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Parcel Delivery in Urban Areas: Opportunities and Threats for the Mix of Traditional and Green Business Models

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Abstract. In recent years, freight transportation and parcel delivery became a key activity in the urban areas, supporting the economic and social development of the cities. At the same time, this industry is affected by different issues, inefficiencies and externalities, particularly in the last mile segment. In this scenario, it emerges an increased awareness to improve the urban mobility and the transportation, making them more sustainable and competitive by mixing traditional and emerging technologies, as cargo-bikes, autonomous vehicles and drones. The paper is introduced in this context with three purposes. First, it defines the main actors involved in the urban parcel delivery, analyses their business models and the interaction between them. Second, it investigates the integration of traditional and green logistics (mainly cyclelogistics), from both business and operational perspectives, in order to identify synergies, conflicts, operational and economic consequences of the green vehicles adoption. Third, it introduces a simulation-optimization decision support tool capable to assess mixed-fleet policies for the management of parcel delivery in urban areas. The test over real data of the city of Turin are presented.

Keywords: Green transportation, GUEST, last mile, parcel delivery, City logistics.

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1 Introduction

In recent years, freight transportation and parcel delivery became key activities in the urban areas, supporting the economic and social development of the cities. At the same time, this industry is affected by different issues, inefficiencies and externalities, particularly in the last mile segment [32]. In this scenario, it emerges an increased awareness to improve the urban mobility and the transportation, making them more sustainable both from the economic and the environmental point of view. The need to increase the efficiency of the delivery while the marginal revenues are decreasing led the different actors to identify new delivery options in the emerging technologies, including dropbox [14], cargo-bikes [35], electric vehicles [45], autonomous vehicles [16] and drones [23]. Unfortunately, the integration of the different delivery option is not a free meal, due to the interaction and the conflicts between the delivery options themselves, as well as of the actors operating them and their business models [44]. In this direction, this paper contributes to the literature studying the issues of the integration of some of the most popular new business models as the green delivery operated by cargo bikes, with those of the traditional ones, presenting an analysis conducted in a medium-sized city as Turin (Italy). The paper gives an holistic vision of the above defined context, including a first comprehension of the system by means of qualitative tools (i.e., Business Model Canvas, Social Business Network and SWOT analysis), from a managerial point of view. This represent the basis for a context-aware integration of business and operational models, provided by a more quantitative analysis of the topic. We also show how mixing qualitative and quantitative analyses we can derive better results that with the sole operational and quantitative one. In details, our contribution can be summarized in the following points:

- identify the different players involved in the transportation and parcel delivery system, considering several mixes of the traditional (i.e., they use fossil fuelled trucks and van) and green (i.e., they use electric or hybrid vehicles, bikes and cargo bikes) operators, investigating through a managerial perspective, their business models and behaviours;

- investigate through a more operative perspective how the mix of traditional and low emission logistics could coexist in the parcel delivery field in urban areas, leading to an optimization of the overall system, according to a win-win strategy, avoiding the risk of cannibalization between the two models.

- finally, we introduce a Monte Carlo-based simulation-optimization method to decline mixed-fleet board policies for managing freight delivery in urban areas, clarifying their cost mix (economic and environmental).

The paper is organized as follows. In the Section 2, we discuss the literature review and the main research challenges of the urban freight transportation system. In the Section 3, a brief description of the methodology GUEST is provided. In the Section 4, we describe the multi-actor system on parcel delivery, presenting the business models of the actors involved. In the Section 5, we analyse the operational models, in terms of times, distances and especially costs (both operating and environmental) generated by the different options of vehicles. In the Section 6, we show the results of a Monte-Carlo based simulation-optimization conducted to highlight synergies between the operators in the last mile segment and to extrapolate the mixed-fleet policies. Finally, some conclusions are discussed in the Section 7.

2 Literature review and research challenges

Freight transportation represents a vital link for the companies with their suppliers and customers and a key aspect for the development of urban areas [13]. On the one hand, it is a fundamental part of the procurement chain through which they obtain raw materials and semi-finished products to enter into the production process and it allows firms to reach their customers, sell them final products and deliver them the value proposition below their business model. On the other hand, freight transportation is part of purchasing and consumption process, through which customers could buy goods to satisfy their needs and wants. This is also helped by the advent of e-commerce, that changed the customer behaviour and the basket of goods purchased. Thus, freight transportation demand derives from the interplay between producers and consumers [11]. Between these two actors are placed other two figures: shippers and carriers. The first can be intermediary firms or correspond to the producers of goods and they require transportation services to deliver their products and to serve their customer segments, offering them the value proposition defined in their business models. Carriers (normally called in the parcel delivery business "courier delivery services", or simply "couriers") response to this demand and represent service providers, carrying out transportation concretely from the origin point to the destination.

The relevant literature concerning transportation systems and the parcel delivery, can be split into three main streams: operation management and optimization models, sustainability issues and emerging business models. The first axis covers the optimization models ad methods, including Operations Research and Operational Management methods dealing with the planning of the transportation and parcel delivery activities at tactical, strategic and operational levels. Several models and methods were introduced in the past decade, including multi-tier transportation ([12, 13, 21, 31]), rich Vehicle Routing Methods ([25, 37, 47]) and capacity planning problems ([33, 43]). Normally, the models present in the literature operates at the technical level, heavily relaxing or totally disregarding the management aspects, with a lack of focus on the strategic vision.

The second literature framework concerns the concept of "sustainability" and it investigates the solutions to make mobility more sustainable, due to the emerged awareness of the environmental problems caused by the transportation activities in urban centres. In particular, the literature provides several measures, grouped into main three categories: material infrastructural (e.g., areas for loading and unloading operations, urban distribution centres, etc.), immaterial or technological (i.e., Intelligent transportation systems) and finally, governance (e.g., road-pricing, maximum parking times, restricted access zone "Low Traffic Zone" (LTZ), etc.) measures ([39, 46]). Moreover, the European Commission has provided another important contribution identifying among the seven priority societal challenges under the "Horizon 2020" programme, the realization of "Smart, Green and Integrated transport" with investment in research and development (R&D) and innovation in new business model and green vehicles. Concerning this last topic, different contributions face the interesting challenge of the cargo bike adoption to make City Logistics more sustainable, encouraging their diffusion. A general overview of relevant findings of the literature review related with the subject and of the case studies of major cities, the mostly limited to the European context, as Paris, London, Brussels, Barcelona, but also Manhattan, can be find in ([9, 18, 20, 24, 40]). Other contributions in literature as for example ([5, 22]), propose operational research models concerning the scheduling and the routing for the green or heterogeneous fleet management, considering the costs and emissions factors.

Finally, the third literature stream includes several contributions that are addressed to analyse the new business models based on vehicles with low and very low emission impact, identifying the effects of their adoption in substitution of traditional commercial vans. In particular, [6] developed a System Dynamics (SD) model concerning this issue, in a freight distribution system. Through this SD approach, they observed as the savings, in terms of both CO2 emissions and operating costs, give rise to interesting feedback loops for the adoption of the new distribution system based on electric or hybrid vehicles. Similar approaches can be found in [42] and [28]. Those works all shares a similar theoretical framework based on the Bass diffusion model [41], which provides also the theoretical background for other existing models in the City Logistics and the Last Mile area.

According to our vision, the literature is lacking in many aspects. In details, the literature focuses on the operational aspects disregarding the business model and the business development. This requires an analysis of the system made by the international courier and the sub-contractors, as well as their business models. Second, the integration of different modes (traditional and green) should be studied. This requires a detailed cost and revenues analysis. In fact, although in literature few contributions devoted to the study of the last-mile costs are present, as the aforementioned contributions and [17], our analysis gives the first attempt to consider the cost structure of these different options for delivering goods in urban areas by introducing both economic and environmental costs. In particular, we consider the emissions and the costs connected to the overall last mile chain according to latest regulation, the ISO/TS 14067:2013 "Greenhouse gases - Carbon footprint of product - Requirements and guidelines for quantification and communication", which is not present in the literature. Third, it is needed a strategic discussion of the different options and policies available for an International courier delivery services for developing and building a win-win overall system. Our paper is the first attempt to fulfil these gaps and to give answer to the above-mentioned questions.

3 Methodological framework

As stated in the Section 1, the main innovative feature of this paper is the purpose to propose a holistic vision of the parcel delivery complex system, including both the business and the operational perspective. In this direction, we adopt the GUEST Methodology, developed by Perboli and Gentile ([29, 30]). It is a lean business approach extending the work done by [27] and all the Lean Startup movements, adapting their results to the environment of a Multi-Actor Complex System (MACS), as those of freight transportation. GUEST is the acronym of the five consecutive steps of the methodology, which in this specific application to the urban parcel delivery context, the were declined as follows:

- Go. In this phase, a preliminary analysis of the stakeholders involved in the last mile segment is conducted, through a primary research focus on the city of Turin and in general, in Europe and the interaction with an International courier delivery services operating in Italy. The aim is to gather information and provide a full description of the stakeholders profiles by means of the knowledge of their needs and their cost structures.

