                                                                                  | Eurostat | Percentage                    | EU       | 1990-2019  | Several                           |
|             | Air pollutants by source sector (source: EEA)                                                                                       | Eurostat | Tonnes                        | EU       | 1990-2019  | Several                           |
|             | Air emissions accounts by NACE Rev. 2 activity                                                                                      | Eurostat | Tonne                         | EU       | 2011-2020  | Several                           |
|             | Greenhouse gas emissions by source sector (source: EEA)                                                                             | Eurostat | Thousand tonnes               | EU       | 2011-2020  | Several                           |
| Technology  | Stock of vehicles by category and NUTS 2 regions                                                                                    | Eurostat | Number                        | EU       | 2016-2020  | Several                           |
|             | Road, rail and navigable inland waterways networks by NUTS 2 regions                                                                | Eurostat | Kilometers                    | EU       | 2016-2021  | Several                           |
|             | Length of other roads by category of roads                                                                                          | Eurostat | Kilometers                    | EU       | 2011-2020  | Several                           |
|             | Railway transport - length of tracks                                                                                                | Eurostat | Kilometers                    | EU       | 2011-2020  | Several                           |
| Demography  | Population density by NUTS 3 region                                                                                                 | Eurostat | People/km2                    | EU       | 2015-2020  | Several                           |
|             | Census- Methodological Note and Data Extraction                                                                                     | INE      | Several                       | Portugal | 2021       | Geographical dispersion (NUTS II) |
| Sales       | Retail trade turnover index                                                                                                         | INE      | Percentage                    | Portugal | 2022       | Table                             |
|             | Imports and Exports of goods by municipality, annual                                                                                | INE      | Euros (€)                     | Portugal | 2016-2021  | Table                             |
| Transport   | Goods transported by road transport companies: total and by main goods - Continent                                                  | PORDATA  | Tonnes                        | Portugal | 2020       | Temporal regression               |
| Technology  | Motorized road vehicles in circulation: total and by vehicle type                                                                   | PORDATA  | Number                        | Portugal | 2020       | Temporal regression               |

The main source selection for this assay means that a large part of the datasets came from it. The existence of numerical tables, linear temporal regressions, bar graphics and maps led to their translation into *Several*. The choice for the displayed examples did not follow any guideline, solely for the purpose of illustrating variety in data topics, including sets from Portuguese sources. Sales and Transport data are the most common between the mentioned websites, which evaluate costumers and firms confidence in e-commerce market and what weight of goods is delivered.

A thematic review corresponding to dataset categories from Table 4.2 is performed. For each one, a labeling according to analytical trends is given. To understand how these relate to different representations, examples of datasets and their visualizations are exhibited, with suggestions for future analyses.

### 4.2.1 Demographic: Spatial representation

Geographical context on population already been proved to be helpful in last mile data analysis. Census are part of *INE* resources but for those sources with no role in their implementation, demographic analysis can be performed with NUTS representation. Territorial separation is based on the NUTS system [94], which was created by *Eurostat* in cooperation with European statistical institutes for the single purpose of territorial statistical analysis. It is based on a coherent and structured division of the community's economic territory, which can vary according to the greater detail desired. From NUTS I, which limits each national territory, to NUTS III, which considers each district municipality.

To equally consider what NUTS are being used for, demographics help quantify the number of inhabitants per square meter of territory. Therefore, based on Population density by NUTS 3 dataset, all municipalities were gathered to show how transversal NUTS territorial methodology is, introducing Portuguese population density per NUTS II region considering a NUTS III visualization (Figure 4.1). Age group and economic status can also be contextualized.

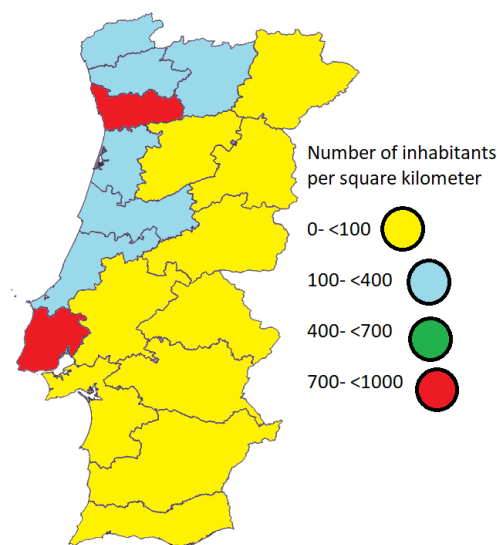


Figure 4.1: Portuguese population density by NUTS 2 in 2019 (own figure).

Portugal's population has declined in the last decade, which, in addition to a lower birth rate, is caused by the greater number of emigrants than immigrants. The aging of the population also contributes to these indices. The only two areas where the population has been increasing are *Algarve* and Lisbon. Porto is also a very inhabited region, which together with the previous two, forms the most technologically developed areas.

Spatial representation is also frequent in other data categories. Figure 4.2 shows the road network across Portugal. A territorial representation based on lines led to identify main national roads, but other geographical shapes can be employed if precise locations are needed. All networks are presented by kilometers, not regarding their type according to length. Different types as national and municipal roads can be distinguished in graphical designs if colored differently.

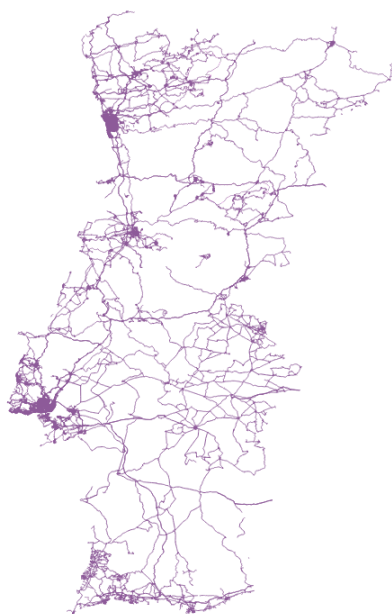


Figure 4.2: Portuguese main national roads design [2].

The map representation in Figure 4.2 matches to typical GIS representation [95]. GIS are operation tools employed to represent maps and employ territorial analysis. Its acquisition makes it a good alternative to NUTS system, which represents only an idealization of territorial division.

#### 4.2.2 Technology: Transport Infrastructures

In e-commerce and transportation context, Technology concerns the existing infrastructure or equipment that facilitates deliveries. The two main topics identified concern what vehicles are used and roads they move on, with each being measured accordingly. Freights of vehicles are numerically divided according to their purpose, which means whether they are for the public transport of citizens, for their own use, or, as intended in this document, for material transport purposes. *Eurostat* and *PORDATA* study this topic very similarly, although the second source presents more limitations in the variety of representation.

At least 80 thousand different vehicles are used in the annual transport of goods on the Portuguese mainland. But in 2020, due to the global pandemic, that figure decreases by almost 20 thousand, including trucks, trains, and articulated vehicles. These conclusions on a single area are obtained in Figure 4.3 from Motorized road vehicles in circulation: total and by vehicle type dataset, with temporal regressions, which is the main method of representation in *PORDATA* page, but also present in the reviewed *Eurostat* datasets.

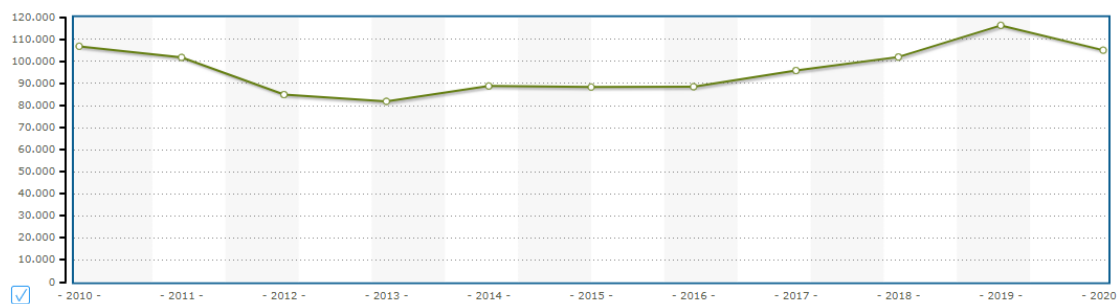


Figure 4.3: Annual freight delivery vehicles in Portugal [3].

