Sustainable Urban Logistics

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Sustainable Urban Logistics

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Jesus Gonzalez-Feliu

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Preface

Nowadays, urban logistics is a topical subject. This is evidenced by the large quantity of articles (both scientific and specialized press), events, as well as the various actions at play to support training and mentoring (there are four training and research Chairs[1] in France, two VREF centers of excellence and an international platform, the Urban Freight Platform, which together advance this subject, assembling more than 300 researchers and practitioners for this subject). Nevertheless, the subject remains difficult to address due to a lack of a consensus on the proposed definitions and methods, and by continuation, those components which make it so rich: the wide diversity of stakeholders and the multidisciplinarity of available methods and techniques.

The subject of urban logistics is not new: it was already a consideration for the leaders of ancient Rome (as shown by several of the writings of Julius Caesar, but also during the early Empire), and has continued to evolve throughout history, both in terms of governance and organization. Many of the actions that are nowadays considered "innovative", such as off-hour deliveries, inland river transport or urban consolidation centers (UCCs), were already deployed and operating throughout several historical eras. The same can be said for aspects pertaining to the governance and regulation of urban logistics: under Imperial Rome, public action was strong and was responsible for the procurement planning of major cities; in the

1 The FRELON Chair in Paris, the LUGM Chair and the HORREA young researchers' initiative in Lyon and the La Poste Chair in Marseille.

Middle Ages and into the Renaissance, this public planning gave rise to the guilds and assemblies of merchants and craftsmen; it was not until the 20th century that regulation and public policy by public authorities became predominant.

The subject of urban goods transport was only addressed by researchers in the 1970s, where for the first time a focus was made on the last mile transportation of commercial and/or industrial activities, which extended incrementally to other economic activities [WAT 75, SON 85, OGD 92, ERI 97]. However, the approach that identifies urban logistics to last kilometer delivery continues to be the most common [WOU 01], but it is not the only one. The uptake of the term *city logistics* occurred in the 1990s [RUS 94, KOH 97] and was later popularized by Taniguchi *et al.* [TAN 01] through an approach that was very much focused on private actors. In France, the national program "Marchandises en Ville" (for the transportation of goods within cities) also studied this question, but in the context of public stakeholder's regulation capabilities[2]. Nevertheless, some of those works have demonstrated an interest in considering urban logistics as a set of flows greater than those of the last kilometer, and in particular the flows for the transportation of goods at the place of consumption and those linked to the management of the city [SÉG 04].

It is only recently, despite longstanding opposition, that several authors have begun to develop a viewpoint of urban logistics which not only considers the relationships between different stakeholders (already emphasized in the 2000s by [BOU 02, GER 05]), but also considers them in an equal manner, i.e. outside of a system of classification that favors one over the others [ALL 10, GON 14i].

In addition to these different perspectives, the flows involved, and the relation between the different stakeholders involved, are the added challenges of quantification, qualification, planning and the evaluation of urban logistics through a unified methodology, as well as the challenge of communicating unification. Indeed, since the works completed on urban logistics are so varied in nature, they do not give the impression of having

2 Moreover, much of the work arising from this program advocates for an organizing "freight" public body, equipped with policing powers at the local level, and by consequence, an increased decision-making capacity for these stakeholders.

successfully reproduced standards as it occurs in other sectors of transport and logistics. This statement appeared to be evolving, at the very least up until the end of 2016, when at the third VREF Conference on Urban Freight that was held in Gothenburg (Sweden), showed that signs of the early development of unification are in fact beginning to take place.

Within this complexity we can observe that, on the one hand, France has fostered enormous efforts in providing knowledge on urban logistics, as is reflected by the great many works on this theme, which on the other hand, have a tendency to only cater for the French context, occasionally forgetting that some “good ideas” have already been put into practice under different contexts. Nevertheless, the internationalization of “French” urban logistics as well as its “globalization” has been accelerated in recent years which is a situation that has favored the homogenization of certain practices. It is also important to note that some French innovations, such as pickup points, are today a global reality (for example, UPS, who bought Kiala, have been deployed outside of France with great success).

It is evident that within the urban context, where space is less and less easy to find, and congestion, pollution and noise are commonplace, urban logistics needs to become more sustainable. This takes an important dimension considering that logistics is both a factor of economic development as well as a nuisance [CRA 08]. However, if the notion of urban logistics is not perceived in the same way by the various stakeholders involved, how can the notion of sustainable practices be assimilated in both a consensual and unified manner? This unification, which is difficult, but at the same time necessary, has been a constant theme in my work, and seems to me a critical point on which very little has been discussed, but nonetheless needs to be formalized.

My first contact with the field of urban logistics was through the construction industry (as part of the framework of my training as a civil engineer and urban planner). Although, my interest turned to airports after that. The focus of my first research contributions to urban logistics were in development from 2005 to 2008, during the realization of my doctoral thesis at the Politecnico of Turin (Italy) that also included a stay of approximately six months in Montreal (Canada). Since this PhD was in computer and systems science, my methodology for addressing the topic was very much quantitative. Following on a brief position with an engineering consultancy, I embarked on a career with the Laboratory of Transport Economics in Lyon for approximately six years, where I was able to approach and understand the French vision of urban logistics and at the same time expand my own theoretical and methodical approach with a more applied viewpoint which combined statistical approaches with qualitative analyzes. It is from this context that the collective work behind my viewpoint of sustainable urban logistics comes, and upon which the work I seek to present here, not without difficulties, has been designed [GON 14i]. In 2014, I became assistant professor at the École des Mines of Saint-Étienne, switching discipline yet again and returning to the Engineering Sciences, wherein I initiated regular collaborations with institutions across Latin America (Colombia, Ecuador, Mexico and Peru), and which led me to discover other contexts, opportunities, as well as other innovations, in some cases yet unknown in Europe. To honor my six years in the human and social sciences, as well as ten years of research in urban logistics, my dissertation for Habilitation to supervise research (a French degree necessary to supervise PhD students) focused on supervising research in the field of Economic Sciences at the University of Paris-Est in 2016 [GON 16a]. Despite this multidisciplinary background, the two resulting documents (undoubtedly very academic) as well as several courses addressed mainly to a "research" audience, nevertheless succeeded in arousing the interest of many strategic professionals. With this as my motive I set about formulating my own vision, which would include a set of methods and techniques, to assist the planning and assessment of sustainable urban logistics as well as demonstrate that although a unified approach exists, it cannot be brought about through the waving of a "magic wand" (that I personally do not believe in), but rather through a methodological framework and set of methods, techniques, indicators and practices that allow for the easy comparison of different experiences, which can in turn be evaluated by a simple decision-making tool that is both systematic and efficient.

Nevertheless, it is not my wish that this book imposes that specific vision, or that it be used to advocate an "absolute truth"; on the contrary, it is written in the spirit of openness and a desire to share a common vision for urban logistics established with the experiences, disciplines and even the many different contexts, which can (and should) coexist in synergy.

This book draws on over ten years of personal research on the topic, together with my experiences with several teams wherein I contributed to many different projects. It intends to promote a unified approach (which is gaining popularity and is used at an international level) for the planning of sustainable urban logistics. It begins by presenting an overview on urban logistics, starting with its history, the main research contributions that occurred in France and abroad, and how this research has been applied and put into practice (Chapter 1). It then goes on to the description and definition of the main components of sustainable urban logistics (Chapter 2): flows, stakeholders, relations to sustainability, visions of urban logistics and key components (infrastructure, management issues, technology, regulation mechanisms and financing elements). A unified vision of those elements as well as a definition of sustainable urban logistics is proposed, in the most extensive vision of urban logistics (in terms of flow, stakeholders and issues considered).

Next, the book presents the basics for planning and managing sustainable urban logistics. Chapter 3 introduces the foundations of the general assessment approach, based on before–after analyses. Although this approach is traditionally used for evaluating pilots and experiences, this book proposes to systematize both the evaluation of physical systems and the assessment of scenarios. To achieve those types of analyses, two sets of methods are necessary: flow estimation frameworks and assessment indicators calculation methods. This book presents the dominant approaches for the estimation of flow within this broader approach. Chapter 4 focuses on inter-establishment flows, while Chapter 5 focuses on the other two categories (end-consumer and urban management flows). These methods are illustrated using several examples. The section on the estimation of flows concludes with a presentation of the approaches for estimating change and solution probleming - two complementary approaches that are at the center of the unified framework introduced in this book.

With regard to evaluation and assessment, this book first presents a framework for choosing sustainable indicators and dashboards (Chapter 7). Chapter 8 follows this up with the leading methods for evaluating the economic, environmental, social and accessibility aspects of the considered urban logistics system. These are accompanied by tables and figures necessary for a real-world application.

This book aims to be a practical guide for the implementation of key methods that are the result of much scientific research, and presents examples of real-world applications explained both quantitatively and qualitatively. It seeks to synthesize and present the principle methods of the unified approach to assist decision-makers in the execution, planning and management of urban logistics and the transportation of goods within the city context, not from a perspective of obligation, but rather towards consensus of an aperture, that is as much interdisciplinary as it is international.

Jesus GONZALEZ-FELIU
December 2017

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Where Are We After 20 Years of Urban Logistics?

1.1. Introduction

The issues regarding the organization of logistics and freight transport in urban areas are not new: the first written document that deals with the regulation for the transport of goods within a city is attributed to Julius Caesar in the 1st Century BC [QUA 08]. In fact, the *Lex Iuliana Municipalis* (municipal edict) that regulated urban deliveries by establishing night-time delivery schedules in the city of Rome is the oldest example of a law written in the interest of urban stakeholders to solve the nuisances that goods deliveries commonly cause, even in antiquity.

Even though other older civilizations were also interested in the supply of cities (the Greeks, the Phoenicians and the Persians were known to have major commercial activities and cities closely linked to the trade of goods, [GAR 89, TEP 11]), it is ancient Rome, and in particular the Roman Empire, which has provided the oldest and most significant written examples of urban logistics[1]. So much so that the *Lex Iuliana Municipalis* remains as the exclusive record for night-time deliveries in ancient times. The Roman Empire subsequently developed real skills in the organization of supplies for the imperial capital. Indeed, under the rule of Augustus, in the 1st Century AD, an exemplary position was created: the prefect of Annone (*Praefectus*

1 Archeological analyses and discoveries of objects and buildings for the pursuit of logistics show the importance of logistics in Phoenician, Egyptian and Greek cities before the Roman Empire, however, the first written legal texts date from the time of Julius Caesar, with the next one at the time of Augustus [PAV 76, GON 16].

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Annonae). Although a similar role had existed centuries before, its function was of limited duration and only in cases of extreme drought or famine (*Tite-Live*, Jacques Heugron edition [HEU 70]). This prefect had the vital mission of supplying the city of Rome and managing food stocks, first to alleviate problems pertaining to famine and malnutrition, and second to oversee the proper functioning of the city. In the 1st Century BC, Julius Caesar created the station of *ediles cerealis*, an office responsible for the supply and management of the grain and cereal stocks of Rome. Augustus, between 8 and 14 AD, reformed this function by bestowing it to an equestrian knight and permanently establishing the Annone prefecture [PET 74], whose primary charge was over grain and cereal supply, which was then extended to include wine and gradually expanded to oversee other foodstuffs. This prefect had both a logistics and spatial planning role [PAV 76], when he decided on, or at least suggested, the construction of the *Horrea* grain warehouses, grouped in zones according to activity (such as those found in current urban logistics zones), where the planning and management for the supply for grain distribution areas coexisted with the purely operational functions of buying and managing arrivals, stocks, and their distribution to markets and key families [VIR 11, MIM 14]. These *Horreas* have also been the subject of numerous studies [VIR 87, ARC 11, MIM 14], as well as those affairs between the port of Ostia and the city of Rome, and the transport of food items from the seaport to the distribution warehouses [VIR 15]. This function was also extended to other important cities such as Alexandria [BOW 05], but not to Constantinople, where the municipal organization did not provide for a specialized prefecture to govern over the city's supply network [PAV 76]. This example is the first documented case of the public management of urban logistics [CHA 60, PAV 76, RIC 80, VIR 95, VIR 00, VIR 07, VIR 11, MIM 14], and yet it still remains relatively unknown to both experts and practitioners[2].

With the decline of the Roman Empire and the changing of the capital (from Rome to Constantinople), the public functions associated with the cities in the western part of the Empire gradually lost more and more power[3].

2 Retrospectives on urban logistics do not generally go beyond the second half of the 20th Century. Libeskind [LIB 15] is, in our opinion, one of the first to have attempted the difficult task of retracing the history of urban logistics; although this book was developed in a French context, antiquity is included all the same. Nevertheless, it relates interesting and little known facts of logistics in the cities throughout the course of history.

3 The most thorough study on the subject presents the Annone prefectures as having significant functions until the end of the 4th Century [PAV 76].

In the Middle Ages, a completely different organization took over. Nevertheless, the supply of cities remained structured [BRI 95]: instead of centralized management, an oligarchic structure, sustained by the guilds of traders and craftsmen of large cities and by the feudal lords in smaller ones, made it possible to ensure the supply and nutrition of populated centers [DES 09]. We also begin to observe the rise of inter-urban logistical organization within Muslim kingdoms (North Africa and the Iberian Peninsula), which allowed cities to both supply and develop the production and trade of goods between those kingdoms [BOO 90, KID 05], and which followed the logic of a “system” or logistical cluster (a concept taken up centuries later, [CED 06, CAP 15]). Nevertheless, actions in the interest of the public, primarily for the development of wharves, the construction or restoration of canals and roads, were necessary for the growth and development of commerce within the city, and as a result, the need for logistics. One of the most illustrative examples is that of the supply of goods for Paris, which were mainly conveyed by river, and whose facilities required supervised enhancement in order to increase both their capacities and efficiencies [NOI 11].

From the Middle Ages up until the 20th Century, the supply of cities was predominantly driven by private stakeholders, first by the guilds and later on by other forms of associations and groups. Procurements made by commercial stakeholders and the associated infrastructure were limited (before the beginning of the 20th Century, the main access routes to cities were via river channels, after which came the railway, Libeskind, [LIB 15]. Major innovations (linked to the increase in the range of products that will not be dealt with here) were achieved through technical advancements (mainly in terms of the vehicles and means of transport) or in terms of infrastructure: improvement of the river courses, the return of urban warehouses during the Renaissance and the Restoration or the invention of the steam engine which stimulated, among other things, rail transport.

The logistics underpinning the supply of Paris oversaw various phases for the development of its waterways [LIB 16]: canals were built in the 17th Century to connect the Loire and the Seine, thereby improving communications between the Atlantic ports and the French capital. In addition, food warehouses were created and developed so as to facilitate long distance (river) and urban (road) transport. The 19th Century saw the rise of rail transportation and the progressive development of urban trams (the first were horse drawn, later upgraded to coal locomotors, and over the course of the 20th Century, replaced with electric locomotors). Although these trams were mainly dedicated to the transport of people, we find many examples where goods were transported by rail (and in some cases tramway) in several European cities [LIB 14].

With urban expansion in the 1950s and the large-scale construction of roads, coupled with a boom in the automotive sector (and subsequently in commercial road vehicles), a new era of urban logistics arrived on the scene: driven by quasi-exclusive private stakeholders who were responding to the market. Indeed, two related phenomena promoted the development of transport and logistics stakeholders: the first is the strong priority given to the transportation of people in the construction and planning of cities, which did not account for the transportation of goods since at that time city planners were not well aware of this sector; the second was access to commercial vehicles, a result of the industrialization of their production, which allowed companies of all sizes to specialize in freight and transport logistics. For those reasons, logistics in cities were left to private stakeholders [CRA 08] and held little interest for public stakeholders [CER 98] who introduced few tangible initiatives, the urban section being considered as the last kilometer of a longer, more organized transport system as a whole [AMB 85]. An emblematic example is the Sogaris-Garonor road freight terminal [DAB 96], which operated in the Paris region between 1967 and 1969 as a true urban consolidation center (the scope of this freight terminal was the Paris and Ile-de-France region, and the services offered were of the same nature as those offered by urban consolidation centers that were to be developed later in the 1990s and 2000s). This consolidation platform evolved into a multi-purpose logistics platform (and later on, the domain of urban logistics) responding to the ever-changing needs of a purely liberal and competitive market.

The 1970s were characterized by the beginnings of scientific works on urban freight transport and the introduction of goods transport in retailing and industrial zones [WAT 75]. Although cities are still developed and organized with the priority of personal mobility, economic activities remain of vital importance to the success of urban areas. An increase in the urban population indirectly leads to an increase in the flows of goods for the supply of cities. This is reflected in the United States and Japan where roads and parking facilities in the retail and industrial areas of some cities are extremely overcrowded, accounting for the rise in scientists and practitioners who began to address the quantification and qualification of goods transport within urban areas [DEM 74, WAT 75, MAE 79], predominantly in the context of North America. Those works correspond more to the needs of private stakeholders (industrialists, traders, transport companies, etc.) than to those of public stakeholders. Those works being pioneered by the United States [OGD 92, HOL 12] remained largely unknown in France. This is partly due to the fact that in France at that time, priority was given to the urban transport of people. It was only later in the 1990s that public authorities began to really take an interest in the transportation of goods [AMB 99a].

In Europe, the first actions in terms of the promotion of urban logistics instigated by public authorities were to combat the rise in congestion that worsened throughout the 1980s. However, public awareness for the need to act in a coordinated way so as to alleviate inconveniences and mitigate problems originating from urban freight transport and urban logistics shortfalls only became widespread in the 1990s. Indeed, the first actions by public authorities in the 1980s were regulatory and temporary in nature, mainly in the form of access regulations or parking restrictions that were implemented locally by the municipality and without much coordination or a desire for unification at the regional or national level [DAB 98, GON 08, MAG 07, SPI 08].

It was only in the 1990s that major concepts supporting urban logistics were developed and the notion of urban freight transport was approached by various countries somewhat differently, but which nevertheless had many parallels [COS 98, ECM 99] with Germany, France, the Netherlands, the United Kingdom and Switzerland being the more active of the European countries. Several authors state that the concept of urban logistics used today on an international scale can be derived from its German namesake *city-logistik*, according to Thoma [THO 94], often further citing the works of Ruske [RUS 94] and Kohler [KOH 97] as pioneers in the field. Nevertheless, in addition to the report by Thoma [THO 94], there is a previous record for the use of the term “city logistics”: that of McKinnon [MCK 91], who used it during a seminar dedicated to urban logistics. However, it was only at the International City Logistics Conference, through Eiichi Taniguchi, that this term became popular, and where at the same time, one of the three predominant definitions was presented as well [TAN 01].

Furthermore, coordinated actions (initiated by public and/or private stakeholders) were being amplified in Europe, mainly in Germany, France, Italy, the Netherlands, the United Kingdom and Switzerland [ROS 05]. However, the involvement of public stakeholders was not homogeneous throughout Europe. Indeed, while in France, the national awareness allowed for the development of the national program "Marchandises en Ville" (Goods in the City), which started in 1993 [DUF 99, GON 12g], Germany and the United Kingdom adopted a completely different path: one where urban logistic actions in those countries were primarily carried out by private stakeholders, with little or no financial support from public stakeholders, and where regulations regarding urban freight transport remain neutral [GON 08]. The Netherlands, on the other hand, adopted a hybrid path, where a strong initiative from private stakeholders is being regulated and administered by local and regional public stakeholders to reward and encourage good practices [COS 98]. Other countries, such as Spain and Italy only became aware of the necessity and challenges regarding urban logistics in the early 2000s. Northern countries adopted a similar logic to that of Germany and the United Kingdom at the end of the 2000s. Central and eastern European countries began to focus on urban logistics issues in the mid-2000s, although some experiments took place in the past [BES 09]. Outside Europe, the rationale remains similar to that of the 1970s, however, new problems of optimization, relating mainly to the localization and organization of routes, are beginning to appear, in addition to a growing demand for the estimation of urban logistics, as previously mentioned.

The 2000s was the most active era for urban logistics, both in terms of research and practice into communities (we will examine this in greater detail later on). Nevertheless, it was not until very recently (the first observations of unification by the scientific community are presumed to have taken place in 2016) that we began to observe heterogeneity in the research and practice of urban logistics, which have for a long time made it difficult to produce methods, as well as approaches. That has made it possible to tackle the questions of urban logistics in a unified and homogeneous way, thereby opening them up for comparison.

We will next present a summary of those research and practical actions, by no means an exhaustive list, but nevertheless useful for a general overview of urban logistics, not only in France but also internationally. We thus first present an overview of the main research topics worldwide, making particular mention of those being extended by French research. Then, we propose an overview of significant urban logistic actions and practices according to the classification proposed by Ville *et al*. [VIL 13]. Finally, at the end of the chapter, a discussion will take place on the difficulties, concerning the apprehension and categorization of urban logistics.

1.2. The valorization of research in urban logistics: French and international approaches

Urban logistics has been a subject of interest for researchers for several decades. In France, the need for a better knowledge and understanding of urban logistics together with a strong scientific and political resolve culminated in the emergence of the "Marchandises en Ville" national program in 1993 [DUF 99]. At the same time, the topic was also being embraced by other scientific communities in different European countries, mainly Germany [RUS 94, THO 94, KOH 97], the Netherlands [COS 99] and the United Kingdom [MCK 91]. Nevertheless, the challenges facing the supply of goods for economic activities within the context of the city were already a popular topic in the United States as far back as the 1970s [WAT 75].

Internationally, urban logistics (or urban freight transport) up until the mid-1990s was considered to be a specific subject in the domain of transport engineering and continued to develop within a small community. It is important to note, however, that works charged with estimating the urban flows for the transportation of goods have existed since the 1970s [DEM 74, MAE 79, SON 85, ERI 97]. Following on from a series of communications insisting specifically on a growing need for freight transport planning, the specialized urban logistics research community finally saw the day in 1999 of the first international conference on City Logistics, organized and held in Cairns, Australia.

Indeed, during its first year, the conference hosted less than 20 presentations[4]. Since then, however, most notably in 2003 (the third conference which was held in Madeira, Portugal), City Logistics has grown to include more than 100 participants from many different countries and

4 These statements were given at the ILS 2016 conference in Bordeaux by Jesus Muñuzuri, Professor at the University of Seville, and Ron van Duin, Professor at the Delft Technical University, both of them having participated in the First International conference on City Logistics.

across many disciplines. Other conferences followed, such as the I-NUF (organized in 2005 by the Metrans Center in Long Beach, California, with a predominantly national scope that has since, as of 2013, become international), although it remains firmly anchored around a vision of urban logistics for cities in the United States. A series of conferences and seminars by the European NECTAR research network were also organized in the late 2000s and early 2010s [MAC 11], but have now transitioned towards a broader conception of the topic: sustainable logistics [MAC 14]. In 2013, the Volvo Research and Education Foundation (VREF) launched two centers of excellence in the field, in addition to organizing their first conference in 2012, followed by a second in 2014, with the latest one having taken place in 2016 (the first conference was by invitation only, while the second and third conferences were open to both academics and practitioners and always held in Gothenburg, Sweden).

Other conferences (CTUA – Commercial Transport in Urban Areas held in Berlin in 2012; the International Workshop on Urban Freight Modeling held in Rome in 2012; URBE – Urban Freight Behavior held in Rome in 2016), as well as group sessions on various urban logistics themes held at prestigious international conferences (TRB Annual Meeting, WCTR, ILS, etc.) have also contributed to the international exchange between researchers.

In France, a conference on urban logistics has been organized in Nantes annually since 2011, becoming an international event in 2015. It remains one of the more representative reference events for Francophone research in this field. The pioneering conference led by the French community in urban logistics, however, remains the Jacques Cartier symposium on urban goods transport, first held in Montreal in 2000 [PAT 01], which, while presenting a broad overview and international speakers, was primarily addressed to a Franco–Quebec audience. To that can be added the many one-day workshops of recent research, under the auspices of the national "Marchandises en Ville" program or PREDIT (the French "program for research and innovation on land transport"), the FRELON chair ("freight and urban logistics") at the Ecole des Mines de Paris, as well as the extensive research being done at the various academic institutions and universities. These reflection days are aimed at a diverse public made up of both researchers and practitioners. Urban logistics also plays a major role in French-language conferences such as the CIGI ("international industrial engineering conference"), the RIRL ("international logistics research meeting") and the MTL ("mobility, transport and logistics"), events that are typically academic in character.

In addition, of course, there are the many scientific publications on the subject, a testimony to both the popularity of the subject and its growing need as perceived by the scientific communities. On the contrary, this has resulted in greater heterogeneity and a general lack of unification among the works being put forward. Moreover, significant differences between the publication and diffusion channels for urban logistics research in France and the rest of world are obvious: in France, the research tool for urban logistics research has traditionally been the research report, and to a lesser extent technical notes, mainly related to the role of the PREDIT program and its modes of research justification; overseas, however, although reports are often used (at the European or North American level) to give an account of the results of collaborative projects, they are more often than not accompanied by numerous academic publications, preferably in peer-reviewed scientific journals. While in some countries and disciplines, publications in the national language are prioritized[5], the global trend is to publish in English.

More specifically, the results of an online search using the Google Scholar engine give out 668 French urban logistics documents, made up of 80 peer-reviewed journal articles, 9 monograph books and 2 collaborative books as well as 15 doctoral theses. The rest of the documents include book chapters (the identification of which is difficult and time-consuming given the small number of books on urban logistics), articles in specialized non peer-reviewed journals (mainly "*Transports*", "*TEC*" and "*Transports Urbains*"), as well as reports, notes and research papers. On the contrary, it would take far too long to analyze in detail the equivalent English Google Scholar results (3,900 documents contain the expression "urban logistics" with a further 7,550 for "city logistics"). Nevertheless, a search in the Thompson and Reuters Web of Science database (an international reference site for academic research on peer-reviewed journals) links 735 articles[6], about half of which are in the engineering sciences, and a quarter are associated with economics and management sciences, with the other quarter made up by social sciences, such as planning or regional and urban sciences.

5 This is the case for France and Italy, notably in humanities and social sciences, as well as in Germany, China and Latin America, not only in the humanities and social sciences but also in engineering sciences, among others.

6 Articles containing the terms "city logistics", "urban logistics", "urban goods" or "urban freight".

To this bibliographic research, we can add the main collaborative works in urban logistics [MAC 11, GON 14, TAN 15], and the proceedings of the nine international “City Logistics” conferences, the five I-NUF conferences and the last two VREF conferences. With the view of establishing a foundation upon which to examine the dominant research topics taking place in urban logistics, the main recurring themes at international conferences and English-speaking, peer-reviewed journals can be grouped into seven broad categories:

– demand estimation: international demand-based works are centered either on identifying determinants in the interest of systematizing freight transport demand generation [HOL 11, SAN 16b] or on the theoretical aspects of modeling, which give very few operational models. However, some of them [SON 85, DEL 89, ERI 96, JAN 05, MUÑ 09, COM 13] are used in spite of being rather unknown in France;

– supply estimation and transport optimization: those approaches are mainly derived from operational research and the optimization of vehicle routes [TAN 99, TAN 12, CRA 08, CRA 09, CAT 17];

– regulation, public policy and key stakeholders: the main works concern the regulation of access to cities [DAB 08, VIL 13] and the possibility of action by public authorities [HES 04, LIN 10, LIN 13];

– logistics planning, spatial planning and the spatial dynamics of urban logistics [AND 05, DAB 10, DAB 12, DAB 15];

– experiments and pilots, case studies and best practices [ROS 05, SPI 08, BES 09, DAB 11b, ALL 12a, ALL 14b];

– data collection issues [HUN 06, ALL 12b, ALH 15];

– evaluation of sustainable urban logistics [TAN 00, VAN 08, VAN 10, PAT 10, MEL 11, VAG 11, MAC 14].

On the other hand, the French perspective focuses predominantly on the following themes:

– quantitative surveys and demand modeling, with a strong research orientation based on the FRETURB model [PAT 99, AUB 99, AMB 10, ROU 10];

– characterization of urban logistic spaces [BOU 13, BOU 15, GUY 15];

– qualification of e-commerce practices, home deliveries and other forms of urban commerce and distribution [ALL 07, BAR 13, DUC 13, BEL 13];

– operational research and decision-making support [HUA 11, GIA 15, GON 15, GUY 15];

– regulation and public policies [DAB 98, DAB 10];

– aspects of organization and stakeholders [CHA 12, CAP 15];

– spatial aspects and planning logistics [DAB 10, DAB 11b, HEI 17];

– monitoring and evaluation of the urban logistics experiences [GÉR 07, HEN 08].

From those non-exhaustive overviews, we can deduce that, although most French research topics find their place in international communities, we nevertheless observe several differences between the French visions and approaches and those of international communities. The first is the approach of "pairs", i.e. the positioning of research and studies in relation to that of other members of the community. Most French works have historically been positioned in relation to the French context and research taking place in France. In fact, most of the work carried out by the national "Marchandises en Ville" program is derived from projects financed by PREDIT (French national research program on inland transport), ANR (French national agency of research) or ADEME (French agency of energy and environment), and naturally their results have taken the form of research reports and books largely written in French. The notes and articles on the research and its popularization have also always been written in French. Those articles mainly cite Francophone sources and compare French experiments with one another or, in some studies, with close neighbors, such as Belgium or Switzerland. This is the case of the Urban Logistics Spaces (ULS) studies for example, which present a typology and a comparison that is only based on France (excluding overseas territories) [BOU 06]. In Italy, similar studies are made using comparisons, but from an international standpoint [ROS 05, SPI 08, MAG 07]. In addition, scientific articles in English offer international comparisons [WHI 99, BRO 05, ALL 12b]. The same observations can be made for the works on e-commerce [DUR 09, DUR 10, BEL 13], works on regulation and stakeholders [CAP 11, DAB 11a, GÉR 07], and those regarding practical experiments and their evaluation [GÉR 07, HEN 08, GÉR 15]. Still, we observe some French works that can be seen to have been generated from an international perspective [DAB 96, AUG 08, AUG 09]. Only the community working on decision-making support (Decision Sciences) has a distinctly international positioning, with publications systematically released in English [HUA 10, GUY 12, GON 12c], and whose works are seen by the rest of the French urban logistics community as more theoretical than applied [GON 12b]. In summary, the dominant vision of urban logistics research in France is often limited in terms of scope and activities taking place in the French context, with several actions sometimes going in a different direction to that of the international context.

Let us take, for example, the case of the works based on demand modeling[7], which in France, follow a logic wherein the model must be closely linked to the data source used to generate it. Furthermore, this source, if possible, should be constructed with the clear goal of a determined model [AMB 10]. By this logic, the model first determines the data requirements and then determines the resources that must be used to collect this data, with a set margin through which adjustments are made possible. We find four main modelling approaches: the IRT ("Institut de Recherches sur les Transports", 1977[8] [INS 77], "transportation research institute") who model the flows of goods entering cities, the FRETURB model [AUB 99] and the CERTU method for the sizing of delivery spaces (that includes a simplified estimate of demand in terms of the number of vehicles), CERTU, [CER 13], taken from both city freight surveys [AMB 10] and descriptive models built from shipping surveys [GUI 09, GUE 14]. These static and systematic approaches have an immediate operational focus, while in international communities, the aspects put forward are more theoretical and conceptual in nature. Moreover, the two main visions for urban freight transport modeling in international communities are to make the best of the data available, often with small quantities and/or granularity [MUÑ 09, SAN 14], or to collect data based on available resources and then apply the best available model [HOL 14]. According to those two rationales, the model

7 One of the main research topics of the author, as we will see in Chapter 5, is demand modeling. In this field of research, contributions to FRETURB modeling [GON 14f] have highlighted the gap between the French vision and what has subsequently been, if not the international standard, the dominant vision [HOL 11, GON 17]. For that reason, it seems pertinent to illustrate the general vision of this book through this example of the divergence between the French vision and international standards.

8 That work remains not often quoted; however, in our opinion, it is the first real attempt to model urban logistics in France, and as such deserves to be taken into consideration.

is adapted to the available resources and the needs defined after, implying a path that is inherently opposite to classical French modeling.

Moreover, research objectives are not always similar, even when subjects coincide. In addition to the modeling work presented in the preceding section, French work on e-commerce is mainly aimed at qualifying practices [PAT 04, AUG 08, DUR 09, DUR 10, DUR 10, BEL 13, AYA 14] while at the international level, the main objectives are optimization [NEM 04], categorization (quantitative and/or qualitative) of e-commerce customers [ROH 04] or quantitative characterization of practices [GEV 11].

Qualitative work on experiments and pilots, even those with different perspectives and scopes of vision, offer comparisons between methods and analyses that are easier to compare. Furthermore, work on public policy and regulation – which in general remains closely linked to each country, even to each city, through the context and specificities of the regulations in question – also seem comparable by nature. Finally, work on decision-making support, which as previously stated follows the standards set by international journals, appears to already be well-positioned in relation to other countries, and yet generally remains theoretical or computational, with little application (already the case as early as the 1970s, as pointed out by [ACK 79]).

Even within each category, where we may come across a like-minded community with the same objectives and discourses, the work is still extremely varied and we observe little unification. Qualitative studies do not always provide enough detail on their methodologies and information sources in a homogeneous way, which in turn makes comparison difficult. Assessments are made for specific cases, and despite attempts at unification, there is currently no methodological reference by which to evaluate sustainable urban logistics, as is the case for other fields (e.g. global supply chain and logistics management). In other words, we observe a large body of work with very little unification. Operations research works remains poorly applied and varied, with the standard based on the types of models used, on the way results are produced, presented and discussed, and on the highly computational and conceptual aspects of the approaches under which they fall. The different types of modeling frameworks also illustrate the difficulty of converging towards a standardized model, as the standards for urban transport of people or long-distance freight transport cannot be transposed into the context of urban logistics, or in any case do not give satisfactory results [GEN 13].

It is only in the field of regulation and public policy that comparable and international works have been proposed [DAB 08, LIN 13], since these are inspired by comparable works, even if they are made over different kinds of applications. The unification of methodologies and analytical frameworks thus appears to have been made as a sub-theme of law and/or political sciences, with derivatives into urban logistics being seen more as an applied field.

However, if in France the research on urban logistics seems to have taken a different position that is from the outset somewhat France-orientated, what is it in practice? Hence we propose to look, in a synthetic and non-exhaustive but nonetheless general way (taking into account the main activities and key projects), at how research has influenced practice, not only in France, but also throughout the world.

1.3. From research to practice: a plethora of projects, initiatives and their practical application

As just described, the valorizations of scientific research activities being undertaken in urban logistics are different in nature, and can be grouped coherently through a set of subjects. To this must be added the various research activities which result from collaborations between the scientific and practical communities, notably those taking place around collaborative projects. Without listing all the projects and actions (this list would be extremely long and, to the best of our knowledge, without a more or less exhaustive and objective systematic syntheses of research projects in France or Europe, it would be difficult to get a complete overview that appreciated the detailed analyses of the works resulting from these projects, and besides this it is not the purpose of this book), we will nevertheless attempt a non-exhaustive overview, which shall take into account the most significant or most-quoted achievements in the literature, not only in terms of science but also those that are more technical and practical in nature.

Actions connected to research projects are rare before the 1990s, or even the 2000s. In the United States, a series of works, promoted by the TRB (Transportation Research Board) in the 1970s and 1980s ([DEM 74, WAT 75], among others) was particularly interested in the knowledge and modeling of city freight and heavy goods traffic flows [HOL 12], mainly motivated by the congestion that goods transport induced in terms of city access and the car parks of large commercial areas. Parallel needs, pertaining though to issues of congestion and parking in historic city centers, can be identified in several European cities, which resulted in instructions to research institutes for the development of models for forecasting freight transport flows, mainly in France [INS 77], Germany [SON 85], Italy [CRO 06], Sweden [ERI 97] and Norway [MIN 96], among others.

However, the first major transnational achievements for urban logistics were the European Cooperation in Science and Technology (COST) project number 321, which was developed between 1994 and 1998 and included 12 participatory countries (Denmark, Finland, Germany, France, Greece, Italy, the Netherlands, Slovenia, Spain, Sweden, Switzerland and the United Kingdom). The purpose of that operation was to synthesize and unify the various actions being undertaken on a viewpoint of urban logistics, first to identify the national logical frameworks, and then to give a European reference framework [COS 98]. That collaborative action produced a large number of documents (more than 50 documents, comprised of reports, technical documents and summaries of meetings, the vast majority of which had an English version in addition to the original version that was recorded in the respective national language[9]). Yet, those documents are not available online, although the final report [COS 98], published by the European Commission, has recently been uploaded free of charge. That document, which is perhaps the first real effort to unify urban logistics, is unfortunately hardly known and cited (an in-depth search of Google Scholar reveals less than 10 citations of the document; disappointingly, the document is referenced in different ways, which in turn raises the difficulty of finding all the works that make reference to it). Nevertheless, it constitutes a fundamental basis for understanding the beginnings of urban logistics in Europe [GON 08] and merits a thorough reading by those wishing to have a solid comprehension of the topic.

Another pioneering project is that of ELCIDIS (Electric Vehicle City Distribution Systems), which, within the framework of the European Commission's Energy program, grouped six cities (Erlangen, La Rochelle, Milan, Rotterdam, Stavanger and Stockholm), according to the growth of their

9 According to the list of documents provided by COST 321 [COS 99], only four reports have no English version: two are for a technical work on flow modeling in Düsseldorf, but the main results and conclusions are reported in the summary which has an English version; the other two are French works, which are the only national works not to have been translated into English.

electric and hybrid vehicle industry. The aim of that project was to experiment with electric vehicle urban delivery solutions, in particular those that enabled the development of the La Rochelle Urban Consolidation Centre[10] (UCC), one of the oldest and most cited examples of urban logistics in France [GON 13d]. In addition to the UCC, the use of light electric commercial vehicles was tested in both Rotterdam and Stockholm, while electric and hybrid vehicles were used for mail distribution in the remaining three cities. Although somewhat more quoted than the COST 321, that work is also poorly cited in the scientific literature (less than 20 quotes, according to a Google Scholar search, openly refer to documents in the ELCIDIS project).

From the year 2000 onwards, and following the COST action, the European Union has really become aware of the urban dimension of freight logistics and the need for action. That is reflected in the rise in calls for projects specific to the urban distribution of goods. According to Russo and Comi [RUS 04b], it is through the Fifth Framework Program (1998–2002) that the European Union outlined its priorities for European Union research in the field of urban freight transport. The Competitive and Sustainable Growth subprogram has brought many projects into being, including[11]: BESTUFS[12] (Best Urban Freight Solutions), CUPID[13] (Coordinating Urban Pricing Integrated Demonstrations), EUTPII[14] (Thematic Network on Freight Transfer Points and Terminals), MOST (Mobility management strategies for the next decades), PROGRESS (Pricing regimes for integrated sustainable mobility), OSSA (Open framework for Simulation of transport Strategies and Assessment, 2000–2003) and REVEAL (Remote Measurement of Vehicle Emissions At Low cost). Those projects were the first to propose assessments, pilots and evaluations on the concrete actions being taken on urban logistics, even if these were only under projects

10 This multi-term is referred to as an Urban Consolidation Center (UCC), an Urban Distribution Center (UDC) or a City Distribution Center (CDC). We use here the first declination of the term (i.e. UCC).

11 That synthesis is not exhaustive; the projects proposed here are examples. An exhaustive synthesis would require a specific study and a detailed bibliographic analysis for which resources should be mobilized and remains complementary, but outside the objectives of this book.

12 See: www.bestufs.net. A summary of the project and its main challenges was put forward by Zunder and Ibáñez [ZUN 04].

13 See: www.ttr-ltd.com/Project-Archive/Transport-Pricing-CUPID/.

14 See: www.uirr.com/fr/projects/completed/item/9.html.

with broader themes such as urban mobility or electric vehicles. Only BESTUFS, a project specific to urban logistics, focused on the identification of good practices and was the first to launch momentum on that subject (we could also think of it as the basis for the growth of trend projects based on good practices, as we will see in the following section).

The Sixth and Seventh Framework Programs continued along this logic with two priorities: the identification of good practices in terms of urban logistics and the continuation of experiments and evaluations. Of the CORDIS[15] information system's database, 35 projects from those framework programs (i.e. FP6 and FP7) deal directly with urban freight transport, 10 of which are exclusive to urban logistics (other projects, urban logistics as a sub-part of freight transport in the broadest sense, rail and freight transport, urban mobility or spatial planning). Of those projects exclusive to urban logistics, two were from FP6 with the other eight coming under FP7. The prime examples of projects under these two framework programs are: BESTUFS II (the BESTUFS sequel, which took place between 2004 and 2009, for which a summary of both projects was produced in 2009[16]) and FIDEUS (Freight Innovative Delivery in European Urban Space) for FP6, and BESTFACT (Best Practice Factory for Freight Transport[17]), CITY MOVE (City Multi-role Optimized Vehicle), CITYLOG (Sustainability and Efficiency of City Logistics), DELIVER (Design of Electric Light Vans for Environment-impact Reduction), FREVUE (Validating freight electric vehicles in urban Europe), FURBOT (Freight Urban Robotic Vehicle), MODUM[18] (Models for Optimizing Dynamic Urban Mobility), OPTICITIES (Optimise Citizen Mobility and Freight Management in Urban Environments), SMARTFREIGHT (Smart freight transport in urban areas), SMARTFUSION (Smart Urban Freight Solutions), SPIDER PLUS (Sustainable Plan for Integrated Development through the European Rail Network – Projecting Logistics & Mobility for Urban Spatial Design Evolution), STRAIGHTSOL (Strategies and measures for smarter urban freight solutions) and TURBLOG_WW

15 See: cordis.europa.eu/.This is a web page listing all the European projects and their various updates. The site does not have all the deliverables, but presents an overview of the research funded by the European Union.
16 All BESTUFS I and II project documentation is available at: www.bestufs.net.
17 See: www.bestfact.net.
18 Not to be confused with the ANR MODUM French project, which we will also discuss in this chapter. For MODUM (FP7) project: modum-project.eu/.

(Transferability of urban logistic concepts and practices from a world-wide perspective) for FP7.

The last framework program, Horizon 2020, was built around expert groups that define the priorities of the calls for projects and saw a move towards more technical projects. The six exclusively dedicated projects below can be identified:

– GALENA (Galileo-based solutions for urban freight transport), aims to offer technical solutions to assist urban deliveries by using Galileo satellites (the European equivalent of GPS);

– NOVELOG (New cooperative business models and guidance for sustainable city logistics), based on the proposal of cooperative services for urban logistics;

– PORTIS (Port-cities: Integrating Sustainability), which studies the role of ports and their logistics in terms of the development and sustainability of cities;

– SUCCESS (Sustainable Urban Consolidation Centers for Construction), which aims to unify the concept of the UCC in terms of the construction sector;

– CITYLAB (City Logistics in Living Laboratories);

– PROSFET (Promoting Sustainable Freight Transport in Urban Contexts: Policy and Decision-making Approaches).

The last two projects reflect the objectives for experimentation and the identification of good practices. We also note that there are more proposals for services and land use planning, and fewer for good practice or more traditional projects.

In the year 2000, the European Commission launched the CIVITAS (City-Vitality-Sustainability) initiative, which supports cities through bold and innovative measures to radically improve urban transport. The program took place in four stages:

– CIVITAS I (2002–2006) involved 19 European cities that cooperated under four projects: VIVALDI, TELLUS, TREND SETTER and DES MIRACLES;

– CIVITAS II (2005–2009) involved 17 European cities that cooperated under four projects: SUCCESS[19], CARAVEL, MOBILIS and SMILE;

– CIVITAS PLUS (2008–2012) involved 25 cities that cooperated under five projects: MIMOSA, ELAN, ARCHIMEDES, RENAISSANCE and MODERN;

– the fourth component, CIVITAS[20], in collaboration with Horizon 2020, consists of two projects that include urban logistics: CIVITAS ECCENTRIC (Innovative solutions for sustainable mobility of people in suburban city districts and emission free freight logistics in urban centers) and CIVITAS SATELLITE (Support Action Towards Evaluation, Learning, Local Innovation, Transfer and Excellence).

In all cases, the CIVITAS projects are the result of urban networks on subjects broader than just urban logistics, but nevertheless have enabled the comparison of practices and experimentation of several urban logistic actions.

Urban logistics has also held an important position ever since the third year of the INTERREG program [FRO 04]. The INTERREG III program was a community initiative of the European Regional Development Fund (ERDF) created to facilitate cooperation between regions of the European Union over the 2000 to 2006 period. It encouraged transnational cooperation, building on the interaction between national, regional and local authorities and a wide range of non-governmental organizations. The objective was to achieve a sustainable, harmonious and balanced development of the community with better territorial integration. Important urban transport projects were launched, including: CITYPORTS and MEROPE. The SUGAR project, for its part, was launched under the framework of the INTERREG IV program, in 2007, for a period of four years. The objective of that project was to study good practices in urban logistics as promoted by local and regional authorities. A guide to helping public decision-making has been produced [DAB 11], however, issues of transferability plagued the project at an early stage; in any case, that contribution remains one of the first to address the issues of transposition and transferability of urban logistics practices.

19 Not to be confused with the H2020 SUCCESS project on urban distribution centers for the construction industry. The CIVITAS SUCCESS (Smaller Urban Communities in CIVITAS for Environmentally Sustainable Solutions) project grouped three cities (La Rochelle, Preston and Ploiesti) around the challenges of urban mobility (people and goods) for medium-sized cities. See: www.civitas.eu/content/success.

20 See: www.civitas.eu.

In France, research on urban logistics has been structured around the national "Marchandises en Ville" program (a summary of which can be found in [GON 16d], and about which we will not go into detail here, but instead limit ourselves to stating its main objectives and organization). The program was created in 1993 and was managed up until 2013 by the DRI (*Direction de la Recherche et de l'Innovation*), the DGITM (ministry departments in charge of infrastructure and/or sustainable development according to its denominations over the years, *Direction Générale des Infrastructures Terrestres et de la Mer*) and the ADEME (*Agence De l'Environnement et de la Maitrise de l'Energie*). The objectives of the program were originally to organize, support and finance the research of freight transport in cities in order to create a knowledge base and to support public authorities in their decision-making. The first wave of quantitative surveys took place in the cities of Bordeaux, Dijon and Marseille [AMB 96, AMB 99a, AMB 99b, AMB 10], and supported by a set of books on the diagnosis and the support of public decision-makers as well as the logistics of urban spaces [CER 98, DAB 98, BOU 02, PAT 02, BOU 06], among others). In fact, given that the program is created around local authorities and the challenges they face [DUF 99, FRI 98], the work is mainly oriented towards the public and institutional decision-making sphere.

Urban logistics was then one of the main fields of application for the French "research and innovation program for land transport" (PREDIT). Urban logistics falls into two fields of study, which are often considered separately [ROU 13]: on the one hand is urban personal transport that has historically been linked to the mobility of people, and on the other is freight transport logistics, often considered at the intercity, international and/or intercontinental scale. In addition, the French vision for urban logistics developed in a context of strong support (but in a way, also biased) for public administrations [GON 16d]. For that reason, urban logistics has no specific section in the PREDIT program, but nonetheless appears explicitly in three of the steering groups: urban mobility, freight and transport logistics (GO4 of PREDIT 4), and decision-making support for public authorities. A summary of PREDIT's work on urban logistics can be found in [ROU 13], not on an administrative (i.e. program-related) or chronological basis, but on the basis of the following three criteria:

– their sphere of operation, according to the three leverage actions to achieve sustainability, as identified in [GON 12d], i.e. the technological, organizational and regulatory aspects of urban logistics;

– the scale of their implementation, i.e. their scope, which may be global (the size of the urban area or an agglomeration thereof, are the minimum scales considered to be representative of an urban system), local (neighborhoods, downtown or a dedicated site such as a shopping mall or activity area) or specific (linked to a particular niche or link in the chain);

– their level of utility, i.e. the position within a general situation for the development of an operational solution, starting with the estimate, through to the operational implementation of a technical, technological or organizational solution.

In addition, other sources of funding, such as the national research agency (up until 2013 under its Sustainable Cities and Buildings program, and its generic call for projects ever since), ADEME and PUCA (*Plan Urbanisme Construction Architecture*), among others, were interested in urban logistics.

Several projects labeled by PREDIT (whether financed by this program or by others) are mostly involved in the overall supply chain, with a section dedicated to urban logistics. The FIDES (*Flexibilité et Impacts de la Demande de transport des différents secteurs Economiques, et simulation de Scénarios d'Evolution*) project is studying levers with which to control the flexibility of transport demand, with its third component, from a prospective standpoint, highlighting the importance of sustainable e-commerce (with the development of logistical organizations that reduce the number of home deliveries near the place of consumption) and logistical pooling. On this subject, two neighboring projects have been developed: LMD (*Logistique Mutualisée Durable*), which is oriented towards collaborative distribution strategies, notably the shared VMI (vendor's management inventory), between producers and retailers, and LUMD (*Logistique Urbaine Mutualisée Durable*), linked to the control of the urban delivery of non-food products. In both cases, specific freight exchanges are recommended and analyzed. The ECLUSE (*Etude des Changements en Logistique Urbaine dans la région de Saint-Etienne*), PLUME (*Plates-formes en centre-ville pour la Logistique Urbaine*: study on Marseille), MODUM, SILOGUES and ANNONA (decision-making tool for the development of sustainable urban logistic schemes) projects are concerned with the development of decision support tools in terms of the evaluation of urban logistics scenarios, and also an attempt at unification has been envisaged, although that unification is still in the preliminary stages. The MILODIE project made it possible to study the impact of information sharing in and on e-commerce organizations, the behavior of online buyers and the reception of ordered goods. Other projects deal with logistics organizations (Signature, FUSION CO2, VLD, Epilog, Open Freight), but do not take a direct look at the problems specific to urban logistics. Regulatory aspects and policies on land use, planning, public space management and transport (people and goods) communities. A study on regulation in terms of access to cities was carried out by the firm Interface Transports. In addition, these issues are addressed in several projects funded or supported by PREDIT, such as EVAL (methodology for the evaluation of innovations in urban logistics), FIDES, ALF (*Aires de Livraison du Futur*) or MODUM (for more details on French projects and the unifying role of PREDIT, see [ROU 13]). Although this overview nevertheless remains non-exhaustive, it shows the difficulty of unifying and completing an exhaustive inventory of the applied research that has taken place in urban logistics in France.