- Uniform (Section 4). The knowledge of the system must be assessed in a standard way, in order to obtain a shared vision of the MACS. In particular, in this phase the system is represented by means of the Social Business Network (SBN), and the governance and the business models are explicitly described for each operators deriving their Business Model Canvas [27]. Moreover, a series of opportunities and threats are identified by means of a SWOT Analysis.

- Evaluate (Section 5). The full structure of the costs and of the revenues is explicitly described for each transportation options. A deep analysis and comparison of the business models is performed bringing out the main key linking factor between the business and the operational models. This study is then supported by a performance analysis for both the Traditional and Green subcontractors, based on the main variables that affect the last mile logistics in the urban areas (e.g., distances, delivery time, etc.).

- Solve (Section 6). Given the outcomes emerged by the previous phase, a Monte Carlo simulation is conducted to obtain a more comprehensive vision of the overall complex system, not focused only to the central area, as the previous step.

- Test (Section 6.3). The findings of the Monte Carlo simulation are tested and analysed in order to extrapolate some mixed-fleet policies.

These analyses are conducted using real data set related to the customer distribution and daily volumes of deliveries occurred in Turin, during the three weeks at the end of 2014 and the beginning of 2015. The primary data are provided by an International parcel delivery company operating in Italy and involved in the URBan Electronic LOGistics (URBeLOG) Project [4]. Concerning the Business Models, the data were gathered by interviews to CEO and COO of parcel delivery companies in the URBan Electronic LOGistics (URBeLOG) [4] and Synchro-NET H2020 [2] projects.

4 Parcel delivery business model analysis

Analysing the transportation and parcel delivery industry with emphasis on the urban areas, we can state that, due to number of players involved, it can be defined as a multi-actor system. In order to obtain a more comprehensive study of this industry, the operators and their interactions, we adopt a business-oriented approach, which not received enough attention in literature, through several qualitative techniques. The results of this section represent the starting point and the knowledge base needed for the quantitative part of the analysis conducted in this paper. As discussed in the Section 3, the information used are the results of a primary research conducted with focus on the parcel delivery in Europe, with emphasis on the city of Turin, combined with data gathered and provided by an International courier delivery services company operating in Italy. First, to represent the system, we first adopt the Social Business Network (SBN) shown in Figure 1, designed in the GUEST Methodology ([29, 30]). The outcome of this tool is a graph-based representation of the multi-actor system, where each player is a node and the arcs are proportional to the interaction and relationship between the actors. The arcs can be of different types: commercial, policy or regulation, partnership/stakeholdership and competition. Then, to obtain a more comprehensive study of the main operators involved, as illustrated by the SBN, we define for each of them the business model by means of the Business Model Canvas tool (BMC) proposed by Osterwalder [27]. The purpose of this analysis is to identify, for each of the nine building blocks, similarities, conflicts and possible synergies between the different strategies adopted by the companies and in general, to evaluate their coexistence, especially in presence of complexities typical of the last mile segment. For an easier exposition, we provide in this section a brief definition of the main ac-

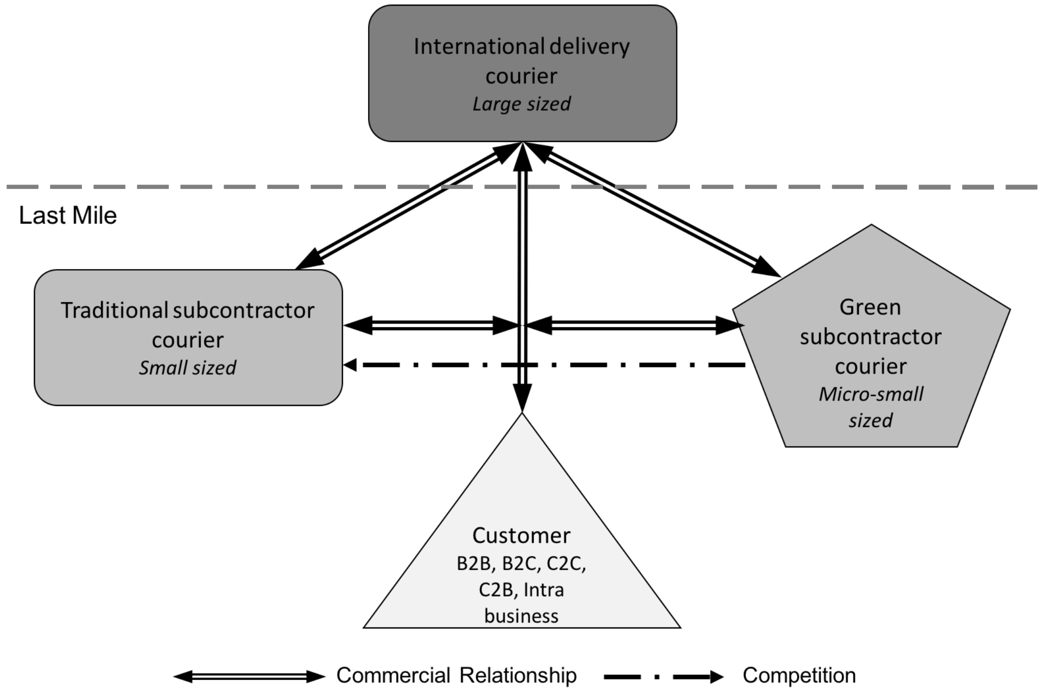


Figure 1: Social Business Network

tors involved and the discussion of major outcomes emerged by the analysis of the BMCs, while a detailed description of each canvas is reported in the A. Moreover, adding a further level of detail, a SWOT analysis is conducted to provide for both the traditional and the green ones the lists of strengths, weakness, opportunities and threats, which characterized them and bringing out how these models could have a strategically fit. The first result of this analysis is that the urban freight transportation system is composed by three main actors, as shown by the SBN and following listed:

- International courier delivery services (hereinafter named International courier). It represents the company that generally operate in international and national long-haul shipment (e.g., TNT, FedEx, UPS, etc.) and its business model is illustrated in the Figure 2.

- Traditional subcontractor courier delivery services (hereinafter named Traditional subcontractor). They are small or at last medium sized firms, generally organized as a legal form of cooperatives with limited financial capacities but they are capable to manage parcel deliveries locally. Its business is described in the Figure 3.

- Green subcontractor courier delivery services (hereinafter named Green subcontractor). The increasing awareness about environmental problems related to the transportation and the intent to make it more sustainable has led to the development of new business models for a more conscious and optimized management of the parcel delivery on last mile segment. In fact, new firms arose in several European cities (e.g., Turin, Milan, Paris, Berlin, London, Copenhagen, etc.) proposing business model similar to those traditional, but they also consider the environmental impact of their activities, through the use of green vehicles such as bikes and cargo bikes (see Figure 4 for the related business model canvas).

- Customers. They are represented by the final users of the logistics and transportation activities, including Business-to-Business (B2B), Business-to-Customer (B2C), Customer-to-Business (C2B), Customer-to-Customer (C2C), and intra-business segments.

Analysing their BMCs, an important outcome emerged is that all the operators offer to their customer segments, a value proposition consisting in time sensitive transportation services and express delivery. Although, the representation provided by the SBN, highlights as actually, the dynamics within the urban transportation and parcel delivery system, become more complex due to the diffusion subcontracting. In particular, the major International courier in the industry do not manage the entire process. In fact, to serve their customer segments they generally realize the long-haul shipment, while they outsource the deliveries in the last mile segment to subcontractors, both traditional and green. This process allows to gain better operative performances and economic efficiency from road transportation in urban areas, as well as capillarity and strategic diffusion on territory leading to a customer proximity. In order to add a further level of detail, a SWOT analysis is conducted to provide for both the Traditional and the Green subcontractors the lists of strengths, weakness, opportunities and threats, which characterized them and bringing out how these models could have a strategically fit. Analysing together the SWOT (Figure 5) and the BMCs, the main critical point emerged is that for the Traditional subcontractor, the main sources of weakness and threats consist of the environmental impact and the urban criticalities affecting different European regions, as the Italy (e.g., traffic and congestion, LTZ zones, absence of loading and unloading zones). These factors compromise the management of the deliveries, inducing disadvantageous conditions for courier with traditional vehicles. On the contrary, they represent strengths for the Green subcontractor. It offers low emission vehicles as bikes in its value proposition benefits related to last mile parcel delivery with a low environmental impact, allowing it to obtain an additional incoming from CO2 savings and carbon credits trading, as highlighted by the revenue streams block of BMC (Figure 4). However, the operational model of the Green subcontractor has the limitation represented by the reduced capacity of the bike that constrains its performance in presence of large sized parcel. This bond is in part overcome by the use of cargo bikes, which have a maximum payload of about 100-150 kg per bike, according to the estimate provides by [38] regarding examples conducted in Europe. For all the operators, vehicles represent a main item of the cost structure, both for the operative costs and for the social cost related to the externalities. Due to the relevant role of these costs, a further quantitative analysis is provided in the Section 5.2. Finally, the SBN shows how the International courier can guide the subcontractors by the financial lever. On the other side, the clique when we consider also the competition arcs between the traditional and the Green subcontractor represents a threat, confirmed by the SWOT. In fact, if the subcontractors start to compete uniquely on the operational costs a reduction of the service quality perceived by the International courier customers may occurs. This price war might be caused by the coexistence of the Traditional and the Green subcontractor in the same geographical area and by the similarities of their business models, also concerning the costs and revenues structure, which reduce the margins of differentiation.