To show temporal evolution of any variable, regressions show increases and decreases over the years and such extremes may reveal some performance deficit. However, this variation concerns a single unit, in this case, a country, which can be compensated with several regressions, but the more there are, the more complex the interpretation. Other evolution can also be represented in yearly quarter based granularity, which is further demonstrated.

Roads are by far, the path most used to transport deliveries. Upgrading them or designing new ones to upgrade logistics can reduce traffic. To contextualize each country infrastructures reach as presented in Portuguese roads design from Figure 4.2, they can be characterized into category of roads depending on the locations linked, from districts with the highest population to more isolated provinces with less access.

### 4.2.3 Environment: Quantification of emissions

Europe is one of the most industrialized continents in the world and there is the objective of making it a leader in industrial production in the continent, maintaining such ambition for environmental sustainability [96]. Greater industrial activity in a specific area condensates the emitted gases. Just for the transport and storage market sector, tonnes of GHG released have increased, despite decreasing in 2020 due to the pandemic lockdown. Representation of data in *Eurostat* datasets is also done with bar charts like in Figure 4.4 from Air emissions accounts by NACE Rev. 2 activity dataset, that stand out for numerically ordering results.

It is possible to order countries' PDS emissions and do it per year. Thus, those with the greatest impact can be identified and the granularity of annual representation makes it possible to assess which ones have more consistency in the emission of gases, measured in tonnes or thousand tonnes, depending on the scope of the variables.

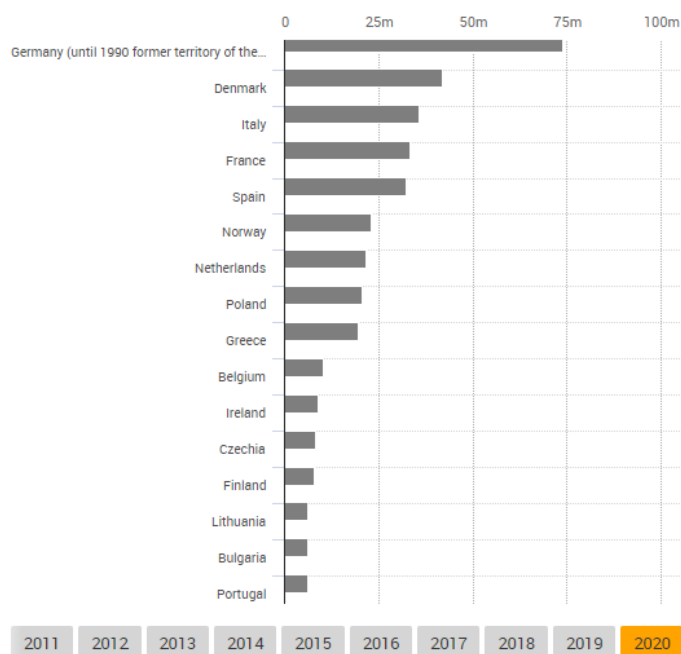


Figure 4.4: Annual transportation and storage air emissions of European countries [4].

The evolution of GHG emissions from parcel delivery is a result of more online purchases and if each company has more deliveries in hand, extra efforts are required. Despite not being linearly dependent, the more vehicles there are, the higher the emissions will be. Across Europe, different ratios on total vehicles and emissions arise. To highlight some cases, the 2020 Stock of vehicles by category and NUTS 2 regions and 2020 GHG emissions from Air emissions accounts by NACE Rev. Two activity on Transportation and Storage were combined in Figure 4.5.

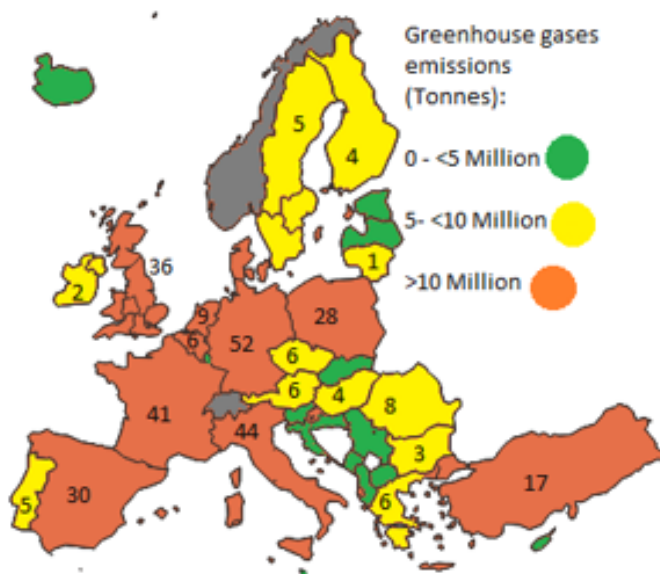


Figure 4.5: Millions of vehicles and Tonnes of GHG across Europe in 2020 (own figure).

The numbers presented were extracted from Stock of vehicles by category and NUTS 2 regions, which presented the total number of national vehicles. In that set, dimension of analysis, by category, concerns the vehicle size, not their purpose.

From the collected Environment sets, one aims directly at transport emissions, while the other three go beyond emissions caused by vehicles and allow representations focusing on other industrial activities. The specification of which gas whose emissions are intended to be measured is made available, specially methane, nitrogen oxide,  $CO_2$ , and equivalents. The generalized measurement of GHG is also featured. Numerical tables are therefore practical for gathering specific information on a previously determined unit as a GHG, within a country or continent in a certain period. However, the possibility of a large amount of numerical information thickens their interpretation.

#### 4.2.4 Sales: Social and business adherence

Although sales have increased, not every company can establish online sales. With the extra impact of the COVID-19 pandemic, more firms reached bankruptcy in some countries than in others, between 2020 and 2021 (including Portugal). Figures 4.6 show each of those years percentage of firms with online sales, also present in the e-commerce sales dataset.

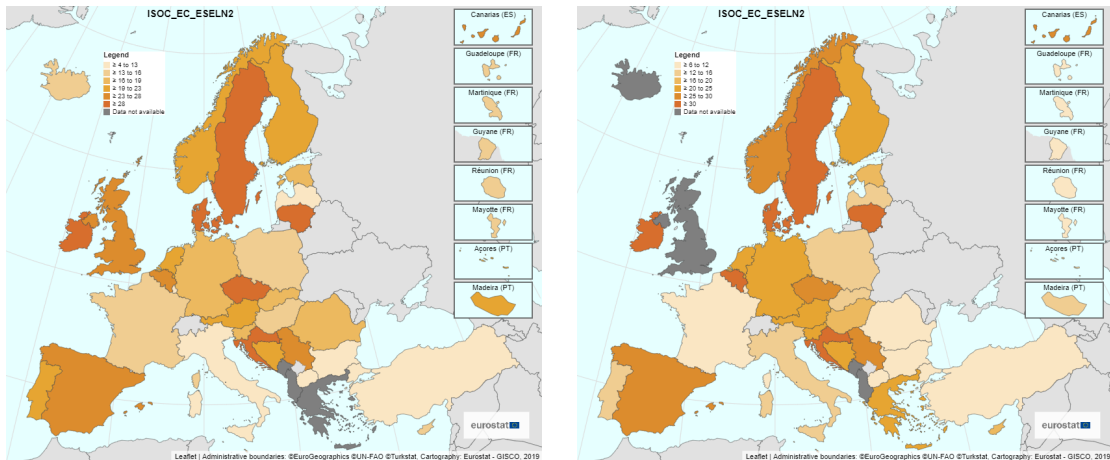


Figure 4.6: Percentage of businesses with e-commerce in 2020 and 2021 [4].