To that is added a plethora of experiments and activities, not always financed by collaborative research projects, not only in France but also in Europe and throughout the world. A preliminary non-exhaustive overview was made by Gonzalez-Feliu [GON 08]. We propose to extend this to include an overview of worldwide urban logistical practices (again, non-exhaustive, but which includes the main works and key actions happening in this field). The examples shown in the following section far from constitute an exhaustive inventory (in terms of limited space, but also because of the difficulty and resources required to carry out an exhaustive inventory, the examples presented here are certainly representative of the different countries listed, but nonetheless are only a sample of the vast plethora of urban logistic operations in the world). They nevertheless show the diversity and complexity of urban logistics activities in the world and the difficulty of understanding the different needs and phenomena of urban logistics in an organized and unified way.

1.3.1. *France*

The activities taking place in urban logistics in France have classically been closely linked to the national "Marchandises en Ville" program, at least up until 2013[21]. According to Dufour and Patier [DUF 99], this program was initially implemented in two phases. The first phase was devoted mainly to the acquisition of knowledge (both quantitative and qualitative) on urban freight transport and had specific funding, with the program being strongly integrated into PREDIT 2 at its launch in 1996 [ROU 13]. The second phase began effectively in the 2000s [BOU 02] with the objective of developing and analyzing the various French experiments taking place in the field, while continuing the development of knowledge and methods. It received support from the ministry of transport through PREDIT 3 and 4 [ROU 13]. In addition to these actions, bi-monthly meetings in the form of a technical committee, tasked with an important mission of monitoring, were held up until spring 2012, when the last meeting took place[22]. A final meeting of a subgroup of the technical committee for the national "Marchandises en Ville" program (aimed at establishing a scientific committee) was held in 2013[23] with the objective of re-launching the program, and a further meeting was held in late November 2016, by a new scientific committee. Nevertheless, little information has been released and no official announcement has been made.

In the meantime, the main French cities (Bordeaux, Lille, Lyon, Marseille and Paris, among others) have managed to continue without the need for or support of the program and seem to be autonomous in their approaches and developments. Moreover, during the reorganization of the program, many urban logistic skills began to appear within public authorities, particularly

21 The program was active from 1993 to 2013 [GON 16], with the last meetings taking place in 2012. Although a DRI boost was launched towards the end of 2016, communication about this new program, which appears under construction, is poor. Moreover, due to the multiplicity of stakeholders currently working in urban logistics, both in research and practice, in both the public and private sector, it seems difficult to re-center everything around the program without creating biases or imbalances, particularly after almost 4 years of absence, and uncertainty about its real continuity and international positioning, all the while its ability to mobilize funding in the current period of severe budgetary constraints persists. This view is, of course, personal and is not presented as a truth, but as an anxiety, that eagerly awaits more information on the future of this program.

22 The author participated in meetings as part of the Technical Committee for the national "Marchandises en Ville" program from 2009 to 2012.

23 The author participated in the meeting, which had fewer than 10 participants.

those located in large and medium-sized cities (with a network of city planning freight referrals (or commodity advisers), launched by Diana Diziain in 2014, who was at the time a commodity adviser in the Greater Lyon area, which currently includes some 20 referents, including those from the above-mentioned cities and also including those coming from smaller cities such as Grenoble and Saint-Etienne). CEREMA (an entity created in 2014 to bring together several departments of the Ministry of Sustainable Development around mobility and spatial planning) also has several functions related to urban logistics, both in terms of their territorial technical centers (former CETE) and as part of their central services (former CERTU and SETRA), which have proposed several technical documents on the issue. The DGITM and the DRI also have, among other things, functions related to freight transport that deal with urban logistics. For example, the unification criteria for the establishment of charters or the collection of data. Nevertheless, the various attempts at unification are only concerned with those within the French territory and take little account of international actions and standards. Nevertheless, that institutional importance has given rise to an obligation to include freight flows in urban transport plans [CER 98], a definition of the various urban logistics spaces[24] [BOU 14], the FRETURB software (a detailed description of the model in its global vision can be read in [GON 14f]) and to numerous methodological documents and technical guides on the topic (generally published by CERTU and then CEREMA[25]).

To this can be added the numerous pilots, trials and actions, notably the Paris Charter for Sustainable Urban Logistics, which as of 2013 has served as a guide for the coordination of the various urban logistics actions occurring in the capital city; the concerted actions being made in Greater Lyon, various pilots like the *Vert Chez Vous*, *Distripolis* and *Tram Fret* projects; as well as urban freight train operational systems such as that of Samada-Monoprix [DEL 12], the inland *Franprix* waterway delivery [LEN 14, GON 14g]; or the UCCs of La Rochelle or

24 Nevertheless, attempts at alternative definitions and misuse of the ULS (Urban Logistics Space), which is often confused with LDP (Local Delivery Point), have recently been observed.

25 See: www.territoires-ville.cerema.fr/transports-de-marchandises-en-ville-r207.html.

Lyon [TRE 12, GON 13f], the latter having been stopped at the end of 2016[26] due to incidents and difficulties in achieving economic profitability despite having a good initial capacity to capture part of the demand [GON 13f].

1.3.2. *Italy*

Unlike France, Italy did not have a ministry-linked national body to promote urban logistics. Nevertheless, it is one of the countries with the most active urban consolidation centers, along with the United Kingdom [GON 13d, GON 14b]. This can be linked to the role played by the City Logistics Italia association which operated between 2004 and 2009 and promoted urban logistics practices, especially among private stakeholders[27] [GON 08]. Moreover, the strong autonomy of the Italian regions meant that it was never the state which regulated and stimulated urban logistics [MAG 07, SPI 08]. Nevertheless, urban logistic actions were spread unevenly across the regions. Two regions were the first to promote and regulate good practices in urban logistics: Emilia-Romagna (notably in collaboration with the municipal urban logistics plan of Bologna, and the UCCs of Modena and Parma, a van-sharing system in Reggio Emilia, as well as regional regulations, the setting up of a system for financing municipalities to carry out urban logistic actions[28], and the development of urban logistics as a priority theme for the regional Institute of Transport and Logistics) and Veneto (notably the UCCs of Padua, Vicenza and Venice, in addition to regional regulations). Three other regions followed: Piedmont (with the rise of Turin, mainly in recent years), Lombardy (with the UCCs of Como and Milan and several regulatory actions and delivery support in Bergamo and Milan) and Tuscany (notably with the UCC of Lucca). Other experiments, such as the Genoa UCC and ticket system that

26 Remarks made by several people from the company's direction in various technical meetings conducted in December 2016 and January 2017.

27 The author participated in several meetings and exchanges with key players of the association between 2005 and 2007, during the realization of his doctoral thesis. The association, created in 2004, played an active role in promoting good urban logistics practices in Italy until 2009, the last time it carried out official activities.

28 That region has proposed its first "air quality program agreement" for different zones, and for each of them, specific funds have been set up to finance urban logistics projects on cities of more than 50,000 inhabitants.

aimed to limit the movement of heavy goods vehicles (both terminated), the Naples freight train (also terminated) or the Frosinone UCC, also took place. Furthermore, Italy has also relied heavily on European projects, Turin, Rome and Emilia-Romagna being the most active territories in that regard.

City logistics Italia, at its second congress held in Rome in 2006, also determined that separate measures do not constitute a sustainable and competitive urban logistics system, stressing that certain measures already adopted by Italian cities are only provisional and will not lead to long-term planning without the integration of other measures. Those measures can be organized into four groups [GON 08]:

– regulatory policies, which can be restrictive or incentivized;

– information and communication tools;

– contributions in infrastructure, technology or civil engineering;

– partnerships between public and private enterprises.

The association also organized, twice, a trade show dedicated to urban logistics. Unfortunately, this was discontinued due to a lack of funding. Following on this, the institute of transport and logistics (Emilia-Romagna region) carried out numerous actions for the unification and valorization of urban logistics planning. These included a wave of surveys on freight transport into the city [ROS 05], as well as a model for the diagnosis of this transport, called City Goods [GEN 13], in the image of the French surveys and inspired by the FRETURB software; City Goods proved to be both popular and useful in Italy. In 2012, collaboration between PTV and the creators of City Goods was initiated to investigate the possibilities for internationalizing the model and integrating it into the VISUM[29] software. The Piedmont region, the municipality of Turin and the agency for the mobility of the Turin metropolitan, also played an important role in Italian urban logistics. Surveys were carried out in Turin (in 1995) and Cuneo (in 1997) to quantify the movement of goods and parking practices in urban businesses[30], mainly in the city center, and a large local project

29 Remarks by Guido Gentile in a telephone conversation conducted in May 2013.

30 The author had access to the 1995 Cuneo surveys, as well as two Politecnico Turin studies on the Cuneo and Turin surveys, which were not referenced at the request of the university, during his doctorate; however, later on, when he wished to use this data in his thesis, no official documents could be found online.

(URBELOG[31]) took place between 2013 and 2016 to identify the main technologies needed to assist logistical operations in areas with limited traffic (Areas Limited to Traffic or ALT).

Moreover, those ALTs, areas wherein access is regulated by different permits depending on the type of transport (people and/or goods) and the characteristics of the vehicle or trade with which it was concerned, constitute one of the main contributions by Italy to the field of urban logistics. The ALT's concern stems from the nature of Italian legislation as well as its culture. As exceptions to the rule are common and widespread, real life application resulted in waivers of access restrictions being commonplace with freight operators often more inclined to pay fines than to comply with restrictions. Nevertheless, electronic access control (badges and cameras) and a hardened policy of these controls and fines (for example, in Turin, which implemented an incremental fine system to penalize repeat offenders, such as the case of Vicenza and Florence, which were the subject of a lawsuit brought about by the association of key stakeholders in express transport in Italy as a result of a desire by public stakeholders to adopt derogations and the principle of the polluter pays system) show that the issue of urban logistics is being taken more and more seriously. The other important contribution (as already stated) is that of urban consolidation centers, with about 20 experiments and projects having taken place since 2003 with about two-thirds of those systems still in operation [GON 14b].

At the national level, the Italian Ministry of Transport has included urban logistics in their 2011–2020 national logistics plan [MIN 10] and proposed an agreement between the Ministry of Transport and the urban communities of Turin, Milan and Naples on the planning and management of urban logistics [MIN 12]. Urban logistics is also present as a joint decree of the ministry with the university system, and research on the dissemination of Intelligent Transportation Systems (ITS) and their application to the transport of people and goods [MIN 13].

1.3.3. *Southern Europe (Spain, Greece, Portugal and other countries of Mediterranean Europe)*

Cities in Southern Europe (excluding France and Italy) are often viewed as "imitating" cities or users; in other words, cities which have applied and

31 Electric Urban Logistics: icelab.polito.it/ricerca/progetti/nazionali/urbelog.

adapted urban logistics solutions that have already been experienced by other cities. Indeed, the body of work dedicated to good practices pays little attention to Portuguese, Greek, Spanish and Mediterranean cities outside of France and Italy: for example, in the set of good practices identified in the SUGAR project [DAB 11b], only three out of 44 actions are taken from cities in these countries, all three of which were Spanish (night deliveries and vehicle reception points are practices which are already recommended in the Netherlands and in France). Nevertheless, these countries have made significant contributions to the existing *status quo* of urban logistics in practice. These contributions can be grouped into two categories.

The first is the fact that practices already in existence in other countries have been adapted to the local context and have therefore actively contributed to their perpetuation and transfer (the transferability of urban logistics actions is a sensitive topic, and the applicability of these actions onto other contexts seems to us an important contribution). Here, we find the UCC of Malaga, inspired by those of La Rochelle, and which were profitable for several years, until the Spanish economic crisis (which precipitated their closure). We can also mention the case of San Sebastian (started in 2013), night deliveries in Barcelona, the deployment of urban logistics spaces of different natures (taken from the French model, Boudouin, [BOU 06]) and transposed onto the main Spanish cities such as Barcelona and Seville, in addition to the increase in electric scooters, also in Spain, as well as the proposed Greek transport plans that included goods and which were inspired by the French UCCs [ROS 05].

The second are the innovations originating in these countries. Three systems seem particularly interesting to us: the variable use of taxiways in Barcelona, the intelligent area delivery systems in Bilbao and the logistics pooling system in Evora (Portugal). In 1997, the city of Barcelona carried out one of the first urban freight transport surveys in Europe [PRO 97]. In the early 2000s, the city set up two ring roads within the city (Balmes and Muntaner streets), installed signs with interchangeable messages to indicate a differentiated use of lanes of these roads according to the time of day: in the evening, the lanes on the right are dedicated to residential parking; in peak hours, they are used as bus corridors; for a given period in the morning, they are used as loading and unloading areas; and for the rest of the time, they operate as a taxiway. This system, well established and functional as of 2001 (several new streets and intersections were adopted this year, according to

[GAR 01]), was only publicized in Europe after being included in the best practices guide that was compiled by the SUGAR project [DAB 11]. Lyon, for example, began adopting this system in 2015 [CHI 16].

Intelligent systems for the reservation of delivery areas have been experimented with by the FREILOT project [BLA 10] in two cities (Lyon and Bilbao), while in Lyon (which was developing at the same time a delivery area reservation system under the ALF project, [DAV 14]), the experimentation was not conclusive, and in Bilbao, it aroused a strong interest among private stakeholders, despite the skepticism of public stakeholders[32]. In the end, following an evaluation that showed an interest in the deployment of systems that freed up space for the loading and unloading of goods [PLU 12], public authorities used the Euskadi ML Cluster to initiate a consultation phase to evolve the system, by replacing the reservation system with a sensor-based information system that covered a wider range of delivery areas and indicated their immediate availability. This delivery area communication system was still communicated with the municipal police in order to ease and improve illegal parking controls [LEK 14]. Finally, the city of Evora in Portugal hosted the ECOLOGUS project, which was developed on the initiative of an association of transporters (ANTRAM) in response to a change in the regulation of access to the city center. The objective was to develop a collaborative UCC (i.e. on the basis of cooperation, not the imposition or promotion by public stakeholders) with biodiesel powered vehicles. The organization of the transport and delivery system in the city center was organized by ANTRAM with the support and endorsement of the transporters [GON 13f]. The experience, which started in the 2000s, seems to be inactive today (little information is available), but it has nonetheless inspired, directly or indirectly, other initiatives. For example, the City Logistics system in Lyon started out from a similar organization, although it is important to note that the two business models are completely different (Evora was associative, while City Logistics was founded as a company).

32 The author was in charge of the evaluation of these systems for the FREILOT project and had discussions with the public authorities of Bilbao which asked for a rapid evaluation in order to close the experiment, while the transport carriers wished for it to continue. The final evaluation showed that there was an interest in deploying it, not in terms of direct pollution it averted, but in terms of the time it saved for companies [GON 13c, GON 14j], leading the different stakeholders to have a dialogue in order to find a solution that was relevant and acceptable to all.

1.3.4. *Germany*

Germany was one of the first countries to develop urban logistical solutions. In many cases, these came about in the early 1990s [COS 99]. The notion of urban logistics, as popularized by Taniguchi *et al*. [TAN 01], has its origins, among others, in the German *citylogistiek* [KOH 97]. Most of the cities concerned were small or medium-sized (less than 1,000,000 inhabitants), although we can find an operational urban logistics infrastructure in Berlin (the Potsdamer Platz). What characterized the German urban logistics of the 1990s was the weak (sometimes non-existent) intervention of public authorities [COS 98, GON 08]. Most of the German experiments in the 1990s proposed UCCs, promoted and piloted by private stakeholders, as examples (little known in France) of logistic pooling (in the strictest sense of the term, i.e. the sharing and pooling of logistical resources; Gonzalez-Feliu and Morana, [GON 10c]). More than 15 UCCs were created during that period [BRO 05, GON 13f], but all have since been stopped apart from the Potsdamer Platz, which has evolved and become a shared infrastructure, although no longer a UCC, and the Dresden CarGo Tram, which originated from a private initiative (to connect a Volkswagen factory in the heart of the city with the periphery). According to Gonzalez-Feliu [GON 08], the commonalities for these German projects are:

– the need to coordinate and optimize the vehicle load. The average load of vehicles used in these UCCs was approximately 70 to 80%;

– a high degree of privatization and voluntary collaboration between private enterprises;

– the use of light vehicles in urban areas, the reduction in the total number of vehicles (on average 55%) and transport costs (20–30%).

However, as these initiatives are linked to economic performance, most of the German UCCs have been stopped. Only the underground infrastructure of the Potsdamer Platz in Berlin still seems to be active today. Public stakeholders focused on other aspects, such as urban transport plans, including trade flows and the support of Chamber of Commerce on transport development. The German experience cannot, however, be considered a failure, given that those private UCCs worked and were economically viable (at least for the greater part) for several years. As they were mainly private operations with little intervention by public authorities, and they were the result of real collaboration and consultation between transport and logistics stakeholders as well as traders, the decision to terminate each UCC was motivated by the identification and adoption of more relevant or efficient urban distribution strategies for these stakeholders.

Other innovative urban logistics solutions originated in Germany. The most emblematic are the delivery instructions to the final consumer; in particular, those promoted by DHL, which allowed recipients to withdraw their orders without a time constraint and at the same time facilitate the last kilometer transport. Another emblematic example is the Dresden CarGo Tram, which was created in 2000 to meet a need for a Volkswagen plant in the heart of the city [ARV 13]. This system was initially planned for the internal needs of the car manufacturer but was opened up to other flows in the late 2000s. Recently, it was tested, using the same equipment, to serve a shopping center with more than 100 shops [ARV 13, ARV 16].

Although there has been little intervention at the national level, Germany is the only country with systematic standard surveys (i.e. conducted in several cities at regular intervals): the KiD (Kraftfahrzeugverkehr in Deutschland) surveys or transport vehicles in Germany; possibly, the databases of the federal motor transport agency (Kraftfahrbundesamt or KBA) can be used to supplement them [LEN 13]. Nevertheless, these surveys and databases are linked to commercial transport, i.e. to transport carried out in the context of professional activities. Those data sources include freight carried by professionals (whether on their own account or by others), but not the movements of individuals mobilizing goods. They remain one of the most comprehensive and up-to-date knowledge bases in the world.

At the level of public action, the Berlin Senate was one of the most active players. Their first action in the 1980s, to quantify and model commercial transport flows, gave rise to the Wiver model [SON 85]. This model is now part of the VISUM software (for modeling urban transport) of the company PTV, making it the first module for commercial transport. Another model, combining both personal and commercial transport, is VENUS [JAN 05], which is today still widely used in Germany [GON 12b]. The Berlin Senate has also contributed to the development and regulation of air protection zones (the German equivalent of the Italian ZTLs) as well as regulations seeking to organize and regulate freight transport in the German capital [HES 04, MEN 13].

1.3.5. *Belgium and the Netherlands*

Belgium is a country that does not feature prominently in the “good practices” of European urban logistics; however, that does not mean that it was last to come to the table. On the contrary, the country was one of the first in Europe to define short-haul goods transport (generally speaking, transport whose range of action does not exceed 10 kilometers of the urban center, Ambrosini, [AMB 89]), governed by specific regulation that required drivers to carry a legally recognized category permit. Although these categories were mainly linked to ports (such as Antwerp), in practice they also included a group of carriers operating in urban areas [AMB 89]. In addition, Belgium is one of the first countries to launch surveys and quantitative works on e-commerce flows [GEV 11, BEC 16, CAR 16].

The Netherlands has always been regarded in urban logistics as an intermediate country in terms of public intervention by authorities. Indeed, while Germany (and to some extent the United Kingdom and Northern Europe) are often in urban logistics seen as less interventionist countries, and France (and Italy to some extent) as countries where the regulatory role and power to ban communities is seen as strong, the Netherlands is often seen as a country where private action is strong and public intervention remains moderate, but not negligible. Although there have traditionally been no national regulations in this domain [QUA 08, VAN 12], several Dutch cities have been heavily involved with the application of urban logistics. We find examples of UCCs in Amsterdam, Utrecht, Leyde and Nijmegen, among others [SCH 02, ROS 05, GON 08, QUA 11]. The first three have since been terminated, while the latter is still currently operational [VAN 10]. The Netherlands was the first to promote and disseminate to several cities the permit (sticker) systems linked to regulations controlling access to the city center according to the pollution level of the vehicle in question [GON 08]. It was also in the Netherlands that the PIEK program (noise emission standard for night deliveries) was tested and disseminated [SCH 05].

Another field in which the Netherlands is a leader is that of intermodality. In addition to the experience of the Amsterdam cargo tram (started in March 2007 and stopped in November 2008, [ARV 13]) and the delivery of beverages via barges [VAN 14, VAN 13], we can observe the electric road train, electrically assisted bicycles and/or bicycle delivery systems [SCH 15].

1.3.6. *The United Kingdom*

The United Kingdom has two distinct characteristics: given that the country is an archipelago (hence the important role of ports for freight transport; Ducruet, [DUC 09]), the transport sector was one of the first to undergo a strong liberalization [WEB 98]. The second characteristic influences the fact that the United Kingdom is one of the countries where there is the least public intervention (specifically, restrictive regulations). The flagship example is London, with its urban toll system, which operates on the "polluter pays" principle, and applies to both the transport of people and goods [PRU 05].

The United Kingdom is also one of the countries with the most UCCs in operation [GON 13f, ALL 14b], most of which are linked to airports and/or factories [BRO 05], or to shopping centers, which assume, through their commercial tenants, any additional costs of the system. Bristol [GRA 16] is one of the better known examples of this.

1.3.7. *Northern Europe (Sweden, Norway, Finland and Denmark)*

Northern European countries have been investing in urban logistics since the end of the 1990s [ROS 05], particularly in incentivized and regulatory actions without a strong interventionism by public stakeholders [GON 08]. In other words, few UCCs or "public service" systems have been developed in these countries, but have taken actions aimed at improving the operations of transport and logistics companies [COS 98, ROS 05]. Indeed, most of the urban logistic actions in northern-European countries follow the logic of improving the performance of private stakeholders, rather than the logic advocating taxation under a goal of collective utility. In these countries, we come across studies to improve the logistics of the catering sector [BOS 13], logistics pooling projects in terms of an economically driven collaboration among private stakeholders [COS 98], and surveys [SÁN 16] on the basis of those used in the main studies on unified demand generation models in the United States [HOL 11].

1.3.8. *North America*

In the United States of America, urban logistics is a promising subject: the early work in this field dates from the 1970s [DEM 74, WAT 75] and the flagship institution in transport research and studies, the Transportation Research Board of National Academies (or TRB), has established a committee dedicated to urban freight transport. Nevertheless, the challenges and objectives of urban logistics within cities of the United States (and Canada) vary significantly[33]: the common challenges related to freight transport within inner cities and the shortage of parking bays for deliveries, have not been a priority for most cities (San Francisco and New York being the exception, due to their high population densities and similarities to European cities); however, the main problems and nuisances are linked to congestion in the major arteries that provide access to cities and their impact on delivery performance [WAN 16]. In this regard, a large part of the actions concern road infrastructures and their improvement, in order to smooth traffic congestion as well as to understand and control the slackening of logistics [DAB 12, DAB 14, ROD 17]. The research and applied practices of the United States can be credited with the generalization and standardization of night delivery experiments [HOL 14][34] for non-assisted reception systems, as well as two methodologies of data collection and modeling, which are complementary: the categorical generation methodology of Holguin-Veras *et al*. [HOL 11, HOL 13] and the MIT km² methodology[35] [MER 15].

In Canada, a number of urban freight surveys have been conducted, mostly in Toronto: a first wave focused on establishments to model freight generation and urban route estimates [HUN 06, HUN 07]; a second study focused on the use of GPS devices to collect transport data by comparing them to conventional transport surveys [MCC 08, SHA 11]. In addition, the province of Quebec has carried out studies on truck traffic [PAT 01]. Recently, the city of Montreal carried out a study on urban deliveries by adapting the STAN and EMME3 models to the Montréal metropolis [SIM 17]. Another important contribution is the depository system for glass

33 These differences were presented at the fifth conference on urban freight transport, I-NUF, held in Long Beach, California, in 2013.

34 Although already experienced by the Netherlands, night deliveries struggled to spread around the world. The New York experience, wherein they introduced unattended delivery systems to bypass the need to deploy night staff, has been successful not only locally but globally. Indeed, the New York Protocol has been tested successfully in several cities across the United States, as well as in South America, and more recently in Europe.

35 See: http://lastmile.mit.edu/km2.

and aluminum can collection in the province of Quebec and the reverse logistics system for recycling and reuse which results.

Mexico, a country that began to take an interest in urban logistics (late 1990s) a little later than their northern neighbors, however remains very active in this field. In 2006, the city of Mexico carried out a comprehensive study on freight transport in the metropolitan area, which included an analysis of carriers, origin–destination matrices and a supply-and-demand analysis, among others [LOZ 06]. Mexico has also given attention to urban logistics zoning [LOZ 08], with examples of practical application throughout the country, as well as informal transport [CED 16].

1.3.9. *Asia-Pacific Region*

Since the 1990s, the countries of Eastern Asia and the Pacific Islands have distinguished themselves through their involvement with urban logistics. In fact, the first two international logistics conferences were held in Australia and Japan [TAN 99, TAN 01]. In 2005, the Eastern Asia Society for Transportation Studies (which includes Chinese, Japanese, Korean, Australian and New Zealand researchers and practitioners) set up a research and exchange group on regional and urban logistics[36]. China, in its period of full development, was very concerned with the development of urban logistics zones within major metropolises, while issues of congestion and pollution began to emerge in the late 2000s [MA 14]. Regulations and legislation, mainly related to vehicle access, have since been developed and are now active. In addition, nine pilot cities have played host to several urban logistics experiments (China Ministry of Commerce, 2012), and three of them now have a logistical authority, an authoritative body that is also present in four other Chinese cities (Ma, 2014).

Japan is irrefutably one of the pioneers in urban logistics [TAN 01, SPI 08]. In addition to the research contributions it has already made (notably the work of Professor Eiichi Taniguchi and his team, among others), we observe many practices specific to the Japanese territory. We will highlight here the beginnings of urban logistics systems in Tenjin in 1978 [TAN 14], the logistics of multi-function proximity supermarkets [DAB 09, CAP 12], urban logistics hotels [BOS 09] or the two emblematic

36 See: www.easts.info/activities/irg/list.html.

UCCs: Motomachi, Yokohama and Soramachi, all taking place within the metropolis of Tokyo [TAN 14].

Australia is one of the other countries in the region that has been heavily involved with urban logistics. However, the congestion and pollution problem characteristic of Chinese metropolises or Japanese cities are not relevant in this country, which has smaller, less densely populated cities that span large tracts of land. Nevertheless, challenges with road infrastructure and compliance with delivery schedules are apparent, similar to cities within the United States. We can highlight a set of data collection studies, mainly done through GPS, to identify and characterize delivery routes [GRE 08].

1.3.10. *South America*

South America is often seen as a "transfer" region for actions and solutions already developed in other regions. We observe here the deployment of night delivery systems and data collection protocols in Brazil, Colombia and Ecuador [DEO 14, HOL 16], urban distribution systems in Chile [TUR 11] as well as considerations for decision support systems [PAR 17], among others. Nevertheless, those countries also have sound and interesting practices. Despite the high rate of informal transport observed, these countries have developed services via the non-motorized delivery to the last meter (although this work remains precarious), with relay systems and chains of carriage delivery with a high degree of organization and coordination[37]. We also observe highly specialized urban logistics zones, linked to a strong presence of industries (mainly textiles and food) in dense areas of South American metropolises, which have resulted in advanced systems of logistical collaboration and logistic urban zones not on the outskirts, but in the heart of the city. That context (high informality, urban industry, etc.) allows for the development of trades or actions specific to Latin America, such as the delivery system to the last meter in the streets of Lima, which are closed to motorized traffic [TUR 11], and the shared use of public transport by people and goods simultaneously [AMA 12], the dispersal of small, non-franchised and independent multi-functional businesses [CED 16] or multi-stage systems for wholesale markets [PAL 17], among others.

37 These systems were observed in the cities of Bogotá (Colombia) and Lima (Peru), during two visits in March and May 2016, respectively.

1.3.11. *Other regions of the world*

– Central and Eastern Europe. Central and Eastern Europe is still in the very early stage of deployment. It appropriates and adapts existing actions which have already proved their worth in other European countries [DAB 11].

– Africa and the Middle East. For the time being, African and Middle Eastern countries have had little presence in the scientific and technical literature concerning urban logistics. Nevertheless, urban logistic practices do exist, although these are difficult to identify in the international community. For example, two-wheeled motorized transport is characteristic of logistics in sub-Saharan countries [AKI 16], while countries along the Mediterranean basin are beginning to draw heavily on European experiences (Moroccan Logistics Development Agency, 2014).

– Southeast Asia. The cities of Southeast Asia also remain little studied, but the various challenges regarding the freight transport within cities seem important given the large size of the principle cities in the region. A good example is that of the Indian "*dabbawala*" [PAT 06, BAI 13], C2C (consumer to consumer) food deliverers, who, for more than a century, have constituted a sustainable delivery system (it supports the economy of many families, is non-motorized and at the same time contributes to the social integration of the populations concerned). Several authors have taken an interest in this system, and a Harvard case study has been developed and used when teaching to demonstrate the different contexts worldwide [THO 10].

This non-exhaustive overview shows the heterogeneity and diversity of both research and studies of the institutional, commercial, logistical and practical actions occurring worldwide, and also indicates the dominant set of actions and the quest for unification which has been difficult to realize in theory, but which is nonetheless realized in practice. For example, despite efforts to formalize actions related to overnight deliveries in France (i.e. in a white paper), US experiments have given rise to a methodology that is followed by several countries in South America and Europe. The actions on parking are recurrent, as are those regulating access to cities and urban logistics spaces, and although the unification of regulations and implementation procedures is not yet a reality, we can observe that practices remain very similar. Finally, the UCC, the main battleground of urban logistics, has an unequal fate in the world: while in France, that type of structure has difficulty in being perpetuated, in Italy, similar structures remain operational, while in Japan, the United Kingdom, the Netherlands and Chile, those structures have adopted a different organizational model and are now a reality.

1.4. Key questions in the quantitative and qualitative identification of urban logistics

As mentioned earlier, one of the main challenges in urban logistics (possibly the most complex one) is to create knowledge of the current practices so as to be able to define benchmarks for measuring the impact of new actions or proposals. In this regard, a multitude of scientific works have been developed over a period of more than 40 years. Nevertheless, these approaches are not unified, although in the case of data production, several efforts have been made to impose order. Knowledge of how that happens is important for the quantification of freight transport within cities; however, it is equally important that we use the extensive qualitative data to understand why.

In urban logistics, to identify and characterize sustainable practices and solutions, four categories of methods can be deployed:

– measures or observations;

– surveys and interviews;

– analyses of the sources and existing databases;

– reproducibility by substituting the data, model and/or simulation.

Observations and measurements result from the transcription of reality, either through human observation or through the capture and measurement by devices (usually automated procedures). Although these are met using different objectives, resources, procedures and treatments, they nonetheless respond to the same principle: under a given, predefined framework, the phenomena is measured or captured, then reported and recorded for further processing. In statistical terms, two main sources of error need to be considered. The first is the measurement error of the device or operator (for example, a reading error on the part of a person; an oversight or a miscount; or errors relating to the sensitivity of sensors or the malfunction of measuring mechanisms). The second is related to possible errors when transcribing or manipulating the results (whether by manual transcription or during the computerized transmission of the data, for example GPS data).

The main methods and techniques for collecting data in this category are:

– manual vehicle counts;

– automated vehicle counts;

– field observations (actual parking practices, mainly for delivery);

– observations of actual practices of conduct and delivery docks (that in general take place without any interaction with the driver);

– collection of the GPS data of truck routes and truck stops.

Surveys, on the contrary, are administered on the basis of a questionnaire and generally collect quantitative, categorical and/or qualitative information. According to Allen *et al*. [ALL 12a, ALL 14a] and Gonzalez-Feliu *et al*. [GON 13b], several types of surveys can be deployed to describe urban logistics. These surveys can be general (i.e. aimed at different types of stakeholders and activities, including the practices taking place in different phases of urban logistics) or specific (i.e. targeting a single group of stakeholders, spaces or phases). On the whole, general surveys combine several specific surveys, which are deployed in parallel, which have been coordinated upstream and which are integrated later on downstream.

The main specific surveys are:

– establishment surveys, which identify the different delivery practices, but from the point of view of the institutions;

– transport carrier surveys, which examine practices from the point of view of the transport carrier(s);

– driver surveys, which track delivery drivers, either through a logbook, filled in by another entity or self-administered, or else in the form a survey at the end of the excursion, either by an on-board survey or a situation where the investigator interacts with the driver;

– foot-to-highway surveys, which combine first-hand observations with a survey of the stakeholders encountered during these observations;

– individual surveys (consumers, households) and surveys of logistical service providers;

– surveys on technical functions, support and operational profiles of the communities.

With regard to general surveys, we find:

– surveys on goods transport within cities, based on a survey established and compared with surveys by carriers and shippers [AMB 10];

– surveys on the flows of goods, also called shipping surveys [GUI 09, HOL 09];

– surveys on German or Canadian commercial transport [HUN 06].

Other methods and techniques relate to the analysis of sources and data, mostly documents containing information such as transport plans and also (in some cases) fuel or electric consumption. In general, this type of data requires prior processing and interpretation if it is to be used in the description of urban logistics. They are often combined with other methods to supplement data gaps, to provide details on issues that have received little attention, or in the event where surveys have been poorly answered.

When facing data gaps (whether due to the non-response or simply the absence of relevant databases), data reconstruction can be a viable alternative. It can be done either through statistical procedures (based on averages or probabilities) or by using methods for data estimation through modeling or simulation.

As far as qualitative studies are concerned, we can observe a multitude of works in urban logistics that attempt to qualify different actions and experiences. Three main approaches are proposed:

– case studies;

– comparative analyses;

– guides for good practices.

Research case studies are very popular in urban logistics. They can be of two types: inductive or descriptive. Through the description of a concrete example, inductive case studies [EIS 89] aim to induce theories, mostly with management or urban planning as the end goal. Descriptive case studies (of the Harvard School variety) are synthetic examples of how to illustrate existing theories, and provide a field-based source to input knowledge on a variety of topics, mainly management sciences, based on a standardized method that allows for a certain degree of comparability.

Comparative analyses aim to create knowledge through the comparison of two or more case studies, mostly on a purely qualitative and descriptive basis. However, some works support a comparison of quantified facts that help to emphasize the qualitative aspect [BRO 05, ALL 12b, ALL 14b, LEO 12, GON 13c, GON 14b].

The "good practices" guides (unlike comparative analyses), do not make comparisons, but are intended to show descriptive examples of actions or experiments that are considered exemplary with a view to promoting and reproducing them elsewhere. Nevertheless, most of these guides remain very descriptive (sometimes bordering on advertising) and cite few examples of analyses as to the transferability and applicability of these practices onto other contexts [DAB 11, TUR 11].

From this brief and non-exhaustive overview of the academic literature, we can conclude that the quantification and qualification of sustainable urban logistics does not follow a standard or unified logic, and more often than not, the marked absence of unification makes it difficult to compare the case studies presented by different authors. Moreover, most of the work is limited to presenting good practices in urban logistics, without necessarily proposing an evaluation that allows for them to be compared with others, or even to serve as a basis for consequent experiments. Furthermore, comparative studies and those focused on the transferability and applicability of these practices remain few in number.

It is therefore imperative to tidy up this vast body of work and, from this position of improved organization, propose a case study structure that is more systematized and unified. A common knowledge base can then be created that is able to relate and compare a new experiences with those that have already been applied in practice. To this end, it is important to define both unified and transferable frameworks for the understanding, analysis and planning of urban logistics. The main aim of this book is thus: to propose an approach for sustainable urban logistics, albeit non-exhaustive, but as open and as objective as possible, outlining the various methods that can be used for its planning, estimation and analysis. As we will see throughout this book, despite the fact that few standards in urban logistics are officially recognized, the dominant practices and actions suggest a *de facto* unification and standardization of several methods and techniques. Over the course of the following chapters, it is to these approaches in particular that attention will be given.

2

A Unified Definition of Sustainable Urban Logistics

2.1. The components of sustainability

As we saw in the previous chapter, the main difficulty in identifying and describing the practices and patterns of sustainable urban logistics can be attributed to two facts: first, the lack of a convenient standard and widely acknowledged definition adopted by the different communities; second, the substantial diversity of methods and approaches for the quantification, qualification and evaluation of urban logistics, which do not always allow for a comparison between different actions or experiences on a general basis. This second fact is closely related to the first one, since it is very difficult (if not impossible) to produce a comparison between two evaluations when the object of the evaluation is not defined according to equivalent bases and references. To this end, we need a clear definition for sustainable urban logistics, as well as a comprehensive scope that considers the urban logistics schemes and flows emanating from them. To be clear, the aim of this work is not to impose or elevate an exact definition as the standard, but rather to refer to existing works and methods that have been explicitly defined, so as to enable interested stakeholders to use them and/or compare the results of diverse works. For those reasons, we propose here an approach to sustainable urban logistics which is guided by the works presented in this book, and which is as broad as possible.

To begin, we will first present a summary of the different approaches to the sustainability of urban logistics that have influenced this book. Sustainable development has been studied and processed by the majority of

Sustainable Urban Logistics: Planning and Evaluation,
First Edition. Jesus Gonzalez-Feliu.

disciplines and to this date has many practical applications. Sustainable development is essentially an organizational principle aimed at bringing human societies to a desirable future state in which living conditions and the use of resources meet human needs without constituting a danger to the continuity and development of natural systems [STI 76], thereby ensuring the availability of resources for future generations. That notion has since been generalized and accepted by society, notably through the signing of the United Nations Framework Convention on Climate Change [DEP 00], also known as the Kyoto Protocol, although it is strongly oriented around the respect of natural resources, the environment and energy. Since then, several works have extended this vision to be more global [GID 02, RED 05], very often in relation to regional [ZUI 00, THE 02, BRU 10, DEM 11] or entrepreneurial and intra-organizational matters [ELK 94, MOO 07]. In the field of transport and logistics[1], sustainability is generally categorized into three main spheres [MOR 13]:

– *economic*: a logistics and transport system must be first economically viable in order to ensure its continuity over time. This is why the economic sphere (in logistics mainly associated with Supply Chain Management or SCM) is the best known and therefore given priority. This place of priority is confirmed by many academic works in addition to practical requirements, both to reduce costs and/or lead times, and to maximize on the quality of service offered to clients [CHR 00, GUN 07];

– *environmental*: the respect of the environment and the reduction of pollutants are traditionally seen as constraints in the field of logistics and freight transport. As a result, most stakeholders act only when they are obliged to do so [GON 16d]. It was only in the 1990s that this was seen as an opportunity, when Green SCM received recognition from scientific literature [SRI 07]. This is also the case in the transport sector, where today the production of more eco-friendly vehicles makes up a significant part of the market at the same time motivating the development of more advanced low-emission transport systems [FAV 14]. In this area, we find several concepts such as eco-conception [ADE 06] and eco-design [MIC 04], inverse logistics [LAM 03] and reverse logistics [ROG 99], and also the uptake of clean technologies in logistics and freight transport [FAV 14];

1 We refer here to *Sustainable Supply Chain Management* [MOR 13], which was the basis for the reflections on the sustainability of urban logistics presented in this book.

– *social/societal*: the impacts of a logistics and transport system on society, on the social and territorial environment (social aspects of this sphere), or on the company and working environment (societal aspects) are not taken lightly [GON 16d]. Indeed, a logistics and transport solution must take into account these aspects (i.e. both social and societal) in order to be considered truly sustainable [MOR 13]. That is especially important given that the human and social environment is also undergoing impacts and has a strong influence on the continuity of practices, and therefore has an effect on sustainability over time. Hence, the development of notions in recent years of corporate social responsibility (CSR), which has also come to the transport and logistics sector, mainly driven by large-scale retailing [BEZ 07, SEN 09]. In this context, it is important to consider both the intra-organizational (i.e. internal to the company or organization being considered) and the inter-establishment (i.e. external) stakeholders.

From these three spheres, an expanded approach for sustainable development can be defined on the basis of six areas: the three spheres described above and their three interactions. This point of view is becoming increasingly widespread within the field of urban logistics [LIN 10, PAT 10, MOR 15]. The three traditional spheres of sustainable development can be interfaced with other three, more transversal spheres, as shown in Figure 2.1.

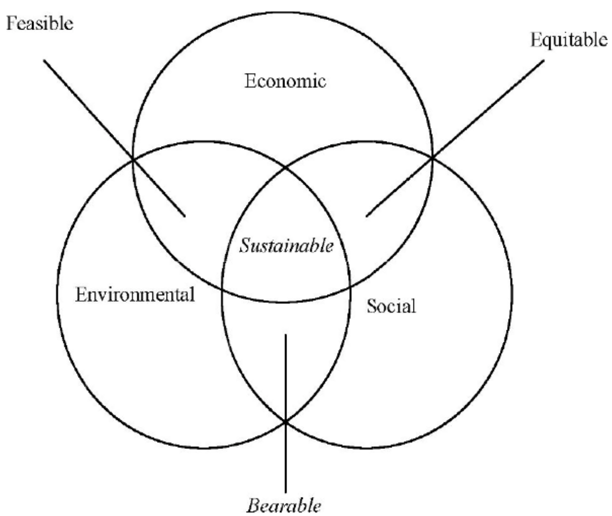

Figure 2.1. *Components of sustainable urban logistics ([LIN 10], adapted from [STI 76])*

To that vision of sustainability is linked the notion of viability (also referred to as feasibility), which seeks to fulfill a set of economic and environmental criteria. Bearability refers mainly to environmental and social aspects, i.e. in its ability to improve the quality of life. Finally, equity is related to both economic and social criteria, and mainly linked to the equitable distribution of resources and economic gains.

This approach has also been projected on the grounds of the relationship between logistics and territories [MAS 12]. The economic sphere would thus be related to the logistical performance, the environmental sphere to the environmental sustainability, and the social sphere to the spatial equity. The combinations of these three spheres (viable, bearable and equitable logistics) remain the same as those in Figure 2.1. Upon this, the authors then go on to question the conditions under which sustainable logistics can be defined. Contrary to the classical logic underpinning the three spheres, the authors show an antagonism between logistic performance (economic sphere) and spatial equality (social sphere), as well as between spatial equality (social sphere) and environmental sustainability (environmental sphere). Furthermore, according to the authors, logistical performance is not necessarily antagonistic towards the environment, a point which is also being stressed by other authors in the field of logistics, who insist on a growing trend for logistics performance in harmony with an environmental vision for logistics management (green supply chain management [SRI 07]). That being said, some stakeholders see the relationship between the three spheres not as intersects but as exchanges (and therefore do not draw three interconnected spheres but rather depict spheres that communicate with each other): visions of viability and equality would not emerge from the overlap of those three spheres, but as transverse concepts instead [BRO 16].

An alternative vision of sustainable development was recently proposed, mainly related to transport, either people or freight [MAC 16]. Instead of the conventional spheres, it proposes a view of sustainable development based on four characteristics, known as the “four As”. Here, we will refer to them here as the “four capabilities”[2], since each characteristic represents a capacity that any successful sustainable transport system must have:

2 In the original version of this book, written in French, it was impossible to translate the four As by words all beginning by the letter A, so the author related each A to a capability in order to keep the same reasoning of Macharis and Kin [MAC 16].

– *awareness*, or the *capability to know and understand*, and this may be further defined as the state or capability to perceive, feel or be aware of events, and more specifically the reality that the transportation system represents. The first step towards sustainable development is thus to become aware of the need for action;

– the *capability to act and shift* is defined by [MAC 16] as the reactivity and capability to perform a modal relationship in order to reduce transport pollution. To extend this definition to cover all transport flows (people and/or freight) we define this capacity as the responsiveness and ability to change the transport system, whether it be through vehicle or modes, or the system by which it is organized. The second stage of sustainability can be seen as the will to change the modes and organizations of transport so that they are cleaner and more socially equitable;

– such changes would not be effective without the notion of *avoidance*, i.e. the *capability to avoid* pollutants generated by logistics and freight transport. Certainly, the third stage of sustainability is the act of avoidance, which allays the need to try and fix a set of circumstances later on;

– finally, in conjunction with this capability to avoid must be added the desire to anticipate. Therefore, the fourth phase of sustainability is the *capability to anticipate*, or *anticipation*, i.e. the potential for forecasting and identifying possible challenges to logistics and freight transport in advance, thereby making it possible for them to be avoided.

To those visions of sustainability, it is important to add the notion of dynamics. A system will not be sustainable if it is static: it therefore must be flexible, reliable and evolving, i.e. a long-term, comprehensive, complex and collaborative systemic approach [BRO 16]. Many actions only take into account the short term (e.g. alternating traffic to combat pollution peaks); however, these must be complemented by longer-term actions that have a lasting effect (e.g. the use of dynamic demarcation lines, vehicle-specific incentives or policies to promote change, among others). Most actions start off with being implemented in a local context and must evolve in order to be transferable and applied to a global context (examples of which are the many urban logistics platforms or local policies such as night deliveries, which inspired Manhattan and many other cities around the world [HOL 15]). Similarly, sustainable urban logistics must be simple to implement and evolve, so as to take into account the complexity that is the urban environment [GON 17a]. Finally, the right balance between competition in the marketplace, the share of government promotion, and collaboration and co-ordination between the various stakeholders involved, seems critical to ensuring the sustainability of an urban logistics system.

Although those visions are complementary, they are not at present always articulated. While the three spheres seem to be adopted and understood by a great many stakeholders, the linkages between these three spheres are not always so simple to understand or establish. This approach is used to define whether or not a system is sustainable. The approach of the four capabilities seems to be more prospective and makes it possible to define the predisposition of a transport system to become sustainable. It makes it possible to identify the improvement potentials and the arrangement of the system in question with regard to this change.

However, in order to be able to make these changes, it is important to know why. And in order to know why, it is important to have a clear definition of the flows and stakeholders of urban logistics. The next two sections present, respectively, the flows attributed to urban freight transport and the key players in urban logistics.

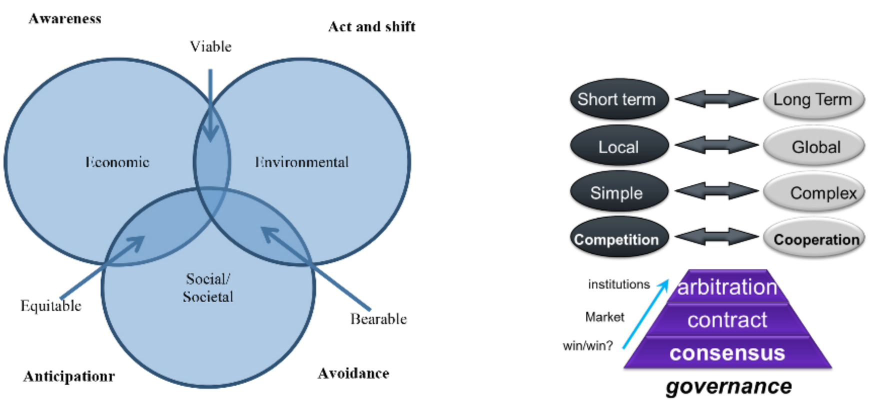

Figure 2.2. *Approach to sustainability (adapted from [BRO 16, GON 17a])*

2.2. The flows considered in urban freight transport

The categorization of flows attributed to urban freight transport has been addressed by different authors over the course of the past 40 years [WAT 75, OGD 92, WOU 01, SÉG 04, CAT 01]. The literature contains different approaches for the flows of urban freight transport and urban logistics, and yet we can still observe that these visions are both more or less extensive, and more or less inclusive. To this end, we propose to start with the broadest view of all the flows attributed to urban logistics. If we take the basics of global logistics management (Supply Chain Management [LAM 01, LAM 08]), that which is under consideration can be of several types[3]. Of these flows, we can of course highlight the physical flows, i.e. the flows of goods, and also information flows, financial flows and other transaction flows, work flows and decision-making flows. Given that the theme of urban logistics has traditionally been linked to engineering and transport economics, the flows that are generally put forward are those related to the transport of products.

Furthermore, in logistics (whether urban or not), physical flows are not limited to only those between two levels of the chain, but also those internal to each level. To that end, we propose to divide the physical flows of urban logistics into four categories, three related to freight transport (and so-called external logistics) and a fourth dedicated to internal logistics:

– *inter-establishment flows* [SÉG 04] include all transport flows between two economic activities (thus a large majority of urban B2B flows). These flows account for between 45% and 55% of the road occupation for the total urban freight [SÉG 04];

– *end-consumer movements* include all the movements of the goods made between the point of sale or terminal warehouses and the location of the end-consumer. These generally represent 45% and 55% of the road

3 We will not go into the detail of these logistics management flows, but it is important to bear in mind that in the *supply chain management* vision, there are different resources that need to be managed along the supply chain and/or that the value of a product is not only linked to the physical flows of materials and products but also to other non-physical flows linked to different physical, technical or supply chain management components [LAM 01].

occupancy rate by vehicles in circulation ([SÉG 04] estimate these flows at 50 to 55%, but [CAT 15] obtain an estimate of about 46% for the urban areas of Lyon). These flows contain the movements of purchases by households (whether motorized or not) and B2C flows, i.e. transport flows between an economic activity and an individual;

– *urban management flows* [GON 14f]. Often associated with residual or accessory flows [PAT 02], this category is nevertheless far from negligible; in fact, it represents between 8% and 10% of the road occupancy rate [SÉG 04]. However, it seems the most difficult to define, as it is the most heterogeneous [GON 17]: in this category, we find flows linked to the collection of waste, those related to the construction and maintenance of buildings, infrastructures and networks or removals (professional or on behalf of individuals), among others;

– to those three categories, we propose the addition of *internal or intra-organization flows*, which do not have an impact on the occupation of the road network, as they are internal to urban settlements and activities, but nonetheless may have impacts on the economy, the environment or society. This is the case, for example, with internal flows of warehouses and cross-docking platforms, and also to certain production activities within the city (for example, the Volkswagen plant in Dresden or typical industrial areas in the heart of a normal Latin America city, as described by [TUR 11]), and which in some cases are necessary for generating action plans (for both public or private stakeholders).