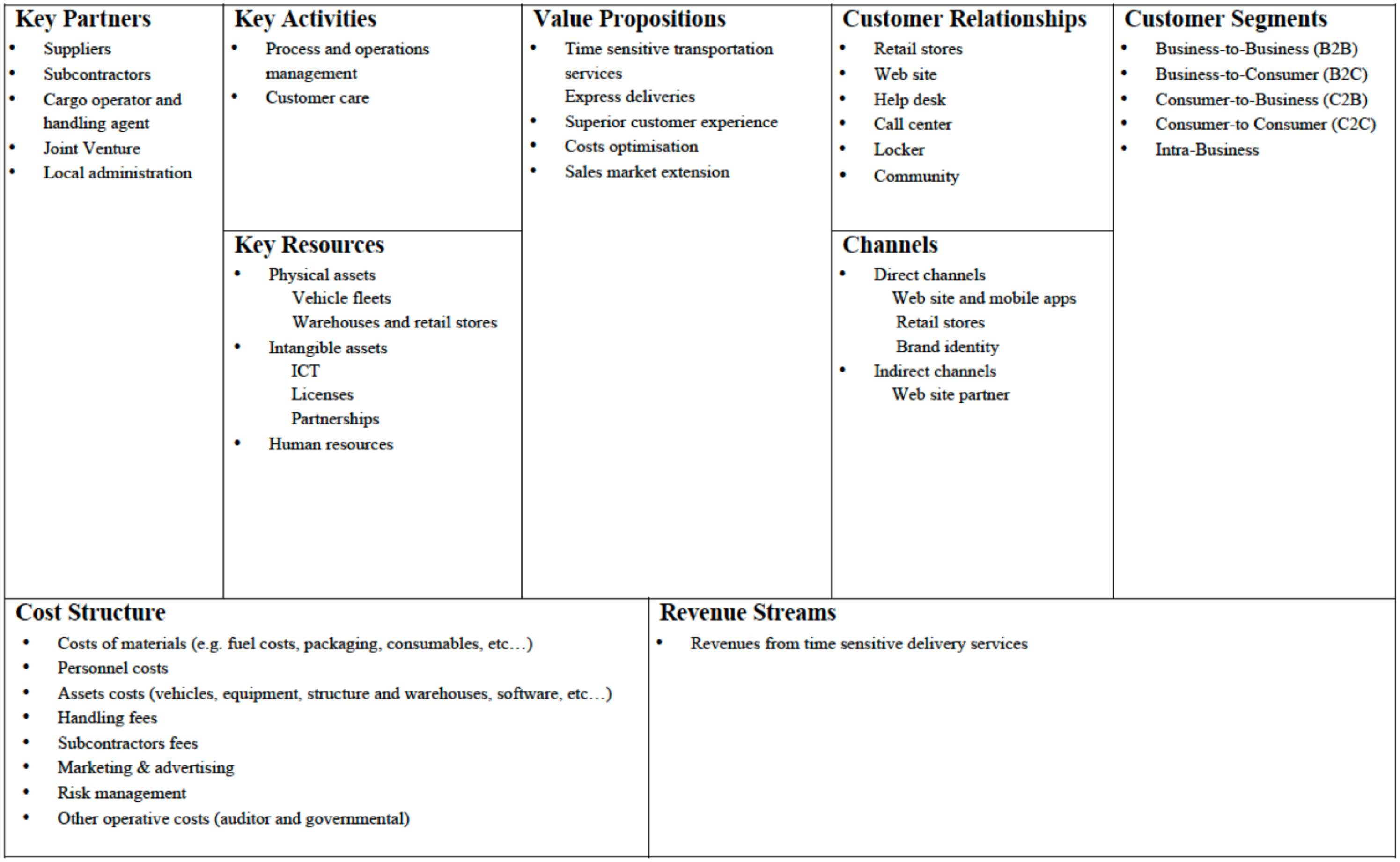


Figure 2: Business model canvas of the International courier

Key Partners	Key Activities	Value Propositions	Customer Relationships	Customer Segments
• Suppliers of strategic assets (vehicles) • Drivers	• Operations and dispatchers management (ground operations) • Anomalies management • Coordination with international express courier **Key Resources** • Physical assets Vehicle fleets (van road vehicles) Warehouses • Human resources	• Last mile parcel deliveries • Efficiency and flexibility • Geographical coverage • Costs reduction • Focus on core business activities • Access to specialised resources and know-how	• Information exchange process (tracking and feedback) **Channels** • Commercial agreements and tenders • Web site	• International courier
Cost Structure • Costs of materials (e.g. fuel costs, consumables, etc…) • Personnel costs • Assets costs (vehicles, equipment, structure and warehouses, etc…) • Penalties		**Revenue Streams** • Revenues from last mile parcel delivery services		

Figure 3: Business model canvas of the Traditional subcontractor

Key Partners
- Technological partners
- Investors
- Partner
- Bikers
- Local administration

Key Activities
- Operations and dispatchers management
- Anomalies management
- Fund raising

Key Resources
- Physical assets
  - Vehicle fleets (bike and cargo bike)
  - Warehouses
- Human resources (bikers)
- Intangibles assets
  - Partnership
  - ICT tools

Value Propositions
- Cycle-logistics services
- Costs optimisation
- Small sized parcel delivery (0-3 kg and 3-6 kg)
- Green image and green credentials

Customer Relationships
- Information exchange process (tracking, feedback, CO2 savings)

Channels
- Web site
- Media and interviews

Customer Segments
- International courier
- B2B and B2C for intercity and intracity postal services

Cost Structure
- Costs of materials (e.g. consumables, bags etc…)
- Personnel costs
- Assets costs (vehicles, equipment, structure and warehouses, ICT tools etc…)
- Marketing & advertising

Revenue Streams
- Revenues from last mile parcel delivery services
- Revenues from CO2 savings and carbon credits trading

Figure 4: Business model canvas of the Green subcontractor

5 Parcel delivery operational models performance analysis

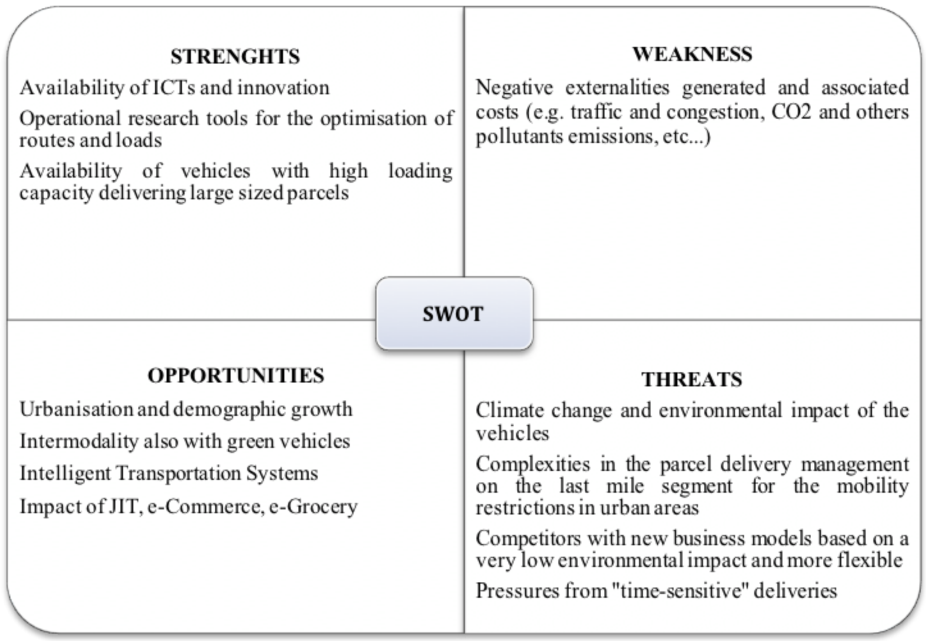
The analysis of the BMCs (Section 4) has emerged that the mixing of Traditional and Green subcontractors could determinate benefits in terms of efficient last mile supply chain management but, at the same time, it hides the threat of a price war, reducing the service quality level. Thus, there is the need of a better understanding of the costs and the performance indexes that affect the system. In details, we explore two issues which are disregarded in the literature: the analysis of the the break even point of vehicles and a cargo-bikes in term of distance between two consecutive stops for determining the portion of the city where they can coexist (see Subsection 5.1) and the operational costs per kilometre of the different classes of vehicles (see Subsection 5.2). For the latter, partial data can be found in the literature, but no detailed cost analysis was previously performed for the parcel delivery sector.