Graphical representation by year functionality is available and instead of a single temporal regression as Figure 4.3, sequential screenings of temporal based maps as Figure 4.6 have the advantage of considering more than one measurement and still allow to study temporal evolution.

Once again, NUTS I boundary method is employed. Nevertheless, a greater division of the territory can be led as Figure 4.7 illustrates on clients, within a certain age gap, portion among population from People ordering goods or services online dataset. In comparison, NUTS II helps in achieving contextualized data on each country delimited regions.

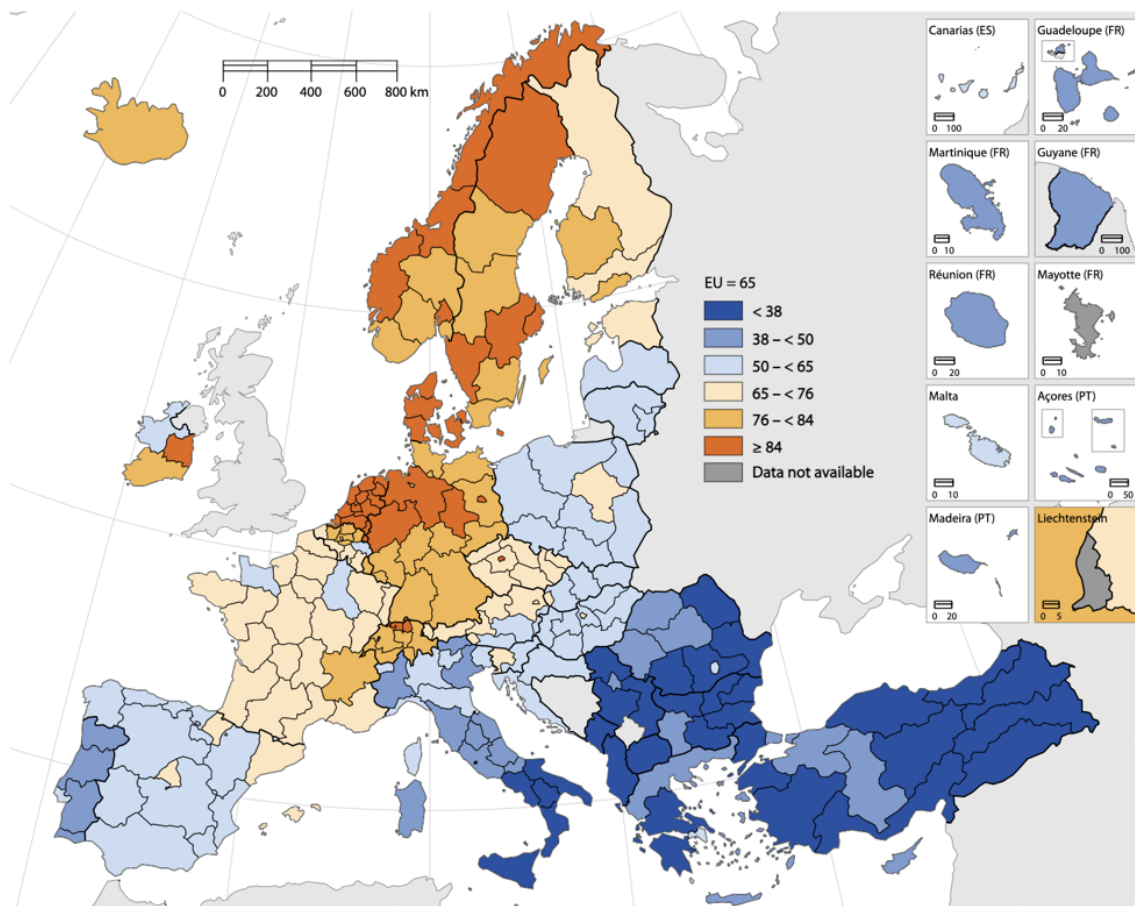


Figure 4.7: Percentage of 16-74 aged people buying online in 2020 [4].

For example, Portugal stands out for being less regular in purchases, with percentages between 38 and 50%. Comparing both maps (Figures 4.6 and 4.7), countries from North Europe turn out to be the most solid in e-commerce. These two sets assay what ratio of population and firms are active in online shopping, so different stakeholders can be analysed.

The temporal volume of transactions presented in Figure 4.8, in this case per NUTS II region, can be an element that predominates over doubts about the feasibility of investments in last mile logistics. From *INE data Imports and Exports of goods by municipality, annual*, which measures transactions from the monetary value generated, the most active Portuguese areas in the market were identified in 2021.

These examples show how evaluating different websites offer other research procedures, as units of measurement. On Sales category, *Eurostat* relies on social percent engagement but in *INE* dataset present in Figure 4.8, transactions are monetary evaluated to detect profits or losses. Nevertheless, percentage-based evaluations also occur for Sales datasets.

Percentage assessments are also used to investigate customers' experience, trying to identify barriers like uncertainty regarding the payment method and the possibility of returning the product or requesting a refund.

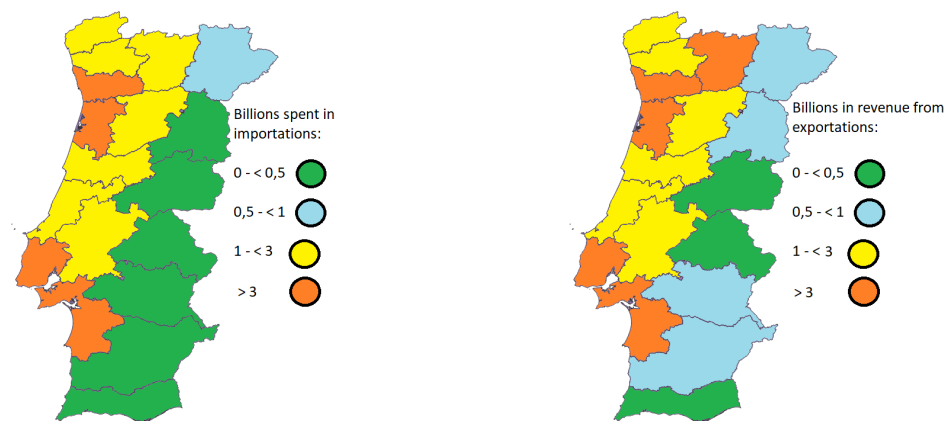


Figure 4.8: Money spent and gained by Portuguese transactions, in 2021, by NUTS 3 (own figure).

#### 4.2.5 Transport: Weighing parcels

Transportation data is the defined data category with greater analysis reach, in particular, on results scalability [97]. In addition to gathering the most amount of datasets reviewed, their titles are the most representative. However, measurements do not go beyond dispatched quantities in tonnes or also considering distances (Million tonne-kilometre).

Despite the greater use of road transport, the use of the sea and air vehicles to transport goods is also measured. From the collected datasets on the Transport category, five attain land delivery methods, four strictly relate to sea transport and one counts deliveries between airports.

As mentioned, several dimensions of analysis are identified, some cases with multiple within a single dataset.

- *By type of good* if measures reflect what type of products are transported
- *By type of transport* appears in five datasets to differentiate if e-commerce stores do provide their parcel delivery or hire companies specialized in last mile transportation
- *By distance class* to group deliveries according to the distance necessary to travel during the same
- *By type of traffic* when for the area in question, there is a distinction between the transport being an import or an export
- *By load capacity of vehicle* to identify orders according to tonnes of goods that vehicles can carry.
- *By type of vessel* to separate water vehicles according to their size

From the mentioned dimensions, an example of *By type of traffic* application is verified in Figure 4.9, directly comparing transaction of volumes inwards and outwards from Portuguese ports, originally in Gross weight of goods transported to/from main ports - Portugal - quarterly

dataset. Dimensions of analysis can be combined with measure variables. Although most considered datasets measure variables per year, this example determines the total tonnes of goods transported by water vehicles per annual quarter.