It is important to remember that some of these flows can be carried out by the same vehicles and along the same routes. For example, in the postal services or parcel distribution industry (express or not), the delivery median is the same for both professional and private customers alike. In terms of transport demand, the flows for professionals will be generated as inter-establishment while those for individuals as end-consumer flows. Nevertheless, for all intents and purposes, the construction of the logistics systems and delivery routes of these two requests can be treated together as the same flow [DUC 12].

Urban Logistic Flow Categories	Sub-category	Displacement Percentages	Distances (%)	Road Occupation (%)
Inter-establishment movements	Deliveries to shops and tertiary services	16%	6%	10%
	Supply flow of intermediate activities	11%	9%	17%
	Industrial and Urban Agriculture	5%	3%	5%
	Maintenance, crafts and other services	29%	7%	8%
	Total	**61%**	**25%**	**40%**
End-consumer supply movements	Motorized shopping trips	27%	63%	41%
	Home delivery	5%	5%	6%
	Deliveries away from home	3%	1%	2%
	Total	**35%**	**69%**	**49%**
Urban management flows	Waste collection	–	1%	2%
	Construction and network management	2%	3%	6%
	Removals and other flows	1%	1%	2%
	Total	**3%**	**5%**	**10%**
Other flows	**Flows not in previous categories**	**1%**	**1%**	**1%**

Table 2.1. *Estimation of the main physical flows of urban logistics (excluding internal flows) in terms of road occupancy by vehicles in circulation (km.PCE[4]), based on an estimate of the urban area of Lyon[5] [GON 17a]*

4 Passenger car equivalent.

5 For this estimate, several of the models proposed in Chapters 4 and 5 were used.

In addition to these physical flows, information flows are also being studied, particularly when setting up information systems for urban logistics [GON 10a, MOR 14, PAR 17]. These information flows are a prerequisite for the successful realization of transport and logistics transactions [GON 11] and form the basis of a series of experiments and urban logistic actions [GRA 04, GON 10a, GON 10c, GEB 11]. Workflows and financial flows can be considered, however, their identification and study in urban logistics remains for the moment very rare [COM 16]. Decision flows, decision chains, as well as multi-stakeholder and group approaches have also been considered in the literature [GON 13d, MAC 14b].

Although non-physical flows have been considered on a smaller scale, it is important to note that they are an integral component and can be the success or failure factor for deployment actions as well as urban logistic solutions. Once the flows of urban logistics are defined, it is important to present the different stakeholders and their interests (see section 2.3).

2.3. The stakeholders involved and their interests

2.3.1. *Introduction*

In urban logistics, we can observe many different types of stakeholders, as evidenced by the many works on the theme [DAB 98, BOU 02, MOR 11, CHA 12, ABD 13, BOU 14]. These authors propose different aggregations and classifications, but always based on the notion of public and private stakeholders. An alternative view, based on the relation of stakeholders to their use of space, is first proposed in [GON 14], and later completed in [GON 16]. In this vision, the stakeholders are not classified according to their association with the public or private sector, but according to their direct relationship (in terms of their functions) with the land and thus with space and territory. We can thus define two categories of stakeholders:

– the *users of space* are the stakeholders based in the area and whose functions have a direct impact on the occupation (static or dynamic) of that space, and include four categories: goods’ consumers, consumer interface roles, field public services (i.e. operational, not planning) and other economic activities necessary for the functioning of the city. The three main subgroups of space uses are:

- the city's economic activities, which account for about 46% of road occupancy by vehicles in circulation[6], as per the estimate proposed in Table 2.1 (between 40 and 50% according to authors [PAT 02, SÉG 04, GON 10d], and 26% for parked vehicles [GON 17]). These activities can be broken down as follows:

  - activities related to agricultural and industrial production;

  - activities related to distribution and wholesale trade;

  - retail parks and supermarkets;

  - activities related to the services and tertiary sector;

  - transport and logistics professionals.

The first four sub-categories of activities are generally dispatchers and/or recipients of freight, but may also be involved in carrying out their own transport (on their own account). Transport and logistics professionals carry out transport on behalf of others and, in the case of warehousing activities, may also be dispatchers or recipients (usually intermediaries);

- the end-consumer contributes (directly or indirectly) to 46% of the road occupancy by vehicles in circulation and about 64% of parking (time);

- the public and private activities aimed at maintaining and operating the city's life (such as waste management and construction) contribute to 8 to 10% of both road occupancy by vehicles in circulation and parking time.

– *spatial organizers* are those whose role is to plan and organize the urban space. From the decision maker to the various territorial technical services, these functions have a direct link with spatial and urban planning. In this category, we include consultancies (public or private) or groups of professionals. With no purely "territorial" function, these stakeholders have a direct influence on the choices and reflect the positions of economic stakeholders within the context of the city. The main subgroups of urban spatial organizers are:

  - public authorities with a competent legislative role (including their various technical services): municipalities, urban communities, provinces, regions, etc.;

6 Since these are by definition at the origin or destination of inter-establishment movements.

- public authorities with a technical or expert role, but with no competent legislative role: urban planning agencies, urban areas, macro-regional or European bodies, etc.;

- professional bodies: trade associations, transport federations, chambers of commerce and industry, economic clusters, competiveness centers, etc.;

- the technical offices and the research and development activities (public or private) focused on the city and transport: technical services of the ministry of sustainable development and ADEME, research organizations (public or private), stakeholders in logistics real estate, etc.

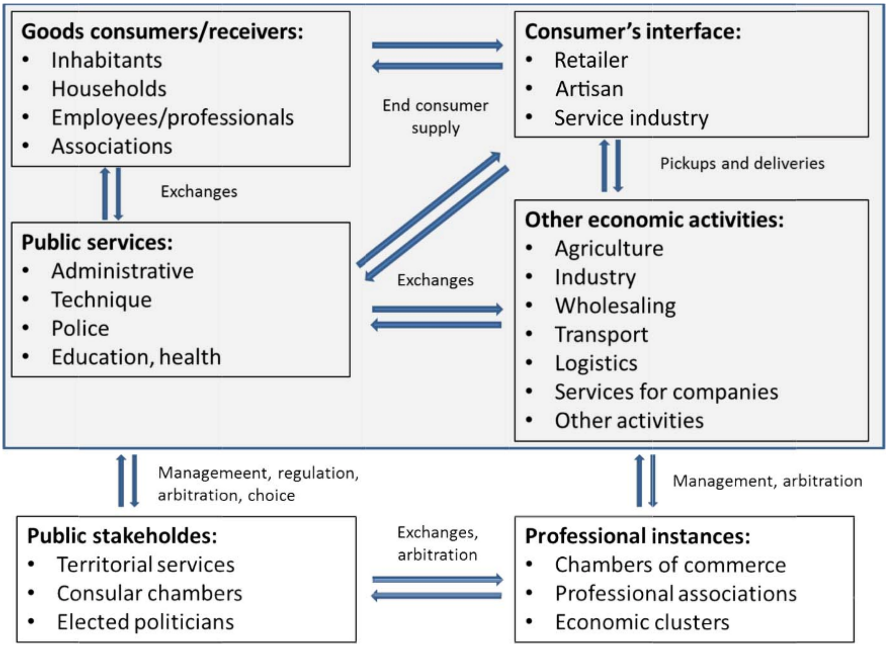

Figure 2.3. *The different stakeholders of the city according to a functional classification directly related to space (after [GON 12c])*

2.3.2. *The urban logistics interests of these two categories of stakeholders*

It is clear from this diversity of stakeholders that the objectives and interests of each are different and, in some cases, in opposition with one another. Nevertheless, we can summarize these interests into three major groups, according to the type of stakeholder. This is proposed as follows.

For the space consumers in urban areas, the challenges associated with urban freight transport are linked to the activities of each stakeholder and their specific contexts (from businesses for economic activities to household or person-to-person activities for individuals, division or service for public entities). These can be summarized by the well-known triad of cost-quality-time [MOR 13], i.e. the reduction of logistical costs, the improvement in quality (product, service and labor, etc.), and reducing turnaround times and/or the misuse of resources (in other words, increasing the available time in working days).

For the space organizers of urban space, the vision is considered to be collective in its concerns for the city (or urban space in question). The challenges, in this case, can be reduced to the notion of sustainability according to the different declensions, as noted in the first paragraph of this chapter. The city must be a space where activities and households, which are located and exist there, are viable over a given period. Moreover, it is important that cities stay functional and that activities necessary for a city's existence continue to develop in the places allocated for that purpose. The city must also be a habitable, less polluted place, which is at the same time safer while generating less noise. Finally, it must also be a fair and equitable place, and urban space organizers must ensure that there is a balance which allows for, and promotes, this equity.

In principle, these challenges are not contradictory, but nevertheless are often seen as being in opposition. For example, an action aiming to reduce congestion (and therefore improve the quality of life within the city) may entail limiting the access of heavy and/or polluting vehicles. This in turn could have significant impacts on delivery costs, which in turn might affect the vehicle itineraries [MUÑ 14] or influence a change in the type of vehicle being used [GON 15]. In both cases, the change induces an increase in cost which is usually passed on to dispatchers and/or consumers. On the contrary, a public road management system, deployed for the same reasons [DAB 11b], if guided well, can induce a reorganization of the transportation, thereby reducing costs. This type of system aims to optimize and thereby reduce, among other things, the downtime, thus engendering a positive impact on travel times not only for passenger vehicles but also for carriers [CHI 16].

Moreover, in the distinctive occasions where a dominant stakeholder imposes choices on others, in a strong manner, in the end the deployed urban logistics systems have proven unsustainable, and, as a result, most were terminated. Two examples, however, are still in operation: the UCC for Monaco and the UCC for Vicenza (Italy) but, in the first case, the particular regulations of the principality and its geographical characteristics justify the choice to impose a tariff on the arrival of any freight into a particular urban consolidation center (UCC); in the second case, the UCC's scope of action remains small (two main streets and a few secondary streets) and the carriers nevertheless filed a complaint and won a trial on the first instance, although the city finally won the appeal in view of the specificity of the city and due to the fact that the scope was too small for it to become a transferable case [DAB 10]. Moreover, in its final decision, the Italian high court pointed out that Vicenza was a special case and that its decision should in no case be taken as a rule but rather treated as an exception. Under this context, it seems difficult to set priorities in the decision chain, to give a stakeholder (or a type of stakeholder) decision-making powers that exclude the opinions of other parties. Moreover, and as pointed out by Gonzalez-Feliu *et al*. [GON 13g], in the context of multi-stakeholder decision-making concerning logistical pooling, it is difficult to find a solution that satisfies everyone. It is therefore essential to negotiate and reach a consensus (unification), in order that a solution (after possible compensation, if necessary) is accepted by all the stakeholders, although some will be aware (and will therefore have to accept) that this may cause a loss or disruption of operations in relation to the current practice.

2.4. Visions for sustainable urban logistics

2.4.1. *The main definitions of urban logistics*

Although urban logistics is a very popular topic in research (as it is in practice), the terms used by different authors or practitioners often differ. What is more, although several attempts have been made to unify concepts and definitions recently, we are currently able to observe several visions of urban logistics that merit consideration and comparison.

When considering the flows involved, the majority of authors and practitioners limit their field of action to the last kilometer of retail delivery [TAN 99, CRA 08, MAC 11]. Indeed, the first quantitative work on urban logistics was linked to deliveries coming from commercial areas [DEM 74] and the first authors who spoke on urban logistics emphasized the deliveries to and from shops as the main flows to be taken into account [RUS 94, KOL 97, TAN 99].

A broader view is that of urban freight transport which considers all inter-establishment flows (which, as we have seen, represent only about 40% of the freight transport road occupancy rates of a city). Indeed, many authors consider that urban freight transport only involves B2B flows [WOU 01, BEH 08].

Another vision of urban freight transport is the one advocated by [DAB 98, DAB 08]. Here, the flows considered are those that are carried out by transport professionals or economic stakeholders on their own account, but which include deliveries to individuals [DUR 09].

The broadest view, which includes all of the flows presented earlier, was formalized by [PAT 01, PAT 02]. This vision is increasingly accepted by the community [RUS 04, RUS 06, LIN 13].

Nevertheless, there is no standard definition for "urban freight transport". Although the French Ministry for Sustainable Development (*Ministère du développement durable*[7]) has tried to promote a broad view of the terms "urban freight transport" and "urban logistics", researchers and practitioners in that country do not infer the same concepts and definitions when conferring about these two terms.

Similarly, the definition of urban logistics does not follow a particular standard among international communities. Nevertheless, in the last years, three major definitions coexist. The first is that of city logistics, which defines it as "*the process for totally optimizing the logistics and transport activities by private companies with the support of advanced information systems in urban areas considering the traffic environment, its congestion, safety and energy savings within the framework of a market economy*" [TAN 01]. According to several authors, that definition has two major

7 At the time when this chapter was being the finalized (March 2017), its official name was the Ministry of the Environment, Energy and Sea (*Ministère de l'environnement, de l'énergie et de la mer*).

restrictions: the first is that it limits urban logistics to transport carried out by companies, leaving aside the transport carried out by individuals (mainly purchase journeys) and part of the urban management flows; the second is the vision of pure optimization which does not always correspond to real or accepted action(s). The second definition is translated in English as urban logistics, and can be defined as a "*pluridisciplinary field that aims to understand, study and analyze the different organizations, logistics schemes, stakeholders and planning actions related to the improvement of the different goods transport systems in an urban zone and link them in a synergic way to decrease the main nuisances related to it*" [GON 14d]. This vision is broader in the sense that it covers all commodity flows, a space larger than just the city center. Nevertheless, it relates strongly to research and can be viewed as limiting the field of action for the benefit of understanding and analysis. Another definition is proposed by Rodrigue and Dablanc [DAB 14] with a vision for the urban geography of transport which considers urban logistics as "*The means over which freight distribution can take place in urban areas as well as the strategies that can improve its overall efficiency while mitigating congestion and environmental externalities*". This third definition is also restrictive in terms of the flows being considered, however, it has the advantage of being a definition that is more neutral and general in its field of action.

Each of these definitions has interesting aspects, and also certain limitations. To this end, it is important to propose a general definition for (sustainable) urban logistics that integrates these three definitions, taking the strengths of each one to give a field of action that is as general, and the least limited, as possible. Nevertheless, before proposing this definition, it is important to investigate another aspect: namely the urban logistics visions of the various stakeholders' in terms of the types of actions and intervention of legitimate stakeholders. In this regard, two visions (often antagonistic) are observed: that of urban logistics as a consequence of the search for a collective utility, and that of urban logistics as a means to make freight distribution efficient.

2.4.2. *Vision of collective utility versus individual profitability*

We have seen that logistics were already being developed in ancient Rome, mainly related to the food supply of the imperial capital. In this context, the town was managed by a prefect (Praefectus Annonae), who had a budget and decision-making powers [PET 74]. Nothing followed on this and, for several centuries, cities did not have any real regulation or organization pertaining to logistics and freight transport. Moreover, even in the 1980s, government actions were limited to the localization of activities or management of emergencies [CRA 04]. It was not until the mid-1990s that some countries began (France was the first) to consider the systematic regulation of freight transport in cities [GON 08].

This regulation was based on a collective need: the fact that cities are shared and constituted as multifunctional spaces. In addition, the need for regulation and action, in terms of urban logistics, arises from the fact that cities are increasingly becoming congested and polluted. The transport of passengers has been regulated by public authorities longer than those regulating the transport of goods. The two components of urban transport (for both people and freight) interact with one another and contribute to urban pollution. The reduction of these pollutants is a necessity that affects the city as a system and as a common space. And who can manage common space better than communities?

Consequently, and following this vision of collective utility (i.e. improving the quality of life), the first of the urban logistics actions in France (and also those in Italy and/or the Netherlands, for example) follow this vision of collective utility. This approach is specific to spatial organizers, who, in order to organize the system, needed to regulate it, and as such had a global, more neutral vision. Nevertheless, some authors advocate a need to bestow on regulators more and more power through which to regulate, which runs counter to the corporate vision and is responsible for the creation of conflict. Indeed, while more than 100 urban consolidation centers are currently operational, the main reason for their failure is due to the low level of acceptance among the private sector, and this is the same even in contexts where the powers of regulators are strong.

Although most players in urban logistics agree on the fact that they contribute to the major portion of the pollution generated by urban transport, users of space are not always ready to follow the regulations imposed by spatial organizers. This is due to the fact that users of space in their development follow the logic of economic profitability. Indeed, economic stakeholders, in order to survive, must make their investments profitable, by reducing their costs and increasing their profits. However, certain regulations or charges have a negative effect on economic profitability. Hence, the fact that some countries (mainly Germany, the United States and Japan) have developed an urban logistics strategy based on free competition and the market. German urban consolidation centers have generally not received public subsidies, and have had varying durations depending on the profitability of the associated enterprises that supplied them during these periods. Although few such platforms are still active in Germany, the logic of economic profitability has made it possible to develop (and make sustainable) several UCCs in the United Kingdom, two more in Japan, another in Chile, among others. Nevertheless, the logic of pure economic profitability favors major economic players to the detriment of smaller ones. In addition, the logic of economic profitability is individual, whereas the city is a system as a whole.

The two visions presented above are often perceived as antagonistic, however, they can also be complementary. In his work on traffic dynamics, Wardrop [WAR 52] defined two states of a transport system: the optimum of the system and user's equilibrium. By transposing this to urban logistics, a system will obtain its overall optimum when a collective utility approach is followed, while the user equilibrium will be achieved when each individual obtains a satisfactory (but not necessarily optimal) situation that is in keeping with the logic of profitability.

Sustainable urban logistics can only be achieved if both of these visions are taken into account, as well as the interests of all the various stakeholders involved. In addition, sustainability has several facets and elements which, as we have seen before, must be taken into consideration. On the basis of all these fundamentals, we propose below a broad definition for sustainable urban logistics, which underpins the general vision of this book.

2.5. A unified definition of sustainable urban logistics

On the grounds of all these considerations, we propose here a unified definition of sustainable urban logistics. This definition takes into account the various notions introduced above and will be the one to which we will refer throughout this book.

In this context, sustainable urban logistics will be defined as all logistics and freight transport activities of a given urban area that respects the following principles:

– they are economically viable and contribute to the improvement of the environment, quality of life, as well as social issues;

– they conform to the logic of the four As (or four capabilities) and have a vision of continuous improvement; in other words, that the logistical schemes concerned are well identified, known and understood, that the possibilities for an action to change have been well defined, that the means to reduce pollutants have been studied and that anticipatory measures have been set out, and all this in a dynamic and continuous vision;

– they take into account the interactions between the different stakeholders concerned, and propose solutions that are appropriate to the different stakeholders. Indeed, the two categories of stakeholders (both the users and the organizers of the urban space) do not necessarily have the same objectives and visions, so urban logistics will only be sustainable if all the visions have been taken into account (even if everyone is not necessarily satisfied, their vision must at least be taken into consideration and the actions justified, so that each of these stakeholders understands the purpose behind the proposed actions);

– sustainability, in terms of earnings relative to a certain benchmark, must be quantifiable and qualifiable. In other words, it is also important to produce quantitative results to show potential or real gains that explain why and how these gains can be achieved, the limits of the actions proposed, and the action levers necessary to achieve them.

In addition, and as reported in [GON 08] and [VIL 13], a sustainable urban logistics solution is composed of the following six elements:

– *Infrastructures*. Once urban logistics occupy the space of an agglomeration, infrastructures become the central element of any integrated sustainable urban logistics solution. We observe two types of infrastructure [GON 13f]: linear infrastructures, i.e. road, rail and river networks, and nodal infrastructures, i.e. urban logistics spaces. Examples of the first category are preferential road lanes or the development of railway infrastructure for freight transportation (railway and tramway installations), while examples of the second category are: the urban logistics zones or

ULZs, [LIU 12], urban logistics hotels or ULHs [BOU 14], urban consolidation centers or UCCs [ALL 12b, GON 14b], local delivery points or LDPs [GON 13c], delivery areas or urban logistics boxes or ULBs [BOU 06), and Food Hubs [MOR 15, PAL 17], among others.

– *Vehicle and logistics equipment*. Another important component, especially in recent years, is that of physical tools that help improve urban logistics and make it more sustainable. First, we can cite vehicle technologies, mainly related to [FAV 14] vehicle options for improving logistics (such as tail lifts and bi- or tri-temperature vehicles), which allow for a more efficient use of the vehicle as well as a reduction in the pollutant emissions linked to the transport of goods, including the introduction of new modes of transport such as barges [LEN 14], trains and freight trams [ARV 13], or soft modes such as delivery tricycles [RIG 15]. In this category, we also find all the equipment used in the loading and unloading of vehicles as well as the warehouse equipment that can help improve logistics operations [VAN 07].

– *Logistics organization and transport*. This component includes the main actions used in the design, planning and optimization of the system's supply chain. These aspects make it possible to define the main logistic organizational strategies of the system. In this component, we find the design and configuration of the logistics and transport network [CRA 97], the location of logistics platforms [GUY 15], the optimization of fleets, personnel and routes [CAT 15], and the tactical and operational management of transport, among others.

– *Information and communication technologies (ICT)*. This component includes ICT that promotes: data exchange, the real-time monitoring of freight or vehicle tracking, and other transport support operations which can improve effectiveness, and which can be studied and monitored in order to avoid risks and dysfunctions [SAV 98, FAB 07]. According to [FAB 07], these are of three types: technologies for the realization of transactions, communication tools and tracking technologies.

– *Communication and consensus-search actions*. This component includes the actions and means for communicating to potential users of the system, as well as with other stakeholders directly or indirectly involved in the urban logistics system [GON 08]. Here, we find all the communication campaigns aimed at presenting and helping to accept new urban logistic solutions, and also actions in the form of consultations and meetings between various stakeholders with the aim of informing and discussing possible improvements in urban logistics [GON 10c].

– *Funding*. Although the previous components are fundamental to *ensuring* the technical feasibility and acceptability of a sustainable urban logistics solution, this component includes all the tools that allow this solution to be financed and thus become economically viable [GON 10]. In many urban logistics systems, the gains generated by tariffs are insufficient to cover their implementation costs. Normally, subsidies from public authorities and the low-cost use of existing platforms are the most common forms of start-up assistance for an urban logistics project [GON 14f]. The operational costs of these systems may in some cases be covered by income. This is particularly true for systems where the manager is also the logistics stakeholder in charge of real estate.

– *Regulation*. Finally, public authorities may introduce legislation or other forms of regulation to promote the use of the proposed system. These regulations are deployed mainly for environmental reasons [DAB 08]. They may be restrictive [MUÑ 14], limiting access to certain parts of the city and/or applicable at certain time periods, or conversely, based on advantages granted to users [GON 08].

Although all sustainable urban logistics solutions do not necessarily include all of these components, we find them in their totality, at different stages, in most innovative actions that have had continuity over time. For this reason, we propose to articulate that any sustainable urban logistics solution is encompassed by these six components, when studying its sustainability.

3

The Evaluation, Assessment and Analysis of Scenarios as Decision-making Tools

3.1. Assessment and evaluation in urban logistics: a body of work with little unification?

The sustainability assessment and evaluation of urban logistics has been, since its inception, one of the key issues for study and research in the field and one of the fundamental reasons for the success or failure of the different actions and practices implemented [TAN 01, GON 14d]. A rigorous and justified assessment (and evaluation) of a new service or urban logistics system can help to predict its effects on the urban environment, its capacity for profitability, and the overall sustainability of the system. A good example of this is the French Monoprix railroad delivery system in the area surrounding Bercy station. The *ex-ante* assessment of the project as well as its subsequent development revealed an additional total cost of about 15%, an extra cost that was assumed by Samada and Monoprix to be for environmental and image reasons (a description of the Samada–Monoprix case can be read in [DEL 12]). The system, operational from November 2007 to the end of 2016, was one of the main showcases for Monoprix. Nevertheless, the system was terminated at the end of 2016 (when the SNCF[1] contract for the operational management of trains expired), due to concerns about the reliability and regularity of service, which over time had become fundamental to Monoprix, and because a delivery system made of generic fuel vehicles had become

1 *Société National de Chemins de Fer*, the French railway company operating most of the railway lines at the national level.

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prevalent over the rest of Paris. The various evaluations (*ex-ante* or *ex-post*) were used to check the priority criteria for Monoprix in terms of the new strategies to be supported. Similar reasoning led several private UCCs to close or change their function (notably the Sogaris UCC, established in the 1960s, as well as the majority of German experiments, according to [DAB 96, GON 08], respectively).

Before going into the details of the assessment and evaluation approaches for urban logistics, it is important to introduce here what we mean by the assessment and evaluation of sustainable urban logistics. Since the notions of sustainable urban logistics have been defined in the previous chapter, we will present the main definitions for the assessment and evaluation of sustainability that will be used throughout the rest of this book.

According to the French national center for textual and lexical resources, the term "evaluation" can be defined as "*the action of evaluating, appreciating the value (of a thing)*", but also as the "*technique, method of estimation*" [CEN 17]. According to Jean-Baptiste Say [SAY 46], "*in any evaluation, the thing that is evaluated is a given quantity, to which nothing can be changed. [...] The other term of the comparison is variable in its quantity, because the evaluation can be carried more or less high*". In other words, we can define assessment and evaluation[2] as processes by which a phenomenon can be quantified and qualified to measure (and thus appreciate) its value in relation to a particular reference point. It is important to note that without a reference (and/or a referral), it is impossible to carry out an assessment or an evaluation. Moreover, although an assessment/ evaluation can be carried out both quantitatively and qualitatively (we will not enter into philosophical debates which oppose certain quantitative and qualitative trends[3]), the notion of measurement (i.e. the estimated value of a

2 In French, the term "évaluation" is used for both forecasting/*ex-ante* and *ex-post* analyses. For this reason, we will use both assessment and evaluation terms here: the first refers to the process of estimating impacts in an *ex-ante* analysis vision, i.e. from scenarios or future situations that are not already physically developed, and the second refers to measuring impacts (or estimating them from measures and observations) *ex-post*, i.e. from a pilot or real experience.

3 In the author's opinion, the debate on the merits of quantitative over qualitative analyses, and *vice versa*, today achieves very little as the one is as important as the other. For instance, when qualitative analyses are necessary to better understand and measure a phenomenon, the use of quantitative methods is equally necessary. Nevertheless, the debates still persist, hence the need to specify here this personal position.

phenomenon is necessary in order to measure it), albeit not necessarily a fine quantification, requires the definition of a scale of values so as to be able to compare this value with the reference point. In order to decide whether or not the results obtained are satisfactory, objectives to improve the value in relation to that reference should be set. Assessment/evaluation therefore depends on two main factors: the definition of the reference point and the objectives to be achieved, generally linked to the interests of the stakeholder(s) concerned.

The evaluation of a project can take place at different times. *Ex-ante* evaluation (often referred to as an assessment) is used when it takes place upstream to the launch of the project or system, in order to assess the hypothetical situation(s) in which it will be deployed in accordance with the various pre-determined assumptions and choices and in view of the best developments and strategies that might be implemented. Since the system is not yet physically extant, this assessment is based on hypothetical situations, called scenarios, through a simulation or estimation of what these scenarios might be, in both quantitative and qualitative terms.

Operational or routine evaluation is defined as an (often continuous) evaluation conducted at regular intervals throughout the operation of the system (e.g. daily, weekly and monthly), which are then used to describe the everyday health (or other regular interval) of the system in question. These evaluations are commonplace in companies, notably in the form of dashboards and other management control tools [BOU 01]. Here, measurements are executed regularly, and comparisons are often made with respect to the state of the system at the time horizon n-1.

Ex-post evaluation (commonly referred to as evaluation) is carried out after a system has been installed and is already in operation (it may be the outcome of an experiment or a retrospective vision in the medium-long term for the improved operation of a system). In most cases, these evaluations measure the state of the context before implementing the new system, after which the system (before and after) is then compared (we will discuss more on before–after analyses later on), although several intermediate states may also be considered depending on the needs and type of issues.

It remains to be said that given that the evaluation is linked to desirable objectives to be achieved in relation to the initial reference point, the conclusions of those evaluations will vary according to the stakeholders concerned and their interests.

Sustainability evaluations have become a priority in transport [BAN 08, LOP 10] and in logistics [BEL 10, MOR 13]. In urban logistics, sustainability evaluations have generated a large and wide range of works; however, none of those methods have as of yet succeeded in becoming universal or transferable. Indeed, even if some authors advocate their methods as being universal and transferable [HEN 08, FIL 10], they remain to date little used aside from the work of the teams that created them. Moreover, due to the wide variety and heterogeneity, the body of work on the evaluation of sustainable urban logistics suggests that it is difficult to propose a general method that is applicable and transferable to all cases. But are these works really all that different? Is it so hard to find a common field? Can we still not yet define a unified foundation for the evaluation of sustainable urban logistics? To understand this better, it is important to examine the literature to which it relates in greater detail.

This analysis of the literature is difficult because of the heterogeneity of the approaches, and also due to the nature of the channels used for the valorization of works that focus on the evaluation of sustainable urban logistics. Therefore, to our knowledge, there is no systematic and comprehensive literature review on the evaluation of sustainable urban logistics. We propose here an analysis of those works, which is again not intended to be exhaustive, but which nonetheless attempts to identify the predominant visions and methodological approaches for this evaluative goal. Given the complexity and diversity of the body of work in this field, we will be particularly focused on those that propose evaluations and analyses taken from the results of simulations.

It is widely accepted that the first set of works on the evaluation of urban logistics is linked to the first international conference for urban logistics [MIZ 99, OOI 99, TAK 99, VIS 99, WHI 99]. This group of authors mainly proposed simulation methodologies and/or scenario analyses. The indicators they used were mainly logistical (in relation to distances traveled) or environmental - mainly the emissions of greenhouse gases (even though these were derived directly from the first set of indicators). They focused more on the modeling aspects than on the evaluation indicators or the analysis and discussion of the results.

Taniguchi and van der Heijden [TAN 00] and Taniguchi *et al*. [TAN 03] proposed methodologies to evaluate urban logistics initiatives on the basis of dynamic traffic simulations combined with vehicle routing and scheduling optimization, and offered indicators such as total distance traveled, the cost of vehicle routing or greenhouse gas emissions. Similar work on evaluation can be found through the reading of Crainic *et al*. [CRA 04, CRA 12], Qureshi and Hanaoka [QUR 06], and Tamagawa *et al*. [TAM 10]. These are mainly based on the proposal and refinement of models rather than on the impacts themselves. In addition, Hosoya *et al*. [HOS 03] proposed a methodology for the evaluation of urban public transport policies based on a framework of evaluating urban public transport policies [HEN 00]. Using a classical four-step model [ORT 01], these two authors estimated the freight flows, followed by the monetary (operating) costs as well as the NO_x emissions associated with those flows.

Approaches based on the production of data are also present in the literature. For example, Ségalou *et al*. [SÉG 04] proposed an estimate on the environmental impacts of urban logistics by quantifying transport flows taken from various data sources (mainly French Urban Goods Transport surveys, household trip surveys, and databases on construction and waste management logistics) and used a direct emissions model to estimate the greenhouse gas emission rates for several pollutants (including NO_x, SO_x, CO and HC emissions). Other evaluations, based on surveys or measurements, were also proposed to evaluate actual cases, such as the e-commerce delivery systems [ESS 06] or UCCs [MOR 11, VAG 11, TOZ 14]. These assessments were mainly based on direct emissions from transport (i.e. greenhouse gases and other air pollutants).

Behrends *et al*. [BEH 08] discussed the sustainability of urban goods transport from the point of view of transport carriers. The authors proposed a sustainability indicator based on the relationship between the level of CO_2 emissions and GDP, transport intensity, traffic intensity (traffic levels) and technical capacity (ratio of CO_2 emissions as a function of traffic intensity). This point of view was expanded upon by Lindholm [LIN 10] to illustrate the perspective of local authorities. Muñuzuri *et al*. [MUÑ 10] were interested in the ecological footprint of urban logistics. Here, the authors proposed a demand-based model followed by an analytical model to estimate the routes and hence the allocation of traffic, in order to estimate the road occupancy and ecological footprint.

These methods propose indicators based on the distances traveled and do not take into account travel times or certain operational costs, such as investment costs or depreciation. In this regard, Van Duin *et al*. [VAN 08] were the first to present a systematic and generic cost-benefit analysis (CBA) as a method for evaluating urban logistics. The authors simulated through vehicle routing optimization, several medium-termed UCC development scenarios and evaluated these monetary costs in accordance with the CBA. Subsequent scientific work, to our knowledge, does not use the CBA to evaluate the feasibility of urban logistics projects, but have remained predominantly focused on operational costs. Only very recently have works begun to systematize that type of analysis [GON 14, GON 16e, DEL 14]. In addition, other works addressing the operational costs of urban logistics [GON 13d, COM 16] or analyses of margins on variable cost [FAU 15, FAU 16] began to appear.

Further still, there are other works concerned with the definition of sets of indicators and dashboards. Henriot *et al*. [HEN 08] and Patier and Browne [PAT 10] proposed a methodology to evaluate logistics projects, using a definition of five categories (economic, environmental, societal, ergonomic and regulatory), instead of the standard three spheres used to describe sustainable development, identifying more than 30 indicators as a core set of an even larger set of secondary indicators. Nevertheless, their methodology has proven difficult to apply when comparing different solutions and applications, but it is still nonetheless useful for comparing evaluation methods between them [PAT 10]. Melo and Costa [MEL 11] defined a set of approximately 50 indicators, mainly economic and related to the transport of goods. Morana and Gonzalez-Feliu [MOR 15b, MOR 15c] proposed a set of more than 80 indicators, as well as a methodology for building dashboards that used 5 to 10 main indicators and the possibility of secondary indicators.

Finally, a body of works taking into account the Multi-Actor, Multi-Criteria Analysis (MAMCA) nature of urban logistics has been proposed [MAC 14, GON 13f]. This work makes it possible to define priorities of the criteria that take into account their importance, with the aim of guiding the search for unification; however, the definition of these criteria and their quantification (or qualification) must be carried out beforehand (upstream of the launch) if those methods are to be used.

We note that there is currently no standardized or unified method for the evaluation of sustainable urban logistics schemes and solutions, and that currently the definition of a "one-size-fits-all" methodology seems difficult to attain. In addition, the fact that the main approaches for the evaluation of sustainable urban logistics are of paramount importance to the environmental and economic aspects is not often emphasized. Nevertheless, the idea that the systematization and unification of the methodology (or general procedure) for evaluation can be realized is a vision that is gaining traction and is already shared by several authors worldwide [GON 17a].

In this context, the works presented in Chapter 8 will complement the existing literature on three main points:

– the proposal of methods for carrying out economic analyses for the deployment of sustainable urban logistics solutions as well as those defining their feasibility and sustainability conditions;

– the development of methods for estimating direct and indirect environmental impacts;

– the introduction of questions on the relationship between freight transport and territorial development. This is a primary contribution for the definition of both economic and social indicators to be used in the evaluation of urban logistics: more precisely, we define two main types of accessibility indicators specific to the transport of goods and urban logistics.

3.2. The role of scenario construction in assessments and evaluations

In an evaluation, at least two situations are compared. Those situations must therefore be defined and characterized. We will talk here, and in the rest of the book, of scenarios (representing either real or hypothetical situations). To this end, we observe in the literature four main categories of scenarios that can be constructed:

– *current or real scenarios*, which may represent either a common case or a past case, but on which information exists to reconstruct it [LEO 12]. We can construct these scenarios either empirically through field work and data collection or by using models that replicate missing data;

– *business as usual forecastings*, which are obtained by projecting current trends into the future [NUZ 14]. It is necessary to define and quantify these trends in order to be able to carry out these projections;

– *realistic but fictitious scenarios*, which come about from the application of models (or methods, such as those presented in Chapters 4–6) and which require the definition of working hypotheses [DUR 10];

– *contrasted or limit scenarios*, which, contrary to realistic scenarios, are the result of strong but unrealistic assumptions, which are generally used to study the limitations of different trends [GON 09].

As to the question of which type of scenario(s) to simulate in an evaluation, it is necessary to add the type of analysis to be carried out. Five main types of analysis are identified in the literature:

– *before–after assessments*. These compare an initial situation, where the new system is not yet implemented, with a final situation where this system is already deployed and operational [GON 17]. Although generally applied to *ex-post* evaluation [LEO 12], these principles are nonetheless applicable to *ex-ante* evaluation. In such cases, the comparison is made between a simulated scenario and the baseline situation or scenario;

– *comparison of contrasting alternatives*. Another possibility is to compare different alternatives without defining an initial situation [GON 09, MAC 14]. These alternatives are different (the one does not come from a variation of the previous one), and the initial situation cannot be defined or is not relevant. For example, when the objective is to find the most appropriate alternative from a set of given solutions, regardless of the initial situation;

– *incremental analyses*. These result from the comparison of several situations, each obtained from the last one, and is achieved by modifying the parameters or input data incrementally [DUR 12]. In this category we can find cost-benefit analyses of variable cost margins [FAU 15, FAU 16], and sensitivity analyses of estimation models [GON 12i, VAN 08, GON 13a], among others;

– *combined analyses*. These combine the construction logic of both incremental and contrast scenarios, and can be used to generate scenario comparisons both with each other and with a baseline scenario [GON 12h]. They are generally designed to test the impacts of unique actions or features, and then to identify the scale effects or synergies between different solutions and actions [BAT 14];

– *backcasting assessments* [LOP 10, GON 12d]. These are mainly used in the assessment of long-term issues. First, several future configurations are tested to determine a set of appropriate scenarios, and then these are examined retrospectively, from the future to the present, in terms of how these scenarios can best be met (at what cost and at which point in time it is best to implement them). The most appropriate scenario in terms of evolution can, in this way, then be selected.

In all these analyses, a comparison is made between two or more situations. Therefore, we can treat all of these analyses as if they were before–after comparisons, stating a given scenario (usually the reference point) as scenario 0, or as “before”, and all the others as possible scenarios (1, 2, 3, etc.) as “after”. For this reason, it is important to introduce the key notions involved in a before–after analysis.

3.3. Before–after assessments

Before–after assessments and analyses are widely used in experimental research, principally in medicine [MOH 01, MIC 06], psychology/psychiatry [MOR 00], sociology and anthropology [SHA 02], among others. In transportation, they were first proposed for the study of safety issues [HAU 97]. This methodology is often used in experiments or quasi-experiments and is found in the logic underpinning the evaluation or identification of change [GRI 97].

In urban logistics, although widely used for evaluations, methodology has classically not been seen as important (few authors explain its use when comparing two temporally different situations), and it was not until the work of Leonardi *et al*. [LEO 12] that the terminology became widely used.

In urban logistics, experimental before–after comparisons often make use of this methodological framework [VAG 11, ALL 12b, LEO 12]. Nevertheless, it is possible to carry out before–after analyses on a simulation/assessment basis. In this case, instead of obtaining results through measurements or surveys, we replicate them through simulations or other types of estimation. For this reason, it seems important to define a unified framework for carrying out before–after analyses in urban logistics.

Before–after analyses aim to identify the impacts of a change on the existing urban logistics system (or reference scenario). That change results in a differential gain or loss relative to that reference point. This type of analysis is then based on an estimation of two states for the same system:

– state 0, the "before", reproduces either the current situation or a reference situation, or in some retrospective studies, a past situation to which we can compare the current situation. It represents the state of the system prior to the application of a specific modification;

– state 1, the "after", reproduces the state of the system after the application of a modification. It generally represents the situation after the application and deployment of a proposed urban logistics solution, but in some cases, it can describe a current situation that is compared to either a certain reference point or a past situation.

In order to estimate the two situations, it is important to quantify them (Figure 3.1). For that purpose, the various techniques presented in section 3.2 above can be used, both for the initial situation as well as for the final situation, in order to construct the two scenarios being assessed. In order to do this, it is important that the two scenarios are constructed on the same basis, in order to ensure comparability between the before and the after simulations. For this to be effective, in addition to being built on the same basis, it is important that the methodology to estimate the impacts are the same for both scenarios, and sourced from identifiable, verifiable and comparable bases and assumptions taken from other simulations. In other words, the proposed methodology for assessing the sustainability of urban logistics must be easily understandable for both scientific and practice communities, with the inherent assumptions made easily identifiable, in order for consistency to be demonstrated.

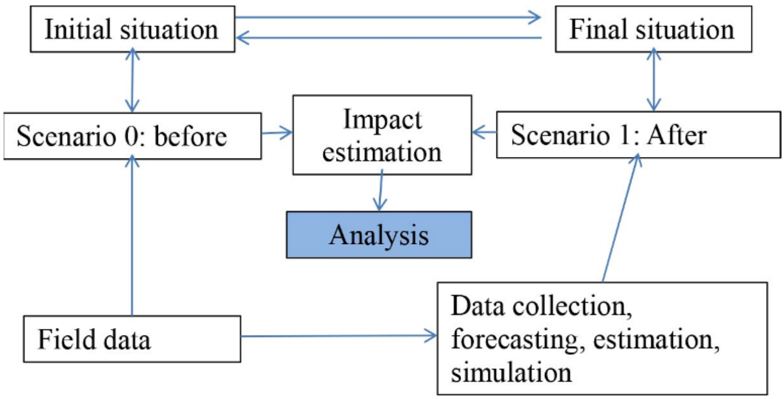

Figure 3.1. *Representation of a generalized methodology for a before–after analysis [GON 17]*

The general methodology of the before–after analysis can thus be described as follows [GON 17a]:

– construction of the initial scenario. For this, it is important to define the objectives of the analysis, as well as the input data and the assumptions necessary for the construction of the scenario;

– construction of the final scenario. For this scenario, we will take into account the same considerations as those for the initial scenario;

– quantification of the scenario transport flows. In the case of an *ex-post* analysis, this quantification is done by analyzing (or even reconstructing where necessary) the data collected for the two states (initial and final). For an *ex-ante* before–after analysis, this quantification is done through modeling or simulation: estimating demand, estimating transport flows, and from these, the distances and travel times (Chapters 4 and 5);

– sustainability evaluation of both scenarios, or the changes between them (the main indicators and the proposed evaluation methodological techniques will be presented in Chapters 7 and 8);

– comparison of the two scenarios, analysis and proposals. After analyzing the impacts, it is important to analyze, interpret and comment on these results so as to identify the various elements used to quantify and qualify the four capacities of sustainable urban logistics.

It is important to note that for the comparison of two situations, two main types of approaches can be used: the first consists of quantifying all the flows of the initial scenario and then those of the final scenario (in both cases, all the flows are estimated). These scenarios are then compared; the alternative is to identify the significant changes (or those upon which the analysis will be carried out), which imply the estimation of these changes, but not of all the flows. If we want to know the magnitude of these changes, a quantification of the initial scenario is necessary, however, for instances where the flows do not change, that quantification can be done in an aggregated, less precise way which will not require redoing for the final scenario. In this book, we propose to follow this second method.

To do this, we will present the main aspects for the construction of scenarios followed by a general methodology for estimating this change and the subsequent post-evaluation of its sustainability.

3.4. Proposal of a methodological framework for the assessment and evaluation of the impacts of sustainable urban logistics

This section presents a proposal of a methodological framework for estimating the impacts of actions and solutions of sustainable urban logistics. It does not seek to be a unique, "one-size-fits-all" framework, but it allows, through its desire for transferability and versatility, for the proposal of a methodological approach that is compatible with most existing methods, which allows it to be put into context and thus made comparable with other methods and results whose estimation methodology is known. Indeed, this framework provides guidance for the estimation of scenarios and refers to existing methods and techniques (some of which will be specified later), the relevance and precision of which are known and quantifiable. Therefore, if two methods are different (for example, in a case where the urban freight transport flow estimates for two different cities are known), and where the differences between the method and those provided by the context are identifiable; the estimation can then be compared (taking into account, of course, the accuracy and possible errors incurred by these methods). For example, different night delivery trials were conducted in North and South America, but since they followed the same methodological framework, it was possible to estimate the homogeneous and comparable flows (and thus the impacts), showing that the impacts in the United States and Brazil were more significant than those in Colombia [HOL 16]. A qualitative analysis of these three cases showed that the activities concerned were different: retail businesses in the United States and Brazil against warehouses, wholesale and supermarkets in Colombia, which were characterized by better optimized transport systems.

The first rule for a homogeneous estimate is to assess the initial situation and the final situation in a homogeneous manner, i.e. by using the same methods and the same assumptions. In order for an assessment of change to proceed, we first seek to identify and then model the fundamental changes of a simulated urban logistics system in parallel with the initial situation (one that is not undergoing the changes that are being implemented).

The second rule relates to all modeling, and is the representation of a reality that is relevant and consistent with the objective set. It is important to emphasize that relevance and consistency is relative and depends not only on the objectives of the assessment but also on the available data, the expected accuracy of the results, and the ability of the stakeholders involved to interpret these results.

To this end, when a model or a method is developed, it will be important to validate these, not only through statistical, mathematical or computational terms (i.e. with respect to the theoretical approximation of the data or to the computational performance of the resulting tool), but also (and this requires interpretation or even a complementary qualitative analysis) the model’s ability to account for the reality it aims to represent as per the aspirations of the modeler as well as its users. This principle (called “solution probleming” and first formulated by Ackoff in [ACK 77]) is important as it makes any model consistent with its context. For example, although an algorithm for a vehicle route construction that seeks the theoretical optimum will be useful for business optimization, in reality it may fail to guide the vehicle schedule (in some cases, because certain “optimal” solutions are difficult for drivers to accept). If the objective is to estimate a change, a method that maintains the consistency and fairness of an error (i.e. the estimation error with respect to the measured reality will be of the same nature and magnitude for any simulation) will remain a relevant and valid method. A method that carries out a very detailed estimation but which requires large aggregations to convert these estimates into distances and impacts, thereby losing much of this detail, deserves to be confronted by a method that achieves a homogeneous estimate (i.e. one that ensures that the level of detail does not change between estimates).

In order to estimate the changes between two situations, it will be important to identify the main variables and phenomena that are expected to change and then carry out an analysis to model these changes. Those analyses may be different in nature, linked to measurements (experiments) or simulations. Here again, a consistency in the modeling of change with the context is necessary to ensure the homogeneity of the overall approach.

Finally, the estimation of impacts must be done using identifiable methods that are recognized by the different communities involved, if the results are to be comparable. To do this, it is necessary to propose a scale for the indicators and measures in order for the two scenarios to be compared in terms of the impacts they cause. This set of ideas leads to the definition of a unified framework for the estimation of the impacts of sustainable urban logistics, not to a unique method of evaluation which, as we have seen, cannot be envisaged. Given the fact that each context sometimes needs to address various specific elements, the important thing is not to have a single method (or a single software), but rather to make estimates that are homogeneous and comparable, thereby empowering the stakeholders involved with a certain degree of freedom to choose the impacts that they wish to be assessed, as per their objectives. Nevertheless, these impacts focus predominantly on distance traveled and the amount of time spent standing still (among others), hence the interest in creating flow estimates using relevant but transferable and reproducible methods [GON 17a]. We will see in Chapters 7 and 8 that the main indicators to measure the impacts of urban logistics and the main types of analyses can be carried out respective of the other.

Based on these considerations, we propose a possible sequence for the estimation of the impacts. It is in the form of a generic framework organized according to the following stages:

– definition of the initial situation (input data). The definition of an initial situation, if any, is based on actual data. In general, it is important to define the necessary input data prior to the simulation in order to collect and produce the information required for the various evaluations. In order to achieve this, it is important to define the variables used in the flow estimation models (see the third stage below), taking into account the available data and the different modes of data production;

– definition of the scenarios to be assessed. Similar to the definition of the initial situation, the different scenarios need to be defined. This usually insinuates that several previous assumptions and estimates have been made (mainly related to the variables used in the flow estimation models and the parameters used in the impact estimation methods);

– estimation of flows (for each scenario). Once the scenarios have been characterized, a flow estimate must be prepared. We believe that the estimation of flows should be as complete as possible, even if its accuracy is not always guaranteed, as this will give an overall idea as to the significance of the transport systems being considered in relation to the general urban freight transport currently in place. To do this, the main stages of flow estimation can be divided as follows:

- demand generation: for each zone (or establishment, or group of households, if any), a particular number of journeys are assigned. This is done for each sub-category of inter-establishments, end-consumer and urban management flows, respectively. The generation function is generally linked to demographic variables (relative to the population), socio-economic variables (linked to economic activities) and possibly to geographical variables (end-user and urban management flows, as well as collective housing zones that may have different influences on the modes of production pertaining to the transportation of goods);

- route construction: all flows can be represented by itineraries. In order to do this, it is important to first define the origin of the route (the depot for a delivery route, a household or a workplace for a shopping chain, and a depot or technical location central to several urban management flows). To achieve this, different approaches can be used: catchment area models, discrete choice models, O-D estimation approaches, etc. These routes can then be defined either by empirical statistical approaches or through the optimization of vehicle routes;

– calculation/computation of distance and time: these are based on the results of estimated road distances (directly) and the times taken (indirectly, on average, by the distances traveled on the different roads and streets of the urban area), and can also be estimated. It is also possible to estimate the number of vehicles and possibly the number of drivers. These basic indicators are needed for the next step;

– estimation of impacts[4] (for each scenario):

- at the economic level, several indicators can be estimated, such as net margins, operational costs and overall costs (in terms of the investment costs per route);

- at the environmental level, two main approaches can be considered: direct emission estimates (CO_2, NO_x, SO_x, VOC, PM10, etc.), or a lifecycle analysis that includes these emissions (for all phases of construction, of use and the end-of-life of vehicles, of infrastructure and buildings), and also several indirect impacts, such as metal depletion, and soil and water pollution;

- at the social level, congestion can be a good indicator. It should be noted that in urban freight transport, both moving and parked vehicles contribute to congestion. Congestion caused by vehicles in traffic, expressed in km.CEU (car equivalent unit), and congestion caused by vehicles at a standstill (e.g. in minutes.CEU or in hours.CEU). However, since distances can be converted to time, an adequate congestion indicator can be one that combines both types of congestion and expresses this as a homogeneous unit (in time, e.g. in minutes.CEU or in hours.CEU);

– scenario assessment and analysis. Given the type of scenarios and the analyses to be carried out, scenarios are comparable on the basis that the indicators have been identified, as have the implications for the management of the decisions and the identified practices. Several methods, such as cost-benefit analysis, conventional multi-criteria stakeholders, remote decision-making methods or Multi-Actor, Multi-Criteria Analysis (MAMCA), can be used in this phase when several criteria and/or stakeholders are taken into consideration.