These analyses are conducted using real data set related to the customer distribution and daily volumes of deliveries occurred in Turin, during the three weeks at the end of 2014 and the beginning of 2015. The primary data are provided by an International parcel delivery company operating in Italy and involved in the URBan Electronic LOGistics (URBeLOG) Project [4].

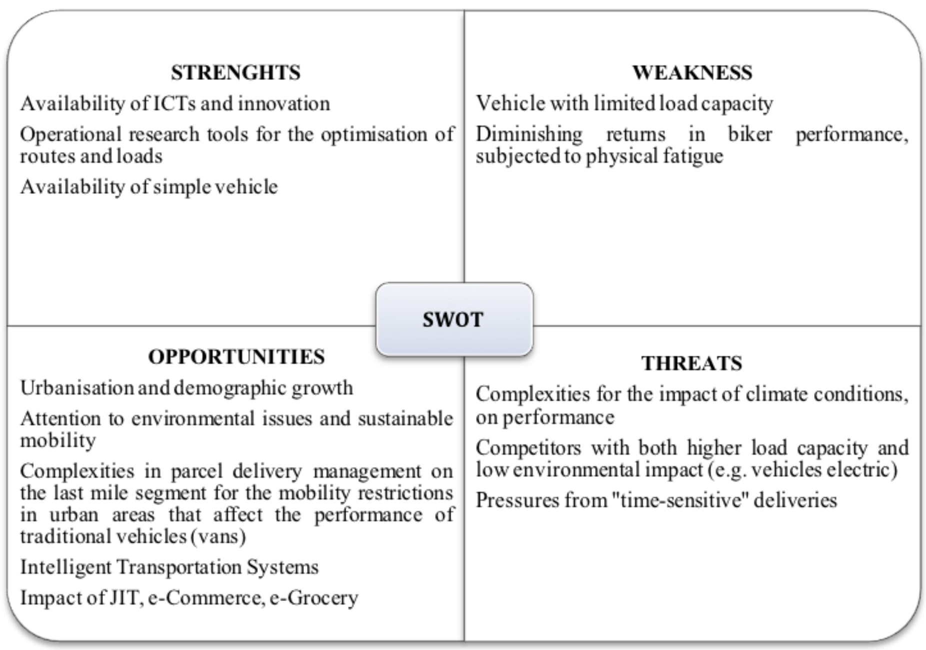
5.1 Break even distance between vehicles and bikes

The methodology adopted is based on the aspects that mainly affect the last mile logistic system: destinations features (e.g., number, localization, delivery frequencies and lead time), parcel features (e.g., quantity, weight and volume) and the performance of the traditional and low environmental impact vehicles. Referring to these variables, next sections analyses the location of the deliveries within the city and the break even distance among them.

Delivery locations and parcel sizes analysis To evaluate the presence of a critical mass for the value proposition of Green subcontractors, we studied the distribution of the destinations in the urban areas and in particular, in the town centrer. In these areas, the benefits related to the use of low environmental vehicles are more relevant due to the presence of mobility restrictions (e.g., LTZ areas) and the several aspects associated with the



(a)



(b)

Figure 5: SWOT analysis referred to the Traditional subcontractor 5(a) and to the Green subcontractor 5(b)

Figure 6: Ideal area of direct coverage by green subcontractor using bikes

maintaining the quality of life of the citizens. With this purpose, we have designed an ideal area composed by the quadrilaterals represented in Figure 6 and of which the coordinates of the vertices are noted. This area includes the centre of Turin and a part of surrounding neighbourhoods directly reachable by bikes.

Considering only the deliveries in this area, we have filtered them using the weight of parcels. As defined by the the Green Paper proposed by the European Commission [15], the term "parcel" refers to boxes with a weight less than 30 kg manageable by a single person. Thus, we classify parcels in: "mailer" that have a weight between 0 kg and 3 kg, "small parcels", between 3 and 6 kg and "large deliveries", more than 6 kg. Table 1 shows the results of the analysis. It illustrates that mailers are the predominant with about the 56.87% of total parcels delivered in urban areas, highlighting the relevant role that e-commerce plays in recent years, characterized by

Table 1: Results of the delivery locations and parcel size analysis

Parcel delivery futures	**n. delivery**	**%**
In centre	3395	22.51
Out centre	11688	77.49
0-3 kg	8577	56.87
3-6 kg	1915	12.70
> 6 kg	4590	30.43
Total deliveries	15083	100.00

frequent deliveries of reduced sizes. Despite the great part of deliveries is directed away from the city centre, the segment 0-3 kg is more profitable for both subcontractors. In particular, mailers are easy to handle for green couriers using bikes, avoiding traffic and restrictions in urban areas. Thus, the distribution of these parcels represents the critical mass to make the business model of Green subcontractor sustainable.

Distance analysis and definition of the break even distance In this step we have analysed the total time per vehicle stop offered by traditional vehicles and bikes, with the aim to find the break even distance, expressed in kilometres, where the performance of Traditional subcontractors are equal to those of the Green subcontractors. Notice that here the term "stop" is referred at the time when the vehicle stops to do one or more deliveries. The term "time per stop" in parcel delivery refers to the time, expressed in minutes, composed by the "travel time" and the "delivery time". The first is the time required to reach the destination point of delivery, from the origin point (e.g., hub, subcontractor location or a previous destination). The second is the time required for parking and to perform the delivery operations (e.g., customer contact, pick up the parcel in the vehicle and collecting of the proof of delivery). The time per stop is strictly related to the distance travelled by the courier. Thus, we have calculated, the distance from a point where is located the hub of a Green subcontractor operating in Turin to each destination point, which is referred to the customer location extracted by the data set available [4]. We have measured distances using two different approaches:

- the Geodesic distance that utilizes the following formula:

$$d(A,B) = R \cdot arccos(sin(latA) \cdot sin(latB) + cos(latA) \cdot cos(latB) \cdot cos(longA - longB)) \tag{1}$$

  where:

  - R is the earth's mean square radius that measure 6372.80 km;
  - lat and $long$ are the latitude and longitude of points A and B, expressed in radiant.

- The Manhattan distance introduces an intermediate point with the latitude of the point A and the longitude of point B. This approach considers the topography at chessboard of Turin, according to the Roman town planning. The distance between point A, B and the intermediate one is measured with the Geodesic distance.

Applying these approaches, we have extracted a representative sample with mean μ and variance σ^2. Then, we conducted an analysis based on the total time per stop (see Table 2), using different speed profiles and delivery times sustained for both the Traditional and Green subcontractors. For the present case study, these parameters are assumed as follows:

- for Traditional subcontractors, the average speed in town centre is 25 km/h, 35 km/h and 40 km/h, while its delivery time is between 4 and 5 minutes, considering the complexities related to the parking activities;

- for the Green subcontractors, the average speed is 15 km/h, 20 km/h and 30 km/h, while the delivery times are assumed equal to 2 and 2.5 minutes.

This analysis, based on several scenarios related to speed and delivery time, for both types of subcontractors courier, and on the location of the final customers destinations, has confirmed the findings of previous qualitative analyses of SWOT and BMCs. Thus, although the higher speed of Traditional subcontractor, the analysis highlights the benefits of bikers. In fact, given the delivery time of Traditional subcontractor, when criticalities of urban mobility compromise the speed (for example decreasing it from 40 km/h to 25 km/h) the total time per stop increase to 5.40 min, with a benefit of the bike performance. Based on these results we have analysed the break even distance (see Table 3), defined as the distance beyond which a

Table 2: Times per stop

Subcontractor courier	Speed [km/h]	Delivery Time [min]	Travel Time [min]	Time per Stop [min]	Travel Time [min]	Time per stop [min]
			Geodesic distance μ=0.48 km σ^2=0.03 km^2		*Manhattan distance* μ=0.58 km σ^2=0.05 km^2	
Green (bike)	15	2.00	1.90	4.33	2.33	4.33
	20	2.00	1.43	3.75	1.75	3.75
	30	2.00	0.95	3.17	1.17	3.17
	15	2.50	1.90	4.83	2.33	4.83
	20	2.50	1.43	4.24	1.75	4.24
	30	2.50	0.95	3.45	1.17	3.67
Traditional (van)	25	4.00	1.14	5.14	1.40	5.40
	35	4.00	0.81	4.81	1.00	5.00
	40	4.00	0.71	4.71	0.88	4.88
	25	4.50	1.14	5.64	1.40	5.90
	35	4.50	0.81	5.31	1.00	5.50
	40	4.50	0.71	5.21	0.88	5.38
	25	5.00	1.14	6.14	1.40	6.40
	35	5.00	0.81	5.81	1.00	6.00
	40	5.00	0.71	5.71	0.88	5.88

turnaround would occur, making the use of bikes less efficient, because the advantages in performance should disperse.

The average break even distance is about 1.89 km and varying the values of speed and time, we can deduct some considerations. In particular, the break even distance increases, when the driver speed increases or the delivery time decreases. Similarly, the break even distance increases when the condition $v_B < v_D^o$ is true and the biker speed increases or its delivery time decreases.