Measure variables are predominantly associated with transported totals, either for an annual or quarterly granularity. It is also present at *PORDATA*, but 80% of selected *Eurostat* Transport datasets place final weight as a good representative of deliveries abundance. The rest 20% also consider weight, but in consideration to distance traveled. Million tonne-kilometer is used in three sets. It is the unit of measurement that is obtained by multiplying the tons of the order by the distance traveled to deliver it.

### 4.3 Summary

For environmental analysis, researchers investigate what gases are emitted. Although the industrial activity is identified, focusing on what was the equipment acting as a source and when it occurs could give other insights. Vehicles are the main responsible and with the aging of their mechanical parts, emissions are consequently higher. Identification or tracking systems can be considered.

On sales analysis, either the selling company or the client is targeted, when sometimes, retailers are involved, the parcel gets stored or it is not immediately delivered. Therefore, separating firms and social participation according to delivery chain phases would help to comprehend the complexity of each one. More details on what type of businesses are involved, from micro-enterprise to large companies, can demonstrate what logistical activities are necessary and operational/ monetary efforts, as the number of workers and whether there is a need to subcontract specialized companies.

Participation in e-commerce is taken into consideration in sales category, which can be seen as demographics. Customers' age and economic status are assessed and for these cases, demography and social engagement (in percentages) in e-commerce appear to be strongly related.

In Transport, measuring distances covered and quantifying tonnes of delivered goods are most performed. Tracking the moment and source of purchase, as well as when it is collected until the delivery date, could account for emissions depending on the product and services required. Similarly to the sales category, investment is necessary, so some companies may see it as a setback.

For emissions and goods delivered measurements, the unit employed is tonnes. Monetarily quantifying the volume of transactions is an option. For technology category, the length of the roads is commonly investigated, expressed by kilometers and freight vehicles are also counted.

Several dimensions of analysis are used, mostly in transport category. All give relevant insights on particles or vehicle specifics, unlike analysis from initial chapters. A similar granularity to *By load capacity* of the vehicle, but taking into consideration what was the initial weight of the vehicle with all parcels, can identify cargo loads and if logistic managers are matching vehicles according to parcel size. *By type of good* dimension can influence analysis as some products require specialized transport, somehow affecting *By distance class* if specific routes are required.

As for granularities, the greatest geographical distinction is then made by the NUTS representation methodology, with GIS application providing more geometrical features. Mapping representations for local contextualization is the most flexible representation. NUTS methodology virtually separates the territory, from NUTS I which identifies countries, to NUTS III which recognizes municipalities. To contain specific areas that are not representative of cities, different coloured shapes can be applied on a GIS map. Temporal granularities consider variables per year or per annual quarter, but different ones can be set for more restricted temporal analysis.

Besides mapping, other visualization methods for statistical data can be employed. This choice is related to the measurement variable, but their selection influences spacial and temporal assessments. Linear regressions in last mile data translate temporal evolution, bar charts to order measurements, and pie-charts for proportions.



## Chapter 5

# Environmental logistics planning

Reports on implementation plans represent a rich data source, specially due to their standard format and approval by institutions with government support.

What data are used to place new sustainable logistics and where it may be collected will be assessed in this chapter by performing a benchmark analysis. With this assessment, is intended to acknowledge most feasible options to mitigate urban mobility and access issues. This assessment is suggested by Reis et al. [1], illustrated in the second phase of Sulp implementation plan in Figure 2.3.

To categorize last mile PDS interventions, a review of logistics areas is essential. SULPs fundamentals are identified by Plazier et al. [43]. Taking into account basic elements for planning and common limitations, there is the proposal of last mile implementations areas as in Figure 2.4.

Technology as its focuses on technological development, was compartmentalized into Land use, Vehicles design and fuel and Equipment and infrastructure. Engagement defends data sharing and stakeholder cooperation, while Legislation focus on mobility restrictions to ensure compliance. Strategic logistics are classified according to these fundamentals and the ones with most potential are further highlighted, including what data collection procedures can be conducted.

Last mile logistic changes are inevitable in PDS and in this chapter, different logistic areas are investigated, including legislation as means to ensure the prosperity of mentioned logistics. A formal project also involves stakeholders and definition of their roles, where cooperation is crucial for the plan to thrive.

### 5.1 Benchmarking analysis of intervention areas

Besides datasets, other sources (reports) with data collection procedures are considered for finding problems on urban mobility and accessibility.

Seabra [45] identifies a set of 10 SULPs in Portuguese soil, working towards less environmental and social impact from transport. These are available in respective governmental institutions and are presented in Table 5.1. SULPs are characterized, highlighting their data collection procedure as well as what mobility limitations are detected.

Table 5.1: Mobility plans across Portugal.

| Ref.  | Area         | Range       | Data source                                                        | What end?                                                     | Transportation problems                                     |
|-------|--------------|-------------|--------------------------------------------------------------------|---------------------------------------------------------------|-------------------------------------------------------------|
| [98]  | Porto        | District    | Traffic count from sensors                                         | Traffic volume in urban area                                  | Mismatch between delivery windows and stores' opening hours |
| [99]  | Evora        | District    | Surveys<br>10+ stakeholders meetings                               | PDS workers daily habits<br>Future perspectives               | Agglomeration of deliveries by intra-city roads             |
| [100] | Lisboa       | District    | Mobility Questionnaire<br>1011 Surveys                             | Urban mobility patterns<br>Demography and policies acceptance | Delivery parking clogging roads                             |
| [101] | Setúbal      | District    | Other implementation projects<br>Mobility Questionnaire            | Legislation and potential steps<br>Urban mobility patterns    | Heavy vehicle parking in urban areas                        |
| [102] | Viseu        | 14 counties | 5+ Stakeholders meetings                                           | Legislation and future perspectives                           | Delivery management tools                                   |
| [103] | Tâmega       | 6 counties  | Mobility Questionnaire<br>Local reports                            | Urban mobility patterns<br>Land-use                           | Emissions by intra-city transition                          |
| [104] | Faro e Loulé | 2 counties  | Mobility Questionnaire<br>Workshops/Meetings                       | Urban mobility patterns<br>Future perspectives                | Lack of parking offer                                       |
| [105] | Olhão        | 1 county    | Mobility Questionnaire                                             | Urban mobility patterns                                       | Inefficient configuration of roads                          |
| [106] | Matosinhos   | 1 county    | Traffic count from sensors and 584 Surveys<br>City-layout datasets | Traffic volume in urban area<br>Land-use                      | Congestion by heavy vehicles                                |
| [107] | Maia         | 1 county    | 1380 Surveys                                                       | Demography                                                    | Lack of legislation                                         |

Two cases counted traffic volume from sensors specifically placed in high traffic areas [98, 105]. Other three collect information by holding regular planning meetings to discuss objectives and outline tasks [99, 102, 104]. Surveys and interviews reappear in prominence, led by 40% of SULPs and with different purposes, such as local demography, acceptance of new plans' ideologies, and collection of existing policies. Identification of last mile issues can be done in sources besides statistical websites and their datasets. Busier areas or areas with logistical difficulties associated to congestion are already available in mobility reports or traffic counts belonging to specialized entities.

Land-use issues are the most detected. There is a greater frequency of parking issues and problems caused by difficulties in moving heavy vehicles in areas of difficult access. Only Sulp in Maia territory identified issues inherent to the lack of mobility restrictions.

Understanding the most common mobility impediments, Technology fundamental is divided into three intervention areas: (i) Equipment and Infrastructure, seeking automation in first/last mile parcel delivery, (ii) Land-use covers issues associated with intensive vehicle circulation and cities layout, having consequences on parking and intracity mobility as examples in Table 5.1 and (iii) Vehicles design and fuel because of their permanent role as source of polluting gases and particles, considering that freight management is not being environmentally maximized. These 3, including Cooperation/Engagement and Authority/Legislation fundamentals, define the five intervention areas considered in Figure 2.4.

It is worth noting that the focus of these projects is on more coastal and therefore urban areas. Only 30 % of mentioned SULPs target inland areas of mainland Portugal. This does not affect the area in which the plan focuses, with four of them taking into account an entire district. There is

equality of three cases that affect a single county in the district or multiple ones.