4 Dashboards and indicators to estimate those impacts are presented in more detail in Chapters 7 and 8.

In order to apply this methodological framework, tools, methods and techniques are needed. We present the main models and methods of flow estimation in the following two chapters (Chapters 4 and 5). Following on from that, Chapter 6 will go into some detail with regard to the estimation of change. Finally, the characteristics shaping the indicators (the choice of good synthesis grids, the calculation of indicators and the relationship between impacts and flows) used in the evaluation of sustainability of urban logistics will be presented in Chapters 7 and 8.

4

Estimating Inter-establishment Flows

4.1. Data collection and modeling: close links but not homogeneous

Inter-establishment flow estimates, i.e. flows for the delivery and pickup of goods to and from various establishments in the city (also known as B2B or business-to-business flows), are one of the fundamental points for the estimation and simulation as well as the diagnosis of existing urban freight transport scenarios. Although those flows can be estimated from surveys, the lack of standardization in data collection, due to the enormous amount of resources that would be needed to do so, means that public and private stakeholders have to look at other possible solutions, such as deployment models and simulators or the use of commercial dashboards or software capable of running these diagnostics and simulations. And yet in France, the conventional belief is that only one or two possibilities exist[1]. This of course is in stark contrast with a plethora of methods, techniques and operational tools[2] being developed and used worldwide. In addition, it was recently observed at the third Freight Transport Conference hosted by the Volvo Foundation for Research and Education (VREF) that the traditional belief that there is no standard for the estimation of urban freight transport

1 This is primarily the FRETURB model [AUB 99] and the CERTU method [CER 13].

2 The Omnitrans, VENUS and VISUM (which, in addition to the Wiver/Viseva model, are currently studying the integration of "City Goods" as a module) and Tranus software offer modules for commercial and/or freight transport. In addition, several research tools are available free of charge (such as the FTG generator by Holguin-Veras *et al*. [HOL 11, HOL 13]).

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flows is gradually being offset with the view that a unified methodological principle has emerged. In particular, this is due to the parallel applications of the methodological principles of Holguin-Veras *et al*. [HOL 11, HOL 13] by a dozen research groups worldwide, and which have been applied to more than 30 cities of different origins, sizes and cultures, in countries with different geographical prospects [ALH 14, GON 14a, ADI 16, SAN 16, DEO 17].

Hence, it appears important that this methodology is adopted, expanded upon, and adapted to the French context. That does not in any way exclude the use of French methods, which of course have their own validity and scope for use in many cases[3], but that opens the possibility for the stakeholders of the urban logistics to deploy different methods, according to their resources and their stakes, and to adapt the most relevant techniques to the context and the needs they have. Moreover, this chapter also claims to open the debate to the collection and production of data by adopting a philosophy and a vision different from that traditional to urban logistics in France. Indeed, in the traditional view where data must first be collected, in large quantities and in detail, without which nothing is possible, this chapter and the book in general presents a contrary vision (very widespread in other countries, such as the United States, Japan, the Netherlands, Northern Europe or South America, among others) where the model, and therefore its quality, depends on available resources. That makes it possible to provide a solution, an estimate, taken from a few resources, of course of inferior quality, but at a time when this model can meet the user's needs and challenges and provide decision-making support that validates the model [ACK 77]. That is the principle of the solution probleming, i.e. how to relate the model to reality in order to estimate its relevance and its applicability, and which will be the subject of Chapter 6. This principle pays particular attention to data and methods of production.

3 The vision followed here is to problematize the use of a tool or a method (see Chapter 6) and to choose, according to the objectives used for the scenario simulations, the tool or the approach that is best suited to the task. It is evident that the French methods, which have been developed to support the creation and redesign of UTPs (Urban Transport Plans), are well adapted to these uses, but nevertheless have limitations when used for other applications [GON 14b]. Any model or approach will have favorable conditions of use and limitations.

Chapter 1 gave an overview on the variety and heterogeneity of approaches to data production in urban logistics, emphasizing the difficulty of unifying and proposing standards. Nevertheless, and even though it is very recent, the urban logistics research community is beginning to converge towards common practices, which are also being applied across several cities around the world. Those practices, stemming from the generalization of methods for freight trip generation, suggested by Holguin-Veras *et al.* [HOL 11, HOL 13], have been systematically disseminated and applied in several contexts in 2015 and 2016. That also seems linked to the founding work of Holguin-Veras and Jaller [HOL 14a] on the relationship between data collection and modeling. The authors provide an overview of data collection, not descriptively and inventorially (as done in other works already in existence and necessary to assess the state of play in this field: [AMB 04, ALL 12, ALL 14a, GON 13e]), but analytically in line with an applied vision.

The authors established their analysis from different sources (more focused on the large American city than medium-sized European cities) and linked the basic information needed to estimate the flow of goods (deliveries/collections or the quantities of goods) with the stakeholders involved. We propose to extend that table by linking it to the different users of space (see the categorization of stakeholders in Chapter 2), after having verified (from telephone interviews of French stakeholders conducted from September 2016 to February 2017) that the needs and data required to estimate the flow of goods are similar, regardless of the context, culture and size of the city (although numerical results may vary, the needs and types of data are homogeneous).

As summarized in Table 4.1, and because of the multiple stakeholders, infrastructures and practices, no stakeholder is in a position to provide a complete picture of the inter-establishment freight transport system. That leads to a situation in which the assembly of a coherent description of the whole requires gathering information from several sources, i.e. agents who know only the aspects of their own operations, and even then sometimes incompletely. Expeditioners and receivers of goods generally know the characteristics of the cargo that they receive or ship. However, they do not have a global view of what is happening upstream or downstream of their location. In other words, surveys provide them with a clear idea of what happens within their localization, but little about the macro organization of transport routes.

Transport carriers are familiar with the details of their own operations, including which journeys are loaded and which are not, but often do not know all the attributes of the cargo being transported. They know who they are delivering to, but they do not always have the complete information about the origin and/or end destination (type of stakeholders and characteristics, the total number of deliveries/shipments in which they play a part), or the entire distribution chain of that cargo. Transport organizers sometimes have a general idea of the distribution chain and/or the share, more or less, of its urban distribution, but do not have details on the type or nature of the goods or their value.

Data necessary for the estimation of inter-establishment flows	Shippers	Transporters (a)	Warehouses, consolidation platforms	Recipients	Commissionaires, transport organizers (b)
Quantity of goods (in handling units)	Yes (1)	Yes (1)	Yes (1)	Yes (2)	Not always (1)
Quantity of goods (by weight)	Yes (1)	Not always	Yes (1)	Not always	Yes (1)
Quantity of goods (by volume)	Not always	Not always	Not always	No	Not always
Number and frequency of deliveries/collections	Yes (1)	Yes (1)	Yes (1)	Yes (2)	Not always
Number of trips with a load	Yes (1)	Yes (1)	Yes (1)	Not always	Yes (1)
Number of trips empty	No	Yes (1)	No	No	Not always
Organization of trip routes	No	Yes	No	No	Not always
Type of freight	Yes (1)	Not always	Yes (1)	Yes (2)	Not always
Value of goods	Yes (1)	Not always	Not always	Yes (2)	Not always
Delivery practices	Yes (1)	Yes (1)	Yes (1)	Yes (2)	Not always
Use of urban space/parking	Not always (1)	Yes (1)	Not always	Not always	No

Notes: (a) stakeholders directly involved in transport (transport professionals who literally carry out transport on the behalf of third parties, shippers and recipients on their own account), (b) stakeholders who contract transport but who do not carry it out themselves, i.e. the stakeholder who subcontracts to other transport professionals.

(1): for the freight they process. (2): for all the freight they receive.

Table 4.1. *Types of data needed to estimate freight flows (adapted from [HOL 14a])*

Urban space organizers, for their part, have a more systemic vision of the urban transport system, which is nevertheless still partial. Indeed, although some organizations, such as community travel services, urban planning agencies and (where they exist) local urban logistics services, all produce the data necessary to create knowledge on inter-establishment flows, most of these data are related to traffic counts and small surveys which focus on parking and delivery practices [GON 13c]. However, the details of those operations are only known to the players involved in their process. A first attempt in France, the French Urban Goods surveys, gave a general picture, but that is still partial (several fields of the survey had a very low response rate and/or a limited level of statistical reliability) and the results of those surveys have a similar level of utility as other surveys (certainly, different in nature) carried out in other countries, be they more detailed or simpler. Moreover, when some of those stakeholders carry out specialized surveys themselves (such as the chamber of commerce, or consulting firms and other technical stakeholders), access to data is not always available externally.

This overview shows that apparently the task of defining inter-establishment freight transport systems is a difficult one. This is mainly due to the fact that there are many aspects which must be taken into account when designing a data-based framework with the objective of estimating freight demand. Moreover, and given the sometimes high costs of surveys used to collect this information [HOL 14a], it is often desirable to estimate these data sets using alternative models and techniques. Nevertheless, it is important to maintain consistency throughout the estimation if the simulations are to be comparable with one another and, if necessary, with other contexts (for example, other cities that have already realized similar estimates so as to obtain a basis for comparison at the national level).

To that end, it is common to use models, generated from existing data or collected as and when required. By the term "model", we mean here a representation of reality as seen by the modeler. In other words, although a model is always a representation of a reality, a model in that sense is the specific reality observed by the person who creates it, and as such that representation can never be purely objective or detached from any context [ACK 77]: thus, the model is the reality of the modeler and not an absolute truth. This maxim is important for understanding the rest of this book as it is the basis of all the modeling and estimation methods and techniques proposed here. In other words, a model depends on the modeler's objectives, his vision of reality and his ability to represent it.

For that, a model representing inter-establishment flows can be defined with the set of elements defined in [GON 12b, HOL 14a]. These two works present small differences, but their discourse is nonetheless very similar, hence why we propose to define these elements through a synthesis of these two works. The main elements that characterize a model are as follows:

– the objective of the model;

– the units used by the model;

– the geographical scope and function of the assessment;

– the methodological approach;

– the modeling techniques.

The objective of the model is defined as the ultimate use of the model once it is operational. The objectives differ according to the end-user (some will require a model for general diagnostics, others for vehicle fleet optimization, aggregated assessments or to study small scale phenomena, etc.), so there can be no universal model that is 100% applicable to any one use. Nevertheless, we can distinguish several leading categories for the uses of these models:

– the diagnostics of the demand for urban freight transport;

– the simulation of scenarios;

– the estimation of parking requirements;

– the simulation of traffic;

– the optimization and management of vehicle fleets.

In terms of units, given the fact that every model uses data, that data must be linked to a functional unit (the unit that allows the model to function and generate estimates). Although often confused, the functional unit (i.e. the one that the model uses when operational) and the modeling unit (i.e. the unit used to construct the model) can sometimes differ, if only at the level of data aggregation (i.e. a very disaggregated construction of the model followed by an aggregation/simplification of the calculations in the operational version of the model). In addition to that is the data collection unit, i.e. the unit that was used as a basis for defining the statistical individuals in the surveys and the data collection protocols which will then be used to first construct the model. For example, French Urban Goods surveys defined the establishment as a statistical unit for data collection and the loading and unloading operation as a modeling unit. We observe in the literature five main units: the vehicle, the trip chain, the transport, the delivery and collection, and the delivery operation and the quantity of goods.

The geographic scope of assessment refers to the spatial area covered by the model. Models are generally linked to a particular zone, i.e. a set of zones, which cover a more or less restricted territory. The spatial scale can be microscopic (one establishment and one street), mesoscopic[4] (a neighborhood, a district and a municipality) or a macroscopic one (the urban area or urban community). The functional scope refers to the activities and subcategories of flows that the model considers. The first models focused on commercial or industrial activities [DEM 74, WAT 75, MAE 79] and several models still have this restriction (as [TAN 01, RUS 10], among others). Other models consider all activities in a given area, but are limited to flows made on the behalf of others. The broadest view is that which includes, for all activities, all of the flows, whether they are carried out on behalf of others or in a personal capacity (for more details on the different types of flows and their definitions, refer to Chapter 2).

By the term "methodological approach", we mean the way in which knowledge is assembled in order to define the model, i.e. the way in which the represented reality and its representation are linked. In other words, the methodological approach is the meta-procedure by which the modeler moves from the observed phenomenon to its representation. The most commonly used is the deductive approach (almost all models are the result of this approach). In this approach, representation choices are made *a priori* and follow a deterministic logic and characterized by a lack of statistical justification for the choices made. In other words, the modeler applies pre-established logic to existing data (or collected *ad hoc*), and the methodological approach consists of validating (or invalidating) the strong hypothesis based on the type of representation used. Typical examples of this approach are constant generation frameworks [BON 14], gravity models, or the well-known four-stage transport models [ORT 01].

4 The mesoscopic level is halfway between the macroscopic and the microscopic and can integrate elements from both approaches [CAS 09].

Several works question the most representative deductive models, such as the four-step model, which is deemed unsuitable for modeling the demand for urban logistics [GEN 13]. Nevertheless, those works mostly used for the demand modeling of inter-establishment flows are either purely deductive or want to go beyond this stage, but nevertheless return in one of the first steps of their methodologies to an explicitly deterministic hypothesis of the deductive approach [GON 12b, GON 14f].

An alternative to those models can therefore be offered if we propose approaches that are not purely deductive. For example, in other disciplines, the inductive approach is predominant or in any case very widespread [ASP 92]. It is therefore possible to apply these methods to the demand modeling of urban logistics. Nevertheless, this approach (which is mainly probabilistic) may have limitations regarding the requirement of large quantities of data, and also the difficulty of generating conclusions for the factors and logic behind choices that are not supported by statistics. In this context, a third option could be adopted: the abductive approach. That would be less burdensome to put in place than inductive models, and yet retains the need to make justifications based on observations (and hence without the need to make strong and deterministic assumptions as in deductive models).

At present, the abductive approach is not only unknown in urban logistics, but also unknown to demand modeling. Given that context, it appears that this would be an interesting way to further explore this approach, and to propose it as a complement to the categorical models for a standardized modeling approach. The beginnings of this process are promising [GON 16b, SAN 16a], however, this work is still only in the initial stages.

As far as modeling techniques are concerned, these can be different in nature and origins. Nevertheless, the various models combine those techniques using identifiable and categorizable methodologies. Indeed, we observe five methodological approaches for models that estimate inter-establishment flows.

The first category is that of *single-generation models*, which produce a number of movements (or a quantity of goods) destined (and/or originating) at an establishment or zone. This modeling paradigm emerged in the 1970s, with the aim of characterizing the demand for freight transport, the dimensioning of infrastructures, and promoting the economic development of commercial areas [DEM 74, MEY 74, LOE 76], in addition to zones for services or construction activities, among others [MAE 79]. Those models were based on the assumption of the constant generation of the employee [SLA 76, HOL 12], i.e. for each establishment, the number of trips is obtained by multiplying the number of employees by a constant obtained by averaging the trips per employee. Recently, these approaches have once again become popular with new categorical models, i.e. generation functions that are not always based on constant generation, but depend on the category of the establishment concerned [HOL 14, HOL 16, DEO 14, JAL 15, ADI 16, GON 16, SAN 16, SAN 16a, DEO 17].

The second category is the *four-stage model*, which is generally described as follows:

– generation: for each establishment (or zone), the number of trips corresponding to attraction (delivery) and production (pickup) are totaled;

– distribution: for each origin and destination pairing, the number of trips are totaled;

– modal choice: for each trip, a mode of transport is identified;

– traffic assignment: the number of trips between each origin and each destination is associated with a specific mode of transport, after which that route within the transport network (mainly road) is calculated.

Those models are mainly used for passenger transport and inter-urban freight transport, where they are considered to be the standard [ORT 01]. Nevertheless, this paradigm seems to be unsuitable for urban freight transport [GEN 13] due to the diversity of inter-establishment flows and modes of organization, where vehicle routes (of different natures and with different modes for management) are predominant in relation to full truck load (FTL) transportation. To this end, several authors have developed other models, derived from the paradigm of the model, but adapting it to the nature of the routes so that they become suitable for the modeling needs of urban freight transport. As a result, we observe two subgroups among the four-step model:

– the classical four-step models, which result from the direct application of the four steps of the model, i.e.:

- generation;

- distribution;

- choice of truck, instead of mode of transport;

- traffic assignment.

These models stem from the need to include freight in traffic simulations and thus to produce freight Origin – Destination (O–D) matrices [WAT 75, SLA 76, OGD 92, ERI 97, MIN 96, DES 00, JAN 05];

– the adapted four-step models are those that propose to adapt the classical model to account for the nature of urban freight transport routes. The main stages of these models remain four in number, and described as follows:

- the generation of the TMV request (number of trips or quantity of goods);

- the distribution of these requests to produce a freight O–D matrix (i.e. the linking of the freight destination with the point at which they were dispatched, which has not yet been consolidated into the schedule);

- conception of delivery rounds with a subsequent estimation of a vehicle O–D matrix;

- the allocation of traffic predicted by the model (a few examples of these approaches can be found in [BOE 99, RUS 10, NUZ 11, NUZ 14, WIS 06]).

Whatever the subcategory of model, the generation stage is mainly based on econometric approaches [BOE 99] or categorical methods, the same as those defined in the first category of models presented above. The second stage is mainly carried out using gravity models [OGD 78, D'ES 01] or maximization of entropy [WAN 08, HOL 10, SAN 14]. The choice of vehicle (subcategory 1) or the routes (subcategory 2) can be done through discrete choice methods [HUN 07, RUS 10, NUZ 11]. Routes are generally estimated via the methods that optimize routes [BOE 99], use empirical procedures for discrete choice methods [HUN 07, NUZ 11] or multi-agent simulation methods [WIS 03]. Finally, traffic allocation can be achieved using traditional traffic simulation methods [WIS 06].

The third category is the *direct generation models for estimating Origin/Destination matrices* (also called O–D synthesis models). These models do not distinguish the generation and distribution stages, i.e. those that directly generate the O–D matrices from a database of vehicle movements [LIS 94, HOL 08, MUÑ 09, MUÑ 11]. They generally use databases that are mainly derived from tallies and generate O–D matrices based on the methodology proposed by Cascetta [CAS 84]. Although less accurate than other models, they remain valuable tools for estimating traffic in well-defined areas to give a diagnosis when only tallied data are available.

The fourth category is that of the direct *generation models for estimating distances traveled*, without an explicit construction of transport routes. These are organized into three stages:

– the generation of demand: as a general rule, the number of deliveries resulting from a constant generation approach [AUB 99, GUE 14];

– the definition of the types and characteristics of routes [GON 14a, GON 14b, CAT 17];

– for each delivery, assignment to a type of transport route and followed by an estimation of the distances traveled [ROU 10, GON 14f].

These models generally follow empirical procedures, without using standard distribution models, but rather by using descriptive statistics based on a detailed analysis of the data [AUB 99, GON 14k].

To those four categories, several authors add a fifth, called “mixed” [COM 12, GON 12b, BON 14, NUZ 14] because they identify a set of models in the category, which could combine different approaches to those presented here. Four models are considered in this category:

– Ogden’s transport/freight approach [OGD 78];

– Wiver’s model [SON 85];

– the works of Holguin-Veras *et al.* [HOL 10] modeling in an integrated and analytical manner both freight transport (with a four-step model based on transport chains) and those of empty vehicles (by complementing these chains with a model inspired by Holguin-Veras and Torson [HOL 03]);

– the “City Goods” model [GEN 13].

However, by exploring these models well and considering only the modeling paradigm, we observe that these models have a four-step basis, which remains the predominant vision for model construction. We can therefore assimilate these models in fact as four-step models, considering one to be classical [OGD 78] and the other three as adapted.

4.2. Methodological proposal

We have seen that approaches to data collection and modeling are different. Nevertheless, we observe several dominant approaches, which are now well disseminated internationally. Although the techniques differ and the concrete real models are often specific to a particular field of application, most of the models presented in the previous section have common denominators:

– they leave (with the sole exception of models for direct estimation of O–D matrices) a generation of demand, i.e. freight transport needs;

– they construct (with different techniques) paths (spatialized or not), whether in transport routes or direct transport;

– they estimate distances traveled.

In the generation of demand (whether in terms of the quantity of goods or in the number of trips or deliveries), a methodological framework has now become widespread [HOL 11, HOL 13], which shall be presented and finalized in this section. For the estimation of the paths, as referred to in the previous section, the majority of models start with an estimation of origin–destination matrices and then define paths, either from a typology of behaviors (often using choice models to assign these behaviors to different O–D pairs) or by using procedures for the construction of transport routes (e.g. operational research methods). As far as the estimation of distances is concerned, this is derived from the formation of these routes and their main characteristics. A category of models nevertheless proposes a categorization of the routes so as to generate a direct estimation of the distances, thereby eliminating the need for an O–D estimation of the matrices. These models are very useful for a general diagnosis (or an overall estimate of the distances in the case of scenario assessment, see [GON 14b]) but are not adapted to the often necessary traffic assignment typical of estimates and simulations at the mesoscopic scale [GON 14k]. For that reason, vehicle (and non-freight) O–D matrices are necessary.

Based on the analysis of the literature proposed above and the conclusions set out above, we propose a set of methods that can estimate inter-establishment flows, and which will have the following structure:

– the generation of demand in terms of number of deliveries/collections, strictly related to the number of trips (and possibly in terms of weight/volume delivered);

– the construction of freight O–D matrices, i.e. a link between the destination of the goods and their point of origin, whether inside or outside of the urban area under consideration;

– the construction of routes from freight assignments and possibly transformation of estimated routes into transport units;

– the estimation of distances and time traveled to serve the calculation of evaluation indicators.

An alternative to that methodology, simpler, but more useful in several cases where an aggregate estimate of distances is necessary, can be proposed. It is structured as follows:

– generation of demand in terms of number of deliveries/pickup operations;

– estimation of the main types of routes and assignments for each delivery/collection in terms of the route type;

– estimation of the average distances traveled and average journey times so as to produce the data needed to calculate evaluation indicators.

This second possibility, already realized with FRETURB [BON 14, GOZ 14k] or through other models like categorical distance estimation frameworks [GON 14f], can be a valid alternative for assessing aggregated scenarios, but from the moment studies estimating traffic requirement O–D matrices are introduced, we also propose the first methodology that has inspired and synthesized the majority of work recognized at the international level.

4.3. Demand generation

The generation of transport demand is one of the most studied topics in the field of urban logistics, and yet it was only until very recently that most authors were still advocating very heterogeneous and unstandardized modeling solutions [COM 12, BON 14, GON 16d]. Nowadays, a dominant approach can now be claimed to becoming popular [HOL 16]. This type of demand modeling makes use of categories, and as such it is also called categorical modeling. The term "category" refers here to a composition of categories, within which the functional forms of generation are identical for all the entities belonging to it. That functional form varies from one category to another, unlike the classical models, which use what are called categorical constants [HOL 11] and of which there are many well-known examples in the literature [DEM 74, WAT 75, OGD 92, AUB 99].

The request can be generated in relation to the number of trips (or deliveries), the quantity of goods, or possibly the number of routes. Nevertheless, the general methodology remains similar, regardless of the variable generated. For this example, we will present a methodology in relation to the number of trips, knowing that it is directly transferable to other variables. In categorical models, freight transport generation functions are assumed to be linked to a typology (or categorization) of activities. In other words, if we divide the set of institutions into coherent and robust categories, establishments within the same category will have the same generation logic. This logic can be very different from one category to the next [HOL 16a] and be more or less random or nonlinear in nature [GON 14f, SAN 15], a quality which favors a category-dependent functional approach rather than a constant-generation model.

According to various studies, there are a number of variables that can be determinants of inter-establishment trip generation [HOL 11, HOL 13, BON 14, JAL 14]: the type of activity, according to a standard categorization (the NAF codes in France, derived from the European NACE codes), the nature of the establishment (in the case of a warehouse, offices, etc.), the number of employees of an establishment and its area, among others. In addition, the demand for freight transport can also be linked to other determinants, specific to the transport itself, such as the type of operation to be carried out at the point concerned (delivery and/or collection), the type of account (the sender's, the receiver's or another's account), or the type of vehicle. In route models, the route type can be included in the generation. It is up to the modeler to make the most relevant choices about whether or not to include these determinants, taking into account the model's objectives, available data, as well as quality and transferability requirements of the results. In other words, there is no "absolutely true" model but, that being said, each model has its own advantages and disadvantages and its use will not only be coupled to the needs and objectives of the user, but also dependent on the availability of data. Nevertheless, it is clear from the literature that some choices are more popular than others. For example, most authors choose to produce a generation on for-hire transport, mainly due to a lack of proprietary information [HOL 11, HOL 12], although some carry out a generation of all management modes in parallel so as to distinguish them later [AUB 99, BON 14, GON 14k]. Some authors prefer to generate all operations (i.e. expeditions and receptions together), while some models only generate receptions, i.e. trip attraction[5] [SAN 14]; models focusing solely on deliveries are more rare [GON 14a]. Nevertheless, we observe the following tendencies. The definition of categories is often based on the category of activity (NAF-NACE codes) and, where available, also on the nature of the establishment:

– the management mode, or trip generation without distinction according to the type of operation being carried out at the generation site, or the distinguishing of receptions from dispatches, may restrict the scope of the model; however, it is not used in its categorization;

– the use of the surface area generally takes the form of explanatory variables (although some models have used the categorization of employment in order to moderate the model so that it is a constant generation model, but this implies a strong disaggregation of the data which strongly limits the statistical significance of the processes being effected, [GON 16b]);

– the location of the establishment, whether in relation to the urban zone or the city itself, has little influence in a similar context (usually for cities within the same country [HOL 11, HOL 12, BON 14] so it therefore seems appropriate to carry out generation at the establishment level of an institution.

5 We will use here the notion of attraction (generation at destination) and production (generation at origin) defined in [ORT 01].

On the basis of those findings, we can define the category classification generation models where each category presents a different functional form as follows. Consider an establishment in an urban area. This establishment is defined by an activity class *a* (defined by the modeler or the user), as well as by its number of employees Emp_e and its surface area S_e. The number of trips on departure and/or arrival T_e^a of this establishment e can therefore be defined as:

$$T_e^a = f(Emp_e, S_e) \quad [4.1]$$

The fact that those trips are the whole or a part (i.e. only the generation or attraction, or only the own account or the account of others) must be defined by the user and/or the modeler. In all cases, the methodology responds to the same criteria and procedures. As Holguin-Veras *et al*. [HOL 11] point out, some establishment categories have a generation function which depends on the number of employees and/or surface area, and yet others have a generation function at their destination. Here are the main functions used in the literature:

– constant generation [WAT 75, AUB 99, MIN 96, HOL 12]. This is used when the number of trips, deliveries or the quantity of goods (depending on the variable generated) is identified as being invariant or constant, and also in cases where the constant can be a good estimator (in general, estimates that aggregate a set of establishments), and can be formalized as follows: $T_e^a = K$. This constant is often fixed at the average number of trips[6];

– generation following a linear logic: several authors argue that the generation is linear in nature, for certain categories in any case, i.e. $T_e^a = s_0^a + s_1^a.Emp_e + s_2^a.S_e$ [HOL 11, HOL 13, SAN 16]. It is important to note that not all variables will be present in all of the models and as such the constant term s_0^aa is not mandatory in all models;

– generation following a nonlinear logic [SAN 15]. The main approaches are:

- the potential model: $T_e^a = s_0^a.{Emp_e}^{s_1^a}.{S_e}^{s_2^a}$;

- the exponential model: $T_e^a = s_0^a.\mathrm{e}^{(s_1^a.Emp_e)}.\mathrm{e}^{(s_2^a.S_e)}$;

6 We next present the models for the variable that describe the "number of trips". These models can be applied to other variables by extension.

- the logarithmic model: $T_e^a = s_0^a . ln(ls_1^a . Emp_e) . \ln(s_2^a . S_e)$;

– generation following a random logic, but responding to a precise statistical distribution. In other words, an alternative to constant or deterministic generation is to associate with each establishment a number of random deliveries, however, these follow a probability law (i.e. by implementing a probabilistic generation).

The choice to include probability distribution in the probabilistic generation category depends on the standard deviation σ. Statistically, the value of a random variable that follows a standard normal distribution N (0 ;1) has a 95% probability of being included in the interval [–1.96; +1.96] [WON 01]. By extrapolating to a normal distribution that is neither central nor reduced, if 1,6.σ < the mean value, then we can define a normal distribution with a 97.5% possibility that the value is positive. Therefore, if 1,6.σ > the average, we will define an asymmetric pseudo-normal law (of Rice or Rayleigh, for example) that avoids negative values [RAY 80].

The methodology proposed to obtain these generation logics is articulated in three main stages, and defined as follows [GON 16b]:

– for each category, a dispersion analysis is carried out, as in [GON 14f]. In other words, we calculate, for each category, the average number of deliveries E (n) (independent of their use) and the corresponding standard error σ (n). Next, the coefficient of variation CV is estimated as follows: $CV = E(n) / \sigma(n)$. It is important to define the validity of the approximations based on averages and/or the relevance of probabilistic generation models;

– next, for each category, and at the same level of aggregation, an economic analysis is carried out for both linear or nonlinear models (as in [HOL 13]);

– all estimated models are then compared with each other using the mean-squared error as an indicator for the comparison. The model that produces the smallest mean-squared error is finally selected. For probabilistic models, a random generation based on a set of repetitions (e.g. 100) can be performed and these errors are then calculated according to the mean value of the data set, thereby ensuring a better approximation. It is important to note that we will prefer constant generation for deterministic aggregated estimates and probabilistic generation for disaggregated estimates and dynamic simulations.

In order to illustrate these methods, we propose to compare different models (derived from different logics and data aggregations), the detailed analysis of which can be found in [GON 16b, SAN 16a]. For that, two models built on the basis of a constant generation (i.e. for each category of establishments, each establishment is associated with the average number of deliveries and collections of the category in question, obtained from the results of the French Urban Goods surveys) and three models which follow the abductive method by which a different generation logic is associated with each category (constant, proportional to the number of employees in the establishment, or mixed, i.e. having a constant term and a term proportional to the number of employees). For the two constant models, a categorization into 8 classes and a categorization into 111 classes are used respectively. For the three abductive models, categorizations of 8, 25 and 44 classes are used respectively. The categorizations have been adapted from the stratification of French Urban Goods surveys [AMB 10] and, although they are adjusted (for reasons mainly due to the lack of data in certain initial categories), they remain consistent with the surveys and thus with the conventional methods formulated in France [GON 14f].

That comparison was made in part to address the issue of adequacy between the quality of the model and the data requirements discussed at the beginning of this chapter. The quantity and quality of the data depend directly on the resources available for its collection and processing, hence the value of seeing whether more aggregated estimates result in less precise models or, on the contrary, whether the difference in the quality of approximation is negligible [CAM 12].

The application of these methods has shown that for aggregation, if ultimately we wish to aggregate the results at the city level, the level of aggregation thus plays a less important role than the definition of a generation logic that is more relevant for each category (Figure 4.1).

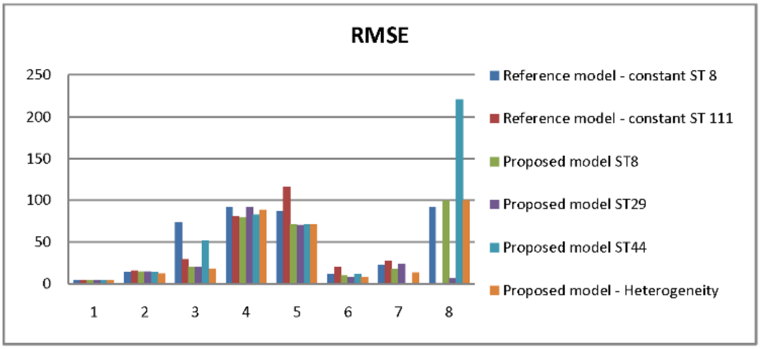

Figure 4.1. *Comparison of several models of inter-establishment trip generation [GON 16b], adapted from [SAN 16a], categorization into eight classes[7] from the Urban Goods surveys conducted in French cities [AMB 10]. For a color version of this figure, see www.iste.co.uk/gonzalez-feliu/logistics.zip*

Indeed, if we look at Figure 4.1, in five of the eight macro-categories, the errors are very similar between the different models. There are only three categories (industry, category 3; commerce, category 5; and transport-storage, category 8) that have different errors. In addition, if we look in detail, in particular at categories 3 and 5, the least relevant models are often models based on constants. Only category 8 presents a significant difference between the models and deserves to be studied in detail, to identify whether it is due to a question of data heterogeneity or a lack or limitation in the modeling approach. Therefore, this exercise is interesting in that it shows the importance for the adaptation of the model to the needs of the evaluation and analysis, as well as the relevance (which we will address later) of the models used in terms of the quantity and the quality of the data necessary for its construction.

4.4. Demand distribution models

Once the demand for freight transport is generated, the routes can be built and characterized. There are several approaches in the literature, although for generation, a standard seems to impose itself, however, that is not yet the

7 Categories: (1). Agriculture, (2). Handicrafts, (3). Industry, (4). Wholesale trade, (5). Retail trade, (6). Shopping centers, (7). Tertiary services, (8). Transport-storage (categories extracted from the French Urban Goods survey [AMB 96, AMB 10].

same for the second phase. Nevertheless, there are two categories of leading approaches:

– distribution models, which generate freight O–D matrices that then use these to construct the routes or distances traveled;

– direct estimation of distance models, which do not use O–D matrices to estimate the distances traveled.

The principles of direct estimation will be discussed in more detail in the next section. Here, we will focus on the estimation models of freight O–D matrices.

With regard to distribution models, we distinguish two predominant visions: trip distribution models and freight distribution models. In the first category, the objective is to find the relationship between the origin and the destination of each trip, often with urban freight transport forming part of the route. In the second category, the model links each destination (delivery point) with the origin of the shipment (for this trip), i.e. the dispatch point where the shipment was loaded onto the vehicle. In both cases, three dominant approaches can be observed.

The first is that of gravity models, i.e. models that link origins and destinations to a function that is dependent on (but not limited to) the distance between the origin and the destination. It is the basis of catchment area models used in marketing to determine the potential customers of a business (or set of businesses), and also the attractiveness (people and/or freight) of an urban area. That was the first method to be proposed in urban freight transport [OGD 78, HEN 00, ORT 01]. The principle follows that of a gravitational relationship, i.e. the well-known law of gravity. In the present context, we will define the set of trips T_{ij} between two zones (i that of the origin and j that of the destination) linked by the following function:

$$T_{ij} = K \frac{O_j^{\alpha}}{O_i^{\beta}} d_{ij}^{-\gamma} . T_j \qquad [4.2]$$

where O_i and O_j are the opportunities (i.e. the determinants that can induce transport from or to these areas, in other words, the determinants of generation), the distance d_{ij} (or time) between the two zones and the constant k. In general, O_i and O_j will be defined by the number of establishments (of a certain category) or the equivalent variable.

An alternative to the above gravity model (also called potential model) is the exponential version, which can be formalized as follows:

$$T_{ij} = K \frac{O_j^{\alpha}}{O_i^{\beta}} e^{-\gamma . d_{ij}} . T_j \qquad [4.3]$$

These models can be estimated by linear regression by applying a linearization using a logarithm. Indeed, the above equations can be rewritten as follows:

$$\frac{T_{ij}}{T_j} = K \frac{O_j^{\alpha}}{O_i^{\beta}} d_{ij}^{-\gamma} \qquad [4.4]$$

and

$$\frac{T_{ij}}{T_j} = K \frac{O_j^{\alpha}}{O_i^{\beta}} e^{-\gamma . d_{ij}} \qquad [4.5]$$

Applying the logarithm, we obtain respectively:

$$ln\left(\frac{T_{ij}}{T_j}\right) = \ln(K) + \alpha . ln(O_j) - \beta ln(O_i) - \gamma . ln(d_{ij}) \qquad [4.6]$$

and

$$ln\left(\frac{T_{ij}}{T_j}\right) = \ln(K) + \alpha . ln(O_j) - \beta ln(O_i) - \gamma . d_{ij} \qquad [4.7]$$

What is in fact a function of type $y = a+b.x_1+c.x_2+d.x_3$ and the corresponding coefficients can be estimated using linear regression techniques.

Nevertheless, those models remain very reductive and often criticized because their approximation to the phenomena of attractiveness is significant (the determinants of this attractiveness may be different from those of the generation); nevertheless, they remain useful in cases where the available data sets are small and/or of poor quality.

Entropy maximization models are a valid alternative that are often preferred over gravity models [SÁN 14]. These methods are derived from matrix calculations and an O–D matrix based on an entropy principle. The basic idea of these methods is to therefore construct an O–D matrix from the generation data (i.e. the set of trips at the origin of each zone i, denoted as T_j, and the trips to each zone j, denoted as T_j). In other words, the objective of these methods is to find the combination of trips T_{ij} which maximizes this measure of entropy (and thus the "disorder" or number of admissible combinations), while simultaneously verifying the following two conditions:

$$T_i = \sum_j T_{ij} \quad [4.8]$$

and

$$T_j = \sum_j T_{ij} \quad [4.9]$$

There are several methods, formulas [ORT 01, CAS 09], and models for urban freight transport which have recently been developed, particularly in the direct generation of O–D matrices (also known as O–D syntheses [HOL 08, MUÑ 09, MUÑ 10, SÁN 14]), which were used in the 1980s and have recently become fashionable once again. Indeed, the new technologies for the measurement and identification of vehicles used in tallies have facilitated the production of tallied data, which in turn have made it possible to minimize biases and to control the uncertainty of data collection. Therefore, these types of models, which require little detail in terms of the data itself, and which remain desirable for overall estimates of vehicle traffic in a given urban area, appear to be relevant to certain contexts and as such should not be overlooked. In addition, new developments in these models now make it possible to produce route estimates according to the types of vehicles. We can even include the temporal aspects of transport which are normally difficult to measure when using manual tallies, largely due to observation bias and the sheer quantity of data (for an example of these models, see [SÁN 16b]).

The distribution models can be constructed so as to split into categories (following the same principle as those used for generation models, i.e. a definition of the different models by category), or used in aggregate for all flows (e.g. for all management modes or according to the mode, or vehicle type). The choice of which level of aggregation and categorization will therefore depend on the objectives of the model and the available data; however, the methodology of modeling will remain consistent and reproducible, so that the standard (used by a majority of authors) becomes the methodology *per se*, and not a precise delineation (in terms of the technique or modeling tool).

Assignment problems are generally derived from operational research methods [ACK 68, FAU 78, WIN 04, GON 16a]. That consists in the assignment of an origin to each destination so that all the origins are linked to at least one destination, and all destinations are linked to one and only one origin. The assignment is based on a criterion, i.e. a function that must be minimized or maximized. The result of solving this problem is an O–D matrix that satisfies the chosen optimization criterion. In the case of urban freight transport, this problem can be formalized as follows:

$$Max \sum_{i=1}^{n_o} \sum_{j=1}^{n_d} U_{ij}.x_{ij} \quad [4.10]$$

while respecting the following constraints:

$$\sum_{i=1}^{n_o} x_{ij} = T_j \quad \forall j = \{1, 2, \dots, n_d\} \quad [4.11]$$

$$\sum_{j=1}^{n_d} x_{ij} = T_i \quad \forall i = \{1, 2, \dots, n_o\} \quad [4.12]$$

$$x_{ij} = \mathbb{N} \quad \forall i = \{1, 2, \dots, n_o\}\,; \forall j = \{1, 2, \dots, n_d\} \quad [4.13]$$

The objective function (or criterion) presented here is a utility function. In other words, the assignment problem will aim to maximize the utility for each O–D pair. This utility can be the inverse of a cost, and also a function of several variables such as distance, attractiveness, routine and loyalty. The form of this function (and its linear or nonlinear nature) will be defined by the modeler and will have to be compared with the reality being modeled so as to study the relevance and the precision of the model. If the values of U are constant parameters (or do not depend on the values of x), the problem becomes linear and can be solved easily with existing linear programming tools. If not, then specific algorithms will be required.

It is important to remember that all these models can be applied to both the number of trips (or deliveries), the number of parcels, or the quantity of goods to be transported. They are approximations that are not always very precise (the gravity model, for example, results from a very strong hypothesis which is not always an explanatory factor in freight transport: distance is the discriminating variable in these models, or, as in many cases, the carrier chosen is not the nearest but the cheapest, or the one that offers a better quality of service, for example). Nevertheless, in the construction of a model, it is important to make informed choices based on the available data; however, it is not always possible to estimate the distribution of goods with high precision. Moreover, when the goal is to have an aggregate flow estimate, the errors made by individuals can be compensated for in the aggregation (i.e. the estimated flows will not be the "true" flows, but rather the probable flows that result in a series of routes whose distances are close to reality). It is to this day impossible to generate an exact reproduction of reality. If we look at the different existing models that have become practical tools [SON 85, ERI 97, AUB 99, JAN 05, GEN 13, COM 13], all are based on an incomplete data set where the statistical representativeness of the routes is generally not entirely guaranteed. For that reason, it is necessary to make assumptions and this continues to make this option a difficult choice over a unique model that is 100% true to reality.

Moreover, if we look at the transport of people, the models used (certainly those which are similar, such as gravity models or entropy maximization models, or of the same nature) remain approximate, but are considered by the scientific and practical community as valid (see [ORT 01], whose model on the urban public transport of people with an average absolute error of 20–25% remains valid for estimates for use in planning). The models presented here have the same orders of magnitude as the models used for the transport of people [GON 14f, SAN 16a], which are now being increasingly used for practical purposes with a significant degree of unification [MUÑ 11, HOL 16]. For those reasons, we thought it important to present them here. Of course, other models can be deployed, but the three approaches presented here have the advantage of being simpler in terms of application and have already been used in practice, which means that their degree of approximation and relevance have already been analyzed and considered satisfactory.

Once the demand has been distributed (or alternatively in some cases where routes are estimated directly without going through the distribution, [GON 14f]), routes have to be constructed. In the last part of this chapter, we will present the principal methods for the construction of those routes.

4.5. The construction of routes and distances

For route construction, three main methods are observed in both research and in practice: analytical models, empirical approaches, and approaches to route construction through operational research.

Analytical models are used when there is little information with which to estimate the distances traveled and the structures of the routes. Empirical approaches are used when a set of available data provides the information necessary to estimate the different characteristics of the routes. Nevertheless, these two types of models follow the same methodological framework. Given that a route has n delivery points (or collection points), it can be broken down into three parts:

– the first is the initial trip, i.e. the delivery to the first point that comes after the starting point in the route;

– the second is the route-set of trips between two delivery points and/or collection points (each of these trips has been termed by several authors as a "section");

– the third represents the last trip in the route, i.e. the return to the depot or the final delivery point along the collection route.

In the case of full truck load transports (also called shuttle paths), the second part does not exist. In the case of vehicle routes (LTL or "less than truck load" transports), three elements are observed.

Before estimating the distances traveled, it is therefore essential to know the distribution of these delivery routes (i.e. direct routes and the different types of routes). The percentage p_{parc}^{c} of the number of routes for a category of an establishment e and management mode c (on their own account or on the behalf of others) of these routes can be explained as a function of several variables:

$$p_{parc}^{e,c} = f^{e,c}(X_{ECO};\ X_{ESP}) \qquad [4.14]$$

where X_{ECO} is the vector (set) of socio-economic variables and X_{ESP} is the vector of spatial variables (in relation to urban and peri-urban space). The main socio-economic variables may be the intensity of activities in the destination area that can be delivered by the route, the intensity of activity in the area of origin which may be the starting point of the route, or the proportion of route types, among others. The main spatial variables may be the area of the destination area, or the distance between two zones, among others. Those different variables can be tested with a linear regression (directly or after log-linearization).

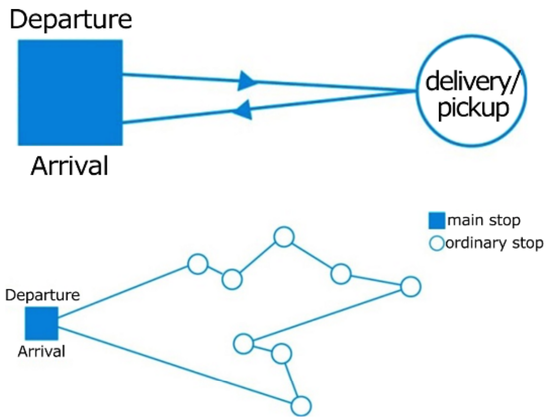

Figure 4.2. *Composition of routes in direct-route routes (adapted from [GON 14f])*

An alternative to the determination of those variables and coefficients is to apply an empirical method onto the survey data. For an example, we propose using the values obtained in [GON 14f] based on the French Urban Goods survey [AMB 96, AMB 99a, AMB 99b]. Once the request is generated, and equipped with knowledge on the number of shipments coming from a given establishment, it is possible to define their distribution through a management mode. In other words, given an establishment *e*, belonging to category *a*, and a number of shipments coming from that establishment ex_e^a, we can define the percentage of deliveries that follow a management mode *m* as p_m^a. There are three management modes: third-party transport (TPT), shipper's own account (SOA) and receiver's own account (ROA). In order for the sum of shipments made by each management mode to be equal to the total number of shipments ex_e^a, the following condition must be met:

$$\sum_m p_m^a = 1; m \in \{TPT; SOA; ROA\} \qquad [4.15]$$

If we assume that each establishment *e* belonging to the same category *ae* has its shipments distributed in the same way by the management mode, the number of deliveries per management mode *m* can be defined as follows:

$$ex_{em}^a = P_m^a . ex_e^a \qquad [4.16]$$

The set of values that take the different p_m^a is summarized in Table 4.2.

Category	Name	P^{TPT}	P^{SOA}	P^{ROA}
1	Agriculture	47.23%	13.05%	39.72%
2	Artisanal craft industry	25.17%	21.40%	53.42%
3	Chemical industry	73.83%	15.57%	10.60%
4	Intermediary industry	76.65%	17.96%	5.40%
5	Consumer goods industry	63.09%	12.81%	24.11%
7	Intermediary wholesale trade	66.61%	9.26%	24.14%
8	Wholesale trade of non-food items	69.84%	14.00%	16.16%
9	Wholesale trade of food items	55.15%	8.03%	36.83%
24	Tertiary services	62.71%	14.96%	22.33%
25	Tertiary other	50.72%	25.77%	23.51%
34	Heavy industry, construction	83.90%	2.86%	13.24%

Table 4.2. *Average distribution by management mode of weekly shipments for selected categories [GON 14f]*

We see a strong predominance of third-party freight transport (nine of the eleven categories selected account for more than half of shipments made on behalf of another's account, with four of those accounting for more than two-thirds). With regard to the proportion of shipments being made on the sender account, the recipient's account (the transport management mode which is the most difficult to model and optimize) is generally lower than the sender's account where the freight originates from, except in the case of tertiary services, chemical and intermediary industries. In any case, neither of these two management modes can be considered negligible.

Following on this, we have to build the delivery (for TPT and SOA) or collection (for ROA) routes. Given the category of establishment *ae* and the proportion of transport routes managed according to mode *m*, we define the statistical composition of the routes from the urban route data as taken from the database in Gonzalez-Feliu and Morana [GON 14c] from the "stop-and-go" table of the French Urban Goods survey [AMB 10]. Those trajectories are defined by the size (number of deliveries), the size of the vehicle, the quantity of goods transported and the distance traveled [GON 14f, GON 14c, CAT 17].

From this, we can divide the total route by types. [GON 14f, CAT 17] propose a distribution on the basis of French Urban Goods surveys, using an alternative adjustment (i.e. assuming that the sample is representative and does not require any other weighting[8]). Based on these results, and knowing the distribution for the number of trips by type, we can define the main types of routes and then define their characteristics. The authors define two categories of third-party transport: that of the traditional postal services and those catering for the postage of small parcels. Consequently, we propose for third-party accounts to distribute the routes according to the different types of routes in those two categories. For their own account, the distribution is done separately for the sender and for the recipient. We show this distribution in Table 4.3.

	Percentage of Route			
Number of delivery points	**TPT – excluding small parcel deliveries**	**TPT – small parcel deliveries**	**SOA**	**ROA**
1 (direct routes)	6.9%	0.0%	11.7%	52.9%
2 to 10	15.9%	2.7%	46.4%	26.6%
11 to 20	9.4%	8.3%	27.9%	20.5%
21 to 30	6.5%	8.3%	12.0%	0.0%
More than 30	5.2%	36.8%	2.0%	0.0%
Total	100%		100%	100%

Table 4.3. *Distribution of routes by management mode (adapted from [GON 14f, CAT 17])*

Once we have defined the number of routes per type, we can estimate those by defining their characteristics. In Table 4.4, we present an overview of the results obtained from the database of the French Urban Goods survey.

8 Indeed, here two hypotheses can be made: one of them is to link routes to establishments and weight them in relation to them, thus linking the results of establishment and driver surveys [AMB 10]; the other is to treat the two surveys (establishments and drivers) separately, assuming the two different samples even if linked (in other words, the samples are considered as linked, but only from the moment when in the driver survey, the survey method and response rates are very different to those of the establishment survey, we consider that each sample is representative for the purposes of its own survey, and there is no attempt to make the sample relative to the other).

We observe that the CA and CPE routes (where transport is organized and carried out as per the same logic) exhibit very similar characteristics in all categories for up to 30 stops. The main difference is in the delivered weights (Table 4.5), but in terms of both the average and standard deviation for the number of stops, the routes for those two categories are very close. However, it is important to note that the spatial component plays an important role, and the first analyses of survey data show a significant difference in terms of the kilometers traveled [AMB 96, AMB 99a, AMB 99b].