Table 3: Break even distances

$v_D[km/h]/t_D[min]$	4	4.5	5	4	4.5	5	
		2			2.5		$t_B[min]/v_B[km/h]$
25	1.25	1.56	1.88	0.94	1.25	1.56	
25	0.88	1.09	1.31	0.66	0.88	1.09	15
40	0.80	1.00	1.20	0.60	0.80	1.00	
25	3.33	4.17	5.00	2.50	3.33	4.17	
25	1.56	1.94	2.33	1.17	1.56	1.94	20
40	1.33	1.67	2.00	1.00	1.33	1.67	
25	-5.00	-6.25	-7.50	-3.75	-5.00	-6.25	
25	7.00	8.75	10.50	5.25	7.00	8.75	30
40	4.00	5.00	6.00	3.00	4.00	5.00	

5.2 Cost efficiency analysis of vehicular and cargo bike delivery

Operating costs analysis In recent years, several companies overcame the idea of a trade-off between the reduced environmental impact of the activities conducted and their economic efficiency eroded by the consequent additional costs, but they recognized the benefits on competitiveness, in terms of value of the reputation and green image. According to this new perspective, they adopted measures arose in the City Logistics domain, as the realization of renewal plan of the vehicles fleet, reducing those with lower class than the Euro 4 and the experimentation of green vehicles. A first type of these vehicles uses innovative propulsion systems (e.g., electric, hybrid or methane vans). On the other hand, we consider alternative vehicles as bikes and cargo bikes, traditional and electric pedal assisted cycle. An actual case is represented by the partnership between Nissan Motor Co. Ltd. and DHL Express within the *"GoGreen"* programme. They introduced totally electric vehicles "e-NV200" in the courier fleet, first testing in Tokyo's urban area and then reaching the steady state in several Italian branches [26]. Each type of vehicle has different impacts both environmental and economic. From the courier viewpoint, financial requirements and investments, as well as outsourcing strategies, and for the costs related to the fleet management and maintenance, need to be considered. The operating costs analysis (see Table 4) has the purpose to compare the different vehicles for the two aspects above mentioned: cost efficiency and environmental impact. The selection of the vehicles benchmark considered in the study reflects the transition occurring in the industry. In particular, we considered: traditional vehicles fuelled (gasoline or diesel), pure electric and bikes. These vehicles types cover a large part of the delivery couriers fleets. In the proposed methodology, we estimated the Operating Costs per Kilometre (OCK) related to each type of vehicle and then, compared them in order to identify the most cost-efficient, considering the operative performance. For the purposes of this analysis, the OCK includes both variable costs (e.g., gasoline) and the total cost of ownership, according to [7], expressed in Euro per kilometres travelled in last mile segment [€/km], which the company incurs for the use of the vehicle in a year of its technical life cycle. This cost is composed by variable costs and fixed costs. The latter are not proportional to the distance and the courier incurs regardless of the vehicles usage degree. The OCK function is:

$$OCK = (FC + VC)/TK = ((v + tx + i + p) + (f + t + mr))/TK \qquad (2)$$

where:

- FC is the total annual fixed costs;
- VC is the total annual variable costs;
- TK is the total annual travelled kilometres.

The entity of each item has been estimated through primary data from market researches on the commercial practices applied by the different stakeholders, and has been supported by the formulation of specific assumptions on the use conditions of the vehicles benchmark. These assumptions are:

- total annual usage, in terms of travelled kilometres in the last mile segment, of about 25000 km/year;
- a total annual usage, in terms of hours required to reach each destination and to do the delivery operations, of about 2000 h/year;
- the commercial speed of vehicles in urban areas is about 35 km/h;
- each driver must make about 80 deliveries per day, with an average time of 4.5 minutes per delivery, to perform all operations, from the parking of the vehicle to the collecting of the proof of delivery;
- each component of cost has charged in refers to the technical life cycle of the vehicle that has been estimated of 5 years.

The components of fixed and variable costs are briefly described as follow.

- **Purchase cost of vehicle** (v): is based on estimates realized by the fleet manager section of several car dealers, and is referred to a leasing agreement of 5 years. During this period, the company operating in the transportation and parcel delivery market on last mile will provide to a depreciation and amortization schedule of this asset.
- **Vehicle taxes** (tx): are referred to the expenditures and taxes related to the vehicles, according to the current regulations, such as the ownership tax.

- **Insurance** (i): is the cost of the truck liability insurance based on the capacity of the vehicle and the third party cargo insurance, while it excludes the theft and fire insurances, included in the leasing agreement. Due to the liberalization process that have interested in the 2014 the insurance industry in different country including the Italy, and that have imposed the right to determine independently the contract conditions and the tariffs, the amount of the policy considered refers to an average value of the prices offered by several insurance companies, as emerged by a secondary research conducted in this work.

- **Personnel costs** (p): is defined as the total remuneration payable by a driver, and also include taxes and employees' social security contributions, according to the National Collective Labour Agreement prescribed for the category to which they belong.

- **Vehicle fuelling** (f): are referred to the costs related to the fuel supply, both fossil and diesel, and to the power supply, in base of the propulsion type system of the vehicle benchmark. Their values are estimated considering the consumption derived from the technical specifications provided by the manufacturer. For the petrol and diesel fuel, prices are measured by the average monthly domestic prices from the statistical data elaborated by the Italian Ministry of Economic Development for the 2015. Otherwise, the electricity price is evaluated as an average cost from the prices charged by major suppliers operating in the energy industry, to a business customer.

- **Tyres costs** (t): are based on the list prices charged, by the leading manufacturers, discounted by a corrective factor of 15% for the purchase of high quantities for the whole fleet. It is also considered the average duration of a set of about 50000 km/year referring to the capacity and the wear out of the vehicle.

- **Maintenance and repair costs** (mr): estimated from the data provides by the Automobile Club Italia (ACI) [1], they are related to the expenditures for the activities required to maintain the effectiveness of the vehicle performance, along his life cycle, known the travelled distance. These activities are classified in time or condition based maintenance, which have the aim to prevent the negative events and to maintain the normal conditions of use. Otherwise, the breakdown maintenance or repair, which is conducted after a failure occurrence.

For more details about the value of each cost item, see the B.

Environmental costs Focusing the attention on the environmental perspective, in the cost efficiency analysis, it is important to considerate the additional costs that couriers operating in the last mile parcel delivery system occur due to the negative externalities produced, particularly the CO2 and other pollutant emissions. According to the technical specification ISO/TS 14067:2013 "Greenhouse gases Carbon footprint of product - Requirements and guidelines for quantification and communication" that define the carbon footprint as the total amount of GHG emitted directly or indirectly by an activity, a product, a company or an individual, we have quantified the amount of emissions along the whole last mile delivery process. In particular, we considered the GHG deriving directly from the fuel combustion utilized by the vehicles benchmark, for the above quantified total travelled kilometres, but also those indirect that are emitted by the production process of the fossil fuel and the consumption of energy related to the batteries and their recharge. However, to focus on the last mile segment, we have missed the GHG emissions deriving from the haul shipment that interconnects the first and the last mile, and those from the production and disposal process of vehicles. We also considered other pollutants involved in the process, such as the nitrogen oxides (NO_x), which are included in the estimate converting them in CO2 by means of an appropriate factor 4.7 kg per litre of fuel consummated [19]. To evaluate how the environmental impact affected the cost efficiency of the courier, we have expressed the carbon footprint in economic terms applying the Pigouvian tax known as Carbon Tax, based on a price paid for the CO2 emission in the atmosphere (see Table 4). This price mechanism does not limit the quantity of emissions, but reduce them making cost-effective the switch to innovative technologies with low environmental impact. In particular, we have conducted a scenario analysis imposing different value of Carbon Tax, based on the tariff applied in several counties, such as 17 €/t proposed by French Government or 150 €/t by the Sweden.

As emerged by the BMCs, all the operators incur in the costs related to vehicles used, including the operative and social ones. As illustrate in the above analysis, this cost is higher for the Traditional subcontractor using fossil fuelled vehicles, than Green subcontractor using electric vehicles and bikes.

Table 4: Cost analysis results.

Costs	Tariffs Carbon Tax [€/tons]	Fossil fuelled vehicle	Diesel fuelled vehicle	Electric vehicle	Bike
OCK [€/km]					
Annual kilometre cost		2.70	2.68	2.66	1.50
Environmental costs [€]					
Direct CO2 Emissions [tons]		4.15	3.38		
Indirect CO2 Emissions [tons]		4.15	3.38		
Equivalent CO2 Emissions [tons]		8.46	5.52		
Total Emissions [tons]		16.76	12.28		
Carbon Tax [€]	17.00	284.92	208.63		
	30.00	502.80	368.18		
	90.00	1508.40	1104.53		
	150.00	2514.00	1840.88		
Electric battery emissions [tons]				3.08	
Carbon Tax [€]	17.00			52.31	
	30.00			92.31	
	90.00			276.94	
	150.00			461.56	
Direct CO2 Emissions [tons]					0.00

In particular, while diesel vans are preferred to those petrol-fuelled that are barely adopted for the highest costs generated, electric vehicles permit more costs savings related to the lower insurance tariff and the exemption from the ownership tax payment. Bike courier obtains an economic efficiency for the lower management costs connected to the vehicles, but also for the lower personnel cost led to the skills of bikers (e.g., it is not required the driving license, lower job time). Moreover, they benefit of an additional revenue from CO2 savings and carbon credits trading. In fact, assuming carbon credits prices the 30% lower than the carbon tax tariffs above defined, using bikes, subcontractors could obtain average revenue of about 0.02 € per stop (see Table 5), compared to traditional vehicles (petrol fuel and diesel), and this estimate assumes greater relevance when compared to high volume of parcels direct in urban areas.