In Table 5.1, mobility plans on wider territory and types of transport, considering also public and private transportation were targeted for the Portuguese territory. SULPs and strategic logistics can either embrace larger territory and place multiple changes on urban mobility or focus in parcel delivery sector and add incisive last mile changes.

A collection of specific strategies from *Google* engine is presented in Table 5.1. Temporal and geographic context of logistics are assessed, as specific strategies to improve parcel delivery logistics are sought for any country. Data collection procedures are also identified, in addition to the information that it allows to extract and if mentioned, the number of sources considered. Each strategy is qualified according to fundamentals for SULPs implementation areas. Finally, the representations chosen for the analysis performed on the data collected are identified. Last mile interventions are not only portrayed in reports and the incidence in articles is compared. The different world wide logistics were evaluated according to the three main fundamentals from Figure 2.4, 12 of which documented in reports. Although 18 of them were collectively included in more than one intervention type, due to the bigger scope of Technology logistics area, it is the most frequent, not present in only six of the 40 cases. Just a slight superiority on Legislation over Engagement, as the first one is implemented in 13 cases and the other one in other 12.

Table 5.2: Last mile sustainable interventions.

| Information |                |             |           | Sources                           |                                            |        | SULPs Fundamentals |            |           | Data visualization |            |     |           |
|-------------|----------------|-------------|-----------|-----------------------------------|--------------------------------------------|--------|--------------------|------------|-----------|--------------------|------------|-----|-----------|
| Reference   | Article/Report | Country     | Years     | Type                              | Information                                | Sample | Cooperation        | Technology | Authority | Bar chart          | Regression | Map | Pie chart |
| [108]       | R              | China       | 2020      | Websites                          | E-commerce sales and EV features           | -      |                    | X          | X         | X                  | X          |     | X         |
| [109]       | A              | Cyprus      | 2018      | Survey and Interviews             | Stakeholders satisfaction                  | 296    | X                  | X          |           |                    |            |     |           |
| [110]       | A              | Italy       | 2019      | Survey and Interviews             | Benefits from parcel lockers best location | 330    | X                  | X          |           |                    |            |     |           |
| [111]       | A              | Vietnam     | 2020      | Survey                            | Ranking of eight psychological factors     | 485    |                    | X          | X         |                    |            |     | X         |
| [112]       | R              | Australia   | 2021      | Survey                            | Willingness to buy EV in near future       | -      |                    | X          | X         | X                  |            | X   |           |
| [113]       | A              | Brasil      | 2018      | Software tool                     | Multi criteria tool for localization       | -      |                    | X          |           | X                  |            | X   |           |
| [114]       | R              | USA         | 2002      | Software tool                     | Geographical local layout                  | -      |                    | X          | X         |                    |            | X   |           |
| [115]       | A              | China       | -         | Software tool                     | Hybrid heuristic algorithm                 | -      |                    | X          |           |                    |            |     |           |
| [116]       | A              | Japan       | 2022      | Software tool                     | Position technology                        | -      |                    | X          |           |                    |            |     | X         |
| [117]       | R              | Canada      | 2021      | Similar projects                  | Metrics for planning                       | -      |                    | X          | X         |                    |            |     |           |
| [44]        | R              | Several     | 2019      | Similar projects                  | Logistical areas with deficits             | -      | X                  | X          | X         |                    |            | X   |           |
| [118]       | A              | USA         | -         | Similar projects                  | Metrics for planning                       | -      |                    | X          |           |                    |            |     |           |
| [119]       | R              | Several     | 2020      | Similar projects                  | Comparison between examples                | -      | X                  | X          |           |                    | X          | X   |           |
| [120]       | A              | USA         | 1999      | Similar projects                  | Necessities according to size and weight   | 2      |                    | X          | X         | X                  |            | X   |           |
| [121]       | A              | Several     | -         | Similar projects                  | Use of IoT in similar projects             | -      | X                  | X          |           |                    | X          |     |           |
| [122]       | A              | Russia      | 2016      | Mathematical equations            | Battery endurance in cold conditions       | -      |                    | X          |           |                    |            | X   |           |
| [123]       | A              | USA         | 2019      | Mathematical equations            | Collision free paths                       | -      |                    | X          |           |                    |            |     |           |
| [124]       | A              | New Zealand | 2012      | Interviews(Workers)               | Logistics for sustainable PDS              | 14     | X                  |            |           |                    |            |     |           |
| [125]       | A              | Australia   | 2012      | Interviews(Workers)               | Stakeholder characterization               | -      | X                  |            |           |                    |            |     |           |
| [126]       | A              | Kenya       | 2021      | Interviews(Workers)               | Stakeholder integration status in Kenya    | 47     | X                  | X          |           |                    |            |     |           |
| [127]       | A              | Sweden      | 2017      | Interviews(Workers)               | Workers association to EV legislation      | 11     |                    | X          | X         |                    |            |     |           |
| [128]       | A              | Singapore   | 2019      | Interviews(Drivers)               | Temporal deficits in Singapore deliveries  | 30     | X                  |            |           |                    |            |     |           |
| [129]       | A              | Netherlands | 2019      | Documents                         | Parcel locker implementation features      | -      |                    | X          |           |                    | X          |     |           |
| [130]       | A              | Jordan      | 2022      | Documents                         | -                                          | -      |                    | X          |           |                    |            |     |           |
| [131]       | A              | Poland      | 2019      | Documents                         | -                                          | 91     |                    | X          |           |                    | X          |     |           |
| [132]       | A              | Iran        | 2016      | Documents                         | -                                          | -      |                    | X          |           |                    |            |     |           |
| [133]       | A              | China       | 2004-2020 | Documents                         | -                                          | -      |                    | X          | X         | X                  | X          |     |           |
| [134]       | A              | Canada      | 2019      | Documents                         | -                                          | -      |                    | X          | X         | X                  | X          |     |           |
| [135]       | A              | USA         | 2000      | Documents                         | -                                          | -      |                    | X          |           |                    |            |     |           |
| [136]       | R              | Netherlands | 2019      | Documents                         | -                                          | -      |                    |            | X         |                    |            |     |           |
| [137]       | R              | Several     | 2019      | Documents                         | -                                          | -      | X                  |            | X         | X                  |            |     | X         |
| [138]       | A              | UK          | 2011      | Documents                         | -                                          | -      |                    | X          |           |                    | X          | X   |           |
| [138]       | A              | Germany     | 2011      | Documents                         | -                                          | -      |                    | X          |           |                    | X          | X   |           |
| [139]       | R              | Several     | 2007      | Documents                         | -                                          | -      |                    | X          | X         | X                  | X          | X   |           |
| [139]       | R              | Several     | 2004      | Documents                         | -                                          | -      |                    | X          |           | X                  | X          | X   |           |
| [140]       | R              | Mexico, USA | 1999      | Documents                         | -                                          | -      |                    | X          |           |                    |            |     |           |
| [139]       | R              | Several     | 2001      | Documents                         | -                                          | -      | X                  |            |           | X                  | X          | X   |           |
| [141]       | A              | Germany     | -         | Deliveries dataset                | -                                          | 742457 | X                  | X          |           | X                  | X          |     |           |
| [142]       | A              | Australia   | 2017      | Datasets and statistical websites | Parcel locker accessibility                | -      |                    | X          |           | X                  |            | X   |           |
| [143]       | A              | USA         | 2018      | Census                            | Economical and life conditions             | 3000   |                    | X          |           |                    |            | X   |           |

Almost half (N=19) of the strategies from Table 5.1 were published in the last three years, equivalent to documents published in 2019 or later. A variety in sources is identified. The most popular one is the interviews, whose number of occurrences is specified in five cases out of the six in which they occur. Three cases use surveys for data collection, with one additionally setting interviews. In most proportion, there is the option for documents or reports of other similar strategies, in the search for scientifically proven information to offer more future viability. The number of sources used is also mentioned in the isolated case where delivery information is made available [141].