	Number of stops			**Standard deviation for the number of stops**		
Route category in the number of stops	**TPT**	**SOA**	**ROA**	**TPT**	**SOA**	**ROA**
Direct route (1 stop)	1.00	1.00	1.00	0.00	0.00	0.00
2 to 10 stops	6.47	6.48	3.47	2.37	2.19	1.83
11 to 20 stops	15.49	15.69	11.03	2.79	2.81	0.58
21 to 30 stops	24.70	24,94	–	2.58	2.34	–
31 stops or more	45.95	30.49	–	12.23	6.43	–

Table 4.4. *The average number of stops and standard deviations for each category of the delivery or collection route*

	Average weight delivered to each stop (in kg)			**Total average weight shipped (in kg)**			**Average capacity of the vehicle (in kg)**		
Class size for the number of stops	**TPT**	**SOA**	**ROA**	**TPT**	**SOA**	**ROA**	**TPT**	**SOA**	**ROA**
Direct route (1 stop)	3,937	3,469	3,940	3,937	3,469	3,940	9,708	7,646	9,000
2 to 10 stops	1,336	352	1,023	5,804	1,794	61	8,479	6,469	5,643
11 to 20 stops	489	103	56	3,898	1,440	116	5,824	6,658	5,872
21 to 30 stops	62	30	–	1,140	1,753	–	5,721	4,976	–
31 stops or more	52	4	–	1,181	1,143	–	5,815	3,200	–

Table 4.5. *Average weight per delivery, average total weight transported, and average capacity of delivery vehicles for each category of delivery or collection route*

From those elements, it is possible to estimate, in an analytical or empirical way, the distances along a route as follows:

$$d_{tour} = d_{0;1} + \sum_{i=1}^{n-1} d_{i;i+1} + d_{n;0} \qquad [4.17]$$

where point 0 symbolizes the deposit and n is the number of points to be delivered along a route. For a direct route, this distance will be estimated as follows:

$$d_{direct\ route} = d_{O;D} + d_{D;O} \qquad [4.18]$$

with $d_{O;D}$ being different *a priori* to $d_{D;O}$ (since, in fact, the return trip may be different from that of the departure, i.e. affected by one-way streets, no-entry signs or traffic intensity, and may force the driver to change course). Nevertheless, in the logic of an aggregated estimation for strategic and/or tactical planning, we can approximate that the distance between inbound and outbound approaches is the same [GON 14k]. The distances of the set of direct routes for a specific category of route can be described by the following function [ROU 10]:

$$d_{direct-route} = a.N_{direct-route}.R + b \qquad [4.19]$$

where $N_{direct\text{-}route}$ is the number of direct routes in an agglomeration, R is the radius of the agglomeration, and a and b are two constants that are generally obtained through linear regression. The authors point out that, according to the surveys used [AMB 10], for a given vehicle, the type of facilities being served is not all that significant. They also offer results that recalculate the values of a and b, but only in an aggregated manner (i.e. for any vehicle and management mode): a=1.2 E-05 and b=3.51.

Nevertheless, those values can be estimated to a greater degree when provided with a set of relevant data. For example, the French Urban Goods surveys allow us to build an empirical relationship between the radius of an urban area (or area to be treated) and the distance of a direct route (Table 4.6).

	TPT	SOA	ROA
Any vehicle	1.68	1.71	2.04
<3,5 T	1.25	1.27	1.52
Carrier	2.03	2.06	2.46
Semi-articulated	3.40	3.44	4.12

Table 4.6. *Values of the parameters a and b for direct routes (reconstructed by descriptive statistics from the LET French Urban Goods surveys conducted between 1997 and 1999)*

In the case of a vehicle route, we can also define an inter-stop distance d_{inter} as in Daganzo [DAG 05], i.e.:

$$d_{route} = 2 * d_{MA} + (n-1)d_{inter} \quad [4.20]$$

It is important to note that for a direct transport ($n = 1$), the second term of the equation is null, so this relation remains valid for both types of routes (direct routes and vehicle routes). The difference between the empirical methods and the analytical methods lies in the estimation of the two distances (the initial trip and inter-stops).

The analytical methods will follow a mathematical relation, mainly that proposed by Daganzo [DAG 05] for the distance of inter-stops:

$$d_{inter} = \sqrt{\frac{S}{n}} \quad [4.21]$$

where S is the surface area of the zone in which the points to be delivered are distributed. In other words, if it is assumed that the route will cater for customers based within a single agglomeration, the surface area used will be that of the agglomeration and if, on the contrary, the delivery area can be defined as more restricted (for example, along the lines of a neighborhood, a municipality or a group of communes), it will be smaller and therefore d_{inter} will decrease. The distance of the initial trip can be estimated by the following function [ROU 10]:

$$d_{direct-route} = a.d_{zc} + b \quad [4.22]$$

where d_{zc} is the direct distance between zone z where the route starts and the location of the city center, and a and b are two constants that are generally obtained through linear regression. The authors give the values of a and b according to the types of activity, by proposing two main categories (see Table 4.7).

Activity category	Management mode	*a*	*b*
Industry, wholesale trade, warehouses, agriculture	Third-party account	0.54	4.28
	Sender's account	0.54	4.28
	Recipient's account	0.54	2.15[9]
Artisan, services, small trade, large-scale distribution, tertiary	Third-party account	0.81	4.65
	Sender's account	0.64	5.75
	Recipient's account	0.81	4.49

Table 4.7. *Values of parameters for determining the main distances a and b (adapted from [ROU 10])*

Once the number of trips T from an area i is known (whether for the sender's account or a third-party's), as well as the total number of deliveries between the two zones i and j, denoted as l_{ij}, the number of delivery routes can be defined as the number of T_i trips leaving the area (since each trip at the start corresponds to the first movement in the route). The number of deliveries per route $\bar{l}$ can be estimated as an average value, therefore:

$$\bar{l} = \frac{T_i}{\sum_j l_{ij}} \quad [4.23]$$

Similarly, for routes performed by the recipient (i.e. collection routes), the number of routes is calculated by using the route starting point, the number of routes in between, and the final destination of the goods. Hence, it is estimated as being equal to T_j. Since the number of collections for these

9 The sample used in this regression is not statistically significent to conclude on the validity or otherwise of the value of this according to [ROU 10].

types of routes is located between the two zones i and j, it is denoted as e_{ij}, and the average number of collection points per turn $\bar{e}$ is estimated by the following equation, also corresponding to an average value:

$$\bar{e} = \frac{T_j}{\sum_i e_{ij}} \quad [4.24]$$

We can also estimate distances by using empirical methods. The difference at this stage, when compared with empirical models, is that these secondary trips acquire the distances already traveled (the initial trip distance between two establishments along a route) by applying descriptive statistics to a representative set of data. However, this necessitates the collection of representative data sets, which is not always possible.

An alternative to constructing routes is instead to estimate each of its components separately (as already recommended in [AUB 99]). Starting with the composition of a route and a direct route (for example, the one presented in this section), instead of constructing the routes by assigning each delivery to a typical route and then individually constructing the distance of each route, we can consider the set of trips and divide these into three categories:

– FTL paths in which the total distance for each direct-route trajectory will be $d=2*d_{TD}$ (where d_{TD} is the average distance of a typical direct route, estimated in the same manner as above);

– trajectories of the initial trips of routes;

– intermediary trips, i.e. a delivery to an establishment that follows on from another delivery (and the same for collection routes).

According to Routhier and Toilier [ROU 10], the number of trips generated in an urban area t_z can be written as follows:

$$Nb_{T_z} = Nb_{TD_z} + Nb_{TP_z} + Nb_{TL_z} \quad [4.25]$$

where:

– Nb_{TD_z} is the number of direct routes that originate from z;

– Nb_{TP_z} is the number of principle points for routes in z;

– Nb_{TL_z} is the number of connections which have their origins in the zone z.

Once the number of each of those routes has been determined, the unit distance can be obtained empirically [AUB 99] so as to be able to estimate all the trips, at the scale of a very large area (an agglomeration). This has advantages since the deployment of those methods is quicker and, if the data is available, easier to implement and explain to the stakeholders involved. Nevertheless, it also has its limitations. Indeed, aside from the need for data, a fact which has been emphasized several times specifically by empirical methods, the estimation of the distances made in this manner is limited to the set of flows within a set of zones. Therefore, the perimeter has an impact on the flows under consideration (only flows between two zones belonging to this set are considered). In other words, if the perimeter is large (an urban area, for example), the estimate remains relevant, but if a perimeter is too restricted, it may produce biased flows or eliminate a large part of the trips (as their origin is located outside of the perimeter). These issues of relevance will be discussed in greater detail in Chapter 6.

Finally, a way to construct the routes, with the view of mapping them (for example, through GIS), is to construct them using algorithms or combinatorial optimization methods. This type of method is very popular in the operational research community, and is reflected in a very rich and varied literature, as shown by several syntheses and books on the problems of route optimization (e.g. [TOT 02]) and more recently, works on the synthesis of these methods specifically in the case of urban logistics [MAN 14, CAT 17]. Three main categories of problems are addressed through route construction:

– the problems of commercial travelers [EHM 12, HOF 13, MAG 14], who naturally aim to optimize the realization of a single route, wherein the number of points to visit is fixed in advance;

– the problems of vehicle routes [TOT 14, MON 15], where the aim is to find an optimal configuration of routes for a given fleet of vehicles whose features can be seen as a set of delivery constraints (capacity, autonomy, etc.);

– the problems affecting the localization and route optimization [MAD 83, HAS 09, GON 12b], which consist of finding both the optimal location for warehouses or logistical platforms and the configuration of routes so as to make deliveries to a given set of customers based around those platforms (provided, of course, that there is data on the fleet of vehicles and the set of delivery constraints). These problems seem interesting in the context of analyses relating to the construction or installation of logistical spaces [GON 14h, MUÑ 14, MON 16].

The development of these methods and algorithms requires special techniques (specific to operational research and, more generally, applied mathematics or computer science). We will not present the mathematical principles of these problems or the main methods for solving them (for that refer to [TOT 02, GOL 08], both of which present an overview of the most significant works in this field, as well as the components needed to reproduce several algorithms). Nevertheless, we wish to explore the question of the applicability of these methods because they have been seen as poorly applied, and as such impractical, by a significant portion of the scientific community[10].

One of the limitations of these methods most often put forward is that which challenges the representativeness of the results obtained. In order to optimize the routes, the results may lead to over-optimized routes in relation to the actual reality. Or else, they may generate routes which drivers never put into practice (because some of the constraints or decision factors have been omitted through approximation). Several experts in operational research propose, on the one hand, robust and efficient algorithms from a mathematical and/or computational point of view (to enrich the literature on these subjects) while, on the other hand, there exist "sub-optimal" versions of the results which are considered by the drivers and transport operators as acceptable practices.

In any case, these methods are useful in some contexts: for example, Transport Management Systems (TMS) increasingly integrate these algorithms (see [HAL 16] for a systematic review of the leading software being used in the optimization of actual routes). In addition to these software packages (most of them offering "turnkey" solutions or tools that allow us to

10 This refers to the eternal and (in the opinion of the author) fruitless "battle" between the engineering sciences and human and social sciences: the first will recognize these methods, while the second will advocate the use of more empirical methods under the banner of the representativeness of reality. Nevertheless, we observe very relevant operational research methods (although most publications focus on the computational aspects and not on its application, with the exception of a few works that apply methods). The "computational" vision of operational research remains the dominant approach in research communities; however, it is not the only one: after Ackoff's original article [ACK 77], which challenged this vision, gave birth to an alternating current option that is interpretative and problem-solving in its approach. We will see the principles underpinning this alternative approach in Chapter 6.

build routes according to the needs of each company), we observe several interesting tools, useful to both the research and practical worlds:

– VRPH library [GRO 08], which is in the form of a C++ library and which includes several algorithms that have been already coded and which can be combined according to the needs of the user. The project is based on the open source principle and everyone can download or even contribute towards its betterment. Nevertheless, Chris Groër, its creator, no longer maintains the library and the documents are not always evident. As a result, it is important that practitioners have a firm grounding in computer science (VRP comes in the form of source code that still needs to be compiled). In any case, this tool can be of interest for the construction of route-production modules for scenario simulations (such as the ANNOA[11] platform, which adapted VRPH to its needs). It can be downloaded from the website created by Chris Groër[12];

– R tsp package [HAH 07], offers a tool for route construction. It can be used, once the components of a route are known (i.e. the number of customers to deliver to), in order to estimate a possible route. Although it is necessary to be familiar with the R statistical software, this library is functional and interoperable. On the contrary, it is limited to a single route, so in order to reproduce a set of itineraries, it is essential to first characterize them. This package can be downloaded as R software (as a library) or through the CRAN-R Project website[13];

– the VRP Spreadsheet Solver [ERD 13, ERD 17] comes in the form of an Excel spreadsheet. It has been developed to show the applications of algorithms more advanced than those of standard software, and at the same time make these accessible to both researchers and practitioners alike. It is simple to understand and can be adjusted to fit many situations, and remains easy to use. On the contrary, it is less flexible and less automatable than the other two. It is accessible through the Verolog website[14].

11 annona.emse.fr/.
12 sites.google.com/site/vrphlibrary/.
13 https://cran.r-project.org/web/packages/TSP/index.html.
14 Research group on the optimization of vehicle and logistics routes under the Association of European Operational Research Societies (EURO): www.verolog.eu/.

Of course, other tools exist (we will not here go through all the commercial solutions available for route optimization, those which are being used extensively in certain sectors of the transport industry, nor the other algorithms or free software that can be downloaded from the Internet). Those three examples show the possibilities of applying these algorithms which have been used both in research and in practice. At the end of the day, it is up to users to find the right methods that meet and satisfy their needs and requirements.

This is applicable to all the methods presented herein. Indeed, there is no miracle solution (or magic wand) and each method, presented here or not (including all existing methods would be too arduous to present and analyze in this book[15]), must be developed and/or applied according to the context or the objectives of the user so that it reproduces, as best as possible, their situational reality. This vision, referred to as a solution-probleming vision, will be expounded upon in greater detail in Chapter 6.

15 The methods presented are often used in several countries and their application remains relatively easy to use and quick to implement.

5

The Estimation of Other Urban Freight Transport Flows

5.1. Estimating end consumer and urban management flows: a topic less studied, but nevertheless more standardized

In contrast with the estimation of inter-establishment flows, end consumer flows have been less studied in urban logistics. On the one hand, this is because their largest component, household purchase trips, is often associated with the transport of people, and on the other hand, because this category remains relatively unknown, in particular the movements of deliveries to the consumer, otherwise known as B2C flows (i.e. business to consumer flows). We therefore observe that two main sub-categories of flows are considered, the purchasing movements of households (whether motorized or not) and the flow of deliveries to the end consumer or in the vicinity near the place of consumption (B2C flows).

With regard to this second sub-category, related data appear to be easier to collect and thus are easier to model, since most parcel delivery companies have advanced information systems that can provide the data required to generate models. Today, however, this is no longer the case, as these datasets are considered to be confidential knowledge as they have the potential to impact the free competition of companies. Therefore, models for B2C flows are limited to just a few professions. A few of these flows are included in some of the models that were presented in Chapter 4, to represent express courier services, since this type of transporter carries out both B2B and B2C deliveries. The e-commerce transport supply models are essentially optimization models, where demand is not estimated but is

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instead considered an input [VIS 03, GEV 11]. Another family of models aims at reconstructing flows and estimating the potential demand through empirical procedures, often making use of partial datasets [MOR 15b, PAT 04, GON 14i]. These models use a generation function linked to the population (they generate a certain number of deliveries per zone according to the characteristics of the population and a predetermined number of routes emanating outwards from each origin point). Next, a typology of the route is assigned according to the distance (relative to the density of customers over a given area and in relation to the origin point) to and from each origin point, thereby constructing B2C delivery route estimates.

Household purchases are often excluded from the modeling of urban freight transport [TAN 01, WOU 01] due to the fact that they are often assimilated with the transport of people. However, questions pertaining to the purchasing motive can be found in every household trip survey, and as such the flow modeling for this activity is more recurrent in reports on public transport than ones on freights. However, as pointed out by Russo and Comi [RUS 04a] and Ségalou *et al.* [SÉG 04], the objective of a purchase movement is to acquire a consumer good, which must then be transported to the place of consumption. It is therefore a journey made up of both people and goods, the objective of all the movements linked to a purchase is predominantly to take the purchased good home or to another point of consumption.

With this in mind, we are able to observe that some integrated urban transport models include a buying pattern. However, these models are developed and calibrated on the basis of work trip choices, so that the buying pattern is characterized on the same basis and with the same assumptions as those for work shifts. According to the results of Cubukcu [CUB 01] however, the factors underpinning the buying trip generation are not always the same as those for trips to and from the workplace. As a result, we focus here on models specifically constructed to estimate the purchasing activity. We can thus identify three categories of models.

The first are *single-generation models* [VIC 84, CUB 01, GON 10b], which are defined by analogy as inter-establishment travel demand models. These aim at generating, for each city zone, the amount of travel into and out from a given area [CUB 01]. These are generally motivated by the needs of retailers and urban planners who wish to know the potential or actual quantity of visits to a particular sale point. The standard approaches used are those employing linear regressions [KEE 66, BAD 97, CUB 01] and structural equations [VIC 84].

The second is the *four-stage model*, which remains the most widely used approach, as purchasing activities remain linked to other personal urban activities [ORT 01]. Two sub-categories can be identified: classical models [ORT 01] and adapted four-step models. Of the latter, two main adaptations are observed in the literature: the first avoids the modal choice (it is therefore essentially a three-step model), generating in the first stage the number of motorized trips, that is, those carried out by car [SÉG 04]. The second makes a double assignment, i.e. distribution and modal choice, after generation or after distribution, as per the approach [CRO 10, COM 11, BAR 14, NUZ 14]. Nevertheless, all of these models remain similar to the classical approach.

The third category is that of *catchment area models* [KUB 07] as a basis for modeling. In these models, the generation is made at the destination and at the place of residence, where the points of purchase and locations of the households are connected through gravitational approaches. The objective of these models is not to estimate purchasing activities in detail, but to quantify the potential of each zone in terms of the distribution of purchasing activities taking place within the vicinity of the purchaser's place of residence [KUB 07, ATH 11].

This body of work remains specific to (mainly motorized) shopping trips. With respect to e-commerce flows and other forms of distribution to the end consumer, the existing work is limited to proposals of descriptive field data [GEV 11] or proposals of delivery optimization algorithms [NEM 04], which are in keeping with the work on supply modeling which are presented in this section. The work carried out on the modeling of end consumer movements represents an initial integration of demand models with those of urban logistics. The main contributions to the literature relate to: the initial generation of demand/needs at the point of purchase and the allocation of these needs to the places of residence; the procedures for estimating the flows of purchasing activities substituted by new forms of distribution; and the modeling of these new logistic schemes.

Do urban management flows involve the least amount of scientific work?

Yes, at least if we look at those interested in the system as a whole. In fact, there are relatively few studies interested in all the flows belonging to this category; however, in terms of unification, it is important to note that this category is the most heterogeneous of the three. Moreover, trips belonging to this category are often integrated into one of the other two categories. For example, Russo and Comi [RUS 06, RUS 10] integrate BTP[1] and postal services flows with inter-establishment flows in a category called "logistics flows", but this does not consider movements. From the first analyzes of the "Marchandise en Ville" surveys, Patier [PAT 99] opted to integrate all of these movements, as well as those for inter-establishment flows, into a category similar to that of Russo and Comi [RUS 06, PAT 02]. However, it is only through the work of Ségalou *et al*. [SÉG 04] that these flows play an important role in the categorization of urban logistics in the broader sense. Ségalou *et al*. [SÉG 04] and Gonzalez-Feliu *et al*. [GON 14f] proposed the first estimates of these flows (but unlike the other two categories, at the time these were not integrated into models estimating urban logistic flows). The methods are empirical and related to urban areas, populations, and other demographic and socio-economic data [GON 17]. Cattaruzza *et al*. [CAT 17] proposes a categorization for these flows in relation to the use of algorithms, for the construction of delivery routes, by estimating these flows with the methods and tools of operational research. Besides those works, to our knowledge, there have been no further attempts at a global and systematic modeling of urban management flows (including those within other flow categories), from a partial and restricted view of professional trips that are normally associated with this category [SON 85, JAN 05, LEN 13].

Nevertheless, several sub-categories of these flows have been described and modeled in the literature. For example, the literature on waste transport is very broad, with many different approaches and methods. The use of operational research methods seems to be the main strategy for dealing with the problem of estimating flows associated with waste collection, through vehicle optimization approaches[2] [BUH 12], approaches for the localization of collection points [BEL 74, TOT 02, BAU 06, DEL 06, BAU 08], to more comprehensive approaches for design and supply chain management

1 *Bureau de télécommunications et poste*, the French postal service.

2 The question of the urban waste collection and its transport was one of the first subjects of urban logistics [BEL 74]; however, these references remain relatively unknown, particularly in France.

logistics and services [DET 01, POK 09, GOL 12]. Geographical and spatial approaches have also recently been proposed, mainly with regards to constructal theory [TAN 16, TAN 17]. These works are presented here as examples, and are not exhaustive, but show that the question has been addressed across many different disciplines and contexts. The same reflection can be made for the other subcategories, for example, flows linked to construction. Construction logistics are sometimes addressed in works on freight generation [MAE 79, JAL 13, JAL 14, HOL 16], with categorical generation models such as those presented in Chapter 4, or in the modeling of consumer-driven supply chains [COO 93, SOB 00]. Here, too, we propose these works as examples. An exhaustive and systematic literature review would require a degree of expertise and resources that are beyond the scope of this book, but perhaps these examples could be a starting point for further research on this topic.

The aim of this chapter is to present the main methods of estimating and modeling the two categories of the least studied flows in urban logistics. Firstly, we present methods for estimating purchasing activities. Secondly, we present methods for constructing delivery routes to the end consumer or in the vicinity of the end consumer. Finally, we propose an introduction to the estimation of urban management flows.

5.2. Estimating household purchasing activities

5.2.1. *Some general information on household purchasing activities*

In studies on the modeling of transport and traffic planning, several different definitions for purchasing activities can be found. Among these, two dominant perspectives tend to emerge [GON 13]. The first (most used) specifies that an activity is considered to be motivated by a purchase if the reason for travelling to the destination is the purchase of one or more products [KEE 66, VIC 84, VIC 85]. However, Ségalou [SÉG 99a, SÉG 99b] uses a different notion for purchasing activities, considered from the point of view of urban logistics: according to these authors, it seems more consistent to consider a purchasing activity as any trip that involves the transport of goods. These include home–shopping trips, in the case of home–shop–home journeys, because according to Ségalou [SÉG 99a], both of these categories of journeys are linked to one another: a trip to a location cannot be motivated by the reason of purchase unless there has already been a previous trip to the point of purchase in question. For this reason, it seems to us important to extend this concept to all modes of travel directly related to the activity of purchasing, that is to say any trip that has for its motivation a purchasing activity, whether it be at the origin or destination of said trip. This is stimulated by the fact that these movements are inseparable (thereby verifying the equilibrium: for every specific point of purchase, the sum of all travel motivated by the reason to purchase at this location is equal to the sum of all travel departing from this location immediately following a purchase). In addition, for inter-establishment transport flows, all trucks traveling without a load move towards the place of loading or else are returning (empty) to the depot, are (logically) taken into account; it therefore seems to us essential to include the trips of the end consumer visiting points of purchase (and who repossesses the goods to be transported), which means that the final point in the journey of any particular good is determined by the end consumer. To summarize, a point of purchase is associated with three types of movement:

– upstream trips (1), getting (from the place of residence or any place, excluding another point of purchase) to the location where the goods are purchased;

– downstream trips (2), getting home, after the purchase has been made, or perhaps to another place where another activity (with the exception of purchasing) will happen;

– purchase–purchase trips (3), which have the peculiarity of having a reason for purchase at both the origin and the destination.

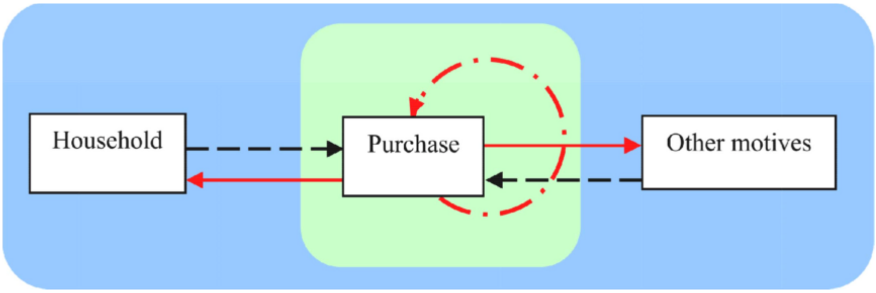

Figure 5.1. *Simplified diagram of the main trips related to purchasing activities (adapted from [GON 12h]). For a color version of this figure, see www.iste.co.uk/gonzalez-feliu/logistics.zip*

Figure 5.1 shows that these trips are linked, and it is therefore important to take into account this link when modeling. Nevertheless, it is sometimes difficult to isolate these individual trips from the chain that is the entire journey of a particular good [GON 12b]. Here the novelty, with respect to the literature, is that the purchase trip is included in the trip chain, which of course includes not only all trips whose origin and/or destination is a place of purchase, but also those that describe what has been achieved before or after these purchase activities. In our opinion, this vision makes it possible to better characterize shopping trips: for example, the trips related to a purchase may be situated within a chain of movements that ends at a household; it is often one of several other trips taking place between the point of purchase and the home (such as the collection of a child, the procurement of a service, or a visit to a loved one), and as such, it would not be an accurate description of the final destination if we only consider the trips where the point of purchase is an origin or a destination.

In this vision, it is therefore important to present the basic notions for the modeling of trips within the supply chain, in order to study the foremost determinants and the key characteristics of these trip chains when they are affected by purchasing activities. A trip chain can be defined as a sequence of movements[3], "having an initial starting point (the origin of the first movement in the chain) and a final end point (the destination of the last movement in the chain)" [GON 12b]. This notion is present in the French trip surveys [CER 08]. However, in these surveys, the only movements that are considered part of the chain are those sequences whose first movement is linked to the origin point (or destination), instead of the reason for the movement [GON 13]. In other words, sequences where the location is the primary purpose (for trip and travel modelling issues) of the movement and not directly related to the origin or destination, are not considered as part of the trip chain. Nevertheless, if we divide these sequences into two parts, where on the one hand, the main motive for the trip is the destination, and on the other hand, it is the origin, we come up with two different chains.

3 That is to say, a series of trips connected via a relation of precedence (for more information on the trip chains, see [ORT 01]).

To this concept is added that of the movement loop, which can be defined as the set of movements included between a departure and a return home [CER 08].

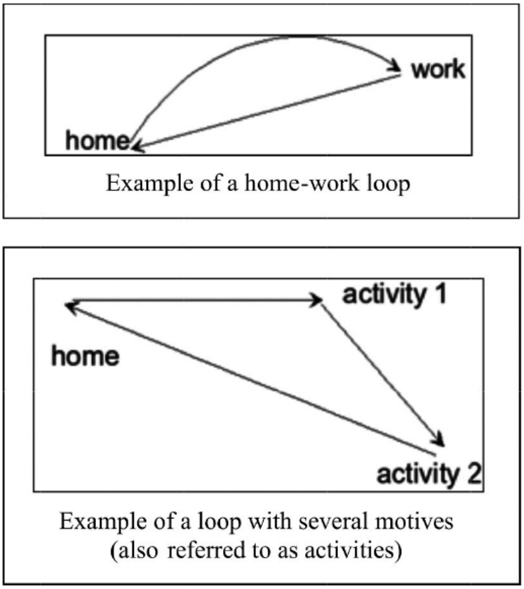

Figure 5.2. *Examples of movement loops according to the standard CERTU definition [CER 08]*

It therefore seems important to analyze the trip chains in order to better understand the causes behind household purchasing movements. First, we propose an analysis of the trip chains linked to household purchases for the urban area of Greater Lyon according to the household movements surveys (EMD-Lyon) for the year 2006. Next, we will carry out a more detailed statistical analysis to study the determinants and parameters of the causes for purchase activities.

Household Trip Surveys (HTS) are carried out in French urban areas with a population of over 100,000 people, in general approximately every ten years [GAS 08], as per the standard set by CERTU [CER 08]. The Greater Paris area, with the Global Transport Survey, is the only exception (which is not quite an HTS, because it follows a specific data collection design and given that the pilot projects are mostly implemented at the local level; its content nevertheless, remains very similar to that of the EMD standard). Interviews are mainly conducted person-to-person, although for the last wave, in cities such as Lille, a mix of person-to-person and telephone interviews were employed. Cities with fewer than 100,000 inhabitants can complete a medium-sized city survey that employs a simplified questionnaire and collects data by telephone. In a city where there is a combination of both urban and rural residents, a Large Territory survey (simplified and thus possible over the telephone) can be conducted [GAB 04, CER 13], as is the case for Grenoble. In 2013–2014, a top-down process[4] was implemented, which sought to update, unify and standardize all of these surveys.

Box 5.1. *Household Trip Surveys*

In the HTS Lyon of 2006, the study area (the urban area in 2005) was comprised of approximately 2 million inhabitants and 800 000 households. The survey divided the study area into 777 finite areas, upon which cluster sampling was conducted in order to obtain a representative sample of the population. The statistical unit (cluster) is the household, composed of one or more individuals. For each household, individuals aged 5 years or more were questioned on all movements they had made the day before the survey. These finite zones were then grouped into larger zones (see [GON 10a, GON 10b, GON 14b] for different models on divisions in 34 and 84 zones). These zones do not have the same characteristics, but nonetheless were grouped into three categories of urban space (see [GON 10b]):

– The *main urban zone*[5] contains the city or the major cities in a particular cluster. For most French cities (which are mono-centric), this zone contains the central city in the cluster (e.g. Paris, Bordeaux, Toulouse or Dijon), however we also observe multi-centric clusters (like Lille or Aix-Marseille). In our case, the center zone is made up of two towns: Lyon and

4 This method is made up of six components, one of which is that of shopping trips.

5 Also called the central urban zone [GON 12c].

Villeurbanne (that is, zones 1 to 8 of the Lyon metropolitan area when it is divided into 34 zones). This is due to the specificity of Lyon, wherein Villeurbanne is, from an administrative perspective, an entirely different city to Lyon; however, from a practical aspect, there is a territorial and functional continuity between the two.

– The *immediate periphery*[6]*, or peripheral urban zone*, corresponds to the towns bordering the central zone, which generally have a less dense urban network (in the case of Lyon, zones 9 to 23). These municipalities are nevertheless very close to the central zone and have similar characteristics, together with some specificities (commercial and leisure areas or the development of a public transport network, among others). We will not use the term "peripheral ring" [GON 12d], because this notion presupposes a mono-centric and very symmetrical configuration, which although is predominant in several French cities is not representative of them all (e.g. the urban area of Lille has a polycentric structure) and is not always the case outside of France [ANT 16]. We therefore prefer to speak simply of periphery in a broader sense, that is to say, a set of towns without any particular form to characterize them by.

– The *distant periphery*[7]*, or peri-urban zone*, comprises the rest of the zones in the urban area (in the case of Lyon zones 24–34). These areas are characterized by a strong presence in the peri-urban or rural environment, with high motorization rates, development of very large retail areas and less access to public transport networks.

First, we will look at the transport chains, whose main motive is purchasing, to define a typology of purchase trip chains, and then delineate the analysis as per the type of urban space. First, we define the number of purchases for a place of residence. Given that for the entire urban area, the total number of daily trips (Monday to Friday), with all motives combined, is approximately 7 million; of these, 11% have as the reason for travel a purchase objective; of these, 82% are trip chains where the primary reason is a purchase or access to a service (health, job search or other steps). Home–purchase(s)–home trips (or shuttles) account for approximately 65%, or almost 70% of total travel.

6 Also called the near periphery [GON 10b].

7 Also called the far periphery [GON 10b].

Residential Zone	All trips	Shopping trips	Included in trip chains where the main motive is a purchase(s) or service(s)	Trips included in household–purchase shuttles
Main urban zone	1,935,789	11.1%	8.9%	6.9%
Immediate periphery	1,972,733	12.6%	10.5%	8.0%
Distant periphery	2,997,085	10.1%	8.4%	6.1%
Total	6,905,608	11.1%	9.1%	6.9%

Table 5.1. *The daily number of purchase trips for the urban area of Lyon using the HTS of Lyon, year 2006. Distribution according to urban space categories (adapted from [GON 12b])*

We see that the number of shopping trips represents between 10 and 13% of the total number of household trips in each zone. We also observe that the majority of purchase trips are linked to chains whose main reason is a purchase or access to a service (82% on average, with very high percentages for each type of urban space). For this reason, we continue the analysis, focusing further on these trip chains.

We begin by looking at the percentage that uses a passenger car (PC) in these trip chains. We observe that the further households are located from the city center (the main urban area being Lyon-Villeurbanne, located approximately in the center of the cluster), the more the use of a vehicle is paramount to their consumption. In fact, people in the main urban area have little recourse for using vehicles to do their purchasing activities (only 20% of purchases in this area are made by car), while, in sections of the two peripheral zones (near and far), the use of a vehicle is clearly in the majority (approximately 64% of trips for the near and distant peripheries).

	Purchase trips in purchase or service chains			Trips in household–purchase shuttles		
Residential zone	Total	Not by car	By car	Total	Not by car	By car
Principle urban zone	172,923	79.5%	20.5%	134,313	76.6%	23.4%
Immediate periphery	206,543	36.3%	63.7%	158,128	45.3%	54.7%
Distant periphery	251,865	29.5%	70.5%	182,621	30.6%	69.4%
Total	631,332	45.4%	54.6%	475,061	48.4%	51.6%

Table 5.2. *Vehicle usage for the purpose of purchasing activities, according to residential zones*

5.2.2. *Proposed methodology*

In the literature, the models proposed are based on simple flows, without a global view of the set of movements within the trip chain. All the research presented here makes it possible to define a new methodology which takes this nature of trip chains into account. Three categories of chains are thus considered:

– shopping trip chains, originating from the home, where the person makes one or more exclusive purchase trips;

– shopping trip chains where other reasons (services, accompaniment, etc.) can coexist with purchases, but whose main reason for leaving home is still a purchase;

– work–purchase–home trip chains where the main reason for the chain is a purchase, even if the chain is part of a home–work–other–home chain, and where other reasons may co-exist within the purchase pattern.

This methodology is structured as follows:

– *Generation of trip chains whose main reason is a purchase*. This is done on the principle that a chain can contain several activities (purchase-oriented or not), but that the one that initiates the chain must be a purchase motive. Unlike the literature, we do not generate all shopping trips; only the destination of the main purpose of the chain.

– *Assignment of each shopping trip chain to a place of residence*. This follows a procedure similar to the distribution of classic urban transport models; however, it does not link an origin with a destination, and because of this, the number of origins is not necessarily equal to the number of destinations. In this way, we are able to associate a number of shopping trip chains with each pair of zones in the city (which may be in the same zone): the first represents the inhabitants' place of residence and is characterized by a number of households, and the second is the points of purchase of these households (the major movements taking place in the trip chains) and is characterized by the number of businesses/shops and the employment rates associated with these commercial activities.

– *Characterization of the trip chains for each home–purchase pair, and calculating the distances of these chains*. For each home–purchase pairing, the number of previously defined trip chains is detailed by specifying the percentage of each chain type. Then, the characteristics of each trip chain type are defined. Finally, the distances traveled along these chains are estimated. For this, we start by estimating the distance between the household's location and the place of purchase (round trip). For the distance of each round trip chain, an average distance of movements made with a purpose other than that of the main motive can be added to this estimate.

Greater detail of these steps in the methodology is presented in sections 5.2.3 and 5.2.4.

5.2.3. *Shopping trip generation*

The first step to be taken when constructing a model for generating trip purchases is the definition of the model's assumptions. The first of these hypotheses is the description of the type of movements being considered. We have already commended the use of purchase trip chains, instead of the simple movements that make them. Next, it is important to define the modes of transport that are included in our model. The preliminary work, which precedes all the research presented here, involves generating all the purchasing activities and retaining those movements being made by private vehicle [SÉG 99a, SÉG 04]. A preliminary model [GON 10d, GON 12f, GON 12h] focuses on motorized journeys (exclusively those by private vehicle). Nevertheless, if we wish to study the impact of retailing-based urban planning on the modal report of consumers in their shopping trips (as explored in [GON 12f]), it is important to consider other modes as well. Unfortunately, with the datasets currently available, trips made by public transportation as well as by bicycle are difficult to include in the model[8]. For these reasons, only two modes are considered: private vehicle and travel on foot [GON 17d].

8 A new survey set, of 2015–2016, is starting to be available, which includes practices such as bike and car sharing, but when writing the present book the author did not yet receive the datasets.

In order to define the general framework for the generation of trip chains, we propose the following mathematical formalization. For a given area i, the number of trips by vehicle which have the purchase of a commercial activity as their destination is defined as STC_i. Furthermore, we define two types of variables, grouped into two vectors: $Hous_i$ is the set of characteristics of households in zone i, Ret_i is the set of characteristics of retailing activities in zone i, and $Tech_i$ is the set of technological characteristics of zone i.

We can therefore write:

$$STC_i = f\,(Hous_i, Ret_i, Tech_i) \qquad [5.1]$$

The vector $Hous_i$ is composed, among others, of the following characteristics:

– *POP*: population in the zone;

– *HOU*: number of households in the zone;

– *MOT*: the average number of vehicles per household in the zone;

– *DPOP*: density of population;

– *DHOU*: density of households.

Those variables are obtained from the population survey files (in France, these are known as INSEE), or in some cases, from household surveys and/or other local sources.

The $Comm_i$ set is composed, among other things, of the following variables:

– *SR*: number of small businesses;

– *BS*: number of supermarkets and specialized superstores;

– *VBS*: number of hypermarkets and very large specialized superstores;

– *ESR*: number of employees working for small businesses in the zone;

– *EBS*: number of employees working for shopping centers in the zone;

– *EVBS*: number of employees working for very large shopping centers in the zone;

– *E400*: number of employees working for businesses in the zone with a total area of more than 400 m^2;

– *SC*: presence of an extra-urban shopping center. This binary variable has a value of 1 if there is at least one extra-urban shopping center, or else a value of 0.

These variables are obtained from the SIRENE file of each urban area.

The $Tech_i$ set can contain several variables, but is the only one that seems relevant to us given the data available to estimate it is HOUI, defined as the number of households in the area that has Internet. Nevertheless, in France, given the widespread use of the Internet and the rise of smartphones and free Wi-Fi points, this variable has little statistical significance. Therefore, we will not use a technology variable in the generation model.

In terms of functional relations, we perform a linear hypothesis. In other words, we assume that the function that connects the number of purchase trip chains with the other variables takes the form of a linear function. The aim of this modeling is therefore to identify the variables that will form a part of this relationship.

Moreover, this model can be defined by the category of urban space. This is based on the hypothesis that the variables that influence the rate of purchase trips by vehicle or on foot are not the same, nor are they to the same extent for different zones of the city. Three categories of urban space are thus considered [GON 10b, GON 12d, GON 12h]:

– the *main urban zone*, which contains the city or major cities within the cluster;

– the *immediate periphery*, which corresponds to the municipalities bordering on the central zone which in general have a less dense urban network;

– the *distant periphery*, which includes the rest of the zones of the urban area, mainly peri-urban or rural.

This categorization of the urban space begins with observations from the data of the household mobility surveys of Lyon and Dijon [GON 10d, GON 12h] and deliberately disassociates itself from the idea of the “ring” (even though, in both cases, the immediate periphery corresponds to the first peripheral ring of the principle urban area, between the distant periphery that makes up the rest of the periphery). This is due to the fact that although the majority of urban areas follow an axial development structure around a city center and can therefore be modeled by following a logic of concentric rings, we observe several cases which are characterized by an asymmetry that does not lend itself to being defined by concentric rings, that is, a multi-centric structure, where each center has its own zones of influence and periphery, with mixed zones being difficult to characterize if following the logic of the ring structure. On the other hand, by following a logic wherein urban spaces are not linked to this notion of axiality or contiguity, as defined here, all possible cases can be represented.

After having defined the working hypotheses, we present the generic model of the generation of the chains of displacement of purchase, which takes the following form:

$$STC_i^e = STC_i^{e-C} + STC_i^{e-F} \quad [5.2]$$

where STC_i^e is the total number of shopping trip chains for zone i (this zone being in an urban space category e), and STC_i^{e-C} and STC_i^{e-F} are the number of movements carried out in private vehicle (PV) and on foot (F), respectively. For each mode h, the number of purchase trip chains (explanatory variable) is linked to the various explanatory variables as follows:

$$STC_i^{e-h} = \sum_k a^{ek-h}.Hous_i^{ek} + \sum_l b^{el-h}.Ret_i^{el} \quad [5.3]$$

where the sets of variables $Hous_i^{ek}$ and Ret_i^{el} represent the variable characteristics of household (demographic) and commercial (socio-economic) networks, respectively. The coefficients a^{ek-h} and b^{el-h} characterize the linear function and give the contribution of each variable to the generation of purchase trip chains.

The global model thus takes the following form:

$$STC_i^e = \sum_k a^{ek-C}.Hous_i^{ek} + \sum_l b^{el-C}.Ret_i^{el} + \sum_k a^{ek-F}.Hous_i^{ek} + \sum_l b^{el-F}.Ret_i^{el} \quad [5.4]$$

In order to define the specific model as well as the parameters of the linear function, we perform a multi-linear regression analysis on the data taken from the Lyon 2006 household survey, using the Microsoft Excel statistical analysis tool. Several combinations of variables have been tested, starting off with a model that includes all the possible variables, then, iteratively, the least significant variables are removed from the model, until finally a new model with fewer variables can be tested. If this model proves itself to be significant, then all its variables are kept; otherwise, the method continues until a meaningful model is obtained.

We evaluate, for each part of the model (i.e. both the PV and the F trips), the model that gives the best results in terms of approximation (estimated by the coefficient R^2 and confirmed by an F-Test). We present in Table 5.3 the results of the regressions for the configurations that we considered better for our model. We present the R^2, the F-value, as well as the critical values.

Category	Car Trip Chains			On Foot Trip Chains		
	R^2	F	Critical value of F	R^2	F	Critical value of F
Main urban zone	0.77	27.30	7.47E-08	0.84	47.87	4.92E-09
Immediate periphery	0.75	20.90	5.41E-06	0.68	52.93	9.22E-07
Distant periphery	0.84	58.02	1.74E-08	0.49	21.28	2.48E-04

Table 5.3. *Calibrated results for the trip generation model of purchase trip chains*

We observe that R^2 is greater than 0.65 for all categories except F trip chains located within the distant periphery. Nevertheless, the regression values for this category remain such that we can consider them to be a statistically valid model (in light of the considerations made by [ORT 01]).

5.2.4. *Distribution of purchase trips: the gravity model*

After generating purchase trip chains, a distribution model has been developed to link these channels to households (i.e. to locate the chain's main purchase location in relation to the trip chain and the household or the final destination, and therefore, the place of consumption for the purchased goods). Given the quality and availability of data, we propose a "catchment area" model to estimate the possible origins of trips where at least one purchase is made in a zone. This model makes it possible to determine the catchment area for the number of purchasing activities taking place between two zones, given the characteristics of the commercial zone for the leading purchase in the trip chain, the demographic characteristics of the associated household zone, and the distance between the two zones. More precisely, the model results in the number of purchase trip chains STC_{ij} for households in zone i who will travel to make purchases in zone j.

The gravity model we propose is based on expanding the distribution model of Ségalou [SÉG 99b] to a catchment area model. Indeed, instead of connecting an origin and a destination of a trip, we will associate each trip chain with a household. These two models, although similar, present a fundamental difference: in the distribution of a number of trips, we know the total number of trips at the origin and the number of trips at the destination. In the present case, we know the number of trip chains associated with each destination (as the primary purpose) and the total number of households. However, we do not know the number of trip chains departing from a given zone (this variable is not generated in the generation phase). The general catchment area model can therefore be described as follows:

$$STC_{ij} = STC_{ij}^{e-C} + STC_{ij}^{e-F} \qquad [5.5]$$

Each of the elements on the right-hand side of the equation can be rewritten as follows:

$$STC_{ij}^{h} = A_j^h . \prod_k Hous_i^{k\,a^{k-h}} . \prod_l Ret_i^{l\,b^{l-h}} \prod_m Ret_j^{l\,c^{m-h}} . dist_{ij}{}^{d^h} . STC_j^h \qquad [5.6]$$

where STC_j^h is the number of purchase trip chains generated by the zone j which is being considered (and estimated using the generation model described above). The variables $Hous^{a^{k-h}}$ refer to the demographic characteristics of households in the zone of origin; $Ret_i^{l\,b^{l-h}}$ and $Ret_j^{l\,c^{m-h}}$ refer to the socio-economic characteristics of households in the zone of origin, and the leading point of purchase, respectively; $dist_{ij}{}^{c^{l-h}}$ refers to the distance between these two zones. In addition, A_j^h is also defined so as to ensure that the sum of all travel assigned to each destination pairing *ij* is equal to STC_j^h [GON 10a]

$$A_j^h = \frac{1}{\sum_k A_j^h . \prod_k {Ret_i^k}^{a^{k-h}} . \prod_l {Ret_i^l}^{b^{l-h}} . \prod_l {Ret_i^l}^{c^{l-h}} . {dist_{ij}}^{d^{l-h}}} \quad [5.7]$$

a^{k-h} , b^{l-h}, c^{l-h} as well as d^{l-h} are coefficients whose determination is the core objective of the modeling taking place. The model is called a *gravity model* due to its similarity with the law of gravity [ORT 01]. In order to define these parameters, we need to linearize equation [5.5], that is, to express it as a linear relation by employing logarithms. We proceed in the same way as the method used to obtain the generation models.

Model	R^2	F	Critical value of F
Car-based Trip Chains	0.95	6619.56	5.57×10^{-26}
Pedestrian Trip Chains	0.83	4889.78	1.27×10^{-23}

Table 5.4. *Calibration results for the distribution model of purchase trip chains*

We observe that, in both cases, the approximation is robust. Nevertheless, the estimate for walking is not as good as that of car-based chains.

5.2.5. *Construction of shopping trip chains*

The construction of purchase trip chains from an OD matrix of purchases in relation to the place of residence is done in two stages: the first step is to define the types of trip chains (home–purchase–home, work–home–purchase, etc.) that will not meet the same objectives or have the same constraints and characteristics; secondly, once these types of trip chains have been defined and quantified in number, the distances traveled can be estimated. The methods used therefore have two different objectives:

– To define the different types of trip chains and their characteristics, three types of approaches can be used: empirical approaches, categorical methods or discrete choice models. Choices for the type of retailer and the mode of transport (which will in turn influence the type of chain and/or its length) can be associated with the type of trip chain. For this, approaches which are derived from operational research, mainly discrete choice methods, can be an interesting tool, provided that they are furnished with the necessary data [RUS 10]. If the needs are to have orders of magnitude (in general, scenario simulations including shopping trips presuppose that there is little change in shopping behaviors, changes in these flows are rather related to location and the form of the commercial network), empirical methods (or relationships derived from linear or quadratic regressions via categorical methods) may be pertinent and allow aggregate estimates to be accomplished with less data.

– For the construction of trip chains themselves, we will also highlight three types of approaches: empirical approaches, analytical models and route construction approaches through operational research. It is important to note that the construction of travel chains by operational research methods cannot be done by delivery route optimization algorithms (or the traveling salesman problem seeking to minimize distances or costs with a profit objective for the company in mind, because these chains are realized by individuals with other motives and objectives). However, this being said, route construction algorithms that are the result of operational research techniques are possible. Other advanced techniques (often related to artificial intelligence) such as ant colony algorithms or neural networks are potentially of interest for the modeling of learning phenomena, however, are not yet used in this context. The estimation of distances can also be achieved by using analytical models (such as those in Chapter 4) with very little data, or through empirical models using survey data. It is important to note that when the vast majority of French cities have regular travel surveys[9] that include purchase trip surveys, empirical methods will be possible using these standard data[10].

For the categorization and choice of chain types, the basis of categorical and empirical methods follows the same logic. Given a zone i, characterized by the number of households, a zone j, characterized by its commercial services, and the number of purchase trip chains T_{ij} for households in zone i that make purchases in zone j which will result in the number of trip chains.

9 Household Trip Surveys (HTS) for urban areas of at least 100,000, Medium City Travel Surveys (MCTS) for urban areas under 1,000,000 and Large Area Surveys (LAS) as an evolution of HTS for certain areas with an urban center that has an area of influence over a large rural area (e.g. the Grenoble region). More information on CERTU [CER 13] is on: www.territoires-ville.cerema.fr/emd-edvm-et-edgt-methodes-et-guides-a679.html.

10 Data from a large part of these surveys are available either through the Quetelet network (www.reseau-quetelet.cnrs.fr/spip/) or directly from CEREMA (tristan.guilloux@cerema.fr).

Once we have identified the number of trip chains, the distances associated with these chains can be estimated either through analytical models or with empirical estimates. The relationships that govern the construction of distances through analytical models are similar to those presented in Chapter 4 (i.e. once we know the start and ending points of the chain, the location of the main purchase of the trip chain and the number of other chain movements, an analogy with the delivery routes can be made and a linear regression is possible (see Chapter 4 for the theoretical bases)). We can thus determine these distances empirically. Table 5.5 shows the composition of purchase trip chains based on the 2006 Lyon HTS.