6 Simulation analysis

As stated in the Section 2, in order to avoid the service quality reduction due to the competition of the Traditional and Green subcontractors, the International courier should identify strategic policies with the aim to build a win-win overall system. In this section we present our contribution to this issue. Moreover, given the outcomes emerged in the previous section, more focused to understand the integration between traditional and green transportation modes in central areas, in this section we extend our analysis to the overall system. It is a Decision Support System (DSS) for the management

Table 5: Revenue streams from the carbon credits trading

Buyer Emissions	Seller Emissions	Δ Emissions	Carbon Credits Prices	Revenues
Fossil fuelled vehicle vs. Electric vehicle				
16.76	0.02	16.74	11.90	199.21
			21.00	351.54
			63.00	1054.62
			105.00	1757.70
Diesel fuelled vehicle vs. Electric vehicle				
12.27	0.02	12.25	11.90	145.80
			21.00	257.30
			63.00	771.91
			105.00	1286.51
Fossil fuelled vehicle vs. Bike				
0.000421	0.00	0.000421	11.90	0.005
			21.00	0.009
			63.00	0.027
			105.00	0.044
Diesel fuelled vehicle vs. Bike				
0.000308	0.00	0.000308	11.90	0.004
			21.00	0.006
			63.00	0.019
			105.00	0.032

and the deployment of mixed-fleet policies in a specified urban area. The overall system is based on the simulation-optimization approach presented in [34] for the air transportation market.

6.1 The DSS

The diagram of the DSS is shown in Figure 7. It is based on a Monte Carlo simulation, a last mile optimization meta-heuristic and a data aggregation and analytic module. The first block is the generator of realizations that takes in input an instance and generates, as output, a set of 30 realizations. These realizations are the input of the Unified Tabu Search (UTS) heuristic [10], which solves them and evaluates in the operative scenarios. The solutions of each realization are then analysed in terms of the KPIs. Finally, the data aggregation block computes the average KPIs as result of the Monte Carlo simulation, which is performed to evaluate the impact of the combination of Traditional and Green subcontractors. For this simulation, we focused only the couriers using bike and cargo bike while, a future development of this study will consider also other green vehicles, as the totally electric and hybrid vans. The simulator requires a logical graph of the city, an instance that describes the deliveries to perform, and the operative scenarios to evaluate. The overall simulation process for a given demand situation it is following described.

- Given an instance defining the number of parcels and, or each parcel, the volume and the class.
- Create a set of 30 realizations $\mathbf{R}$, one for each day of a month, with the same number of parcels and characteristics, but a different destination:
  - Identify the set of parcels located in central and semi-central area;
  - For each parcel, find the nearest node of the logical graph;
  - Relocate the parcels of the same area on a different node of the graph.
- For each realization $r \in \mathbf{R}$, build a vehicle routing problem. The resulting problem is then evaluated for each operative scenario. To evaluate the operative scenarios, the simulator integrates an optimization algorithm that minimizes the cost of deliveries and computes the routes for the fleet of vehicles. The optimization algorithm is based on the UTS heuristic by [10] and successfully applied to routing problems with time windows on deliveries. At each iteration, the heuristics moves from a solution to a different one in its neighbourhood. The neighbourhood is obtained moving each delivery from the current vehicle to another one. The move does not consider the violation of time windows, duration and capacity constraints. These violations are penalized in the objective function. The simulator is also capable to manage time-dependent graph and multi-criteria objective functions. It combines the costs related to both the travel time and the environmental impact of type of vehicles.
- Given the solutions and the KPIs, the data aggregation module georeferences the routes by means of Google Maps APIs, attaches to them their specific KPIs, computed the fleet KPIs and presents the performances of the Traditional and the Green subcontractors.

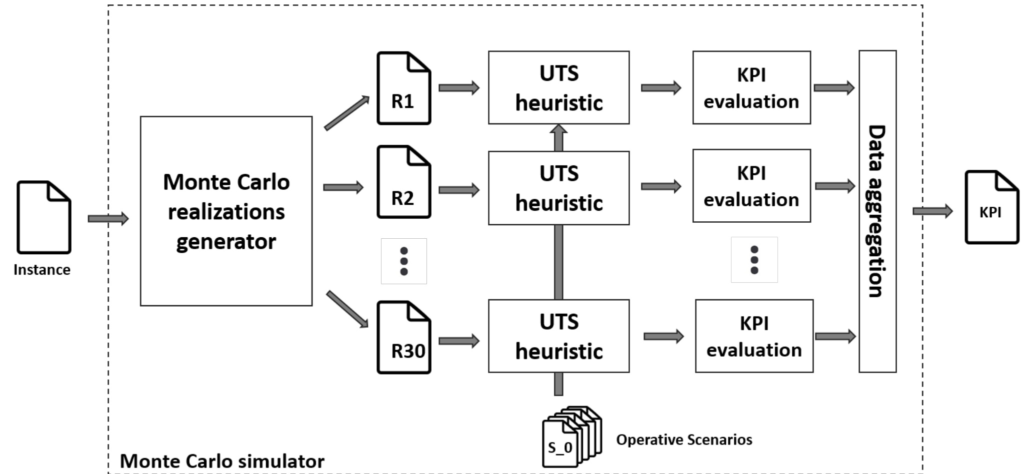


Figure 7: Monte Carlo simulator diagram

6.2 Test instances and KPIs

This section briefly describes the test instances used for the numerical experiments. We performed our experiment campaign using data coming from actual missions observed during the URBeLOG project [4]. More in detail, we have considered three typical settings, named I1, I2 and I3, ranging from 1000 to 4000 parcels. The settings were generated from real data gathered in the time period defines in the Section 5 in a metropolitan medium sized city like Turin, Italy. For each setting, 30 instances were considered. Each parcel is characterized by a destination point (e.g., latitude and longitude), a weight, a volume and a time window within the delivery must be made. We also considered that parcels are available at the depot of the (Traditional or Green) subcontractor at the beginning of the working day. Each instance includes more than 50% of ”mailer” parcels distributed mainly in the central area. ”Large” parcels are in average the 30% of the parcels, but they are located in the semi-central area or in suburban area, where the green courier cannot operate. The courier operates from a central depot outside the city the vehicles, while a secondary depot is located nearby the city center for operating the cargo-bike and the parcels considered in the instances are destined to the urban area only. For lack of simplicity, we consider to have one fleet under usage, that might be made by vehicles or by a mix of vehicles and bikes and there are no availability problems of vehicles of bikes. The OCK are the ones computed in Subsection 5.2.

The Traditional and Green subcontractors are characterized by the classes of parcels that can be handle, the average speed in central and semi-central area, the service time, the maximum capacity. These characteristics are described as follow:

- **Classes**. The Traditional subcontractor can handle any class of parcels, while the green one only handles "mailer" and "small" parcels.
- **Speed**. Vans of Traditional subcontractor have an average speed of 20 km/h in centre, which is usually affected by traffic congestions, and 35 km/h in semi-centrer. The speed of Green subcontractor is in average 20 km/h in both the areas.
- **Service Time**. The service time is about 4 minutes when operators handle "large delivery", while 3 minutes for smaller parcels. On the other hand, Green subcontractor can easily stop the bike (e.g., on the sidewalk), so the average service time is about 2 minutes.
- **Capacity**. Vans have a maximum capacity of 700 kg. The Green subcontractor uses both messenger bags with a capacity of 20 kg and cargo bike with a box that can contains up to 50 kg. When necessary, Green subcontractor combines a cargo bike with a messenger bag.

For each instance, we defined five operative scenarios combining both the two areas to be served by the Green subcontractor and the three classes of parcels that each subcontractor can handle with available vehicles. Notice that for the simulation, we redefined the "small parcel" class as those parcels with a weight up to 5 kg. The scenarios are described in the next list:

- **Scenario S_0**. Only Traditional subcontractor operates in the entire area.
- **Scenario S_3_C**. The Green subcontractor delivers "mailer" parcels (up to 3 kg) in central area. The Traditional subcontractor delivers remaining parcels.
- **Scenario S_3_S**. The Green subcontractor delivers "mailer" parcels (up to 3 kg) in both central and semi-central areas. The Traditional subcontractor delivers remaining parcels.