Although reports appear less frequently, these documents also portray graphics for identifying last mile obstacles. Not administered in Categorization of articles stage, pie charts are used to illustrate portions, associated to percentage measurements. The use of maps appears as the most recurrent, in 15 of the 40 examples for precise geographical illustrations. Bar charts and linear regressions for representation of numeric variables, without clear preference, as they are used in 12 and 13 interventions, respectively.

However, implementing SULPs involves transportation beyond parcel delivery. Public transport is also targeted and infrastructures placement for better movement of civilians. Both intend to achieve environmental sustainability, but for their smaller complexity, strategies from Table 5.1 are considered smaller parts from wider SULPs from Table 5.1. Relevant examples from this table are reviewed, seeking what typology of data is pursued to support implementations, sources to acquire that information and the identification of agents and cooperative roles.

### 5.1.1 Stakeholders engagement

Cooperation between interested parts is critical to successfully perform any mentioned implementation. Data sharing between public sectors and private logistics companies are essential for identifying issues and finding innovative solutions [144]. Modelling city logistics using the simulation and optimisation techniques based on the emerging technologies is essential to anticipate the effects of policy measures and benefits for each stakeholder to make proper decisions.

Logistic and delivery workers may benefit from uniting forces with other companies. Either by working together during deliveries or simply exchanging knowledge or networks, both parts will end up benefiting, despite most firms being unfamiliar with these approaches. Sharing capabilities and capacities, and co-loading, require sharing data with many private and public partners in the supply chain. Dablanc et al. [5] identifies many stakeholders through delivery cycle and what strategies are possible with different stakeholders cooperation are illustrated in Figure 5.1.

Four groups of stakeholders are identified: (i) parcel producers, (ii) freight transport managers and drivers, (iii) clients who purchased online and (iv) general citizens with external view of the chain. The more entities involved, more complex the plan becomes. However, if all agents work together, the range of changes is much greater [145, 146]. For each further logistic, each group should have roles assigned.

|                |                                            | Stakeholders         |                                        |           |          |                    |
|----------------|--------------------------------------------|----------------------|----------------------------------------|-----------|----------|--------------------|
|                |                                            | Producers & Shippers | Freight Transport & Logistic Operators | Receivers | Citizens | Other Stakeholders |
| To Inform      | Letters, Leaflet, Brochure, Newsletter     |                      |                                        |           |          |                    |
|                | Posters and notices                        |                      |                                        |           |          |                    |
|                | Reports & Fact Sheets                      |                      |                                        |           |          |                    |
|                | Web Pages                                  |                      |                                        |           |          |                    |
| To Consult     | Web 2.0 (social networks)                  |                      |                                        |           |          |                    |
|                | Surveys, including web and telephone based |                      |                                        |           |          |                    |
|                | Questionnaires                             |                      |                                        |           |          |                    |
|                | Interviews                                 |                      |                                        |           |          |                    |
| To Involve     | Smartphones or Web Applications            |                      |                                        |           |          |                    |
|                | Public Meetings                            |                      |                                        |           |          |                    |
|                | Information Sessions                       |                      |                                        |           |          |                    |
|                | Deliberative pooling                       |                      |                                        |           |          |                    |
| To Collaborate | Forums, including web based                |                      |                                        |           |          |                    |
|                | Seminars & Topical Events                  |                      |                                        |           |          |                    |
|                | Focus and Reference Group                  |                      |                                        |           |          |                    |
|                | Facilitated consensus building             |                      |                                        |           |          |                    |
| To Empower     | Workshops & Meetings                       |                      |                                        |           |          |                    |
|                | Freight Forum                              |                      |                                        |           |          |                    |
|                | Local Governance, Joint Planning           |                      |                                        |           |          |                    |
|                | Shared Projects, Capacity Building         |                      |                                        |           |          |                    |

Figure 5.1: Examples of cooperation between stakeholders [5].

These interested parts may be involved in the assessment of each logistic feasibility, as phase 2 of Sulp implementation in Figure 2.3 indicates. Either from surveys, interviews, meetings or any *To consult* engagement procedure from Figure 5.1, what is proposed is to collect feedback from stakeholders with different views on logistics, in order to choose the most appropriate to the urban and social context.

### 5.1.2 Last mile legislation

Legal impediments are common to most Sulp planning, but at the same time they can constitute a logistic. Before designing a new logistic, consulting restrictions related to existing ones, as phase 2 of Sulp implementation (Figure 2.3) also suggests, facilitates the perception of areas with greater legal possibility of renewal. Government websites vary by country, but European Commission website ([147]) and Euractiv journal ([148]) are universal for European territory. Taking Portuguese territory for instance, *IMT* is a renowned entity for transportation data and legislation.

Strategies implemented are divided into five intervention areas and each one requires prior analysis to associated restrictions. If there are no legal impediments, adding laws can be helpful. In order to be valid, Luppino et al. [149] defend that new legislation must make reference to four topics, which define if it is advantageous for PDS sector:

- Category of measure
- Territory in which is applicable
- Investment and costs
- Savings

Different classes for measures, considering further applications are defined: regulation, technology, infrastructure, service, industrial, urban planning and energy. Where measures took place is also demanded, which means that sometimes only a specific area is considered or a whole rural/urban area is analysed. Estimating implementation costs influence decision makers, as higher is the investment, less is the chance for it to be accepted. Savings show the potential benefits and can be measured monetarily, in time, energy or emissions.

There are cases where policies are used not to save, but to urge population to adopt some type of behaviour, as economic growth depends on compliance with restrictions [150]. Plazier et al. [43] tries to project future scenarios from the consolidation of different logistics and stakeholders, estimating which laws should be taken into account to better manage the market. An example of these scenarios is lead by Melton et al. [134], by implementing strategic restrictions to induce drivers' mindset to go for electric vehicles.

### 5.1.3 Land-use

Urban areas can be separated into virtual areas with limited emissions, according to their traffic. Examples and steps to follow, from what laws to the type of data needed, can be found in [119]. To successfully plan a zero emission zone (ZEZ), information on related transportation policies and fines are necessary, granting realistic and similar measures as other near emission zones. Clear view of their logistics and accessibility points for future monitoring need to be considered.

The introduction of low emission zones (LEZ) or zero emission zones, that differ as to whether or not fuel vehicles are fully prohibited, encourage parcel companies to invest in more zero emission vehicles. Although it may require much effort to regulate, penalties may be given to those who do not follow the standards or financial incentives to who cooperates, which acts as a guarantee for the cooperation of drivers. Both examples can be found in economic websites, but if legislation prohibit them, engagement plans are the alternative.

Across Europe, some areas have already been designed, either for LEZ or ZEZ [6]. They have been limiting circulation in Figure 5.3 areas, largely due to the constraints associated with non-compliance with logistics. While in some cities only a low emission zone was defined, others took the initiative to do so in other locations. Most of these places are considered urban, which implies a high value of vehicles and transit. The context and typology of vehicles in each region influence the choice of logistics managers regarding ZEZs location.