	Total	**On Foot**	**Public transport**	**Car (driver)**	**Others**
Household–single_purchase–household	55.7%	19.4%	7.1%	23.5%	5.7%
Household–multiple_purchases–household	14.1%	4.5%	1.5%	6.4%	1.7%
Household–purchase(s)+other–household	19.6%	7.2%	1.0%	9.4%	2.0%
Work–single_purchase–household	5.4%	1.9%	0.2%	2.9%	0.4%
Work–multiple_purchases–household	3.0%	1.0%	0.1%	2.0%	0.0%
Work–purchase(s)+other–household	2.2%	1.1%	0.0%	1.1%	0.0%
Total	100%	35.0%	9.9%	45.4%	9.7%

Table 5.5. *Percentages for six types of purchase trip chains versus the total number of chains with at least one purchase (source: HTS-Lyon 2006)*

We see that home–purchase–home chains (with a single purchase) account for almost 56% of the total purchase trip chains, followed by approximately 20% for chains with several purchases (and other motives), and home–multiple purchases–home accounting for approximately 14% of total purchase trip chains. Work–purchase–home chains account for approximately 8% of the total (5% have a single purchase and 3% two or more), and work–purchase and other–home chains account for slightly over 2% of the total.

	Average number of trips	Std. Dev.
Household–multiple_purchases–household	3.3	0.7
Household–purchase(s)+other–household	3.7	1.1
Work–multiple_purchases–household	3.8	1.2
Work–purchase(s)+other–household	5.1	1.4

Table 5.6. *Number of purchase trips (or trips with other motives) in purchase trip chains with at least three trips (source: HTS-Lyon 2006)*

We observe that the number of trip chains with purchases is only slightly smaller than those chains with both purchases and other reasons as the motive. The standard deviations, in general, remain contained, which leads us to deduce that the number of trips in these chains must not vary all that much. We can thus, with a hypothesis of normal distribution for the number of trips, define the minimum and maximum numbers of intermediary trips in these chains, as detailed in Table 5.7.

	Mean	Minimum	Maximum
Household–multiple_purchases–household	1.3	1	3
Household–purchase(s)+other–household	1.7	1	4
Work–multiple_purchases–household	1.8	1	5
Work–purchase(s)+other–household	3.1	1	7

Table 5.7. *Number of intermediary trips in chains with more than one intermediary stop (for purchases or other), with a confidence interval of 95%*

The distance of the first trip will be estimated by the distance between the residential zone and the location of the principle purchase in the trip chain, in the case of home–purchase-(+other)–home (in cases when there are one or more purchases) or the distance between the work zone and the home, in the case of work–purchase(s)+other–home chains (in cases when there are one or more purchases). For the last movement in the trip chain, the distance to be taken into account in all cases will be the one between the residential zone and the location of the principle purchase in the trip chain.

Finally, we can estimate, empirically, the average distance between two stops for trip chains with more than one stop. Table 5.8 shows these average distances based on estimates taken from the HTS Lyon-2006 data.

	On foot		Public Transport		Car (driver)	
	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.
Household–purchase–household	0.80	1.19	2.86	3.47	4.01	4.54
Household–purchase+other–household	0.57	0.51	2.01	1.83	4.27	5.58
Work–purchase–household	0.75	0.68	1.52	1.06	6.40	6.75
Work–purchase+other–household	0.91	2.00	–	–	2.94	3.08

Table 5.8. *Average distances traveled between purchases (or in cases where trips are motivated by a purchase and another motive) in purchase trip chains consisting of three or more trips*

5.3. Estimating delivery routes to households and delivery depots

A subcategory of the consumer-driven supply flows is the increase in this flow to the end consumer, also called B2C flows (Business to Consumer). In France, 35 million people make online purchases and the average annual deliveries being made are approximately 27 purchases per person (an increase of 21% when compared with 2015), which represents more than two deliveries per month, according to Févad[11]. In the United States, it was estimated that, in 2016, B2C deliveries were greater than B2B deliveries, certainly for major cities such as New York City [HOL 16].

B2C deliveries can be divided into two groups [DUR 10]: home deliveries and out-of-home deliveries (mainly to depots or automated package lockers). Out-of-home deliveries can be seen as courier deliveries (classic or express) by integrating with more traditional carrier delivery trip chains or by assigning delivery locations in their own right. Similarly, non-food home deliveries are typically included in small parcels courier delivery routes. These flows are thus pooled together with inter-establishment flows and the methods for their estimations need to take into account both deliveries to places of economic activity, of private individuals and of instructions, and nevertheless, the methods for their estimation remain the same as those presented in Chapter 4. As for food deliveries, we observe

11 Federation of e-commerce and mail-order sales. In ten years, the number of online buyers has doubled, and as a consequence the number of deliveries per person has almost quadrupled in the same period: www.fevad.com/evolution-du-montant-and-du-nombre-dachats-sur-internet-par-les-francais

that these are specifically home deliveries, and therefore, these chains require a precise and exact definition [DUR 10, GON 12e]; nevertheless, these routes can also be defined via the same methods as those used for the other urban routes (i.e. those presented in Chapter 4).

These analytical methods remain the same as those presented in Chapter 4, but require a good projection of the demand as well as an estimate of the delivery route's characteristics. To this end, econometric methods can generate demand models (by analogy with the models presented here), although they require data from logistic e-commerce providers, for example [PAT 04, BEC 16, BEC 16], or surveys of online purchases [CAR 16]. This same reasoning can be applied to the optimization of routes [NEM 04]. These approaches may take into account specific traits, such as the time window at which the customer is available to receive the goods [DEF 12], traffic variability [AND 06] or other aspects, and as with inter-establishment flows, these are used, among other things, to optimize the routes (and thus for planning purposes by the carrier or the logistics service provider), or to set the level of service in terms of delivery schedules, etc.

Finally, empirical methods can be used to define both demand and delivery routes. We present here some data from these empirical approaches, which have been proposed by Durand and Gonzalez-Feliu [DUR 12], who study two modes of order preparation and the impact these have on the urban delivery route. According to these authors, order preparation may be localized (which is the case for orders which are in-store or are available from a nearby storage facility), or regional (which is often the case for preparation orders issued at a central warehouse facility). The first case corresponds to the *System U* strategy (preparation in store) or *Auchan* (preparation at a nearby storage facility), whereas the second relates to the *Carrefour* system (whose *Ooshop* warehouses cover several clusters)[12]. The main characteristics of these delivery routes are presented in Table 5.9.

12 *Système U*, as *E-Leclerc* and *Intermarché*, are networks of associated independent stores. *Auchan* and *Carrefour* mix franchised retailers/stores (for minimarkets/supermarkets) and integrated distribution-sales systems (for hyperstores). *Ooshop* is the logistics operator making *Carrefour's* e-grocery distribution.

	Principle urban zone	Immediate periphery	Distant periphery	Average
Composition – housing units	5%	25%	60%	30%
Composition – housing collectives	95%	75%	40%	70%
Number of delivery points n_i^{LAD}	8	12	11	10.3
Route – average distance d_i^{LAD}	17 km	35 km	80 km	45 km

Table 5.9. *Main characteristics of delivery rounds (source: adapted from [ALI 07])*

	All urban space categories
Composition - housing units	30%
Composition – housing collectives	70%
Number of delivery points n_i^{LAD}	40
Route – average distance d_i^{LAD}	200 km

Table 5.10. *Main characteristics of the home delivery routes departing from a regional order preparation site (source: adapted from [DUR 12])*

5.4. Estimation of urban management flows

For the estimation of urban trip management, we can use the types of models already presented in Chapter 4 (i.e. analytical, empirical and route optimization models). In practice, most approaches have empirical models, and in research most approaches are either an estimation of routes (and have few methodological differences with those already introduced), or are empirical. We present here some generalizations on empirical modeling.

In order to estimate urban transport management flows, independently of the method(s) used, we first need to describe them. This category, although it only represents 10% of road occupancy rates by moving vehicles, is highly heterogeneous [GON 14k]. Furthermore, to our knowledge, there is no exhaustive and standard survey that covers all of these flows. Nevertheless, each sub-category has data sources that can be used to evaluate them:

– transport flows brought about through the construction of buildings and infrastructures can be characterized either with commercial data or aggregate data taken from national studies [SÉG 04];

– the routes associated with the waste collection and its management can be estimated either by analytical models or via specific routes taken from aggregate data or data sourced from municipal or metropolitan services [MAS 13];

– physical logistics flows for the development and maintenance of urban networks can also be estimated through data taken from national studies [SÉG 04];

– trips for personal and professional relocation are generally estimated empirically from national relocation data [GON 14k];

– other types of trips, mainly related to the needs of the community (such as schools and universities) and hospitals, can be characterized by global data from surveys or institutional data for all such flows [PAL 16], which source data from the logistics and transport providers in that sector.

We present in Table 5.11 the main orders of magnitude for the estimation of these flows, as reported in Ségalou *et al*. [SÉG 04].

Activity	**Calculation rule**	**Annual km/hab. (ratio of heavy vehicles / light vehicles and LCVs[13])**
Construction and roadworks	500 vehicles every week per 100 000 inhabitants, 130 carriers per 1,000 m², approximately 20% of VUL	12.1 (80/20)
Maintenance of networks and public services	Total distance by vehicles for network maintenance	17.9 (35/65)
Waste collection	Total annual distance by vehicles used for the collection of waste divided by the number of inhabitants	23.1 (50/50)
Relocation	10% of households move every year	3.9 (20/80)

Table 5.11. *Distances attributed to urban management flows (adapted from [SÉG 04])*

13 Light commercial vehicles

6

Estimating and Modeling Change in Urban Logistics

6.1. Aims, goals and principles of modeling change in urban logistics

The point of the methods proposed in this book, and especially their combination and synergy, is to estimate and model change. That is to say, to identify the different changes brought about by a new logistic plan or scenario under simulation, taking place after the initial situation, with a focus on modeling these changes instead of trying to represent everything and attempting to quantify it. Of course, for some estimates it will be necessary to evaluate the baseline scenario in its entirety (as we will see in Chapter 7), but the degree of detail and especially the overall effort will be less (because for all new scenario simulations, only the flows that change or which are being modified will be estimated), thereby eliminating the need to simulate each task every time (taking into account the difficulty involved in implementing systemic simulations for parts of the system that do not vary).

This chapter presents the principles underlying the modeling of change of examples of this type of model. To that end, we will introduce the elementary notions for modeling change as well as a set of methods and techniques for implementing this type of model. Then, in the following sections, we shall propose examples for the modeling of change through various actions, such as those pertaining to urban logistical spaces, several regulatory actions and actions to do with logistical organization.

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The estimation of change assumes that as soon as changes are made to a system, they will not have an effect on the system as a whole, but on one or more parts, and that some elements of the system will remain unaltered [AND 15b]. For that, it is sufficient to identify the changes made and quantify their effects on the existing system in order to evaluate the impact that the change has had on the system.

In the context of sustainable urban logistics, we observe actions that target more or less important sets of flows (even in situations of restricted access, not all categories of transport are concerned). For that, it is enough to identify the target of the actions that we wish to model and focus on the flows concerned. For example, in setting up an urban consolidation center (UCC) (similar to the *Elcidis* of La Rochelle, the *SimplyCité* of Saint-Étienne or the *City Logistics* of Lyon), it is vital to identify the potential demand of the system and establish the set of routes that are likely to change once the UCC is in operation. On the other hand, the flows that we already know are not involved with the UCC[1] can be set aside and excluded from the model [AND 15b, AND 15c]. In other words, evaluation (by simulation of scenarios or practical feedback) for the purpose of estimating change can be arranged according to the following structure:

– estimation of the initial situation;

– identification of the types of change and the ways of modeling them;

– modeling/measuring changes;

– quantification of the impacts associated with these changes;

– comparison of the initial situation with the final situation.

With regard to the identification of the types of changes taking place in urban logistics, the changes that an action or solution can bring about occur at several levels. This is used to define the categories for the following changes:

– Changes in urban logistics demand: actions such as new services, including new commercial or e-commerce outlets, the relocation of

1 In addition to the end-consumer movements (both shopping trips and home deliveries) and urban management movements, which are not compatible with the current operating system of UCC, we can rule out temperature-controlled deliveries, several large food retailers or not, the own account and some of the courier companies which initially showed little inclination to use these services.

economic activities or local procurement policies, can alter the urban logistics demand. Changes in demand can affect, among other things, the quantities needing to be delivered, the frequency of deliveries, but also have to do with the types of products or suppliers.

– Changes in the urban logistics supply: a new system or service, access restrictions or a change in demand density can lead to a change in transport and/or warehousing systems and can thus affect urban logistics supply.

– Changes in the capacity, autonomy or use of the vehicle: changes in the type of vehicle, in particular switching to less polluting technologies (often with lower capacities and/or autonomy), have an impact on the use of the vehicle, and therefore, on the number of customers whom it can deliver to, thereby having an indirect impact on route construction.

– Changes in distance, scheduling or delivery times: some public policy actions, and also quality of service and availability of the client result in a reconfiguration of the route itinerary.

– Changes in travel speeds and/or downtime: some actions, such as overnight deliveries or smart delivery zones, have a direct impact on the route and may result (in the short term) in the reorganization of routes (in the long-term).

These types of changes are not exhaustive, but show the importance of clearly identifying the causes of change and their main consequences. Although several types of change can have an impact on the distances traveled, this impact is not always direct and its value depends on the concrete actions that the change has had on the different variables that define supply and demand in urban logistics.

For that reason, once changes are identified, it is important to define how they can be modeled. The following are examples of the main ways to model several types of changes:

– A change in demand will generally be modeled on the basis of a model for generating urban logistics demand, either by using models that represent the current reality, under the assumption that the changes in demand are made accordingly [GON 16d], or by quantifying and/or qualifying beforehand the (positive or negative) impacts that the current generation could take into account in view of the situation being simulated.

– Changes in logistics supply are generally reflected by new service parameters (number and type of vehicles, including capacity, vehicle autonomy and other information, types of logistics infrastructure and management policies, number of employees, time, working hours, etc.), from which a new logistical system can be defined and simulated (e.g. by employing analytical models, either in the form of a simulation taken from discrete or multi-agent events, or in the form of operational research methods).

– Changes in speeds and travel times and/or parking have a direct impact on the route's completion time. Nevertheless, those impacts do not always lead to a reorganization of the route itineraries [GON 13d]. For that, sensitivity analyses and threshold estimates for the reorganization of routes may be necessary before affecting route changes (through algorithms derived from operational research, analytical models or empirical procedures, for example).

– Changes in the vehicle require prior study in order to determine whether or not the type of the route can change [AND 15a]. This will determine the significance of the change and the conditions under which this change may be considered negligible or, to the contrary, when it must be estimated. Following that, new route estimates can be made [GON 15].

– Changes in delivery schedules can have different impacts on routes: either they result in a reorganization (and thus a re-optimization) of the routes using the same vehicle [MUÑ 13], or they involve a change in vehicle (for access to restricted areas [GON 15]), or a change in the urban delivery system (passage through a UCC or a change in the type of delivery, type of vehicle and the constraints and characteristics of these deliveries).

It is also important to be able to measure the magnitude of the impact the change estimates might have, both in relation to the elements that change and in the overall context in which they are incorporated. For example, several UCCs, in their initial configurations, captured 1–5% of the total inter-establishment flows. Consequently, the impacts on the total flows of these schemes are negligible, but in relation to the flows concerned (i.e. the flows actually entering the UCCs), reductions in distances and emissions of 15 to 30% were measured, in other words, of the flows concerned solely with the UCC, the impacts are positive. This result may encourage the development of the system and thus the development of studies on the introduction of demand in economic and environmental assessments (see

Chapter 8), in order to study the relevance of these solutions, even though initially these impacts are likely to remain relatively small when compared with all the flows for the clusters involved.

Once the changes have been identified, it is important to model them as representations of reality or a future reality that we wish to exemplify (and therefore solution probleming, the notion developed in section 6.3). Finally, the compilation of the initial and final states will be made from the quantification of these changes and hence the results of the modeling. In that analysis, the problem-solving vision presented in section 6.3 will also be included.

Conducting studies on change amounts to carrying out analyses of tangible and measurable actions, and a purely theoretical presentation of this methodology may not be sufficient to understand the contributions of this method and its uses. For these reasons in the following section, by way of example, we present a set of applications of this methodology. These applications are not exhaustive, but show the potential and the feasibility of modeling the changeover.

6.2. Examples of assessments and analyses using change modeling

6.2.1. *Modeling the changes induced by the introduction of the SimplyCité UCC to Saint-Étienne*

As part of an environmental assessment of the SimplyCité UCC of Saint-Étienne, an analysis on the changes was also carried out [AND 15b]. The objective of the analysis was to estimate the environmental gains associated with the implementation of the UCC. To that end, two scenarios were compared in a before–after analysis:

– the reference scenario, or "before", corresponds to the traditional delivery patterns of downtown Saint-Étienne, handled by remitter carriers[2], that is, the situation before the UCC was implemented;

2 In 2015, deliveries were carried out by four carriers: *Ziegler, Kuehne + Nagel, Heppner* and *Dimotrans*. These carriers deliver their goods destined for downtown Saint-Étienne to the UCC, which is why they are called "remitter carriers".

– the "after" scenario represents the situation in September 2015, which corresponds to the delivery of goods by carriers in downtown Saint-Étienne by way of the UCC.

Before defining the initial scenario, it is important to define the scope of the analysis. Initially, it was decided to focus on the gains in relation to the flows affected by the change, that is, not to contextualize the change in relation to the total flow of goods within the city, but to look only at the UCC and study the unity gains in order to identify the potential of the UCC in view of its development. For that, transport providers using the UCC at the time of the analysis were identified, without the assistance of the UCC. In order to study the change, we defined a time period for the analysis: the weekly operation of the UCC.

Next, the change can be defined. The week-long operation involves 5 × 50 delivery points[3], corresponding to 13.7 tons of freight per week transported in the city of Saint-Étienne. In order to estimate the number of points and the quantities of the goods being delivered in the Saint-Étienne city center, an interview with the UCC manager was conducted and data on the volumes transported during the years 2014 and 2015 were collected.

In scenario 0, each transporter carries out their deliveries (four of which account for approximately 50 deliveries per day). Interviews with these four transport companies were conducted in 2015 [AND 15b] to determine how these deliveries were carried out prior to the establishment of the UCC. From these interviews, the routes corresponding to the initial situation were estimated empirically. At the same time, the analysis of the operating data allowed the reconstruction of routes for scenario 1, also attained empirically. Thus, the routes of scenario 0 and scenario 1 were reconstructed in a coherent way allowing for a comparison to be made and therefore an estimate of the change undertaken. More precisely, scenario 0 resulted in a road occupancy of 403 km.CEU[4], while scenario 1 represents 466 km.CEU. Of the total number of transport carriers considered, which was very small, the impacts on the road occupancy of the UCC were deemed negative (since they are higher than those of the reference situation). This is due to the fact

3 We call the delivery to a given customer the "delivery point". A delivery point may consist of one or more packages, one or two pallets, or even a mixture of packages and pallets.

4 CEU = Car Equivalent Unit. In general: 1 private car or light vehicle = 1 CEU, 1 light goods vehicle (or light commercial vehicle) = 1.5 CEU; 1 small truck = 2 CEU; 1 big truck = 2.5 CEU [GON 12c].

that not only did passage through the UCC imply a change in direction, it also involved a detour, and the employ of smaller vehicles which therefore meant more delivery routes. In order to ensure their deliveries, two transport carriers used Light Goods Vehicles (LGVs) while the other two carriers opted to use a Maximum Authorised Mass (MAM of 13 and 19 tons, respectively). The UCC only uses 3.5-ton LGVs to decrease congestion in the city. In addition, as shown in Figure 6.1, for three of the four transport carriers (located near the UCC), the utilization of the UCC involved a very short distance between their deposit and the UCC. However, for the carrier located further away from the UCC, the distance of the detour was slightly longer (approximately 1.5 km).

This method can be transposed to simulate many scenarios. Indeed, if we are aware of the demand, and we predict the degree of change introduced into the system, as well as the number of vehicles using the UCC, it is possible to reproduce these route itineraries. Indeed, with demand generation models, it is possible to generate demand, and together with qualitative analyses, we are thus able to identify the available demand. Following from this, through the use of analytical or empirical models, the change in the route itineraries can be estimated by analogy with the method presented previously. Finally, the significance of the change(s) introduced can be estimated.

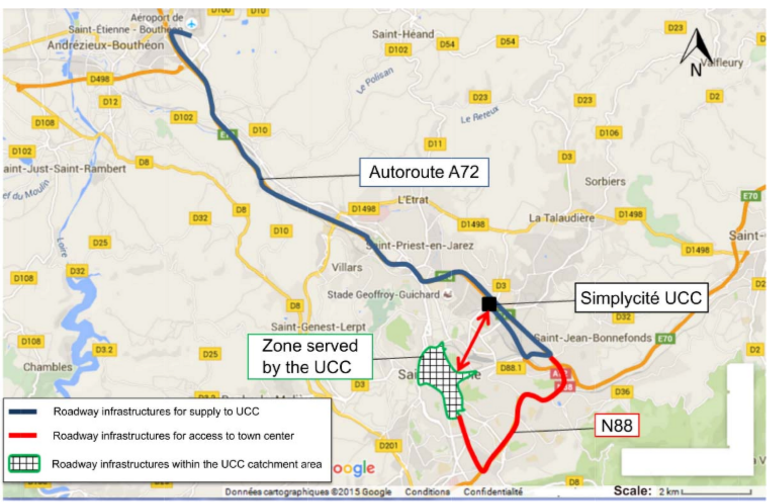

Figure 6.1. *Scope of analysis for change(s) induced by the SimplyCité UCC in Saint-Étienne (adapted from [AND 15b]). For a color version of this figure, see www.iste.co.uk/gonzalez-feliu/logistics.zip*

6.2.2. *Modeling the change(s) brought about by restricting access to the city center*

Another example in which it is important to estimate change concerns the restriction of access to the city center. These restrictions may be of different types, and may involve different stakeholders. For these reasons, it is important to first define the breadth and scope of the study, as well as the stakeholders involved. The definition of the baseline scenario and analyses of the change(s) will be substantially different according to the scope and perspective of the study. For example, a perspective at the level of the local authority will often require an analysis of all the flows and an estimate of the change will entail an analysis of all the flows moving towards the city center and thereby a specific identification of the types of transport concerned and not affected by the restrictions, as well as an aggregated estimate of the new route itineraries brought about by this restricted access, according to normal behaviors. On the other hand, from the point of view of the transport company, the changes are moreover related to the company's choices in terms of which type of vehicle to use, whether to change the route itineraries, whether to apply this to a subset of vehicles or to all of them, which therefore requires greater detail and with the objective of optimization and logistical organization.

The manner in which the analytical methodology is carried out therefore depends on the objectives and the point of view of the analysis. As a result, it is impossible to define a single model or software that applies to all cases, that is to say there is no explicit turnkey solution, although the steps of the change analysis methodology are adaptable to any context.

For example, in the case of an analysis on the overall effect of access restrictions, the initial situation includes all inbound flows into the city center, from which the flows affected by access restrictions are estimated. Once these are estimated, the consequences of the access restrictions must be studied in order to identify the most appropriate ways of modeling them. For example, from a public authority perspective, an analysis of the change induced by the introduction of access restrictions to the city center would aim to estimate the impact on road occupancy and/or vehicle density(s), as a result of that reduction in the time slots in which to access delivery areas, and/or possible changes to vehicle types or the reorganization of logistics to comply with the new limitations. To estimate these changes, an identification of all the inbound flows into the city center within a specific time slot can provide the basis of the route itineraries to be modified, and hence the number of deliveries affected by the new limitations. To estimate those changes, an identification of all the inbound flows into the city center within a specific time slot can give the basis of the route itineraries that need to be modified, and hence the number of deliveries affected by the limited times. Secondly, it is important to identify the main changes that can be considered as feedback: for example, temporary trip routes (i.e. the implementation of the same routes on another schedule [PLU 12b]) and change the shape and size of the routes [GON 14], can involve the reorganization of routes [AND 15b]. In all cases, given the need for comprehensive approaches for large sets of flows, accurate analyses or models from operational research do not seem to be relevant or require access to large amounts of resources. To that end, empirical or analytical methods for estimating flows will be favored.

On the other hand, when a transport company invests in a change analysis, it usually has the objectives of augmenting profitability and improving transport efficiency [MUÑ 14], which require finer analyses. The basic scenario is obtained by identifying all the company’s flows, and only then can the changes in the organization and optimization of these routes be studied. For that, different types of methods can be used, but operational research methods seem to be the most relevant and as such have seen the most development in the literature [QUA 09, DEF 12, MUÑ 13]. The three works quoted here present change analyses on route optimizations; however, they achieve this with different models:

– the first [QUA 09] models access restrictions in terms of delivery time windows, prohibiting deliveries in the restricted slots;

– the second [DEF 12] defines fictitious slots where stores cannot receive deliveries;

– the third [MUÑ 13] defines the slots when vehicles cannot return to the city center and the optimization algorithms take account of these slots.

These optimization algorithms can also be used to estimate the change in vehicles (and the changes that a variation in the maximum capacity can have on vehicle optimization), which may be one of the consequences of access restrictions (i.e. the restricted vehicles which have been replaced by the others that have been authorized). Work on these changes [GON 15, PAL 16] shows that, contrary to popular belief, VULs pollute less and are the more suitable vehicle for city delivery; they are not adapted to certain delivery trades (for which, taking into account the volumes being transported, vehicles of 9 or 14 tons are more efficient). To carry out these analyses, it is important to keep the simulation of the initial scenario and that of the final scenario coherent. To that end, it is important that the algorithm used follows the same logic and the same approximation for both scenarios.

6.2.3. *Modeling the change brought about by new forms of e-commerce*

E-commerce has an impact on the end consumer flows as soon as it substitutes the purchase trips by B2C professional flows. To that end, modeling these changes requires the identification of the flows concerned (purchase trips substituted) and followed by the substitution mechanisms as well as their modeling. However, the substitution of a traditional purchase trip by one of these forms of distribution also has an impact on the commercial delivery itineraries (especially when the order preparation is no longer being carried out at an urban retailer), and therefore, on inter-establishment flows [GON 16a]. We thus realize the importance of defining the changes and studying them as a whole.

Of course, this modeling will also be linked to the objectives and stakeholders involved in the analysis. A first empirical substitution method is proposed in [GON 12d]. This work had to be carried out with the available data, the main challenge being particularly the collection and processing of the data. Consequently, the proposed modeling has been to define very simple, yet intuitive and repeatable, substitution procedures that follow the steps given below:

– the identification of purchase trips to be substituted;

– the identification of the quantities of goods concerned, followed by changes in inter-establishment flows;

– the construction of the new end consumer flows (new purchase trips following a drive delivery, new domestic delivery routes, new relay point delivery schemes and then trips to consumers to collect and return products to the point of consumption);

– the construction of new inter-establishment flows;

– the estimation of changes in the distance traveled;

– finally, the integration in a set of trips to estimate the change by comparison with a more consistent set.

6.3. Generalizing the examples of overall change modeling framework

From the three examples presented above, we can define an overall change modeling framework in a generalization perspective. To do that, we start identifying the main characteristics of the change analysis. We observe that, in each of the three cases presented above, the analysis of the change therefore depends on the scope and point of view, and this can be applied to any application of this type of analysis.

More precisely, before carrying out the analyses, it is important to define who is the decision maker, or for whom these analyses are being carried out. For example, the needs, the objectives, and therefore the way in which the changes are defined and estimated will not be the same if the stakeholders concerned are public authorities, transporters or retailers. Indeed, a public community will generally be governed by public utility and therefore focus on issues of collective well-being, recognizing the need to estimate the overall impacts, but not necessarily to a very detailed degree. In addition, the focus of a local authority (which generally have efficiency targets translated into a need to quantify impacts and evaluate the system, in economic, environmental and social terms, particularly in terms of job creation and the improvement of air quality) will not be exactly the same as for a regional or national entity (whose issues are more general in nature and whose needs are linked to the justification of the means made available to contribute to the good which translates into less detailed assessments, but the need to estimate the magnitude of gains or losses, predominantly in environmental, social and economic terms). However, the logic of transport carriers are focused on optimization and survival (economic profitability being essential to continuity), hence the need to anticipate the possible consequences of the uncertainties and even the errors inherent to an estimation, as well as the need, in certain cases, to predict these analyses with a view to optimize and/or improve them.

Once the decision maker is identified, we can define the precise objectives of the analysis, which may be different according to the stakeholder, but also their degree of maturity to reflect. It is important to note that every change analysis is heavily dependent on these objectives, which stem from the needs of the decision maker, as demonstrated in this section. These objectives will also depend on the construction of the reference scenario and simulated scenarios and, as the examples presented above show, the exact requirements and assumptions underlying the estimation and simulation methods.

This brings us to the question of the methods and tools used, and again illustrates that the logic for a "universal and standard model" cannot be applied to urban logistics. On the other hand, by following the steps of the change analysis and, using the most appropriate approaches at each stage, we can suggest common-sense and easy-to-communicate solutions for all cases. However, in order for these change analyses to be comparable, it is important to use a method that follows the same principles (and whose accuracy differential is measurable). In the case of several analyses from the same reference scenario, it is important to estimate the change using the same method, or else methods that are consistent and comparable, not only with each other, but also in relation to the reference scenario.

Therefore, it is important to identify the types of change and compare only those that are comparable. For example, if in the construction of the reference scenario a very general and aggregated approach was used to estimate the flows, assuming that there is low optimization, and the objective is to estimate the change in these flows by introducing a new type of vehicle, it is important to distinguish those changes related to a difference in vehicle capacity from those which are the result of resource optimization. Similarly, if we want to compare two vehicles with different capacities and different euro criteria, it is important to take into account the change induced by the difference in capacity and the fact that one vehicle will be less polluting than the other.

Therefore, the more the specific changes are identified and treated explicitly, the easier it will be to make comparisons. Finally, as Gonzalez-Feliu [GON 17a] points out, there is no single method or tool, despite what some commercial discourses advertise, and the linking of analyses (currently in existence or possibly those in the near future) is necessary to ensure the relevance and rigor of the analyses proposed.

For this, it is important to look at the aspects related to the relevance of the models used. We propose to introduce the basic notions of the vision of solution probleming and the comparison of a model with the reality that it represents.

6.4. The importance of solution probleming in change analysis

The modeling[5] and application of mathematical methods to forecasting (in urban logistics, and also decision-making support in general) is carried out according to different visions, generally disciplinary ones, which can be seen as being in opposition. Nevertheless, there is a predominant view in mathematical modeling that follows the principle of problem solving [ACK 77], that is to say that the system to be modeled is translated into a modeling problem, for which the best technique or solution is chosen. Generally speaking, this is the more computational or quantitatively robust option. Nevertheless, this vision can sometimes be biased in its relation to the reality that the modeler wishes to represent. One of the most typical examples is the use of route optimization algorithms, which, despite giving solutions very close to the theoretical optimum, are not used in practice because the routes given are not feasible for drivers [AZA 15]. Other examples include precise impact estimation models, which define very detailed vehicle categories when the average fleet or characteristics of these vehicles are unknown; or, in the case of evaluation approaches that provide multiple dozens of indicators when the decision maker only has three or four measures in mind [AND 15b]. Finally, we recall the case of demand estimation models, as shown in Chapter 4, and several of them can be defined with similar qualities of approximation. The model which is most useful in practice does not always seem to be the one with the smallest error margin, but rather the one with the most relevant conditions of use [SAN 16]. The search for this relevance is not contemplated in problem-solving approaches.

5 We mean by modeling a representation (mathematical or not) of a reality as perceived by the modeler. The model is therefore a representation and not the reality in itself, and in that sense depends on the point of view of the modeler and the assumptions that are made during modeling, at least in terms of the techniques used to achieve this representation.

To that end, Ackoff[6] [ACK 77] introduces the notion of solution probleming, whose name is both opposed and complementary to that of problem solving. Indeed, Ackhoff [ACK 77] insists that a model can only be complete if it integrates both sides (problem solving and solution probleming), in an iterative and interactive manner. Problem solving is therefore the step that takes place once a solution (or several) has been found (here the term solution refers to the results of a calibration, error, and use of a model), and consists of comparing the results obtained with the reality that the modeler wants to represent, in order to study the model's representativeness of reality [GON 16a]. If that representation is deemed sufficient, the search stops; if not, it is important to consider whether the deviation from the reality sought comes from the model (i.e. the formalized problem) or the algorithm developed. This representativeness is not always measured quantitatively. Indeed, validations by expert committees or impartial observations, without the need for large amounts of data and calculations, can confirm or deny the validity and representativeness of a model or algorithm. In other words, if an approach is very robust from a mathematical and computational point of view (i.e. the calibration parameters are very satisfactory), but the result obtained is not recognized as a representative of the current reality by the practitioners, the solution obtained may not be relevant. It is therefore necessary either to change the model and/or the algorithm, or to reexamine the data and the context of use in order to define how (and why) the model did not represent reality, or failing that, to review and reconsider the objectives and assumptions of the optimization in question.

Solution probleming has not only been greatly developed in the context of the so-called "soft operational research" [CHE 75, ROS 76, ROS 09, ACK 77, ACK 79, GON 13], but can also be applied to any type of representation modeling or analysis. We propose here the structure for a general methodology integrating problem solving and solution probleming, applicable to any modeling and evaluation inquiry in urban logistics, for the

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6 Russell L. Ackoff was one of the pioneers of operational research, and also one of the most critical academics that turned the discipline around, taking it from its applied origins to become more mathematical and calculated, and sometimes too abstract in relation to the reality. He is considered a "heretic" by some authors, but has inspired a new vision (among a minority, but not insignificant) for operational research, being developed in the United Kingdom mainly [KIR 07].

estimation of change. The steps in this methodology can be summarized as follows:

– definition of the goals and the scope of the analysis;

– data collection and definition of the approach (deductive, inductive, abductive) most relevant for modeling;

– creation (or application) of a first model (or several);

– analysis of the robustness of the model (or models) so as to define its validity from a mathematical or computational point of view[7];

– production of data and definition of situations in order to evaluate the use of the chosen or developed model;

– implementation of a first application of the model in relation to current or possible data and solutions;

– analysis of the relevance, coherence and robustness of the selected model in relation to the objectives and scope of the analysis. This analysis may be quantitative, qualitative or both;

– analysis of the representativeness of the model in relation to the observed reality. This analysis nevertheless requires the support of expert practitioners and cannot be done only by researchers;

– if the model is deemed to be relevant and representative, it is selected and can be used under predefined conditions and application contexts. If not, the model is revised (partially or completely, depending on the results of these analyses) and the methodology returns to step 4. Iterative analyses are then carried out until they converge upon a satisfactory combination which contains the problem, the model, the resolution method (if applicable) and the solution obtained by this method.

It is important to note that, in any case, this method requires the development and/or deployment of estimation models and methods, and for which they need to be accurate and robust [DON 12]. What solution

7 To solution problem the model at a later date does not exclude the problem solving phase. We propose only to supplement it with the solution probleming phase, but without eliminating the necessary and relevant analyses needed to define a robust model.

probleming brings to the fore is the relationship with reality. To study that relationship with reality, several types of analysis can be carried out:

– Analyses on the relevance of the empirical data being measured [BAL 94, BAR 96, DON 12, BON 14], that is to say the estimation of the model's capacity to reproduce observed phenomena and behaviors. For that, it is important to carry out, in addition to the standard calibration tests relating to the construction of a model, error analyses of the model estimation with respect to the collected data [GON 16], other tests designed to study the heterogeneity or dispersion of the phenomena modeled, as well as the capacity of the model to reproduce them [SÁN 16a].

– Some authors also propose a study of the relevance of the model by its ability to reproduce accepted theoretical behaviors in the scientific community [BAR 96, DON 12], for example, by carrying out tests or error analyses on the phenomena estimated by the model and the theoretical relations or laws of statistical distribution defined as hypotheses.

– Analyses on the coherence of the data structures and the phenomena represented [GON 16a]. In other words, even when the errors between the results of the model and the data collected are few, it is important to ensure that the relationships proposed by the models are coherent, and more precisely, whether any missing data or biases in the collected data may have influenced the construction of the model. For example, a linear model (of type $y = ax + b$) with a negative constant can yield good results, but give out negative values when the explanatory variable is zero. Therefore, there is a need for re-examination in order to determine whether the hypothesis is coherent or not. Similarly, a linear model obtained from two distinct point clouds (very small or very large explanatory variable values, but no intermediate point values) can give a very good regression line, but, with an important chunk of missing data, it is difficult to say whether this line is in fact coherent: in order to be able to do so, we would need to collect the data for the missing values of the explanatory variable, or else carry out quantitative and qualitative analyses to see whether this variable can take these values or whether it would be more coherent to define two individual subsets.

– Analyses on the ability of data to represent reality. For example, some models are based on surveys that have different biases and the ability to reproduce reality remains to be verified due to the difficulty pertaining to collection [AMB 10]. The relevance of data in relation to data collection methods is important in determining the capabilities of the model and also to define magnitudes of errors that are acceptable. For example, a four-step model generates significant errors (on average about 25% [ORT 01]), but this is accepted because the collection of the data needed to perform these models contains numerous biases, which in turn justify these errors.

In order to carry out these analyses, different techniques to estimate the robustness, transferability and stability of these models were used; however, it is up to the modeler to define the validity thresholds of his/her model, along with the inherent problems it creates, not to say that his/her model is the best, nor justify its existence, nor for that matter the financing of the model[8], but rather to establish the limits of its application and reflection on where and how it might be improved. In short, by explaining the hypotheses and describing its intended application.

Finally, the validity of a model, or an estimation method, also requires us to confront the objectives for which it is or will be developed or applied. In other words, a model must be able to answer the questions asked by users with a precision that is defined as acceptable. For those reasons, the validity of the model will depend not only on its capacity to represent a given reality, but also on the type of results expected of it. To that end, some simple and approximate models are favored in certain contexts over others (where the results obtained with those approaches allow us to obtain results whose magnitudes are sufficient enough to support the actions and decisions that need to be taken), whereas, in other cases, more detailed models (brought about by a genuine need for modeling and the availability of appropriate resources) will not only be relevant but necessary.

8 Some authors emphasize the virtues of a particular model's representation of reality in their discourses to the extent that it seems like advertising. Although still a minority, these practices still exist, and hence, the importance of checking the source of the discourse (an article in a serious peer-reviewed journal is generally considered to be scientific and neutral, without any hidden publicity) and the methods of validation (even for qualitative approaches, validations that are justified by scientific approaches and which detail their methods and hypotheses in turn make it possible to scientifically validate the discourse in question, whereas the discourses based on hearsay or opinions without any clear validation are not scientific [RAS 14]).

7

Indicators and Dashboards for the Evaluation of Sustainable Urban Logistics

7.1. The need to evaluate sustainable urban logistics for the definition of dashboards

As we have seen in Chapter 3, there is no standard and “ready-to-use” framework to evaluate and assess sustainable urban logistics solutions. Indeed, urban logistics is a complex system involving several stakeholders, each with different stakes and objectives, and located within different spatial and demographic contexts. Therefore, proposing a unique and irreplaceable grid of indicators applicable to any context of a universal “black box” has proved to be neither practical nor theoretically conceivable:

– Patier and Browne [PAT 10] conclude on the impossibility of carrying out experiments on a single set of indicators due to a lack of common indicators[1];

– Melo and Costa [MEL 11] propose a broad grid of indicators but do not advocate how to combine them and/or prioritize them;

– Gonzalez-Feliu [GON 17a] proposes, instead of a single method, the idea that the different evaluations should be based on a coherent estimation of flows and change and that the differences between methods are measurable in order to compare evaluations (not only methods but also outcomes).

1 The authors propose to compare the evaluation methods with each other instead of the results, but this does not lead to a comparison of experiences or to the proposition of a single and universal method for evaluating any sustainable urban logistics solution.

Sustainable Urban Logistics: Planning and Evaluation,
First Edition. Jesus Gonzalez-Feliu.

In any case, it is essential that we should be able to compare, quantitatively or qualitatively, the various actions of sustainable urban logistics taking place between them, in order to discern the truly worthwhile actions from the superficial solutions. This comparison is all the more important given that a knowledge base of urban logistics solutions deployed in different contexts and their potential for transferability and/or adaptation to other situations can help new solutions or actions to become sustainable[2].

Moreover, each experience takes place with different stakeholders, stakes and contexts, and the needs in terms of evaluation differ. A discernible common point is identified: that is the need to estimate flows, from which most of the indicators of the evaluation can be calculated [GON 17]. For this, we propose to look at the evaluation of sustainable urban logistics and, by extension, Sustainable Supply Chain Management [MOR 13], which presents a methodology, based on the definition of Key Performance Indicators. These indicators do not always integrate transport, hence the need to supplement it with the identification of specific indicators for the transport of goods [MEL 11]. With the integration of these two visions, we can propose a set of indicators which, although not adapted to all contexts, nonetheless follows a unified calculation methodology and generally requires the same primary information, which facilitates comparability and the creation of a common base of quantitative and qualitative concepts.

The key to the comparability of sustainable urban logistics assessments would therefore be based on the definition of a broad base of indicators that require unified and standardized primary information. However, in freight

2 Indeed, we observe experiences and systems that develop and which self-identify as being innovative and which are ultimately very similar to others that have already been developed. We also observe that most of the systems that did not work were unaware of their foreign counterparts and that these experiments would have been very useful in making them viable and sustainable over time, or at least aware of foreseeable risks and otherwise unforeseen events that may occur along the way. This is the case with many French UCCs, which develop without knowing that the functioning English, Dutch and Japanese UCCs are used and/or promoted by the carriers, who pay the extra cost, and that such a system does not pose any competitive problems among carriers [ALL 14b, TAN 14]. Another example is that of reservation systems for delivery zones, where in France, efforts have focused on IT developments without taking into account the needs and challenges of carriers [DAV 13, PAT 14]; the international experiences (mainly in Bilbao) have shown that the main hindrance is the fact that these zones are occupied by private cars who have parked there illegally, and that in order to free these places, we need constant vigilance and training on the part of the police [PLU 12a, PLU 12b].

transport, primary information (distances traveled, drive times and work times, speeds, loading of vehicles, etc.) now follow national, European or international standards.

We propose here to define dashboards from a broad set of indicators for a panel of decision makers. The dashboard is obtained according to the management control regulations [BOU 01] and by consensus. The basis of indicators requires logistic and transport information that is considered as being understood and to a certain degree of standardization. The methodology allows decision makers to be guided in their consensus choice of the dashboard, nevertheless leaving them with the final decision [MOR 15b, MOR 15c]. These indicators are then calculated using primary information that is easy to collect or estimate [GON 14c].

The objective of the methodology proposed here is to guide a set of decision makers to create a dashboard for the evaluation of sustainable urban logistics. For this, three elements must be considered:

– The consideration of a maximum number of indicators (between five and ten), as recommended by Bouquin [BOU 01] so as to enable users to learn about the state and evolution of the systems they are planning or piloting. It is important to note that here we add a dimension of planning (i.e. the dashboard can be applied both to the piloting and planning of sustainable urban logistics), mainly for the purpose of identifying trends with the main impacts in the assessed systems on a time horizon consistent with the plan envisioned [MOR 15b].

– The inclusion of the three axes of evaluation obtained from the consideration of the three spheres of sustainable development, that is, the economic, environmental and social/societal axes [MOR 13, MOR 15c].

– The consideration of various stakeholders, the decision-making process of a group or the reasoning of a community [YEA 11], and therefore, the choice of a consensual solution rather than an overall solution that gives the best average or aggregate results [GON 13d][3].

3 The main novelty that group decision theory [DAL 77] adds to multi-stakeholder decision-making comes from the definition of the group (i.e. the set of individuals with a common goal and who are reasoning together as a community): the group has a common purpose or interest, and therefore, in group decision support, it is accepted that different individuals seek agreement, and therefore, there can be no veto actions.

For this, it is necessary to define dashboards which on the one hand, are, multi-sphere (i.e. that take into account the three spheres of sustainable development), but, on the other hand, utilize a limited number of indicators, making it difficult to select a good number of indicators that are simultaneously representative of the three dimensions of sustainable development. Moreover, this choice cannot be made unilaterally. In other words, whether this derives from an expert opinion, a political or strategic choice, or as the outcome of consultation procedures, the choice of the dashboard by a single stakeholder without the others having given their input is counterproductive to the success of logistics solutions, as non-decision makers can oppose or even impair the development of those solutions [GON 11, GON 12c].

7.2. Methodological proposals

In this context, traditional decision-making methods, which presuppose decision-making by a single all-powerful stakeholder[4] (e.g. [TAN 00, BEH 08, HEN 08]), do not seem to be appropriate representations of the multi-stakeholder nature of urban logistics. Multi-stakeholder methods [MAC 10, MAC 14, GON 13d, AWA 16] may be an alternative, but they have traditionally had the objective of the proposal of a solution (or a set of solutions) set into motion via automatic procedures, with little interaction with the stakeholders involved, and even though their evolution does not yet take into account the dynamics of the group or the advantages the interactions (learning) and discussion among its individuals can bring to the table. One discipline, popular in the 1940s and muted until the late 1990s, was that of group decision support [LEW 47, RAI 02]. The theory of group decision-making [DAL 77] assumes that decisions are not made by a single stakeholder but by a number of people, after a process fostering consensus [MOH 01, YEA 11]. Yearwood and Stranieri [YEA 09] also define the steps of this consensus-seeking decision-making in the reasoning of communities (or groups), further complemented by our considerations [GON 11]:

– In the individual phase of reasoning, each individual involved seeks out evidence and decision-making elements, organizes them and finally forms an argument representative of his/her point of view, his/her convictions and therefore his/her individual decision choices.

4 In the sense of a decision that is made unilaterally without any discussion or consultation.

– The communication phase of reasoning describes the transmission of all aspects of individual reasoning, including the choices, preferences, motivations and justifications, to other members of the group. In this phase the position of each stakeholder communicates the motivations and justifications of their position, without necessarily seeking any consensus.

– Finally, the phase of coalescence of reasoning includes all the steps employed to reach a position and reasoning that is representative and deemed acceptable (and accepted) by the community as a whole. A coalescence of reasoning does not mean that an agreement for a solution has been found. The coalescence of reasoning essentially reflects the state where the reasoning of each individual is understood and accepted as valid by the community, even when there exists a divergence of views that consider an agreement (or consensus) to be impossible.

This coalescence of reasoning can thus be defined as the situation where each individual point of view is understood and accepted by all the other stakeholders, but without necessarily reaching an agreement. At this stage, three distinct outcomes seem possible:

– A situation of concordance: all of the stakeholders explicitly choose a solution that they see as the most adjusted of all those presented. It is chosen and accepted by each and every one of them. As such, the agreement is total and explicit. Often their position, to this effect, is written down and countersigned.

– A situation of consensus: a solution is chosen as being the most suitable for the group and no individual is opposed to it. The chosen solution is often judged to be the “least bad”, and the agreement remains implicit. If the concordance can be assimilated to a stable equilibrium, the consensus by contrast is the unstable equilibrium.

– A situation of non-agreement: the third possible outcome from a coalescence of reasoning is when no solution is chosen, where an agreement has not been attainable. In this situation, all stakeholders are aware of the difficulty of reaching an agreement and decide that, under the given conditions, an agreement is impossible to reach. This situation often gives rise to a negotiation phase, which seeks to reach a consensus or concordance.

Finally, the majority agreement could be considered as a possible outcome from the coalescence of reasoning. In this situation, a solution is chosen by one or more stakeholders who constitute the majority in terms of decision-making. This situation is generally the result of a vote in which each stakeholder can have a say (for groups where each stakeholder carries the same weight) or several (e.g. in shareholder meetings or groups where each stakeholder is weighted differently). The solution chosen is the one with the majority of the players (a majority can be determined to be $^{2}/_{3}$, 50% + 1, or a simple majority, i.e. the solution that reclassifies the majority, even if they do not do not represent 50%). This situation, of course, offers a single solution, but generally excludes stakeholders who do not agree. Contrary to concordance and consensus situations, the chosen solution is not agreed upon, but rather imposed (certainly by the majority, and as such the minority may not feel represented). This situation does not, in our opinion, require an adequate representation of a situation of coalescent reasoning, since a solution that is not accepted (explicitly or implicitly) by all the stakeholders reflects a situation in which the individual reasoning of each stakeholder is not fully understood nor accepted by others. In other words, if the chosen solution is not accepted by at least one stakeholder, his/her point of view has not been fully considered, and thus the solution remains imposed and not the result of reasoned group decision-making.

Subsequently, we present two research methods to determine the most appropriate dashboard for the evaluation of sustainable urban logistics. Each method is derived from a different approach that seeks consensus and/or concordance:

– The first derives from the decision-making approach supported by a network of experts, but involving the group of decision makers in the decision-making by experts. Experts thus guide the decision through their expertise, however the final choice is made by consensus.

– The second part of socioconstructivism proposes to define the solution with the decision makers, as and when, instead of proposing solutions that have already configured.

In order to illustrate the two methods, we relate them to the chosen dashboard for the evaluation of urban deliveries (whatever the system). The dashboard should therefore contain economic, environmental and social/ societal indicators (between five and ten in total and at least one per category) and be accepted by all the stakeholders. It is important to note that the results, although illustrative, do not serve as a comparison of the methods' "performance" themselves, as they have not been tested on the same group of decision makers. Indeed, each method has been applied to a group of stakeholders that were different in nature. In addition, the size of the two groups was also different. Nevertheless, the results can be examined to identify the priorities of each group and the similarities of their choices, but not as an indicator of the "best method". Indeed, these methods are alternative and their development was not carried out to compare their "performance", but rather to propose different approaches to support the search for agreement or consensus in the choice of indicators (and dashboards) for the evaluation of sustainable urban logistics.

7.2.1. *The "expert network" method*

This first method was proposed as part of the LUMD project (*Logistique Urbaine Mutualisée Durable*[5], FUI 2009–2012). In that project, a shared urban deliveries system was designed and developed. In order to evaluate it, it is important to propose a methodology that is understandable to both public and private stakeholders that can compare the proposed system with current delivery patterns. In order to choose the most suitable dashboard for the question of urban logistics pooling, as part of the LUMD project, a consensus-based research method based on a group of experts – but based on the basics of research of coalescent decision – has been proposed. The method is detailed in [GON 14c, MOR 15c].