- **Scenario S_5_C**. The Green subcontractor delivers "mailer" and "small" parcels (up to 5 kg) in central area. The Traditional subcontractor delivers remaining parcels.

- **Scenario S_5_S**. The Green subcontractor delivers "mailer" and "small" parcels (up to 5 kg) in both central and semi-central area. The Traditional subcontractor delivers remaining parcels.

To evaluate the efficiency of combining Traditional and Green subcontractors in each scenario, we measured three key performance indexes (KPIs):

- **Equivalent vehicle (Veh Eq)**. The number of equivalent vehicles used by the subcontractors couriers. Notice that to compare Traditional and Green subcontractors we operated a conversion of bikes used to vans. The conversion considers a full-time work shift of the Traditional subcontractors that, for the case study, it is six hours and half. More in detail, we computed the number of equivalent vehicles as the sum of the working time of each biker divided by the hours of work shift the Traditional subcontractors.

- **Number of parcels per hour (nD/h)**. It is common practice to define the efficiency of a courier in terms of the number of parcels per hour. This KPI considers only the speed and the service type of the courier.

- **CO2 savings**. CO2 savings measures the kilograms of CO2 not emitted for the use of the Green subcontractors and its environmental friend vehicles.

6.3 Computational results

The simulation highlights as the emerging of Green subcontractors such as the bike couriers, changes the dynamics that govern the urban freight distribution system in last mile segment. Figure 8 and Figure 9 summarize the efficiency respectively of the Traditional subcontractor and Green one, in terms of equivalent vehicles and number of parcels per hour, when the Green subcontractor delivers "mailer" and "small" parcels. Notice that KPIs are expressed in percentage respect the benchmark scenario S_0. The detailed results obtained from the Monte Carlo simulation are shown in the Table 6.

Concerning the performance of the Traditional subcontractor, the simulation highlights three main results:

- it reduce the number of equivalent vehicles by half;
- it loses in efficiency;
- it saturates the capacity of its vans.

By outsourcing "mailer" and "small" parcels, the Traditional subcontractor manages only large sized parcels (over 5 kg), usually difficult to handle, with a consequent increase of the service time needed to execute the delivery operations. The latter causes the rapid saturation of the vans' capacity and, thus, the reduction of the number of parcels in a single round and of the duration of each route. Consequently, the Traditional subcontractor needs double rounds and lose efficiency, here measured in number of deliveries per hour. Figure 8 shows that the Traditional subcontractor loses more than 15% of efficiency when "mailer" parcels are delivered by the Green subcontractor and more than 30% when also "small" parcels are outsourced. Finally, it is interesting that the area, where the Green subcontractor operates, does not affects the KPIs of the Traditional subcontractor. This is due to the distribution of parcels. On the contrary, the Figure 9 shows that for the Green subcontractor, the area of service is a relevant factor for its efficiency. In fact, both when it manages the mailers and the small parcels, extending the service from the central area to the semi-central one, the efficiency of the Green subcontractor, in terms of number of deliveries, decreases. However, to maintain an equilibrium condition in the system after the transition to low emission vehicles, it is necessary that the improvement in quality service level, consequent to the value proposition of the Green subcontractor business model, must at least compensate this loss of efficiency in which the Traditional subcontractor incurs. In fact, the results of the simulation highlights as when the Green subcontractor manages the parcels up to 5 kg, the benefits are negligible than the consequent inefficiency for the traditional operator. However, particularly when the Green subcontractor operates both in centre and semi-central area, the benefits in terms of costs savings (operative and environmental) are on average of the 29% and thus, lower than the reduction of the efficiency of about 34%. This negative variance discourages the traditional courier to outsourcing this segment, while it is more inclined to outsource the parcel up to 5 kg in central area. Moreover, it is important to extend this analysis distinguishing between the case in which the fleet of vehicles is owned by the International courier (internal fleet) and those of fleet managed by another firm (external fleet). This company incurs in the costs related to the vehicles considered, but also in the general costs and those of the structures, charging a percentage of margin. Thus, according to this classification, the above mentioned values are referred to the case of internal fleet. On the contrary, when the fleet is external, the dynamics change. First of all, we have to move from a cost per kilometre to a cost per stop. This can be done by considering an average distance between two vehicle stops of about 700 meters and a minimum requirement of 80 deliveries per day [4]. Then, analysing the results it emerges how the loss of efficiency for the Traditional subcontractor of about the 30% as illustrated in the Figure 8 must be overturned in an increase of the Green subcontractor performance of about the 70%, without guarantee its desired fee of margin of the 15%. This percentage related to the increase of the performance is traduced into 130 deliveries per day, which is a goal difficult to achieve for the Green subcontractor. Moreover, although in the case of external fleet, the costs savings connected to the parcels with a weight between the 3 and 5 kg in the semi-central area are on average of the 36% compared to a loss of efficiency of the 34%, the consequences of this inefficiency do not justifying the outsourcing. More in detail, the contractual schemes imply a remuneration based on the number of delivery and penalties in case of not fulfilment of the minimum requirements and thus, the loss of efficiency due to the less number of deliveries of the Traditional subcontractor as a consequent of the outsourcing and the remaining deliveries with high distances could have a negative impact, making needed a re-definition and negotiation of the agreement conditions. The new contract should contemplate an increase in the number of deliveries required for the Green subcontractor in order to balance the loss of efficiency of the traditional one without alter the equilibrium state of the service level in the system, but decreasing its costs per stop to a value of about 1.90 €/stop and leading a critical margin of the 10%, nearly identical to the gross contribution margin. Moreover, the outsourcing of all parcels leads to a complexity in the management of a high number of agreements with different contractual clauses, based on the class of parcels. This could imply strategical risks, due to the less control on the process, entrusting the activities that could be strategical levers and due to the increases of the bargaining power of the Green subcontractor.

Concerning the environmental issue, we measured the CO2 savings that occurs outsourcing the "mailer" and "small" deliveries. Table 7 shows the CO2 savings in each scenarios as the difference between the total emissions generated in scenario S_0 to those generated in the other scenarios by traditional vans. By outsourcing both "mailer" and "small" parcels (scenarios S_5_C and S_5_S) to the Green subcontractor can lead a highest reduction of emissions, closes to 14 tons of CO2 per year. The area served by the Green subcontractor has a strong impact on the number of travelled kilometres and so on the emissions. Reducing the accesses to the centre and the semi-centre, the routes' length of the Traditional subcontractor is reduced of about 25%. Consequently, the CO2 savings are more than 40%.

From the analyses conducted and the results obtained by the simulation, it is possible to extrapolate some policies that guide the behaviour of the different operators and the stakeholders in the urban freight transportation system. In particular, the main actions to consider in order to guarantee the balanced mix of traditional and green transportations and thus, the efficient performance of the system are:

- In the case of internal fleet (i.e., the fleet is owned by the International courier), the Green subcontractor must manage the mailers in the central and semi-central areas. In fact, as emerged by the analysis described in the Section 5.1, it is the most profitable segment for this courier, because it permits to maintain the high quality level imposed by the International courier customer. Moreover, Green subcontractor must manage the small parcels in the centre of city where the traffic conditions and the mobility restrictions make more powerful the benefits and the reduction of costs for the Traditional subcontractor. On the contrary, outsourcing the management of the deliveries of the parcels with a weight greater than the 5 kg in the rest of the city not only affects the quality level perceived by the final customer, but also it leads to a decrease of the efficiency reducing the margins for the Traditional subcontractor.

- In the case of external fleet (i.e., the fleet is given by a series of subcontractors), the Green subcontractor must manage the mailers in the central and semi-central areas, but the outsourcing of the parcels with a weight between 3 kg and 5 kg requires a change in the contractual scheme, decreasing the margins of the Green subcontractor that must increase its role in the selling of the energy and environmental credits. Thus, the results obtained show that the goal required to the Green

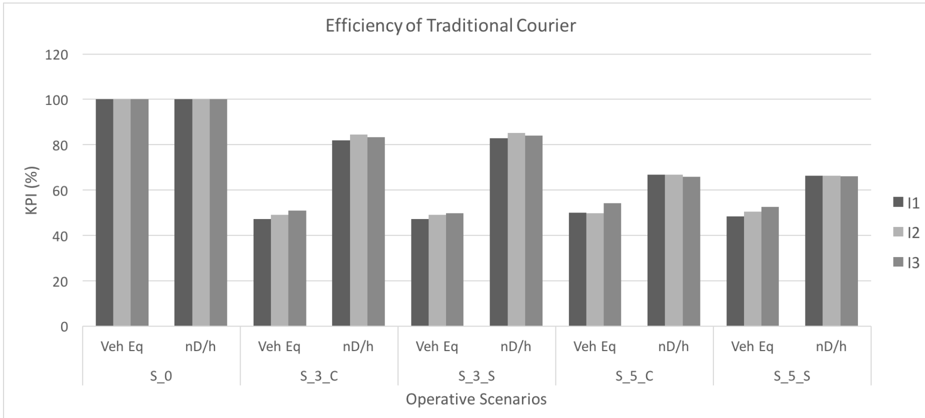


Figure 8: Traditional subcontractor efficiency in terms of equivalent vehicles (Veh Eq) and parcels delivered per hour (nD/h)

subcontractor in terms of increase of deliveries, to face the reduction of the efficiency for the traditional one, makes the model not feasible and sustainable. This highlights that for the Traditional subcontractor, the more convenient solution is to internalize the green fleet, which will be used to manage the parcel up to 3 kg in the central area.