Table 5.3: Low emission zones across Europe [6]

| City       | Year      | Zones | Schedule                   | Restrictions on                                                      | Fines     |
|------------|-----------|-------|----------------------------|----------------------------------------------------------------------|-----------|
| Paris      | 2015/2017 | 4     | 08h to 20h                 | Vehicles without badge and vehicles with badge from class 5, 4       | 68-450 €  |
| Lisbon     | -         | 2     | 7h to 21h                  | Vehicle class: M1, M2, M3, N1, N2, N3; Fuel type: diesel, petrol     | 120 €     |
| Berlin     | 2008/2019 | 2     | -                          | Vehicle class: M1, M2, M3, N1, N2, N3; Vehicles without badge        | 20-80€    |
| Brussels   | 2018      | 1     | 24h per day                | Vehicle class: M, M2, M3, N1; Type of fuel: petrol, diesel, LPG, CNG | 350 €     |
| Vienna     | 2014      | 1     | 24h per day                | Vehicle class: N1, N2 and N3                                         | 90-2180€  |
| Barcelona  | 2018      | 1     | Week days from 7:00 to 20h | Vehicle class: L1-L7 ; Vehicles without badge.                       | 200-1800€ |
| Copenhagen | 2008      | 1     | 24h per day                | Vehicle class: M2, M3, N1, N2, N3                                    | 1 700 €   |
| Oxford     | 2019      | 1     | -                          | Vehicle class: M3; Fuel type: diesel                                 | 100-1000€ |

LEZs are implemented in cities of great national importance, some of them capitals as Lisbon, Paris and Berlin, due to their greater industrial activity. If the same cities are large enough, more than one zone can be implemented, which occurred in three of the cases. Among the examples, there is equality of three cases between those who completely restrict circulation (Brussels, Vienna and Copenhagen) and those who restrict themselves to daytime hours (Lisbon, Paris and Barcelona). Limitations may take effect in relation to the type of vehicle or fuel used and failure to comply them causes the imposition of significant fines.

Instead of virtual applications, investment in modern roadways and parking areas is already a priority in SULPs examples from Table 5.1, which may attract attention of regulators. Transportation infrastructure improvements increases last mile operations, resulting in increased road safety risk at local level. Fekpe [118] focuses on implementing lanes or entire roads for specific use of heavy vehicles. In addition to reducing congestion, it also has the advantage of minimizing more serious accidents between light and heavy vehicles. Therefore, a range of neutral locations where such would be beneficial is evidenced.

High density of traffic is one of the eligibility criteria. It is useful to use tools that allow the visualization of live traffic since it is unpredictable, often conditioned by unpredictable events such as traffic lights or road accidents. Sensors can be used for counting but in some navigation applications, this feature is free, while in others a monthly payment is required. The following ones are the most used, especially in Portugal:

- Google Maps
- Waze

These reflect the momentary state of the roads, needing constant updates. On the other hand, the detailed evaluation of the cities cartography makes it possible to assess their layout, which is becomes useful for choosing parking areas location. The same can be possible using a variety of sources, from applications such as *Google Maps*, to documents/reports/detailed maps from Municipal or Parish Councils.

#### 5.1.4 Vehicles design and fuel

Heavy vehicles provoked more GHG emissions and congestion in SULPs cases from Table 5.1 and Table 5.3 shows what type of vehicles are most prohibited in sustainable logistics. The uptake of EVs is a slowly process, despite the assistance by measures such as LEZ, but mostly because of their initial cost and availability. The long term economical advantages inherent to lower operational costs, less environmental and noise impact and no need for fuel consumption have been encouraged by the multiple agents involved in this process [119]:

- Freight transporters assess and communicate what they need from the grid at their depot
- Charge-point operators develop a business case
- Network and grid operators prepare the necessary grid capacity
- Land and building owners enable the installation process
- Municipalities and other public authorities convene stakeholders, adapt regulations and issue permits

The need for specific charging stations requires a specialized electrical planning [112] to determine the best location. After defining goals on future emissions and strategies to attract new users, a survey was initially launched to businesses and locals, to understand their view on vehicle costs, charging stations construction and implementation range. Palm et al. [127] approaches civilians but also public transport officials by conducting interviews, with the aim of clarifying the procurement process, electric vehicles (EV) related policies, the strategic role of public procurement, the requirements when procuring vehicles, the public procurement organisation, collaborations, barriers and drivers for developing an EV market.

Having in mind all barriers, costs on stamp duty were reduced as incentive, making them more affordable to regular drivers. Hesitations from some respondents on home charging costs influenced researchers to implement charging station in strategic places. To do so, cooperation with jurisdiction makers was permanently necessary, as well as guidelines for users on how to correctly and safely make use of these infrastructures and finally, local power supply analysis. Although EVs batteries last longer, maintenance on stations requires extra training to repairmen and costs.

Changes not on vehicles' fuel, but also on design and size have also been approached, as freight vehicles can be arranged depending on parcel size [151]. Using e-cargo bikes or other small vehicles, along with reducing size of vans and trucks, can be cost effective for smaller companies.

Although the mechanics are similar, the available EV choices are vast. That is why Melton et al. [134] define variables that may influence choice and suggests examples for particular needs. A five multi-criteria evaluation framework is applied for vehicles implementation planning, which can be converted into KPIs in any new Sulp rating:

- Effectiveness at increasing adoption in the long-term
- Government spending
- Public support
- Policy simplicity
- Ability to stimulate confidence and exterior investment

Having in mind these metrics, EV feasibility can be assessed with feedback collection from stakeholders. Human judgment also prevents other options, like drones. People are not used to see robots flying around cities and reports on drone crashes complicate its implementation.

### **5.1.5 Equipment and infrastructure**

Vehicles are not the only assets with performance improvement prospects. Parcels and freight management is still lacking behind in automation, due to the physical restraints of occupying large enough buildings. In fact, robotic sorting supports maximum efficiency, using less space compared with traditional sorting solutions. While many new delivery services come in fully automated, more traditional ones have to learn how to adapt their technologies, without increasing their prices or dropping their performance for the customer. Taniguchi [121] exposes different cases of infrastructural technological innovation. A review is also made of the exchange of data between entities and the extent to which both parties can benefit.

To successfully implement and manage automation in the parcel and logistics sector, organisations must deeply understand the entire delivery chain for their specific products. While realising what is mostly mechanic, as conveyors and sorting, focusing on technological solutions, such as robotics and driverless vehicles. Real time controls and portable components allow unit and parcel sorting to be easily controlled, stored and used separately or together in multiple spaces. Industry 4.0 is established world wide, but Demir & Cicibas [152] see a more flexible Industry 5.0 in the near future.

Internet of things (IoT) and Artificial intelligence (AI) can become part of companies by hiring second party ones specialized in this area or do it from scratch. It is a must for companies trying to innovate in technology. IoT is a multi-layer technology which is used to manage and automate the connected devices, bringing the physical objects online. New transport planning and scheduling systems can be developed using blockchain/ big data to optimize delivery routes. Real time traffic information can also assess availability of unloading/parking zones. The integration of data from across the supply chain could enable carriers to create a virtual model of the network, which could be used to compute and compare multiple scenarios in real time, enhancing decision-making about shipping options. Working successfully with great amount of data also means ensuring security to private data [153]. However, this changes are more appropriate for first mile interventions.

Automation and sustainability can also be developed by adding buildings that facilitate distribution, like consolidation centers or micro hubs. By collecting the goods destined for a certain

area and consolidating deliveries into one large delivery made by high-load vehicles, the number of delivery vehicles would be reduced, which leads to less congestion and better air quality. The setback with distribution centers is that much additional work is required to assemble these large sized deliveries, but once again, IoT and AI can counterbalance.

Smart lockers can be used to store goods until customers can pick them up. Multiple and simultaneous drop-offs are assured in a single delivery and the access codes provide safety and may be used as tracking system. To convince users, deduction on final price if this PDS is chosen from several offered. A not so typical infrastructure are micro-hubs, for the same purposes but typically with larger storing units, which incidence is compared to parcel lockers in Table 5.4, whose examples are extracted from [7]. That same space can be used to gather parcels from distinct routes. Huang et al. [115] reports a mixed routing strategy passing through micro-hubs from a single network.

Table 5.4: Parcel lockers/ Micro-hubs per country [7].

| Country     | Lockers/Hub | Year      | Storage units | Products |
|-------------|-------------|-----------|---------------|----------|
| Australia   | Lockers     | 2014      | 400           | Postal   |
| Belgium     | Lockers     | 2017      | 250           | Several  |
| China       | Lockers     | 2015,2017 | 400000        | Several  |
| Croatia     | Lockers     | 2020      | 301           | Postal   |
| Denmark     | Lockers     | 2019      | 1500          | Postal   |
| Finland     | Lockers     | 2018      | 4000          | Postal   |
| Germany     | Lockers     | 2001      | 7000          | Several  |
| Netherlands | Lockers     | 2014      | 122           | Postal   |
| Spain       | Lockers     | 2019      | 5000          | Postal   |
| Switzerland | Lockers     | 2019      | 162           | Postal   |
| UK          | Lockers     | 2006      | 4000          | Postal   |
| Poland      | Lockers     | 2019      | 225           | Postal   |

Lockers are also highlighted by the number of storage units that have. However, the use of this infrastructure has been directed towards items such as letters or parcels of very small dimensions. Multiple sized units can be built to retain different products.