The scientific committee for the LUMD project is ultimately the group responsible for the deployment of the decision-making of the dashboard. It was composed of 16 people from nine different companies or organizations (details on the composition of the expert committee can be consulted in [GON 12a, MOR 15c]. For decision purposes, each participant in the group (16 people) has a vote, with no possibility of proxy (i.e. non-attendees cannot make decisions at the meeting in question). Nevertheless, as we shall see later, the method of group decision-making involves several individual and collective stages, some taking place in between two meetings, which, if necessary, allows for people to react even when absent from a meeting.

5 Sustainable Pooled Urban Logistics.

In order to support the final decision, the method allocates meetings at which decisions will be made; however, most of these will have to be prepared in advance, through exchange time (via e-mail), in order to confirm the outcome of choices made at meetings and prepare for the next steps. Initially, three meetings are planned (one to initiate reflection, the next to present and select indicators, and the third to validate the final dashboard).

At the first meeting, held in January 2011, the needs of the evaluation and the available means were identified. In addition, a first frame of indicators based on the literature [MOR 09, GON 12a] was presented. Next, an exchange phase took place to define the approach to be followed for the choice of evaluation methodology. It was unanimously agreed that a first comprehensive list of indicators for the evaluation of sustainable urban logistics was needed and that a set of indicators to feed the discussion by which to choose the most relevant indicators needed to be presented to the group. It was also decided to propose a list of indicators, as extensive as possible, before making any *a priori* choices.

A first list of indicators (about 100, summarized in [MOR 15c] was proposed at the scientific committee meeting held on 31 March 2011, and accompanied by a presentation on the methodology for the definition of a dashboard [BOU 01] with suggested avenues for reflection to guide the search of the final dashboard. After a discussion, it was agreed upon to reduce the number of indicators to about 30 and then discuss these in detail at the meeting on 3 May 2011, whereupon these indicators would be debated and commented on. Indeed, the choice among 100 indicators proved difficult, and it was therefore decided to propose a list of indicators by 15 April 2011 in order to give the experts time to examine them and to choose their preferred indicators.

At the conclusion of this meeting, we drew the following conclusions:

– the sustainable dashboard should contain no more than five main criteria, each accompanied by one to three indicators;

– two types of indicators can be defined: those that measure the performance of the system per se and those that measure the effects on the overall economic system;

– to verify the benefits of the actions carried out and to cultivate a comparison with the global economic system, we will then compare these with the averages of the press sector to evaluate performance in relation to non-shared transport;

– the indicators considered as priorities by the people present at this meeting were those concerned with logistic performance (the occupancy rate and the number of kilometers traveled) and environmental effects (greenhouse gas emissions) and other pollutants, as well as changes in use (increases, removals and reconversions) are also important.

Following that meeting, two types of works were prepared: an identification of indicators for economic performance and customer satisfaction, in the form of two working documents (a text document and a presentation), and an in-depth study on the calculation and validity of the environmental and social/societal indicators (two spreadsheets and one text document).

At the scientific committee meeting held on 7 June 2011, an update of the indicators and their applicability was presented. Next, a working meeting gave shape to the dashboard summary, for the evaluation of the sustainable urban logistics scheme proposed by the LUMD project. In this table, presented later (Table 7.1), the various indicators that were selected are defined. Finally, once the exchanges made during several meetings throughout June were carried out, the need for synthesis and validation was highlighted in the scientific committee meeting held on the 15th of September 2011. This document summarizes the main indicators that need to be validated by a group consisting of twelve of the sixteen experts: the two logistic managers (strategic functions) of Presstalis (the project initiator), the three consultant design offices and different domains (project management, logistics and standardization, respectively) and six researchers belonging to six different institutions and disciplines (economics, management, industrial engineering and computer science, among others).

7.2.2. *The co-constructive consensus method*

If the previous method adopted the basis of coalescent decision for the purpose of consensus-building, the second method aims to seek out an accordance (or explicit agreement) between the different stakeholders involved in the group decision-making process. The proposed method borrows from the theory (and practice) of co-construction[6], widely used in active learning pedagogy [CSI 09], mainly for adult learning. In order to achieve the desired result (in learning, the co-construction of notions to be learned), certain techniques of active learning pedagogies make use of a subgroup phase in which the different participants can exchange and thus each subgroup can arrive at a coalesced reasoning. Next, an exchange phase between the subgroups and the facilitator is carried out so as to compare the visions of each subgroup and to co-construct a knowledge common to all participants (of all the groups). By extending this vision to the theory of group decision and the coalescence of reasoning [YEA 09], we can divide the co-constructed decision-making process into six phases:

– The individual reasoning (as in [YEA 09]). In this phase, each individual reflects, reasons, makes choices and takes decisions.

– The communication of reasoning [YEA 09]. In this phase, all subgroups share their reasoning.

– The co-construction of common reasoning. In this phase, the members of each subgroup seek a common proposal to be defended before the other subgroups. It corresponds with the first form of coalescence of reasoning.

– The relation of the subgroup's reasoning. Once each subgroup is linked to a proposal, each group presents its position to the facilitator. This phase is not, in contrast to phase 2, a communication in the sense that each subgroup reasons its position, but one without any possibility of dialogue. The facilitator notes and clarifies the positions, with the least possible decision-making (they must remain as neutral as possible).

– Construction of a common coalescence. Once the summary of all subgroup proposals has been made, the debate and communication phase begins. This is more than a communication phase, as it involves the preparation and construction of the group's preliminary reasoning.

– Search for a common solution and explicit agreement. In the final phase, an accord among the group is sought. For this, the unanimous approval of the chosen solution (i.e. the set of indicators deemed relevant by the majority) is required. If this is not the case, persons in disagreement (or subgroups) express their position and a mutual compromise is sought (in the case of dashboards, if an indicator is not chosen unanimously, it is reviewed

6 Co-construction, the basis of active methods in pedagogy, comes from current thoughts on constructivism and socio-constructivism [PIA 65, VYG 78, WON 01, GAR].

by all members and amended until it is accepted by all participants). To reach an agreement, it is important that all members are willing to reach an agreement[7].

– In order to develop and test this method, an experiment involving 25 operational managers was carried out in 2014. These managers belonged to three categories, each associated with the type of company to which they belonged:

- nine of them belonged to the transport sector (2PL) or logistics services (3PL, 4PL): five were linked to transport management and four to freight forwarder organizations;

- eight were in production and manufacturing: four of whom were associated with production management and four with the purchasing and sales departments of manufacturing companies;

- eight were from the distribution sector: five were involved in wholesale and three with integrated distribution.

The experimentation process took place on two different days in June 2014. A three-day period was required between these for the processing and analysis of the data collected on the first day. The methodology used in this experiment and its actual implementation was organized into six steps:

– In the first stage, we wanted to develop a phase of individual reasoning. We therefore needed to consult each operational manager separately and review their reasoning individually, without the possibility of communicating his/her results with the others. For this, we proceeded in two stages. First, an introduction lasting about thirty minutes on urban logistics was presented, as well as the need for the assessment and the estimated impacts in terms of sustainable development. After this, each manager was asked to identify a set of 5–10 indicators in order to measure the sustainability of urban logistics solutions. In contrast to the previous method, managers had no external aid or support in this phase to guide them in the development of the set of indicators. No communication with other managers was possible, and so they could only call on their own experience. The idea to not allow external support and prevent communication came

7 Spanish popular culture uses the expression "two people cannot have an argument if one of them does not wish to do so" to express the notion that an agreement can be found only by the good will of all the parties involved [MUÑ 14].

from a desire not to influence the individual decisions of each manager, and to allow each and every decision maker to express themselves in their own way. Then, the written responses of all the managers were collected and captured.

– After the collection and capture of all the lists of indicators, the second phase of the experimentation began. Data were checked, standardized, corrected, aggregated and analyzed. Indeed, by giving each manager the freedom to define the indicators, the exact terms used to define certain indicators were slightly different but nonetheless had the same meaning. For this, a reading of all the answers and a process of standardization (carried out manually) was necessary. Once unified, the indicators were sorted by the number of occurrences (i.e. the number of managers who identified them) in order to produce a list of indicators.

– Next, this list (the number of individuals who identified each indicator as a priority was concealed) was supplemented with another list, based on the literature review proposed in [MOR 14c, MOR 15c], where the evaluation indicators were sorted by category and then ordered alphabetically so as to avoid influencing the managers' choices [MOR 15b].

– Three days after the first meeting, a second meeting was organized. Initially, the group was divided into seven subgroups[8]. A preliminary phase of 30 indicators was distributed for individual reflection, in order to prepare them for the group decision process and to complete the choices of each manager. For this phase, managers were provided with both lists of indicators. The objective of each subgroup was to propose a list of 5 to 10 indicators. For this task, they were allocated an hour in which the phases of communication and coalescence were observed. The role of the facilitator was both supportive and facilitative; however, they were not to influence the choice of indicators.

– Once all the subgroups had come to a decision, a group restitution phase took place. For one hour, each subgroup explained why it was necessary to choose their proposed set of indicators, justifying their choices. All the indicators were noted in a table to make the choices visible and to show where the choices of each group coincided and where they differed in relation to one another.

8 Each subgroup had to have at least three people.

Finally, a group concordance phase took place. For this, a criterion for the choice of indicators (number and distribution by category) was decided upon through mutual agreement. Once the whole group had agreed on these criteria, an initial proposal consisting of (the most recurrent) indicators was assembled. However, this proposal was not accepted unanimously. In this case, the reasons for non-acceptance were set out, indicators that gave rise to disagreements were identified and alternative proposals were formulated until there was a unanimous decision on the ultimate dashboard.

Sphere	Category	Primary Indicator	Secondary Indicator
Economic	Logistic	Loaded vehicle trips rating (%)	Loaded trip by weight rating (%)
			Loaded trip by volume rating (%)
		Loading at warehouse rating (%)	
	Balance	Return on investment (%)	Profits (€)
	Service–Quality	Level of service rating (%)	Delivery service rating (%)
			Delay service rating (%)
			LUMD platform service rating (%)
Environmental	Environmental effects	Greenhouse gas emissions (kg CO_2-eq.)	CO_2 emissions (kg CO_2-eq.)
			CH_4 emissions (kg CH_4-eq.)
			NO_x emissions (kg NOx-eq.)
Social/societal	Social/societal effects	Ratings pertaining to the retraining of employees (%)	External collaborations (number of hours/person intra-enterprise)
			Jobs created (eq. full-time)
			Jobs to convert (eq. full-time)
		Loyalty ratings (%)	Shipper loyalty rating (%)
			Carrier loyalty rating (%)

Table 7.1. *Hierarchical dashboard as a result of this method (adapted from [MOR 15c])*

7.3. Examples of use

We present here the dashboards resulting from the two methods proposed. First, the dashboard presented in Table 7.1, derived from the expert network methodology, is organized into three categories (derived from sustainable development) and comprises seven main indicators and 14 secondary indicators:

– *economic component*, which includes three categories of indicators: logistical performance indicators (two primary and two secondary indicators), economic sustainability indicators (one primary and one secondary indicator) and quality indicators (one primary and three secondary indicators);

– *environmental component*, which has a single category of indicators (one primary and three secondary);

– *social/societal component*, which includes two categories: impacts on uses (one primary and three secondary indicators) and client satisfaction (one primary and two secondary indicators).

We can observe here a predominance of social indicators, linked to strong demands from public decision makers (noted in the specifications of the evaluation). The economic indicators are also numerous, taking into account both cost and quality aspects (delays were considered through a secondary quality indicator). Environmental aspects remain less extensive (only one main indicator), but are nonetheless fundamental (three secondary indicators are included, and in addition, a condition required in order to be part of the LUMD system is to support "clean" means of transport [MOR 14a]. The majority of secondary indicators (eight out of 14) are intermediate indicators used to calculate key indicators, or indicators that specify some aspects of interest. The remaining three (one environmental and two social) are complementary to the primary indicators.

Next, we presented the results of the collaborative decision-making procedure. We proposed to examine the results after the different steps. After step 1, a total list of 182 answers was obtained, that is, so that each operational manager has selected 7.3 indicators on average. Overall, 95 different indicators have been defined by the total panel of experts, that is, about 3.8 per individual[9]. This leads to a long list of indicators, most of them identified by one or two individuals. We report in Table 7.2 the 21 indicators that are identified by at least two experts. We observe that no indicator makes the unanimity. Indeed, only one of the triad indicators (cost–quality–time), the service rate, is identified by more than half of the group. However, it is identified by only 13 of the 25 experts. The greenhouse gas emission

9 This figure was calculated after the results of the individual phase had been cleared.

rate, one of the main indicators by which to measure environmentally urban logistics, comes in second position, with 12 of the 25 experts proposing it. The logistics costs and the customer satisfaction rate, also used in classical logistics evaluation, remain popular among the set of experts: they are proposed by respectively 11 and 10 experts. The rest of the indicators are proposed by less than eight experts. Only nine indicators are proposed by at least five experts, which make about 9.5% [9/95] of the total number of different indicators. Moreover, five indicators are proposed by three experts, six by two experts and 71 by only one expert.

Position	Indicator	Frequency of responses (no. of experts/25)	Consolidation Category	
			Type	Stakeholder*
1	Service rating	52% (13/25)	Economic	PrA & FC
2	Greenhouse gas emissions	48% (12/25)	Environmental	PrA & PuA
3	Logistical costs	44% (11/25)	Economic	PrA
4	Client satisfaction rating	40% (10/25)	Economic	PrA & FC
5	Number of trucks	28% (7/25)	Economic	PrA & PuA
5	Resident satisfaction rating	28% (7/25)	Social/societal	I
7	Total delivery time	24% (6/25)	Economic	PrA
7	Energy consumption	24% (6/25)	Environmental	PrA & PuA
9	Level of congestion	20% (5/25)	Environmental	PrA & PuA
10	Job creation rate	16% (4/25)	Social/societal	PrA & PuAut
11	Rate of economic profitability	12% (3/25)	Economic	PrA
11	Number of deliveries	12% (3/25)	Economic	PrA
11	Noise level	12% (3/25)	Environmental	PuA & I
11	Economic gains	12% (3/25)	Economic	PrA
11	Number of logistics platforms	12% (3/25)	Economic	PrA & PuA
16	Rate of claims	8% (2/25)	Social/societal	PrA
16	Average delay	8% (2/25)	Economic	PrA & FC
16	Vehicle loading rate	8% (2/25)	Economic/ environmental	PrA & PuAut
16	Level of maintenance	8% (2/25)	Economic	PrA
16	Number of reloads	8% (2/25)	Economic	PrA
16	Delay due to congestion	8% (2/25)	Economic	PrA

** PrA: private stakeholders, that is, enterprises (suppliers, producers); distriPuA: public stakeholders; FC: customers (retail); PuAut: public authorities; I: inhabitants.*

Table 7.2. *Results of phase 1 indicators selected by at least two experts at the culmination of the individual reasoning phase [MOR 15b]*

Number (position at the end of step 4)	Indicator	Frequency of selection (no. of sub-groups/7)	Position at the end of step 2	Consolidation Category	
				Type	Stakeholder
1	Service rating	100% (7/7)	1	Economic	PrA & FC
2	Client satisfaction rating	100% (7/7)	4	Economic	PrA & FC
3	Level of congestion	71% (5/7)	9	Environmental	PrA & PuA
4	Rate of pollutants in the air	57% (4/7)	n.c.	Environmental	PrA & PuA
5	Operational costs	57% (4/7)	n.c.	Economic	PrA
6	Monetary gains	57% (4/7)	n.c.	Economic	PrA
7	Client evolution	57% (4/7)	n.c.	Economic	PrA
8	Vehicle loading rate	43% (3/7)	18	Economic/ Environmental	PrA & PuAut
9	Price of products	29% (2/7)	n.c.	Economic	PrA
10	Employee rotation rate	29% (2/7)	n.c.	Social/societal	PrA & PuAut
11	Delivery times	29% (2/7)	7	Economic	PrA
12	Number of deliveries	29% (2/7)	11	Economic	PrA & PuA
13	Average distance per delivery	14% (1/7)	n.c.	Economic	PrA
14	Employee satisfaction rate	14% (1/7)	n.c.	Social/societal	PrA
15	Greenhouse gas emissions	14% (1/7)	2	Environmental	PrA & PuA
16	Logistics reliability	14% (1/7)	n.c.	Economic	PrA
17	Rate of job creation	14% (1/7)	10	Social/societal	PrA & PuAut

Table 7.3. *Summary of indicators at the end of phase 4 [MOR 15b]*

It is important to remember that, in the first phase of the experiment, the experts received no help other than their own recollection and professional experiences to define the set of indicators. This makes for a difficult exercise, but without external help or communication and exchange with peers, each expert identified indicators according to his or her personal vision. Consequently, and as shown above, a chosen group of indicators that stands out for the majority of experts seems hard to achieve. For this reason, and taking into account the analyses (second phase) summarized above, two sets of indicators were defined during the third phase without asking the expert's opinion: the first one includes the 95 indicators extracted from the results of the first step, renaming them if necessary to produce a standard set of indicators; the second comes from the extension of the 75 indicators proposed in [GON 14c], adding 25 indicators from classical accounting and management studies [MOR 13], which gives us a set of 100 indicators. These two groups of indicators were developed and presented to the experts in the fourth phase, where seven subgroups were established, each tasked with identifying the most relevant set of indicators (5–10) to be taken into account in the evaluation of sustainable urban logistics.

To summarize the results and generate the fifth phase (the preparation for the group's overall decision), all of the indicators identified by each subgroup were classified (by their frequency of selection, i.e. the level of occurrence as a percentage of the subgroups that chose that indicator) and aggregated in Table 7.3.

After the phase of concordance (phase 6), and in agreement with the indications of Bouquin [BOU 01], 8 indicators were selected as appropriate by the whole group (thus chosen by total agreement). As the first 7 indicators were identified by the majority (see Table 7.2), these were naturally accepted by all subgroups. The eighth indicator (social/societal) was more difficult to define, as it took almost an hour to decide whether or not other indicators should be added to the set. After a complex discussion, it was decided to add a single indicator. A dashboard with more than 8 indicators was considered too heavy by the group. As such, the resulting dashboard, shown in Table 7.4 below, can readily be adopted.

Sphere	Category	Indicator	Position at the end of step 4	Consolidation Category	
				Type	Stakeholder
Economic	Logistic	Operational costs	Ind. no. 5	Economic	PrA
	Audit	Monetary gains	Ind. no. 6	Economic	PrA
Economic	Quality	Service rate	Ind. no. 1	Economic	PrA & FC
		Client satisfaction rating	Ind. no. 2	Economic	PrA & FC
		Evolution of clientele	Ind. no. 7	Economic	PrA
Environmental	Environmental effects	Level of pollutants in the air	Ind. no. 4	Environmental	PrA & PuA
Environmental	Reduction in congestion	Level of congestion	Ind. no. 3	Environmental	PrA & PuA
Social/societal	Social/societal effects	Rate of job creation	Ind. no. 17	Social/societal	PrA & PuAut

Table 7.4. *Final dashboard resulting from the concordance phase [MOR 15]*

7.4. Inputs and limitations of the proposed methodology

The work proposed here demonstrates the possibilities of applying support logic to the definition of dashboards through group decision-making. Moreover, this logic leads to the definition of a unified methodology, not for an assessment in itself, but for the choice of indicators. This should then be coupled with common baseline data production to ensure comparability between different assessments, but the assessments are already open to comparability if the base of indicators to be chosen is the same. These methodologies are currently being used and have been employed in the reflections of urban logistics stakeholders, such as the UCC in Saint-Étienne [AND 15b, AND 15c, NIM 17], reflections around the urban logistics information systems for the municipality of Bogotá [PAR 17], ZASCA's collaborative procurement and joint production strategies, and the grouping of small footwear producers located in a central district of Bogotá [GON 16c].

Another contribution of this work is the facilitation of communication and understanding on the dynamics of group decision-making, mainly through co-constructive methods. Moreover, the fact that these methods are not “automated” makes it possible to identify the impediments or qualms of the stakeholders as the method is developed and to better assist the search for consensus or concordance between these stakeholders.

The main limitation of these approaches derives from one of its strengths: the lack of automation means that time allotted for the implementation of these methods is important and may become a damper on their application. Moreover, this can also lead to acceptance complications for certain stakeholders. To this end, a method with a high degree of automation seems necessary in some contexts.

On the other hand, the choice of these indicators does not for the time being allow for the possibility of priorities or weighting factors to be applied, for subsequent multi-criteria analyses. A multi-criteria method that takes into account group dynamics would complement the existing work on multi-criteria and multi-stakeholder analysis [MAC 10, MAC 14], by extending the notion of a multi-criteria multi-stakeholder method to the needs and characteristics of the group.

Therefore, once the indicators have been defined, they still need to generate their estimates in order to be able to carry out evaluations and analyses on the results. For this purpose, we propose in Chapter 8 an introduction to the main impact estimation methods for application in both research and practice.

8

Estimating the Impact of Sustainable Urban Logistics

8.1. Introduction

In Chapters 4 and 5, the principles of flow estimation were discussed, in Chapters 3 and 6, the main concepts of scenario construction and change estimation and, in Chapter 7, identification and choice of indicators for evaluation. With all these elements, it is possible to carry out quantitative assessments of sustainable urban logistics. However, the main work on the evaluation of sustainable urban logistics has not resulted in a standardization of methods, although there is an observable dominance and, in many cases, the methodologies (or approaches) coincide, mainly on three points:

– an economic evaluation is still not explicit, but rather the core of the work associated with the conversion of distances and travel times into economic costs (operational or investment) is the analysis of costs in relation to benefits, in terms of both analyses of margins on variable costs [FAU 15] and cost–benefit analyses [GON 13a, DEL 14, GON 16c]. In addition, most of the approaches make an estimate of the distances traveled [MAC 11, GON 14d, TAN 15] and the estimation of travel times is possible with very little additional data [SÉG 04];

– the environmental assessment is generally derived from a conversion of distances into greenhouse gas emissions, mainly CO_2, or otherwise in terms of pollutants, such as NO_x and PM10, through the application of direct emission models as a function of vehicle type and speed ([TAN 00, SÉG 04, GON 12a], among others). Only a few studies propose evaluations based on the estimation of direct emissions as a function of speed and acceleration

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[PLU 12a, PLU 12b], and the estimation of indirect impacts is only just beginning to appear in urban logistics [AND 15a, AND 15b];

– social assessments are generally qualitative and take place at the initial stage of thinking [BEH 08, GON 10, MOR 14]. Nevertheless, impact analyses on the urban fabric in terms of accessibility or attractiveness, as well as analyses on the changes in urban forms are starting to emerge, in both cases in relation to the proposal of models and quantitative indicators [GON 12b, DUC 16].

From this overview, we can conclude that the main approaches for assessing sustainable urban logistics place a high priority on environmental aspects; however, only direct emissions are considered. In addition, the only economic (or efficiency) aspects are related to the distances traveled and loading rates and, on the whole, economic approaches are few.

In this context, we intend to tackle quantitative analyses for the evaluation of sustainable urban logistics via three main points:

– the first is the proposal of methods for carrying out economic analyses on the deployment of sustainable urban logistics solutions, as well as to define the conditions for their feasibility and sustainability;

– the second is the development of methods for estimating direct and indirect environmental impacts;

– the third aims to introduce questions on the relations between freight transport and territorial development, through the proposal of accessibility indicators specific to the transport of goods and to urban logistics.

8.2. Economic evaluation

In the evaluation of sustainable urban logistics, we observe several methods by which to calculate indicators. If we look closely at the economic indicators, we observe that they are, for the most part, derived from logistics performance [MOR 13] or transports [MEL 11]. Most indicators are derived from the calculation of distances traveled, driving or working time and loading rates [MEL 11, GON 14]. By contrast, valuations based on economic calculation are rare in urban logistics. Indeed, to the best of our knowledge, van Duin *et al.* [VAN 08] are the first to propose an evaluation of urban logistics based on economic calculation approaches. In addition, few studies and experiments openly show the desire to carry out this type of analysis [GÉR 07], despite the need for those solutions to be economically viable. For that reason, the reintroduction of economic analysis in the evaluation of urban logistics is important. Three main categories of economic valuation methods are presented below:

– an assessment/evaluation that estimates direct costs (for a cost evaluation that disregards the benefits, often carried out with tactical or operational optimization of the logistics system in mind);

– analysis of margins on variable costs (to estimate operational profitability, which therefore assumes an operational period of the logistics system);

– cost–benefit analysis (for a given time horizon and, therefore, an analysis of the profitability of a medium- to long-term logistics system).

8.2.1. *Estimating the direct costs of transportation and storage*

The first step in the economic evaluation of urban logistics is that of estimating the costs of carrying out logistics and distribution activities. As those activities are mainly transportation, warehousing, order preparation and related activities (such as cross-docking and transportation or warehousing), the two sets of operations involved are those relating to transportation and warehousing processes. The estimation of those costs is a necessary component of any economic evaluation (and therefore to all three categories of methods presented here). Nevertheless, the ways in which those costs are calculated and the assumptions made are not always identical.

In direct cost analyses, there is a rather short operating period of the system (usually a typical day, week or month and, in some cases, a year is obtained by extending the values of an ordinary week, weeks or months). In this context, costs can be divided into two categories [GRA 71, LIT 09, AYA 14]:

– variable costs are those that depend on the use of means and infrastructures: for transportation, this depends on distances and times traveled; and for warehouses, this depends on the weights and volumes being transported as well as the use of storage depots and other such platforms;

– fixed costs are those that do not depend on the use of means and infrastructures.

Table 8.1 presents the main categories of fixed and variable costs, as well as the main calculation units. It is important to note that these cost categories are not exhaustive and are presented as examples.

	Criteria	Category	Unit
Fixed costs	Acquisition of the vehicle	Transport	€
	Rental of the vehicle	Transport	€/month
	Acquisition/construction of warehouse or platform	Warehousing	€
	Rental of warehouse or platform	Warehousing	€/month
	Wage function annexes	Auxiliary functions	€/month
	Acquisition of handled material	Transport/warehousing	€
	Buildings and platforms insurance	Transport/warehousing	€/month
	Other fixed costs	Transport/warehousing	€/month
Variable costs	Fuel consumption	Transport	€/km
	Tolls	Transport	€/km
	Parking (in certain contexts)	Transport	€/h
Fixed or variable costs	Delivery driver salaries	Transport	–
	Vehicle insurance	Transport	–
	Warehouse worker salaries	Warehousing	–
	Maintenance	Transport/warehousing	–

Table 8.1. *The main categories of fixed and variable costs in urban logistics (source: author development from [CNR 12, CNR 17, GRA 71, LIT 09, GON 13a, GON 13b, AYA 14])*

Although most authors define fixed and variable costs, some of those costs fall into either category depending on the analyses. For example, staff salaries for personnel working in transportation and warehousing are often set as variable costs (dependent on time worked), which is true for the cases in which these roles have been outsourced (where costs are service costs, which may or may not be related to the time required to complete the activity). However, in transport or logistics service companies that employ their own staff, these costs can therefore be considered as fixed costs (and calculated by day or by month worked), from the moment the wages need to be honored, regardless of the workload of each employee. Maintenance and insurance costs can also be considered as fixed costs (in the case of fixed-price contracts) or variable (under contracts with charges depending on the use of the vehicle or warehouse). Nevertheless, in both cases, the fixed-cost approach is often favored.

Through the identification of these categories, these costs can be estimated. In a practical operational cost analysis, fixed costs are deferred, based on amortization assumptions (for acquisitions) and average usage (for others), either per kilometer traveled (for transportation), by weight and unit volume (for storage), or according to time (mainly for payroll), and to align these with variable costs (usually linked to a typical day of operation).

In general, salaries, as well as the use of warehouses, are carried forward as working hours. The use of storage equipment is usually related to the weight or volume handled (salaries can also be related to weight or volume), and vehicle maintenance and insurance costs are related to distance traveled. Thus, the following relation can be defined for transport:

$$C^{transport}=a.d+b.t^{driving}+c.t^{non\text{-}driving} \qquad [8.1]$$

where d is the distance traveled for the period being considered, $t^{driving}$ the total driving time (for all drivers) for the period being considered, and $t^{non\text{-}driving}$ the time dedicated to the delivery and pickup operations and other activities related to transport.

Similarly, for warehouses, a similar relationship can be defined:

$$C^{warehouse}=a.m+b.t^{work} \qquad [8.2]$$

Where m is the quantity of goods (in terms of weight, volume or packaging units) processed in the period being considered, and t^{work} is the total working time (weighted by the number of employees) in the period being considered.

8.2.2. *Analysis of margin on variable costs*

An alternative to cost analysis is to link benefits to costs, by linking everything to an operational time horizon (day or month). One approach proves to be dominant in practice: the analysis of margins on variable costs. This approach is based on calculating the variable contribution margin (VCM) over a given period, by calculating the fixed costs (FC) over the same period and estimating their difference to estimate whether the logistics system is profitable or not.

VCM can be defined as the difference between turnover (*TO*) and variable costs *(VC): VCM = TO - VC* [LÖN 08]. This can be calculated for the whole activity, for a specific product / service or for a family of products. In the case of urban logistics, the VCM will be calculated for the set of logistic activities concerned (e.g. all the activities of a UCC [FAU 15] or for urban activities within the framework of a company providing urban and interurban logistics services).

In urban logistics, revenues (i.e. turnover) generally come from the invoicing of urban logistics services (and thus depend on the pricing policy), such as transportation, warehousing and freight lockers (relay point). Other revenues could possibly be included, such as public subsidies (for subsidized logistics systems like some UCCs or schemes receiving public support) or revenues from non-logistical activities, such as advertising or the rental of premises for other uses (meetings, training, etc.), among others.

Where costs are concerned, the estimation is generally done using methods similar to those presented in the previous paragraph. More precise cost calculations can be made (e.g. by taking into account the assumptions made on efficiency and nonlinear variability into their calculations, as in [FAU 15]), but the degree of detail will depend on the usage and scope of the evaluation (in terms of solution probleming as discussed in Chapter 6).

Once the fixed costs and estimated variable cost margin are available, they can be compared for analysis. In this comparison, we can distinguish three scenarios:

– If the *VCM = FC*, the system is at the point of equilibrium, that is to say that it has reached its break-even point or dead point. In other words, the result is zero: there is no profit or loss, so the system can work, but cannot grow. In general, the profitability objectives of most UCCs are set at this equilibrium point for the initial phase, after which a new analysis for the determination of a new result objective is carried out so as to allow for developments.

– If *VCM > FC*, the system is in a position of surplus, that is to say that the company exceeds its break-even point for the proposed services. Surplus can be used to develop new services, make investments or generate profit from investors. The VCM analysis will then determine whether the value of this surplus is sufficient in light of the original objectives.

– If $VCM < FC$, the system is not profitable, that is to say that it has not yet reached its break-even point and therefore incurs losses. It is important at this stage to analyze the costs and benefits in order to study what cost reductions would still be possible and what actions could be taken to increase profits and move closer to the break-even point.

From the VCM, we can also calculate the variable cost margin rate T^{VCM}, which is estimated as follows:

$$T^{VCM} = \frac{VCM}{TO} \qquad [8.3]$$

This rate can be used to make forecasts. Indeed, to know the future variable cost margin, we can apply the T^{VCM} to predictions of system development. VCM analyses can also be a preliminary way of identifying the demand needed to achieve or maintain the profitability of a new service. This demand must be confronted with catchable demand and then an estimate made whether the objectives are realistic. For example, an analysis of this type may have determined that the Saint-Etienne UCC would require six to nine vehicles [FAU 15] and service about 1/3 of the catchable demand [NIM 17], which remains realistic. This double estimate of the VCM as well as the demand capture (which links several methods presented in this book) is crucial for the profitability and continuity of a sustainable urban logistics system. Another example, *City Logistics*, the private UCC for Lyon, which was in operation between early 2015 and late 2016, had made profitability forecasts that required a demand capture of between 40 and 60%. Nevertheless, by exploring their analyses in greater detail, in the demand capture was included the actual demand for operators who had formally refused to use the service due to the fact that their demand quota (the remaining 40%) allowed them to reach the breakeven point, and even profits. This meant that the breakeven point should have been obtained by capturing 2/3 to 100% of demand capture[1], which is not feasible under current conditions. In addition, it was found that, in the operational phase, the variable costs were higher than expected and, as a result, the initial pricing

1 Estimation by the author using the feedback from City Logistics (assistance to steering meetings, feedback from feasibility studies and exchanges with management staff) and stakeholders who have openly refused to use the service (various exchanges between 2014 and 2016).

was ultimately insufficient to offset overall costs (i.e. VCM was finally lower than fixed charges), and the price needed to reach equilibrium (about 80% higher than the original rates) was too great for potential customers[2]. These two reasons, which have been identified as the causes of service failure, could nevertheless have been identified with a standard VCM and demand analyses. Potential demand modeling had been done, but only quantitatively, without a qualitative analysis of the potential attractiveness and availability of carriers to use the system, while the costs of the system had been underestimated.

This last example highlights the importance of estimating costs, as well as the sensitivity of analyses such as VCM. It therefore seems important when estimating costs and benefits to carry out sensitivity tests. A sensitivity test on VCM analyses can be obtained quickly by increasing the main costs (one by one) by a percentage value and repeating the analyses in order to study the ability of the system to respond to cost estimation errors. To that end, it is necessary to estimate possible cost estimation errors (e.g. vehicle acquisition costs are known and variations are negligible or at least easy to anticipate, although for personnel and other variable costs, these depend on demand that determines the way in which the routes are done, hence the need to anticipate possible estimation errors). By carrying out several simulations with cost increases and the consequent impact on the breakeven point (and/or on the value of the tariff to be applied), it is possible to anticipate certain unforeseen events or to predict whether start-up assistance is necessary, in order to better understand the conditions for the success of the system. For example, the Padua UCC development plans provided for four years of public assistance (a period in which the system was supposed to be unprofitable). However, due to the overall acceptance of the system, the equilibrium point was reached in two years [GON 10]. This is partly due to the positive response of local carriers, but also to the fact that some risks were anticipated in advance and the system was started with downward forecasts in mind[3].

2 An elaboration by the author based on management feedback from the City Logistics project in March 2017.

3 Conclusions obtained after a conversation with staff of *Cityporto* in 2009 and *Fit-consulting* (a consulting firm involved in the development of the *Cityporto* business model) in October 2016.

8.2.3. *Cost–benefit analysis*

Direct cost and VCM analyses are usually done within a short time horizon (for a given day, month or year). In some contexts, it is important to consider the annual evolution of the system and also the way in which investments and revenues are distributed over the years in order to examine the ability of the system to recover investments. This can be done through cost–benefit analysis (CBA), already recommended for large infrastructure projects [AMB 01, DG 08] and recently back in the forefront of urban logistics strategies [VAN 08, GON 13a, GON 14e, GON 14, GON 16c, DEL 14].

Here, we present the general CBA methodology for simulating scenarios for deploying sustainable urban logistics solutions. This CBA can be achieved in two different ways: either by only considering the direct monetary costs and benefits (monetary CBA), or by considering the direct and indirect costs and benefits for which monetization is possible[4] (socio-economic CBA). In both cases, the CBAs result from the enumeration of all the costs associated with the implementation of an urban logistics solution, then all the monetizable benefits related to the deployment of this same solution, within a given time horizon (and fixed in principle at 10 years [GON 13a]). In other words, for each year of the implementation of an urban logistics solution, since the start of the project (year 0), the different investment and operational costs are estimated and the potential profits calculated. In cost–benefit analyses that are estimated over multi-year horizons, the concept of fixed and variable costs remains secondary to that of investment and operational costs. Indeed, in the calculation of operational costs, both fixed and variable costs come into play and it is therefore important to estimate them (e.g. using route construction methods as seen in Chapter 4). Nevertheless, in the estimation of economic magnitudes for CBA, the important distinction is between investment costs (which are paid before the system is put into place or during the first couple of years, and for which capital must be made available) and operational costs (which can and must be lower than system revenues). In a CBA, the ways in which revenues are earned and the degree of introduced demand have an impact on the speed at which investments are repaid. Moreover, in CBAs,

4 The monetization of indirect costs and benefits gives rise to different positions in scientific and practical communities. We will discuss considerations on the monetization of non-economic impacts at the end of this chapter.

the concept of the rate of return of investment (and thus the gains on the invested capital) is present, as well as the duration for which the system must be in operation before recovering these investments and the anticipated gains. Hence, there is a reasoning here that we do not find in the other two analyses, based on the return on invested capital.

The main cost and benefit categories put forward [GON 13a, GON 13b] are those presented in Table 8.2.

Macro-category	Category	Unit
Investment costs	Construction of linear infrastructure	€/linear.km
	Construction of logistical buildings	€/m²
	Vehicle acquisition	€/vehicle
	Other investment equipment (handling, IT, etc.)	€/unit
	Other investment costs	€/unit
Operational costs	Personnel (drivers, platform, auxiliary, etc.)	€/h
	Vehicle usage (fuel, insurances, etc.)	€/km
	Structures usage (warehouses, offices, etc.)	€/m².month
	Tolls	€/month
	Other operational costs	€/unit.month
Direct benefits	Revenue (linked to pricing policy)	€/service unit
	Grants	€/unit de temps
Indirect benefits	Vehicle usage	€/km
	Gains in time (passed on to personnel)	€/month
	Possible decrease in ecotax due to improved vehicle usage	€/kg pollutant
	Gains in health [VAG 11]	€/kg pollutant

Table 8.2. *Main cost and benefit categories in urban logistics (excerpted and adapted from [GON 13a, GON 13b])*

From these costs and benefit units, the overall costs and benefits of the urban logistics solution for the given time horizon can be estimated year by year. This requires making assumptions about the resources (and thus the supply of logistics) available, the logistics demand of the system and the level of service, that is, the efficiency of the service [GON 16c]. From these assumptions, for each year, the NB_i (Net Benefit) net gain can be estimated as follows:

$$NB_i = (B_i - C_i)/(1+a)^i \qquad [8.4]$$

where B_i and C_i are respectively the profits and costs for the year i, and include the discount rate. It is important to note that this 'gain' can be negative (which is often the case in the beginning years, mainly because the investment costs are counted as of the year 0 when there is generally no profit), or positive (which must be the case in the latter years in order to make the investments profitable). Next, the Net Present Value for year i (NPV_i) can be estimated as follows:

$$NPV_t = NPV_{t-1} + NB_t \quad [8.5]$$

Finally, we can estimate the rate of return. In the case of the monetary CBA, we calculate the Internal Return Rate (IRR), which is defined as follows:

$$IRR = \frac{NPV_n}{\sum_{t=0}^{n} C_t} \quad [8.6]$$

In the case of the socio-economic CBA, we can define the Socio-Economic Return Rate (SERR) calculated in the same way, but following a monetization of these direct and indirect costs:

$$SERR = \frac{NPV_n^{SE}}{\sum_{t=0}^{n} \left(C_t^{direct} + C_t^{indirect}\right)_t} \quad [8.7]$$

According to the LET[5] recommendations, the IRR for a private investor is usually 15%, with the public sector accounting for approximately 4%. Similar reasoning can be achieved with the SERR, but the ratios to be considered satisfactory may vary and are identified by the stakeholders concerned with these analyses, in particular the public stakeholders (the SERR is often used in cases where the system is not profitable and where the public authorities can provide capital in the form of subsidies, provided that the system contributes to the principle of collective utility). We can also estimate different overall rates for Public-Private Partnerships (PPPs) or other mixed financing schemes, depending on the involvement of each of the stakeholders [GON 14e].

5 Laboratoire d'Economie des Transports, Lyon, France. These conclusions were drawn from exchanges with Bruno Faivre d'Arcier, professor at the Lyon 2 University, expert in economic evaluation who teaches methods for the cost–benefit analysis of transport systems. We collaborated on the framework for the FREILOT project, mainly on the task of implementing cost–benefit analyses that I coordinated.

Once the basics of CBA are presented, it is important to define the assumptions and approaches for the quantification of costs and benefits. As far as costs are concerned, two main categories are considered [DG 08]: investment costs and operational costs. Investment costs, which in infrastructure or public transport network projects take place before the construction of the network or infrastructure, are defined as the expenditure costs required to implement the sustainable urban logistics solution. These are usually calculated on a unit basis, but in urban logistics we can find investments at different points in the lifetime of the system (typically we find most of these at the beginning, to help kick start the system, and then again later on, after a few years, with the view to extending service).

Once the monetary costs and benefits are considered, the monetary CBA can be realized. To perform the socio-economic CBA, it will be necessary to consider, in addition to these costs and benefits, the impacts that could be monetized. Non-monetary, but monetizable impacts can be attributed to different causes. Nevertheless, in urban freight transport, these impacts mainly depend on two elements:

– the use of the vehicle (distance and time traveled, and therefore speed, and also driving behavior);

– use of infrastructure (parking behavior, use of warehouses).

The models and methodologies presented in Chapters 4 and 5 make it possible to estimate average vehicle usage behaviors (estimation of distances and time travelled), and measurements related to new technologies (integrated GPS, smartphones, automatic sensors) can define different behaviors for the conduct and use of infrastructures. From this information, we can estimate different impacts that would be monetizable.

The first is the use of the vehicle, which would have a quantifiable impact in terms of its maintenance and repair of said vehicle. This can be estimated by the distances traveled and, if the data allow, by the wear and tear of the vehicle as a consequence of sudden accelerations/decelerations. Nevertheless, these impacts are still difficult to identify accurately and the estimates made are very much marginal and hardly robust [PLU 12b]. However, in the near future, more precise estimates could give stronger, more robust values.

The other important factor is the time gained or lost. This time is in relation to both the distance and speed of the trip in question, and depends on both the behavior of the driver and the speed of the surrounding traffic [LOP 16]. The cost induced by this travel time is easy to quantify for a transport company, because the use of the vehicle over time has an impact not only on the cost of personnel, but also on other indirect costs [GON 13d]. On the other hand, it is more difficult to identify and relate to households or the global population. Although methods are able to associate a cost with time lost, it is an "artificial" value since it is not a real cost that the user has to pay. The only directly monetizable cost is the cost of the fuel used by the vehicles (private or professional), which is closely related to the use of the vehicle (distance traveled, time, speed, driving behavior, etc.).

The third group of factors concerns environmental impacts and quality of life. We observe three categories of impacts: global warming (greenhouse gas emissions), air pollution (mainly NO_x emissions, SO_x, volatile organic compounds and fine particles) and noise pollution. In this context, quantification methods are also carried out, but are based on a fictitious value of these emissions, like a set of credits which, despite having a global significance, are difficult to determine at the local level. Moreover, this value is not a real return or a monetary gain. Therefore, other monetization methods must be found. For greenhouse gas emissions (but also pollutants), we can hypothesize the introduction of a mandatory eco-tax (based on the values of the French project and which was almost adopted in 2014, but which was ultimately unsuccessful). In this scenario, all carriers (and/or users) would be obliged to pay this tax. The reduction of these emissions would therefore lead to lower tax payments [GON 13a]. For polluting emissions, Vaghi and Percoco [VAG 11] propose a method for quantifying the medical costs related to pollution. Indeed, if we could link the pollution attributable to the transport of goods throughout a city to the use of current medical facilities (treatment by physicians and the outbreak of common diseases such as colds and allergies) and measure their evolution in relation to the reduction of these emission pollutants, we could then allocate a cost to the emission unit. These costs were estimated for Padua UCC [VAG 06, VAG 11], but could be generalized for Italian, French or European cities, among others.

Other monetizable impacts (such as those described earlier in this section) are accident frequency, job creation/destruction, or the attractiveness of the territory and the impact on consumption. Nevertheless, the calculation of these impacts is not dealt with here, but could be done later.

The other contribution to the economic evaluation is the use of CBA as a scenario simulation method to define the feasibility and cost-effectiveness of sustainable urban logistics solutions. The methodology proposed and used here can be summarized as follows:

– definition of scenarios and their associated assumptions;

– deployment simulation of the scenario being considered over a ten-year period, calculation of the IRR and SERR linked with the previously proposed CBA;

– sensitivity analysis. For this, we vary the different cost or profit parameters by 10% and redo the CBA in order to estimate the corresponding variations for IRR and SERR. We can thus identify which are the most sensitive parameters and, therefore, which ones to prioritize so as to make the solution profitable.

If the solution is not profitable, the various assumptions and parameters are reviewed, mainly the demand captured by the system and its evolution, unit revenues and eventually certain costs. For this, the cost reduction or targeted increased benefit is estimated, in order to facilitate the search for the parameters that make it possible to obtain the targeted IRR and SERR. The CBA is redeployed iteratively until an economically viable solution is found.

8.2.4. *Example uses of economic valuation methods*

The first example for the use of these methods is based on the case of the Saint-Étienne UCC, which has accounted for several studies in this field [AND 15b, FAU 15, FAU 16, NIM 17]. The UCC currently has three vehicles, but, as advocated in [FAU 15], the UCC would be (from an operational point of view) profitable if it could successfully use six to nine vehicles by replacing their capacities effectively (by combining electric and thermal vehicles). Based on the data estimated in [FAU 15], we have constructed a deployment scenario for the *SimplyCité* UCC, which aims to gradually increase over the course of its ten-year service the capacity of loading 6 vehicles. Given the current context, the proposed scenario remains realistic and does not seek to position itself in a logic that is either overly optimistic or overly pessimistic. The supply and demand evolution of *SimplyCité* would be that shown in Table 8.3.

Year	**Demand**	**Number of vehicles, Variant 1**		**Number of vehicles, Variant 2**
		Electric	**Diesel**	**Natural gas**
0	80 parcels/day	1	1	2
1	200 parcels/day	1	1	2
2	400 parcels/day	1	2	3
3	600 parcels/day	2	2	4
4	850 parcels/day	3	2	5
5	1,000 parcels/day	3	2	5
6	1,150 parcels/day	4	2	6
7	1,300 parcels/day	4	2	6
8	1,400 parcels/day	4	3	7
9	1,500 parcels/day	4	3	7
10	1,500 parcels/day	4	3	7
IRRover 10 years		+1.2%		+4.1%

Table 8.3. *Deployment scenario for the Saint-Étienne UCC, with two variants*

We consider two variants for the scenario (see Table 8.3): the first assumes an evolution of the fleet with the same types of vehicles as in the initial situation, where the second vehicle corresponds to the desires of the UCC, that is to say, moving from year 0 to a park entirely in natural gas. The first variant of the scenario (the evolution over time of the current fleet) gives an IRR of 1.2% over ten years, which is too low to be considered satisfactory, despite being positive. The second variant (switching to natural gas) makes it possible, without changing the evolution of demand or total supply, to obtain an IRR of 4.1%, thus achieving the target of public stakeholders. This is due to two factors. The first is that the total cost of vehicles is lower than the second variant. Indeed, natural gas vehicles have rental costs that are now close to diesel vehicles while electric vehicles are between 2.5 and 3 times more expensive than diesel vehicles. The second factor is the capacity of the vehicles: electric vehicles have a slightly lower capacity than the other two types of vehicles [GON 15], and therefore, their usage results in a maximum number of packages transported that is less than the other two types of vehicles.

A second application of this methodology is the simulation of scenarios for a set of reserved parking areas [GON 13c, GON 14j]. To this end, five governance scenarios for this system have been simulated (details are presented in [GON 14e]):

– S1: the promoter and manager of the system is a public stakeholder and, in view of collective utility, the service is offered for free;

– S2: the promoter and manager of the system is a public stakeholder, but the user is supposed to pay to use the service, corresponding to the view that the project will be repaid by the user;

– S3: the promoter and manager of the system is a private stakeholder. Investment and management costs are borne by a private company;

– S4: the promoter is a public stakeholder, but the system manager is a private stakeholder, under the hypothesis of a public service delegation;

– S5: the promoter is a public stakeholder, the management is done by a private stakeholder, and they are linked together as part of a public–private partnership (PPP). The community covers 60% of the costs, and the private stakeholder, the remaining 40%.

In order to simulate these scenarios, a CBA over a ten-year period is proposed. The discount rate is assumed to be that of projects carried by French public stakeholders, namely 4% [BON 13]. In addition, we set our IRR target at 15% for a private company and 4% for a public entity. Finally, we assume that the funds required for investments and operations are available to each investor.

As far as costs are concerned, we assume that the taxes and duties are specific to the French context, as well as unit costs of personnel, maintenance and construction (for greater detail of these costs, refer to [PLU 12b]). An aggregate summary of these costs is presented in Table 8.4.

In terms of earnings, we looked at three key things: temporal gains, fuel efficiency gains and greenhouse gas emission gains. From the evaluation of an experiment and a modeling of the deployment of the envisaged system, we quantified the unit monetary gains. These are described in Table 8.5.

Category of costs	Year 0	Year 1	Year 2	Year 3	Year 4	Years 5 to 10
Investment costs	77,246 €	70,844 €	66,308 €	61,308 €	60,808 €	10,460 €
Operational costs	0 €	98,017 €	120,898 €	140,078 €	159,183 €	178,138 €
Total	77,246 €	168,861 €	187,206 €	201,386 €	219,991 €	188,598 €

Table 8.4. *Summary of investment and operational costs*

Type of gain	Monetary gain by vehicle
Time	350 €/an
Fuel	85 €/an
Greenhouse gas emissions	15 €/an
Total gains	450 €/an

Table 8.5. *Summary of the main quantifiable indirect benefits, by vehicle and year*

All that remains is to set the fee to be applied to the system. According to the recommendations of Gonzalez-Feliu *et al.* [GON 13a], we fixed it at a little more than half of the total gain, that is to say at 250 €. Next, the capacity and demand of the system need to be defined. Based on a capacity analysis linked to the deployment of a specific number of deployed delivery areas as well as the demand capture, we have defined a number of delivery areas to be deployed over a 5-year period [GON 13a]. We have set this demand at 2,000 vehicles, and tested several capacities by applying the CBA proposed previously. The results obtained are detailed in Table 8.6.