But previous plan is required, specially to choose a location. There are differences if it intended to expand abroad or internally. In general, both will demand smart concepts from project developers and municipal governments for easily accessible city-center infrastructures.

In the same country, study regional market comes first. The number of online commerce deliveries will dictate if the investment would be worthy. If so, get to understand locals shopping behaviours and most wanted items gives insights on what selling strategies may be successful. In case it proves to be potentially advantageous, a concrete location can be decided on near logistics, like proximity to main roadways (or public transports). In foreign countries, extra care should be given to cultural aspects (language included), the type of payment and shipping costs.

## 5.2 Summary

Three fundamentals for last mile logistics are identified: (i) Technology, (ii) Cooperation/Engagement and (iii) Authority/Legislation, for setting logistics areas. Despite this distinction, Technology fundamental can also be robustly planned with engagement strategies and/ or restrictions.

Engaging agents is always recommended because the more people work towards the success of a new logistics, the greater the probability of success. It starts by collecting the point of view of others, which allows a better definition of environmental objectives, either interviews or surveys to shippers, couriers or retailers. These may concern vehicle usage and driver practices or to understand consumers shopping behaviours and acceptance on new PDS logistics.

To ensure strategies success, financial incentives can be set. If they have no success, restrictions are an alternative. The purpose turns out to be similar as both intend to ensure compliance with SULPs logistics. Whether for legislation inherent to SULPs or other cases of independent laws, sources that facilitate requirements for future restriction approval should be considered. In short, implementing laws where society engagement is lacking will provide better performances, evidenced during results monitoring phase from Sulp implementation process in Figure 2.3. The collection of existing laws must also be carried out in advance, so as not to interfere with other strategies and local restrictions.

Although five areas of implementation were identified, logistics planning have in common the need for a previous study of each regional context. To do it, the NUTS separation methodology allows those territorial assays for different dimension regions. Urban issues can be locally identified within information from last mile statistical data such as those mentioned in datasets from previous chapter, or mobility/access issues from reports.

For land-use purposes, geographic applications as GIS or local mapping facilitates the identification of points of interest to limit LEZs, as well as roads for heavy vehicle lanes or new parking areas. Locations in need of ZEzs or LEZs can be identified from websites in Table 4.1 with environmental data. Local traffic also influences that decision, accessible in mobility reports that may include counting from sensors.

The implementation of electric vehicles imply an analysis of electrical distribution if the same plan leads to the insertion of charging stations, as an incentive to attract new drivers. EV energy and battery consumption reports must be consulted in advance from respective producers. Feedback from workers must be considered as it will affect their working routines and to assess whether such investment is justified by the context of total dispatched deliveries.

New infrastructures for order collection or distribution are designed to reduce dislocations. This requires investment in route management tools as well as urban planning on best locations according to accessibility and industrial potential. Until then, industrial equipment is set on industry 4.0, but predictions of 5.0 impact and its focus on society and efficient use of goods suggest innovative changes. Sharing implementations and their effectiveness will be valuable.

## Chapter 6

# Conclusions and future work

In order to demonstrate variety in types of sources for data that, directly or indirectly, is related with last mile logistics operations impact on the environment, a three-stage methodology is considered: (i) Characterization of last mile data, (ii) Data categories and exploration of visualizations and (iii) Environmental logistics planning. This analysis was focused on the development of Sustainable Urban Logistic Plan (SULP).

Considering last mile data accessibility, restriction to certain research literature and firms internal data collection (surveys) is detected, including pollutants environmental impact. Therefore, other types of literature are also considered, as reports and statistics datasets, which integrated with geographical information, is considered an efficient data assessment. Legislators could implement combined data sharing policies between entities, enhancing wider last mile assessments.

In Characterization stage was conducted the state-of-art review of data collection within parcel delivery sector, whose analysis topics are result of thematic clustering of most used terms in those documents. Within the articles assessed, the majority concerns data from consumers. Nevertheless, companies are also targeted to assess what operations have the worst performance. To conduct these analysis, surveys and interviews are the data collection procedures most performed to gather insights from stakeholders. A small portion reinforces data collection by simultaneously conducting both procedures. However, these can take months while in a further chapter, briefer meetings were held during Portuguese SULPs planning.

Responses to surveys and interviews are rarely accessibly, as only audience demographics and/or data collection motivation or procedure are the information most shared. From the 48 articles, less than half makes reference to data collected rather than final analytical results, which, in most cases, come from computational tools for statistics or others that show indices for each simulation scenario (hypothesis research procedure).

Within Visualization stage, websites oriented to statistical analysis and spatial representation were explored. Data from government related institutions is used to understand the main analytical drivers and facilitate the identification of PDS limitations. *Open access* government websites provide last mile data, which can complement other assays, as in articles reviewed in previous stages, dispatched quantities and emissions are not always quantified. These two features are

regularly measured in tonnes in datasets, which is an example why data from different types of sources should be integrated.

Visual representations of data allow better interpretations. Linear regressions in last mile data translate temporal evolution, bar charts to order measurements and pie-charts for proportions. Despite the variety of representations, there is consensus on annual or quarterly granularities within them. For territorial separation, the NUTS limit systems are the most consensual in *Eurostat*. Nevertheless, GIS software provides greater geometric limitation of territory. The use of dynamic tables is, as *Eurostat* exhibits, a methodology transversal to graphical and spatial illustrations.

Dimension of analysis concern the product or freight vehicles. They can trigger emissions analysis based on types of transport companies and the environmental impact of their services and products managed. These could also be placed according to stages of delivery chain as only the overall value of pollutant gases per location in tonnes is statistically measured.

In environmental planning stage, possibilities for mobility and environmental issues mitigation are detailed, as well as what information is inherently considered. Facilities like distribution centers and parcel lockers, fuel environmental efficiency and emissions standards for heavy freight vehicles and parking policies. Land use investments stimulate or restrict circulation in certain zones. Also, ensure the best choice on vehicle size and capacity according to dispatched quantities. Most have in common the necessity to study in detail each region's land-use and local mobility patterns, analysis facilitated with geographical information and technology as sensors.

Mapping is related to electrical distribution assessment for EVs charging stations and identification of entry points for LEZs and ZEZs, as well as viable locations for heavy vehicle lanes. Assessing the best location for intermediate infrastructures also leads to analysis of territorial accessibility. Besides these, spatial assessments should consider local last mile statistics, as datasets or mobility reports, which reveal regions in need of environmental intervention.

For future work, new research queries can be set and consider all e-commerce sub-industries. As shown in the state-of-art review, last mile data analysis depends on the research procedure. In state-of-art review, when stated, grocery products emerged in many articles obtained from a keywords query. On the contrary, introductory review in the first chapter was based on articles with environmental data extraction and postal delivery services were most common. This complements dimension of analysis utility according to product and services provided.

Pursuing similar assays on other websites can help identify other units of measurement and variables per data types, dimensions of analysis and geographical representations, starting with the online pages previously identified for e-commerce/ transportation data. Sources with Transport and Environment data categories are advisable for finding transportation services and environmental pollution related data. Nevertheless, other three data types help contextualize industrial sectors where customer satisfaction is key and their participation can engage innovative PDS.

Besides statistical data, as mentioned, surveys constitute an efficient source for companies operational data analysis. In advance, a considerable sample of last mile operational data from PDS should be identified, in order to determine which metrics will be assessed. These may reveal other variables and granularities that investigators value in last mile assessments.

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