Number of vehicles	Number of delivery areas	Total capacity	Needed capacity	Residual capacity	IRR
2,000	200	5,133	7,000	–27%	10%
2,000	250	6,415	7,000	–8%	15%
2,000	275	7,078	7,000	1%	9%
2,000	300	7,700	7,000	10%	9%
2,000	350	8,983	7,000	28%	5%
2,000	400	10,266	7,000	47%	1%

Table 8.6. *Feasibility analysis to set the desirable capacity in the deployment of a reserved delivery area system with a fixed demand of 2,000 vehicles (details on the evolution within the ten-year scenario are presented in [GON 13c])*

Based on these results, we are able to choose the number of delivery areas that will allow for an unsaturated system, but which at the same time will enable an IRR that allows, by changing the parameters and assumptions, to achieve economic profitability. In this regard, we observe that, for 275 delivery areas, residual capacity is very close to 0; under these conditions, the system can be considered to be saturated. At a lower capacity, the system is supersaturated and none of its potential users will benefit. For delivery areas over 300 in number, the system is at overcapacity and this is reflected by the IRR, which decreases with the increase in the number of delivery areas deployed. For that reason, we have selected 300 delivery areas to be deployed incrementally over five years.

Building on this, we propose a sensitivity analysis of the system. In order to achieve this, we take the main cost categories (Table 8.7) and we vary them by 10% (by excess and by default). We observe that, since the investment costs are lower than the operational costs, the latter will condition the profitability of the system, notably the maintenance of infrastructures mainly due to the initial state of the equipment for the control and usage of reservation-based delivery areas (mainly sensors, reservation software and parking meter adjustment). A 10% change in these costs results in a change in the IRR of approximately 4%, while the other operating costs, that is, current costs and police control, result in a variation (for each) by approximately 2%. Investment costs have little impact on operating costs as a 10% change in their estimate results in a change in the IRR of approximately 1.3%.

+10%	Total costs	Benefits	B-C	IRR up to 10 years
Initial situation	**1,986,273 €**	**2,102,820 €**	**116,547 €**	**5.87%**
Investment	2,011,427 €	2,102,820 €	91,393 €	**–1.33%**
Police checks	2,026,273 €	2,102,820 €	76,547 €	**–2.09%**
Operational costs excluding infrastructure	2,029,073 €	2,102,820 €	73,747 €	**–2.24%**
Infrastructure maintenance	2,061,416 €	2,102,820 €	41,404 €	**–3.86%**
–10%	**Total Costs**	**Benefits**	**B-C**	**10 years IRR**
Initial situation	**1,986,273 €**	**2,102,820 €**	**116,547 €**	**5.87%**
Investment	1,961,119 €	2,102,820 €	141,701 €	**1.36%**
Police checks	1,946,273 €	2,102,820 €	156,547 €	**2.17%**
Operational costs excluding infrastructure	1,943,473 €	2,102,820 €	159,347 €	**2.33%**
Infrastructure maintenance	1,911,131 €	2,102,820 €	191,689 €	**4.16%**

Table 8.7. *Results of the sensitivity analysis [GON 13c]*

From this, we can conclude that in order to increase the profitability of the system, we can either increase the tariffs asked of the carriers who use the system, or (as it was chosen in Bilbao) review the material which composes the delivery areas to propose that a solution may be a little more expensive to buy, but less expensive to maintain. On the other hand, once the success of the system is based in part on the control work done by the police [PLU 12b], these costs can either be reinforced or maintained with a reorganization of the control system in order to make it even more efficient.

In Table 8.8, we assessed five scenarios with the proposed methodology, in order to estimate what the best rate to apply would be. For scenario 1, only a socio-economic evaluation simulation was carried out (thus estimating the SERR). For Scenarios 2 through 5, the rate that achieves the targeted IRR is calculated. We report in Table 8.8 the respective values of the IRR for each scenario, as well as the tariff that makes it possible to reach these values.

Scenario	Stakeholder	IRR	Annual service price (by vehicle)
S1	Public	–	0 €
S2	Public	4.6%	250 €
S3	Private	16.2%	280 €
S4	Private	14.3%	220 €
S5	Public	4.6%	260 €
	Private	17.6%	

Table 8.8. *Results of the five simulation scenarios (adapted from [GON 14j])*

We observe that scenario 1 cannot be profitable (because no income is collected) and as such it is irrelevant to the current economic context. Indeed, it would be of interest to the user (because the service would be free), but it requires the use of public funds to cover the entire cost, although, at the point at which this service can be associated with the management of car parks, it would become entirely possible through a configuration to recover these costs by other receipts. For the other scenarios, we observe that private management is more efficient (the profitability is majorly significant for S3, with a difference of more than 11% of IRR between the two scenarios), but requires that tariffs are higher than S2 (30 € per vehicle per annum). Scenario S4 results in a better price, but this is due to the fact that there is a public subsidy of approximately 20% of the total cost. Nevertheless, this price is only 30 € cheaper than S2. The PPP (S5) results in a price that is 10 € more expensive than S2. The rates are similar (220 to 280 € per vehicle per year), and unitarily they seem close; however, if we consider that some transport companies can have several vehicles (double digits), this difference can become quite significant. Nevertheless, if we consider that the indirect impacts would save 450 € per truck per year, all these prices become interesting. It remains to explore the issue of governance and system acceptability [AIF 12] in order to define the best scenario.

8.3. Methods for estimating environmental impacts

8.3.1. *Main methods for estimating environmental impacts*

For the estimation of environmental impacts, different methods and tools can be used, depending on the objectives of the environmental assessment, the available data, the desired degree of detail and the impacts to be estimated. In this section, we propose a list of existing databases, methods and software used in the estimation of greenhouse gas emissions and other pollutants significant to urban logistics. This list is not exhaustive, but provides a preliminary glance at the diversity of methods and current possibilities for estimating the environmental impacts of urban logistics:

– *ADEME's Carbone*® database is one of the best-known standard tools in France. This public database contains the greenhouse gas emission factors needed to carry out carbon accounting exercises for a wide range of activities, including transport and logistics. It is available online for free[6] and works on the collaborative principle of open source data. It contains within it data on the various sectors of road freight transport (classic and express courier, transport of bulky and light goods, refrigerated transport, exceptional transport, vehicle carriers, container ships, tippers, removal vehicles, etc.) as well as storage activities (temperature controlled or not) and other ancillary logistics activities. It is limited to greenhouse gas emissions (in terms of CO_2 equivalent emissions), but nevertheless allows for direct and indirect emissions to be estimated, and takes into account, if the user so wishes, the life cycle of the greenhouse gas activities of urban logistics. Moreover, it can be considered as a standard method in France and is known by all the different stakeholders involved in the discipline.

– The *Ecoinvent* database [FRI 05] is the international scientific reference for Life Cycle Assessment (LCA). It contains life cycle inventories for a large number of sectors (including transport and logistics) and takes into account a wide variety of polluting emissions and environmental impacts (several dozen indicators). It remains an international reference, in particular for the impacts related to the construction and end-of-life phases of vehicles and equipment used in urban logistics, but remains much more approximate

6 See: www.bilans-ges.ademe.fr/.

than the methods for estimating direct emissions during the operating phase (that is to say, for emissions related to vehicle use or the implementation of logistic activities). In addition, and despite the wealth of this database, some elements of urban freight transport have not been considered as yet, for example, electric versus fuel vehicles, urban traffic patterns, among others.

– Open LCA software enables a life cycle analysis of any context, and can be used to estimate the environmental impacts of urban logistic schemes. Several methods for estimating impacts can be performed [AND 15b], but conversion factors must either be extracted from a database (e.g. *Ecoinvent*) or modeled (as in [AND 15c], for electric and fuel vehicles or the use of exact equations to describe direct emissions).

– Direct impact estimation software of the transport is a valid alternative and widely used in practice. We can identify three pieces software employed in France: *ARTEMIS* (Assessment and Reliability of Transmission Emission Models and Inventory Systems [AND 04]), *COPERT* (Computer Program to calculate Emissions from Road Transport [NTZ 09]) and *IMPACT* [ADE 03]. This third software uses the *COPERT 3* calculation formulas. Both *ARTEMIS* and *COPERT* are the result of European projects and as such have a similar operation. They can be used to estimate air emissions as a function of speed for different types of vehicles. *COPERT* is mainly linked to the normalized emissions and the emission factors that it uses are linked to the average vehicle speeds and a user-defined distribution of user-defined routes [GKA 07]. *ARTEMIS* [AND 05, AND 09] focuses on non-normalized emissions (cold start, new vehicles) as well as the types of roads and vehicle uses that are not contemplated by *COPERT 3*, but which has been integrated into the latest version of the software. To use this software (which in principle is free), it is necessary to know the characteristics of the vehicle or vehicles being used (maximum authorised mass, average load and Euro standard). For emission estimates of all vehicles in a zone, databases on average vehicle fleets in each European country exist, but need to be paid for [AND 15b]. The *ADEME Impact* software already includes the French fleet over several years, as well as evolution forecasts up until 2030 [GON 12a]. The most current version of *COPERT* is version 5 (released in October 2016[7]), which includes, among others, the *ARTEMIS* conversion factors, as well as the results of the *PARTICULATES* project for the estimation of fine particles.

7 emisia.com/products/copert/copert-5/.

– Direct emission models as a function of speed and acceleration [AHN 02, BAR 04] should be applied when we wish to estimate the impacts of driving behavior – mainly acceleration and deceleration – on the environment. However, these models were developed for North American vehicles. To calibrate them according to European emissions, calibrations on the basis of *COPERT* or *ARTEMIS* need to be carried out first [PLU 12a, PLU 12b] in order to be able to have estimates on the instantaneous emissions on these vehicles. To our knowledge, a model of this type is not presently at the European level, but remains the work of several research teams (including the Transport and Environment Laboratory at IFSTTAR). These teams have the necessary components with which to construct these datasets, or at least, provide emission factors that are more representative of the European reality.

As noted above, these methods are not in opposition to each other, but are complementary. Methods for estimating emissions as a function of speed and acceleration (or methods that take into account other factors closely related to the type and use of the vehicle) are used to estimate the impacts of the behavior or type of conduct on polluting emissions and greenhouse gases, and require a significant disaggregation of input data. Velocity-based impact estimation methods can be used in aggregate (for a zone and a city including an average fleet of vehicles), or for the vehicles of a particular company or service, or for a type of vehicle, but always in order to estimate the average impacts (usually aggregated to a typical day, week, month or year), and only for direct emissions related to vehicle use, for which they remain more relevant than the highly aggregated methods including life cycle analysis approaches. For indirect emissions, life cycle analysis approaches are necessary, hence the importance of knowing the principles and modes of operation for this type of methodologies.

8.3.2. *Introduction to life cycle analysis*

Life cycle analysis (LCA) is a standardized method (ISO 14040-14044) that takes into account both direct and indirect emissions in relation to the manufacture and distribution of a product or the provision of a service during the different phases of its life cycle, from the acquisition of raw materials to its production, use and end of life. An LCA is organized into four phases [AFN 12]:

– Definition of the objectives and the scope of the study. In this phase, we set the scope of the LCA according to the objectives. This discipline has several elements, including the system of products and/or services to be studied, the functions of the product system or systems, the functional unit, the system boundary, the chosen impact categories and the method of impact assessment.

– Life cycle inventory (LCI). This second phase involves collecting the data needed to quantify the incoming and outgoing products and/or services of a system. These data then follow a calculation procedure in order to be validated and put in relation with the various elements in the application of the LCA.

– Life cycle impact assessment. In this phase, we estimate and evaluate the potential environmental impacts based on the LCI data.

– Interpretation. This last phase of the LCA involves the analysis and interpretation of the combined results of the inventory and impact assessment, consistent with the objectives and scope of the study defined in the first phase. This phase ends with the main conclusions of the study, the areas for improvement, the limitations of the study and further recommendations, among others.

In the case of urban logistics, the life cycle analysis proposed here is done on the freight transport service and not on the transported goods. We therefore offer an assessment of all stages of the life cycle of vehicles, road infrastructures and logistics buildings, the three main elements necessary to offer a transport service. For each element, we consider the manufacture, use and maintenance, and end of life. Figure 8.1 represents the flow of that methodology as presented by [AND 15b].

We propose to illustrate this method through the case of the Saint-Étienne UCC (from [AND 15b]). We use it as the definition of the objectives and scope of the study for a life cycle assessment of a freight transport service. To do this, a set of indicators is first defined (Table 8.9; for details of the definition of these indicators, see [AND 15b]).

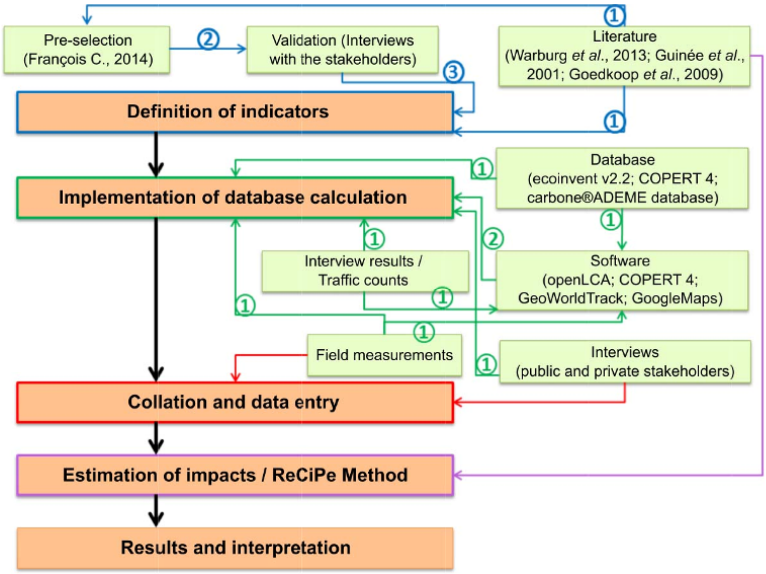

Figure 8.1. *Representation of the methodology [AND 15b]. For a color version of this figure, see www.iste.co.uk/gonzalez-feliu/logistics.zip*

Selected environmental impact indicators	Reference unit
Global warming potential	kg CO_2eq
Formation of photochemical oxidants	kg NMVOC eq
Fine particles	kg PM10 eq
Terrestrial acidification	kg SO_2eq
Fossil fuel depletion	kg oil eq
Mineral resource depletion	kg Fe eq
Soil occupation	m^2*a
Nonrenewable energies, fossil fuels	MJ-Eq
Nonrenewable energies, nuclear	MJ-Eq
Renewable energies	MJ-Eq

Table 8.9. *Environmental impact indicators (adapted from [AND 15b])*

Once the indicators have been defined, it is important to define the functional unit. In the LCA [AFN 12], the functional unit makes it possible to define the quantification of the identified function(s) and also provides a reference to which the incoming and outgoing flows are linked. Like any unit, it must be precise, measurable and additive. In general, the functional unit should contain a functional component, a performance criterion and a duration. Finally, the reference flow is the measurement of the outgoing process flows that are needed to fulfill the function provided by this unit. The functional unit chosen in the two proposed applications is the weekly delivery of a set of parcels representative of the current volume of UCC deliveries (weekly average value calculated over a year of operation).

The second phase is the life cycle inventory. To achieve this, it is important to define the main steps that constitute the freight transport service.

Here, three main steps are considered:

– the manufacture or construction of the infrastructure (linear and nodal) necessary for the transportation to happen, as well as the vehicles and material handling equipment necessary for the implementation of the transport service;

– the use of these infrastructures, vehicles and material handling equipment;

– the end of life (here, only the vehicles' end of life is considered, at least initially, in order to have a simplified first approach). The impacts of these phases must be brought back to the functional unit, both in terms of physical quantity and time units (here, these values will be applied to the total number of vehicles per week for the entire delivery service). The details for the calculation of the environmental impacts are given in [AND 15b].

Phases 3 and 4 (life cycle impact assessment and interpretation) are then carried out. We will present these later in the proposal for the two examples cited in this section.

We then present the results of the LCA for the Saint-Étienne UCC. As the objective of setting up this UCC is environmental, it is important to study the environmental impacts in a broad way. The UCC at the time had 2 vehicles and, until September 2015, delivered goods for 4 shippers. Table 8.10 presents the results for the estimation of the different categories of selected impacts. Direct emissions correspond here to emissions related to the usage phase (vehicles) and indirect emissions to the manufacturing (infrastructure and vehicles) and end-of-life (vehicles) phases. The functional unit chosen here is the delivery of 250 points per week, that is, 13.7 tons over

403 kilometers (scenario 1) and over 466 kilometers [AND 15b]. Included in this evaluation are routes for the UCC delivery by the shippers, made by a combustion engine vehicle, and those from the UCC to the customers, trips made by both electric and combustion engine vehicles. For more details on the calculations and assumptions of this assessment, see [AND 15b].

	Scenario without UCC		Scenario with UCC		Evolution generated by UCC		
Number of delivery vehicles	4		2		–		
Number of delivery routes	4		5		–		
Total distance covered (km)	403		466		+15%		
Impact categories	Direct emissions	Indirect emissions	Direct emissions	Indirect emissions	Direct emissions	Indirect emissions	Total
Global warming (g CO_2 eq)	198,870	15,740	166,146	14,767	–16%	–6%	–15.7%
Photochemical ozone (g NMVOC eq)	1,583	86	1,239	92	–22%	+7%	–20.3%
Fine particles (g PM10 eq)	245	40	204	40	–17%	0%	–14.4%
Terrestrial acidification (g SO_2eq)	557	71	473	85	–15%	+19%	–11.1%
Fossil fuel resources (g oil eq)	61,580	6,065	49,528	6,014	–20%	–1%	–17.9%
Mineral resources (g Fe eq)	697	8,720	975	14,768	+40%	+69%	+67.2%
Fossil fuel energy (MJ)	2,723.3	270.5	2,191.5	259.7	–20%	–4%	–18.1%
Nuclear energy (MJ)	36.5	41.0	936.9	45.8	+2469%	+12%	+1168.0%
Renewable energy (MJ)	6.6	12.7	48.1	13.7	+624%	+7%	+220.2%
Total energy consumption (MJ)	2,766.4	324.2	3,176.5	319.2	14.8%	–1.5%	13.1%

Table 8.10. *Results of the environmental LCA of SimplyCité for the chosen functional unit [AND 15b]*

In our applied example, we analyzed the changes brought about by the implementation of the *SimplyCité* UCC of Saint-Étienne. There were four main findings:

– The share of indirect emissions, that is, emissions in the construction and end-of-life phases, varied from 5% to 94% depending on the impact indicators considered; however, in all cases, the results were considered non-negligible. Among the indirect environmental impacts that play an important role, we can highlight the depletion of mineral resources. The consumption of non-fossil energy is also important in the construction and end-of-life phases but, in total, these energies represent a much lower share than fossil fuels.

– We observe a gain in direct emissions of between 16 and 22% and a total gain (direct and indirect impacts) of between 14 and 20% for conventional indicators of the environmental assessment common to urban logistics: greenhouse gas emissions (16% gains in both direct and total emissions), photochemical ozone (22% direct emission gains and 20% of the total) and fine particulate matter (17% direct and 14% total emissions).

– However, these gains can be significantly offset by losses in other indicators if we take a broader view of the environmental impacts. Indeed, the choice of an electric vehicle has a distinct influence on the results of direct and indirect emissions: here we clearly see the impacts of battery manufacture (a 69% increase in the consumption of mineral resources) and the impacts of nuclear energy consumption during the usage phase (an increase of 2,469%), but also in the production and end-of-life phase (+1,168%). This shows that the environmental impacts associated with the use of electric vehicles are not to be neglected in political decisions.

– The impacts of infrastructure manufacturing should not be neglected either, since they account for an average of one quarter of indirect impacts. This justifies the consideration of road infrastructure in the environmental assessment of urban logistics, as it has significant environmental impacts on the life cycle of urban freight transport organizations.

We note that the implementation of the *SimplyCité* UCC in Saint-Étienne generates a 15% increase in the total distances traveled by vehicles. This is explained by the increase in the total number of delivery routes between scenario 0 and scenario 1. Indeed, before the advent of the UCC, two of the four carriers made deliveries in Saint-Étienne with larger vehicles than those used by the UCC, which allowed them to use a single trip to make deliveries across the city center of Saint-Étienne. This increase in the total distances covered has a direct impact on the infrastructure manufacturing, but it is unevenly distributed over the other indicators: this distribution depends on the choice of vehicles used (a smaller maximum authorized mass, use of their own vehicle, recourse to newer Euro standards vehicles, etc.).

Therefore, each political decision, in terms of regulations such as restricting access to the city center of heavy goods vehicles, or in terms of support (e.g. subsidies granted for the purchase of a clean vehicle), implicates very different environmental impacts.

8.4. Spatial indicators: centrality, inequality, attractiveness and accessibility

As already pointed out in a previous work by the author [GON 16a], the quantitative assessment for the social impacts of urban logistics is difficult and not very systematic. Although it is possible to estimate indicators related to the creation/destruction of jobs [HEN 08], the priority issue in job creation is not the number, but the type of job, valorization of urban logistics professions, the upgrading of skills and qualification of employees, as well as the fight against precariousness [CHO 01, CHO 02]. These aspects can only be assessed through qualitative analyses, and other indicators such as the degree of satisfaction (of shippers and/or recipients, as well as inhabitants) do not yet have a systematic and unified methodology for their calculation or remain, in the case of other indicators, qualitative and subjective [MOR 15b].

Another aspect that can be quantified and which still does not entice much interest is that of accessibility or attractiveness in terms of the movements of goods. These aspects are nonetheless considered fundamental, and accessibility experts (a concept often applied to the movement of people) underline the potential of defining similar indicators for goods [VAN 16]. We observe a small body of work in this area that underlines the potential for these types of methods and analyses.

The definition of accessibility and freight attractiveness indicators can be obtained from the indicators used for passenger transport. Geurs and van Wee [GEU 04] define accessibility as “the extent to which land-use and transport systems enable (groups of) individuals to reach activities or destinations by means of a (combination of) transport mode(s)”. Gonzalez-Feliu [GON 12e, GON 16d] and Gonzalez-Feliu *et al*. [GON 14h] further this notion by linking it to urban logistics, and van Wee [VAN 16] further demonstrates the importance of defining these indicators. From all these works, we can identify three categories of indicators for accessibility and/or attractiveness from the point of view of goods:

– Service level indicators, related to either an infrastructure or a transportation system. The main examples of indicators in this category specific to urban logistics are congestion levels and average travel speeds of a road network [CHI 16, WAN 16, LOP 16], or the difficulty of implementing transport solutions, by means of route feasibility indicators [DEF 12].

– Indicators based on distance or cost of transportation, mainly related to routing and scheduling [GON 14e, GON 14h].

– Gravity accessibility indicators [GON 08, GON 12e, CRA 10, GON 13b].

8.4.1. *Service level indicators*

Road network load indicators can be estimated using methods similar to those of studies on traffic dynamics, but by adapting the methods to explicitly consider trucks [CHI 15, WAN 16], in particular to include the inconvenience caused by the double-parking of these trucks (an event not previously studied). After a series of theoretical studies [CHI 15, CHI 16, LOP 16] propose macroscopic flow diagrams comparing the density of vehicles and the load of the road network, for a real urban boulevard (Cours Lafayette in Lyon, for which a one-day dynamic demand estimate was made) and with variable downtime (from ten to thirty minutes). Several scenarios were tested as shown in Figure 8.2 (for more information, see [LOP 16]).

Figure 8.2 shows the estimation results of Macroscopic Fundamental Diagrams (MFD). The two figures on the left (Figures 8.2(a) and (c)) represent a case wherein the level of demand is high and, therefore, the number of trucks is significant. The two figures on the right (Figures 8.2(b) and (d)) represent cases where the demand levels are low. Figures 8.2(a) and 8.2(b) assume that truck introduction times into the network follow a normal distribution, while Figures 8.2(c) and (d) show a uniform distribution. On each graph, a given curve corresponds to the MFD for a delivery time scenario. The reference MFD represents the traffic states assuming that there are no parked trucks. We observe that, when downtime increases (often when there is double parking), the capacity decreases. However, in scenarios where there is low demand, this decrease in capacity remains contained, while in those scenarios with high demand, the decrease is significant.

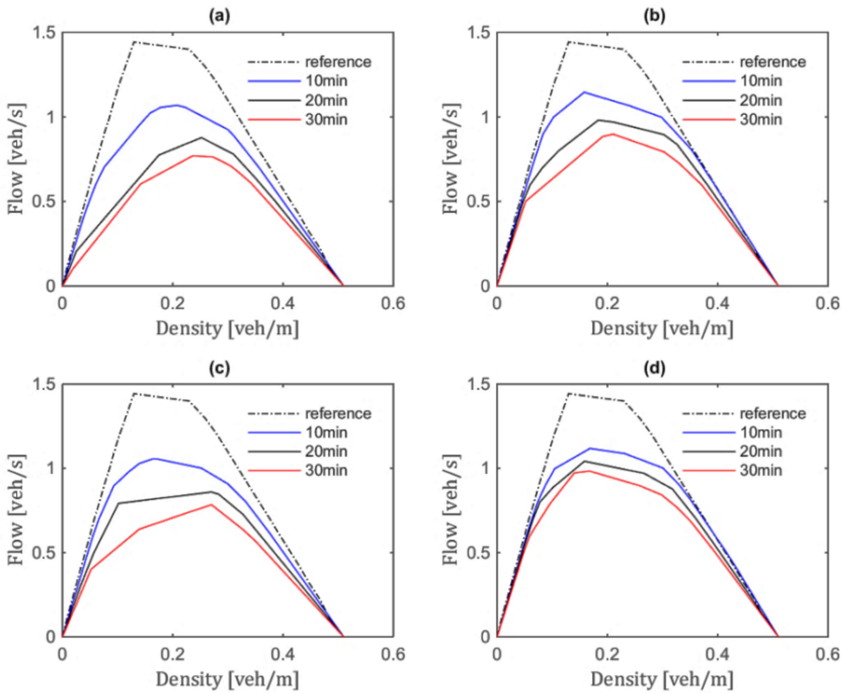

Figure 8.2. *Macroscopic fundamental diagrams for four scenarios [LOP 16]. For a color version of this figure, see www.iste.co.uk/gonzalez-feliu/logistics.zip*

With regard to service indicators, a preliminary study was conducted by [DEF 12] for a case of express mail delivery in a small town. A set of indicators that takes into account the flexibility and compatibility of delivery plans, particularly with respect to often very tight delivery times, was proposed and tested in real time. These indicators are based on the concept of compatibility, that is to say, the possibility of delivering to customer *b* after delivering to customer *a*, given the time constraints of the two customers. Three indicators are proposed:

– average compatibility between two customers;

– the percentage of compatible customer pairs (i.e. achievable route sections);

– the average minimum time between the delivered customer and all other compatible customers.

The results of these analyses show that the shift from a delivery window from one hour to two hours (i.e. the customer's waiting time) has a huge impact on the level of service and the cost of the route, and increasing this window does not significantly increase the cost of the route.

8.4.2. *Distance and cost indicators*

Indicators based on distances traveled or transportation costs, specific to urban routing and scheduling, have been studied in [GON 14, GON 14c]. To estimate this indicator, a method of route construction is necessary [SAL 15], as well as an estimate of the demand for feeding this routing simulation [GON 14h]. From these routes, the total distance traveled (by all routes from a given starting point) is estimated [GON 14e]. The total time traveled (which takes into account both the travel time, but also the delivery and pickup operations, as well as other working times such as breaks or possible administrative operations of the driver) is also estimated. From this, the total cost of freight transport is calculated as follows: the monetary cost (in euros) associated with a route k is noted as Ck and can be estimated by the following relation:

$$C_k = 0.35\ dist_k + 34.52\ t_k \qquad [8.8]$$

where $dist_k$ and t_k are the total distance traveled by the route k and the total work time charged to the same route. Given a zone e, the total cost associated with routes departing from this zone can be estimated as follows:

$$C^e = \sum_k C_k^e \qquad [8.9]$$

Finally, the accessibility indicator for the zone e (or set of routes) can be estimated as follows:

– $A^e = \frac{W}{d^e}$ for a distance type accessibility;

– $A^e = \frac{W}{C^e}$ for a cost type accessibility.

where d^e and C^e are, respectively, the total distance and the total cost of all the routes associated with the zone e, and where W is the parameter that makes it possible to reduce this accessibility to a value between 0 and 100.

8.4.3. *Gravitational indicators*

The gravity indicators take into account two types of variables: the opportunities O_j to reach a zone j, that is to say the set of variables that motivate the trip towards the zone j, and the transport costs c_{ij}, often related to the distances traveled between two zones i and j, but which may take into account other elements such as journey times or the cost of the type of transport used for the trip. Gravity accessibility [HAN 59] can be defined as follows:

$$A_i^P = K.\sum_{j=1}^{n} O_j.c_{ij}^{-\alpha} \quad [8.10]$$

This indicator is also called potential accessibility because of the relationship it has to the form of a power. We can also define an exponential variant as follows:

$$A_i^E = K.\sum_{j=1}^{n} O_j.e^{-\beta c_{ij}} \quad [8.11]$$

These indicators can be adapted to study the attractiveness of a zone by aggregating the indicators not by zone of potential origin, but by that of destination, that is to say:

$$A_j^P = K.O_j.\sum_{i=1}^{n} c_{ij}^{-\alpha} \quad [8.12]$$

and:

$$A_j^E = K.O_j.\sum_{i=1}^{n} e^{-\beta c_{ij}} \quad [8.13]$$

for the potential and exponential attractiveness, respectively.

In terms of opportunities, several authors use the total quantity of goods to be delivered in each zone [GON 08, GON 12b, CRA 10]. This approach requires an estimation of the quantity of goods to be delivered (a demand model). Nevertheless, some authors prefer to align with the indicators of passenger transport, and use either the number of establishments or jobs for the meaning of the term 'opportunities' [THO 03]. This number of establishments or jobs may be based on commercial activities, if we seek to estimate an indicator of accessibility or commercial attractiveness [KUB 07, GON 10b, GON 13b, VAN 14], or else, all the economic activities of the city for a more general indicator. Other authors combine socio-economic variables with those of demand for the definition of opportunities [LIM 08], or with demographic variables such as population [THO 03, GON 17d].

The cost of transportation can also be estimated in different ways. The simplest is to reduce it to the distances between two zones [GON 08, GON 12e, CRA 10], which can be calculated as the crow flies or via distance databases that have actually been traveled. Another possibility is to define an average travel time between two zones. Finally, a transport cost can also be calculated [GON 13, LIM 08].

We take as an example that of the definition of commercial gravity accessibility indicators [GON 13b]. Opportunities are defined as commercial jobs, and costs such as transport costs are estimated from the average distances traveled to reach a zone j from zone i of the urban area by a motorized vehicle. The accessibility analyses proposed are made on the urban area of Lyon (France), which was divided into 743 zones (the *IRIS* zoning in the year 2000) using data from the 2006 household survey, taken from the *SIRENE* 2005 file (to inform institutions) and the *MOSART* platform (for calculating costs and distances [CRO 10]).

We report in Figures 8.3 and 8.4 three maps: the first represents the accessibility for local retail; the second, that of shopping centers (supermarkets, hypermarkets and large specialized distribution centers); and the third, the relationship between the accessibility of shopping centers and small retailers, called differential accessibility.

Figure 8.3 shows that for both small businesses and large shopping centers, the spatial distribution of zones by accessibility quartiles is similar: in both cases, the more accessible zones are located in the main urban area, with zones becoming less accessible as the distance to the urban city center increases. However, the two spatial distributions are not exactly identical: the commercial zones of eastern Lyon have, on average, better access to small retailers than shopping centers.

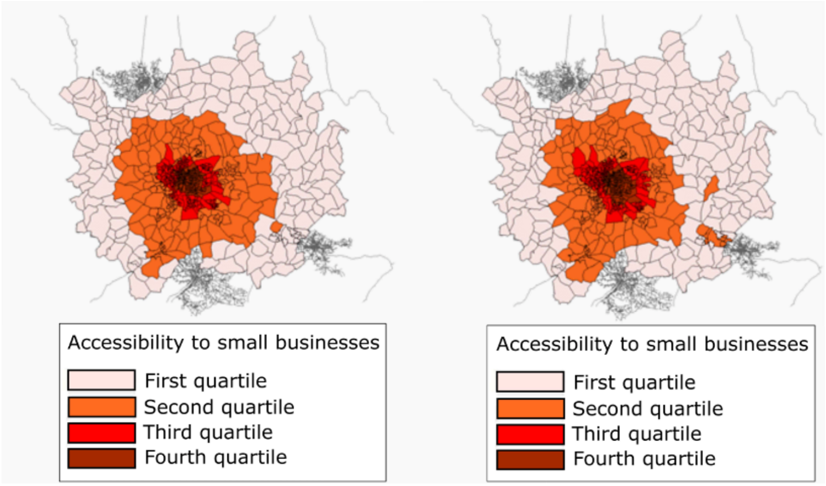

Figure 8.3. *Accessibility of small shops and large shopping centers for the urban area of Lyon (adapted from [GON 13b]). For a color version of this figure, see www.iste.co.uk/gonzalez-feliu/logistics.zip*

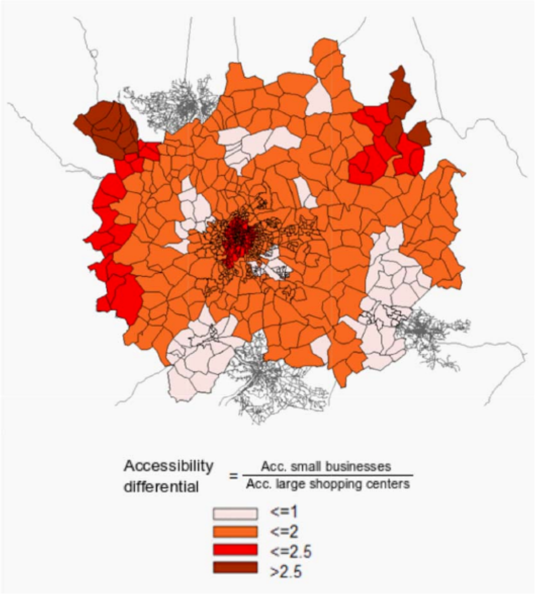

Figure 8.4. *Differential accessibility for small businesses in the urban area of Lyon (adapted from [GON 13b]). For a color version of this figure, see www.iste.co.uk/gonzalez-feliu/logistics.zip*

If we look at differential accessibility (Figure 8.4), we can observe large disparities in the territory (in other words, the relationship between accessibility to small and large retailers is neither uniform nor follows a concentric distribution, although each of the two accessibilities is distributed in this way if examined separately). In the main urban area (Lyon-Villeurbanne), the differential access to small businesses is very high (more than 2.5), which is explained by the large quantity and density of small businesses, which are greater than the number of large shopping centers. In some peripheral areas to the north of the urban area, we also observe a strong differential accessibility in favor of local commerce; this can be explained by the fact that these remote areas of the main urban area have a concentration of local shops around secondary urban areas (municipalities with a high commercial density and important economic activities due to their distance from the main urban area).

We observe that, for the great majority of the territory, the differential accessibility is always to the advantage of local commerce. In the west (one of the least dense parts of the region, characterized by individual habitat and high family incomes), we observe a border effect (a major line with similar differential accessibilities). Only a small group of areas, including four small areas on the edge of the current metropolitan Lyon and two larger areas in the far south periphery, have greater accessibility to large supermarkets than small shops. The four zones around the main urban area correspond to around four major commercial peripheral poles, where large-scale shopping centers are superior to that of small businesses. The other zones correspond to a rural context where local shops are small and widely dispersed, without the presence of secondary urban centers. For this reason, and because of the peri-urban and even rural nature of these areas, large shopping centers remain more accessible, since they can be reached quickly and easily by car because of modern road infrastructures.

8.5. Practical considerations of indicator estimation methods

We have just seen a set of methods for estimating economic, environmental and spatial indicators, as well as several examples of indicators and their possible applications. Through these examples, we can see that the implementation of these indicators requires a knowledge of the context and a solution probleming approach (such as that presented in Chapter 6) in order to make these evaluations relevant and efficient. Indeed, the estimation of costs and environmental indicators depend, in part, on the form and length of the routes as well as the travel and stoppage times. For this reason, it seems necessary to study the relevance of the estimation methods of these routes in relation not only to the context, but also to the stakeholders concerned and their objectives.

The approach of solution probleming can therefore extend to evaluation and is not only limited to mathematical challenges. Moreover, in the logic of estimating changes, it is also important to study the relevance and validity of the assumptions made in the construction of scenarios and thus in the modeling of change.

To this end, it is first important to define the objectives of the evaluation, not only with the concerned decision-makers, but also with the stakeholders who are likely to be involved in the evaluation process. For example, for the evaluation of the UCC in Saint-Étienne, the decision-makers were first approached (Saint-Étienne Métropole, City of Saint-Étienne and FNTR mainly) in order to define their objectives for evaluation and the proposed indicators [AND 15b]. Then, the UCC manager was consulted, not only for data collection purposes, but also for his vision of UCC management and evaluation. Then, the remitters were also interviewed. In addition to the information needed to quantify distances and travel times, they were questioned on their relative position to the UCC, and their answers on the advantages and limitations of this type of system were duly noted [AND 15b]. In other words, an evaluation method should not be imposed without stakeholders having no room for maneuver in the construction of criteria and indicators, but should be built with their help, in order to take into account their experience and moreover their goals. Hence, the need to deploy not an administrative tool that is convenient, but an evaluation framework to adapt and supplement according to the context.

In addition, knowledge of the context is also necessary for the smooth running of the evaluation. For example, the cases of Padua or Saint-Étienne had support from public stakeholders, but also private stakeholders, and therefore was a collective desire for the establishment and sustainability of these respective UCCs [GON 10, AND 15b]. In the cases of Vicenza or

Genoa, the political aims were not adhered to by the private stakeholders, hence the confrontations and difficulties to perpetuate these UCCs (that of Genoa was stopped for lack of financial means, Vicenza continues, but has been the subject of a series of lawsuits: [GON 08, DAB 10, VIL 13]). In addition, the factors of success for the Padua UCC (the presence of a logistics real estate player willing to manage the UCC on the side of their main activities; being part of an international context and the city center labeled as a World Heritage Site by UNESCO) do not necessarily exist in other cities, hence the difficulty of transposing specific urban logistics solutions [DAB 11], but also highlighting the reason why they need to be evaluated (the estimation of marginal costs is not always obvious, [VAG 11]).

If we now look at the possible links between the proposed methods, the cost–benefit analysis could be served by the environmental assessments in order to propose socio-economic analyses, by identifying indirect costs and benefits. Nevertheless, the classic view of socio-economic CBAs that give fictitious monetary values to pollution or greenhouse gas emissions seems to us to be of little relevance if we wish to estimate the feasibility and cost-effectiveness of an urban logistics solution. Although it is possible to identify environmental benefits and transform them into a monetary value, it is important, in our opinion, that this value, even virtual, results in true monetization, that is to say in the identification of a monetary value that could result in economic gain for the business or community. To this end, the approach adopted here is quite different: the monetization is done on values that can or could be associated with these impacts and that result (or will result) in real economic gains (or losses). For example, Vaghi and Percoco [VAG 11] sought to relate air pollution in Padua to the percentage of colds and allergies, which resulted in a series of medical visits and easily estimable health costs. A reduction in pollution can thus have the effect of reducing the costs to the local health system, factors that are identifiable and easy for decision-makers to take into account. Jaller *et al*. [JAL 15] show estimates of additional costs related to congestion (loss of time, increase in fuel consumption, etc.), to highlight the interest in night-time deliveries, whose costs of implementation are much lower than these costs, which are easily calculated and attributable to the transport companies. Another possibility is to hypothesize an environmental tax that should be paid by all users of motorized vehicles, and which would be a function of polluting emissions. A reduction in these emissions would bring the company in question a reduction of this tax [GON 14e]. Nevertheless, in France, this hypothesis remains currently unrealistic, despite the advances that have been made, although it may become a reality in the not too distant future. Another alternative for linking economic and environmental assessment may be to relate costs to environmental gains. For example, when several solutions are compared, we can estimate the extra cost of the kilogram of CO_2 saved [PAL 16].

The key to the proper use of CBA lies, in our opinion, in this monetary quantification of indirect costs and benefits. This quantification results from a true monetization of these impacts (through hypotheses, which is to say, this quantification strongly depends on the choices and assumptions made). Indeed, a "gain" of thousands of euros per CO_2 reduction calculated by taking the CO_2 international exchange rate will not mean much to local decision-makers (since this value does not translate into a cash inflow or monetary gain for users). On the other hand, it is interesting for a company that a gain in travel time and stoppages also results in a monetary gain, mainly related to wages and transportation costs, and can therefore justify the demand for an economic contribution for the implementation of a scenario, provided that this contribution is lower than the economic gain they obtain from improving their delivery routes.

Finally, it is important to look carefully at the context and not only rely on "expert opinion" without any justification, but to look carefully at the relevance of the methods being implemented. For example, before judging the relevance of a UCC, instead of looking at the fact that many cities have adopted this strategy, it is important to estimate the potential gains and risks of this UCC [NIM 17], looking firstly at what has already been achieved, and secondly by quantifying the changes that a UCC may induce and the ratio between the gains resulting from these changes, as well as the additional costs that result from its establishment. We still insist on the importance of economic viability: we have already seen that City Logistics in Lyon was stopped while most of the stakeholders were touting its potential, mainly due to difficulties in achieving the profitability objectives (and underestimates for the actual costs of setting it up). The environmental gains, without an economic model that ensures the continuity of an urban logistics solution, are not enough to keep it running (unless the public authorities assume the additional costs, and yet, even in this case, we should assume that this public financing is part of the business model).

Conclusion

Sustainable urban logistics is a particularly topical and interesting subject not only for researchers but also for practitioners. Nevertheless, the lack of unification and the diversity of approaches and methods have often been criticized as a hindrance to the support process for decision-making by the different stakeholders involved in urban logistics. Furthermore, this inadequacy is backed by the contemporary scientific literature and recent scientific gatherings, which demonstrate a desire by the international community to work towards unification. With that in mind, this book presents an unambiguous view of sustainable urban logistics and provides an analytical framework for decision-making support for this objective. It summarizes about 10 years of personal (and collaborative) work on the subject through the presentation of the key contributions that have been generated on this topic, and also references and describes other approaches that are of potential interest and hence of potential importance to the planning and development of sustainable urban logistics. As already stated, this vision does not claim to be the only truth nor does it seek to be an imposition, but rather is presented to promote openness and complement the contemporary visions of sustainable urban logistics, especially at the international level.

The definitions presented in this book are intended to be broad and comprehensive. The totality of the flows has been considered in the most extensive definition of sustainable urban logistics and therefore covers inter-establishment transport flows, which have been studied extensively in the literature, as well as the two lesser-known categories of end-consumer and urban management flows. In addition, it also explores the internal flows

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(mainly associated with urban production and warehousing), which may be significant in terms of cost, and also the assessment of environmental and social/societal impacts that sometimes need to be taken into account for the planning and forecasting of urban logistics. Furthermore, the vision of sustainability presented here goes beyond the consideration of the three classical spheres (economic, environmental and social/societal) and their three interactions (viable, workable and equitable) to introduce the notions of capabilities (awareness, action, anticipation and avoidance) and aspects of dualities (short-term and long-term, local–global, simple–complex and competition–cooperation). The governance of this sustainable urban logistics is also not easy, mainly due to the diversity of the stakeholders involved and these respective challenges, and also due to the lack of a unified framework for analysis and support tools, not only for decision-making, but also to improve the dialogue and communication between these stakeholders so as to reach an agreement or consensus.

In this regard, this book has proposed a set of methods, all under the same framework, with the aim of being easily transposable, understood and interpreted by the various stakeholders working in this field. The framework is based on three core principles: the definition of before–after analysis reasoning, the estimation of change and solution probleming. The before–after analysis describes the comparison of two scenarios: the evaluation (after) and the assessment (before) that is used as the reference scenario. The estimation of change aims to define the elements of a system that change over time; next, a quantification and qualification of these observations are carried out, by mobilizing certain resources in order to estimate the overall impact of the whole system, for which some aspects remain invariant. Since this estimate of change is an estimate, it is important to link it to the context and thus to solution problem the results obtained, i.e. to study the representativeness of the analyses obtained and the relevance and validity of the solutions and results obtained, in lieu of accepting them as absolute truths. Of course, this approach is not the only one in the world, but can be used as a basis upon which dialogue and the search for consensus, by means of solution probleming, can be promoted. As such, it remains open to evolutions and complementarities with different approaches and methodologies.

In addition, the methods proposed here are based on international dominance (often taken to be standards), in order to facilitate a comparison of the activities taking place in France with those taking place in the rest of the world. Of course, this does not undermine French approaches, but as several studies show [CAM 12, GON 16b, SAN 16a], estimation and modeling in urban logistics is linked to the quantity and quality of the data available, and under current conditions, internationally validated analytical methods obtain results that are very close to the empirical methods applied to French data, hence its promotion, specifically in the field of passenger transport [ORT 01]. Nevertheless, despite the preliminary works aimed at producing standardized analytical frameworks [OGD 92, TAN 01], the interactions and synergies between the engineering and humanity faculties were in the past poorly promoted. It is as a result of a multidisciplinary experience, which summarizes more than 10 years of personal and collaborative research in the field, and of course in the spirit of promoting collaboration and teamwork, that the broad scope and hybrid nature of the vision proposed here has been made possible.

In conclusion, sustainable urban logistics is starting to become an unambiguous subject with methodologies that are unified and accepted by the scientific and practical communities. This book aims to fuel this reflection and unification, and advocates that this should be done through a systematization of methods and practices and not by imposition (as demonstrated at the latest VREF conference in Gothenburg, where the majority of work on demand modeling was based on the founding principles of Holguin-Veras *et al*. [HOL 11], and where territorial approaches such as those of Ducret, 2015 are beginning to be generalized, and where the vision of sustainability assessment in the sense of Gonzalez-Feliu and Morana [GON 14c], where the standard is found in the process and not in the tool, are slowly becoming a reality, albeit still in its infancy). We observe, however, that much remains to be done, and, for that reason, it is essential to cooperate and collaborate. Since this cooperation can be carried out in many ways, we propose here several promising lines of inquiry, which should not be the only avenues of research, but which seem to us, in the vision proposed here, to be more interesting to be put forward.

The first line of research inquiry focuses on methods for modeling urban logistics. Although demand modeling is beginning to be unified, a systematic modeling framework has not yet been widely accepted, although efforts are being made towards this: the work proposed in Chapter 4 contributes to this discussion; however, we observe that the generation–distribution–construction approaches for the route-allocation of traffic are beginning to gain popularity among the majority (and would connect by analogy with the four-step models of passenger transport, albeit by increasing the complexity). Nevertheless, these methods require further investigation and it is still too early to say whether this will be the new standard for freight transport modeling. Nevertheless, it is essential to provide an integrated modeling for the supply and demand of urban logistics, which currently remains under-explored but nonetheless has significant potential, particularly in terms of its scientific contribution (the appraisal of supply and demand requires specific scientific developments and may involve both research and practical communities who have different visions). In addition, the joint modeling of the different logistics flows must be done with decision-making support in mind, and therefore in connection with the methods for the assessment and evaluation of sustainability. Finally, the modeling of new logistical organizations and their relation to the urban area are also major subjects, and have great potential.

Another subject very much related to the expectations of the territorial stakeholders is urban food logistics. The urban areas of Paris, Lyon and Saint-Étienne (among others) are developing sustainable food plans that require better management of logistics chains, all the while promoting and respecting the territorial dynamics. In Latin America, sustainable food for territories is also becoming a prominent topic. Today, the quantification and modeling of urban logistics proposes approaches related to the transportation of non-perishable goods (mainly post, small parcels in B2B or B2C, or transported on people’s own account). Food transportation is not often analyzed in detail in urban analyses, but different research groups are beginning to look at it. The second research avenue is that of the modeling urban food logistical schemes, and also modeling the evolution of economic and environmental evaluation methods to take into account the specificities of this sector. Pioneering works in this area [MOR 11, PAL 17] may serve as the groundwork for these important developments.

A third topic is the development methods for the planning of urban logistics (or city logistics) that take into account resilience. In fact, the latest natural phenomena in Latin America have demonstrated the limits for the current development of cities in the region and the need for orderly, consensual planning that contributes to the resilience of the territory. However, although resilient urban logistics is present as one of the main lines of thinking in City Logistics 4.0 [TAN 16], the subject is still at an early stage. Nevertheless, it has attracted the interest of several public and private stakeholders, particularly in the Latin-American context (see the creation of an urban logistics Living Lab in Querétaro, Mexico, with a particular focus on informal transport and development, local sustainable development, the actions of the Bogotá region on the agro-food technology corridor and the recent collaboration between the École de Mines of Saint-Étienne and the Pontifica Universidad Católica del Perú on urban logistics, resilience and the reduction of vulnerability).

Finally, there is a fourth research topic, which remains linked to the evaluation and implementation of decision support methods, with the particular objective of unification (at the European and even global level), to reinforce the vision for the evaluation of change and the solution probleming of results and the various simulation methods used for the scenarios as well. Validation of the applicability of these methods will nevertheless need to involve qualitative research (feedback, focus groups, etc.), in order to be able to obtain the advantages and limitations, in terms of the use and deployment of these types of research tools as well as any reluctance to do so.

Be that as it may, sustainable urban logistics no longer seems to be a constraint, but an opportunity for the many different stakeholders involved. It is only through scientific support, objectivity and an open-mindedness to listen to the various stakeholders and challenges that they face, that sustainable solutions for urban logistics can be implemented. To this end, the role of research must not be a substitute for decision-making by these actors, but rather serves to provide them with a simpler understanding of urban logistics, as well as the elements and objectives that have been contextualized and argued, to better help them in their decision-making process. In other words, modern research aims to provide them with the necessary elements with which to carry out a quantitative and qualitative comparison between the different activities of urban logistics, as well as a repository and a methodology for the calculation of indicators, thereby allowing them to quantify and measure this comparison. It is hence our responsibility to contribute through collaboration and group decision-making processes, towards a systematization of methodologies and practices so as to be better aware (and then understand), to act (for change), to anticipate (the risks) and avoid (nuisances), thereby advancing sustainable urban logistics in a collective and unified manner.

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