- Although, the green aspects of the problem are today important topics and the introduction of business models based on low environmental impact leads to a reduction of the emissions in a medium sized city, as Turin, an efficient management and control of the system are needed. In fact, the only focus on the reduction of emissions could lead to a cannibalization of the two types of business models. Otherwise, the optimization and the monitoring of the operational process of the two couriers and particularly for the traditional one, are needed. The purpose is to optimize and planning its activities in a view efficiency of the urban parcel delivery, also by means of decision support systems and simulation-optimization methods.

7 Conclusions

In this paper, the freight transportation in urban areas has been analysed, in light of the important role covered in recent years and the emerging of mo-

Table 6: Results of Monte Carlo simulation. Notice that the Green subcontractor has no value in S_0 because it is not implied in this scenario.

Instances	nD/h					Veh Eq				
Traditional subcontractor										
	S_0	S_3_C	S_3_S	S_5_C	S_5_S	S_0	S_3_C	S_3_S	S_5_C	S_5_S
I1	15.65	12.82	12.98	10.44	10.38	7.49	2.16	3.53	2.28	3.62
I2	16.18	13.79	13.77	10.92	10.73	9.89	3.03	4.86	3.07	4.98
I3	15.47	13.29	13.01	10.50	10.21	8.40	2.54	4.18	2.70	4.41
Green subcontractor										
	S_0	S_3_C	S_3_S	S_5_C	S_5_S	S_0	S_3_C	S_3_S	S_5_C	S_5_S
I1	NA	11.94	11.24	12.47	11.94	NA	3.70	6.55	3.88	6.88
I2	NA	12.03	11.36	12.51	12.06	NA	4.96	8.39	5.45	9.02
I3	NA	11.82	11.16	12.56	12.04	NA	3.85	6.89	4.12	7.14

Table 7: CO2 savings per day with respect to scenario S_0

Instances	CO2 savings			
	S_3_C	S_3_S	S_5_C	S_5_S
I1	22%	34%	27%	45%
I2	16%	34%	26%	44%
I3	16%	41%	20%	48%

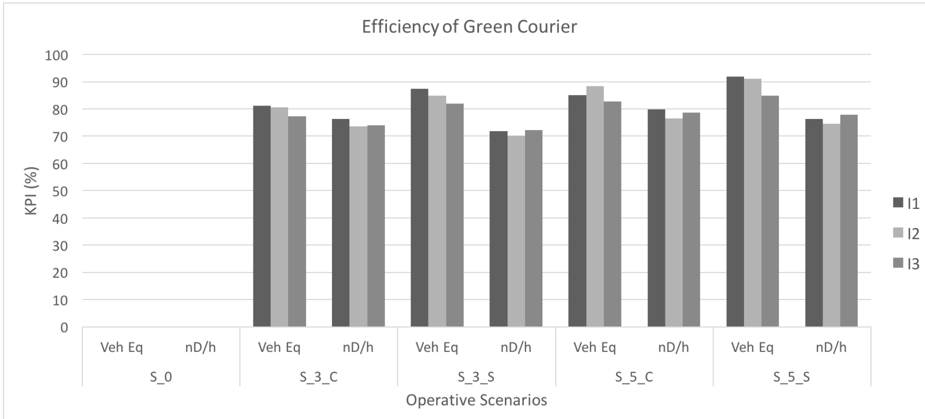


Figure 9: Green subcontractor efficiency in terms of equivalent vehicles (Veh Eq) and parcels delivered per hour (nD/h). Notice that S_0 has no value because the Green subcontractor is not used in this scenario.

bility sustainable issues, also promoted by the "Horizon 2020" programme. In particular, we highlight, by means of the GUEST Methodology approach, the impact of green vehicles adoption, such as electric vehicles and especially bikes, as part of the City Logistics field. Based upon our analysis and simulation results, we highlight how outsourcing parcels deliveries to Green subcontractors could determinate on the one hand, benefits on the CO2 emissions and on the quality level required by the time-sensitive feature of the service, thanks to the reduction of delivery times. However, on the other hand, the switch to low environmental vehicles determinate a loss of efficiency for Traditional subcontractor. For this reason, to maintain an equilibrium level in the system, it is important that this inefficiency is contained and balanced by the increase of the service quality using green vehicles, by a re-definition of the contractual schemes with the Traditional and Green subcontractors or the integration of the green fleet in the International Courier company. Moreover, a continuous process for the optimization of the activities through the implementation of a DSS is needed, in order to achieve reasonable levels of efficiency. According to this emerging bi-vehicular model, a future direction of this work is to analyse how the dynamics in the urban freight transportation systems change introducing other vehicles with low environmental impact as the totally electric and the hybrid ones.

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References

[1] ACI Web Site. http://www.aci.it. Last access 19/05/2016.

[2] Synchro-net h2020 project. URL `http://www.synchronet.eu/`.

[3] UPS Foundation Web Site. http://sustainability.ups.com/the-ups-foundation/. Last access 06/05/2016.

[4] URBeLOG Project Web Site. http://www.urbelog.it/. Last accessed: 06/05/2016.

[5] R. Baldacci, M. Battarra, and D. Vigo. *Routing a Heterogeneous Fleet of Vehicles*, volume 43, chapter The Vehicle Routing Problem: Latest Advances and New Challenges, pages 3–27. Springer, US,, 2008.

[6] A. C. Cagliano, A. Carlin, G. Mangano, and G. Zenezini. System dynamics modelling for electric and hybrid commercial vehicles adoption. In *6th International Conference on Theoretical and Applied Mechanics (TAM '15) Salerno (Italy). June 27-29*, 2015.

[7] Canadian Automobile Association. Driving ccost. Beyond the price tag: understanding your vehicle's expenses, 2012.

[8] M. G. Caroli, U. Monarca, F. Simonelli, and A. Valentino. The business model of international express couriers. from value chain to policy indications. Technical report, LUISS Business School and AICAI, 2010.

[9] A. Conway, P. Fatisson, P. Eickemeyer, J. Cheng, and D. Peters. Urban micro-consolidation and last mile goods delivery by freight-tricycle in manhattan: Opportunities and challenges. In *Conference proceedings. Transportation Research Board 91st Annual Meeting 2012.*, 2011.

[10] G. Cordeau, J.-F.and Laporte. A unified Tabu Search heuristic for vehicle routing problems with time windows. *Journal of the Operational Research Society*, 52:928–936, 2001.

[11] T. G. Crainic and K. H. Kim. *Intermodal transportation. Handbooks in Operations Research and Management Science*, volume 14, chapter 8, pages 467–537. 2007.

[12] T. G. Crainic and G. Ricciardi, N.and Storchi. Models for evaluating and planning city logistics systems. *Transportation Science*, 43(4):432–454, 2009.

[13] T. G. Crainic, N. Ricciardi, and G. Storchi. The-day-before planning for advanced freight transportation systems for congested urban areas. *Publication CRT-2005-19*, 2004.

[14] M. Dell'Amico, W. Deloof, S. Hadjidimitriou, Vernet G., and W. Schoenewolf. Citylog sustainability and efficiency of city logistics: The m-bbx system. In *Integrated and Sustainable Transportation System (FISTS), 2011 IEEE Forum on*, pages 132–135, 2011.

[15] European Commission. Green Paper. An integrated parcel delivery market for the growth of e-commerce in the EU, 2012.

[16] S. Gelareh, R. Merzouki, K. McGinley, and R. Murray. Scheduling of intelligent and autonomous vehicles under pairing/unpairing collaboration strategy in container terminals. *Transportation*, 33:1–21, 2013.

[17] R. Gevaersa, E. Van de Voordea, and T. Vanelslandera. Cost modelling and simulation of last-mile characteristics in an innovative b2c supply chain environment with implications on urban areas and citie. 8th international conference on city logistics. *Procedia - Social and Behavioral Sciences*, 125:398–411, 2014.

[18] M. Janjevic and A.B. Ndiaye. Development and application of a transferability framework for micro-consolidation schemes in urban freight transport. *Procedia - Social and Behavioral Sciences*, 125:284–296, 2014.

[19] W. Knörr. EcoPassenger. Environmental Methodology and Data. Final Report. Technical report, IFEU - Institut für Energie-und Umweltforschung Heidelberg GmbH, 2008.

[20] B. Lenz and E. Riehle. Bikes for urban freight? *Transportation Research Record: Journal of the Transportation Research Board*, 2379:3945, 2013.

[21] B. Li, D. Krushinsky, , T. Van Woensel, and H.A. Reijers. The share-a-ride problem with stochastic travel times and stochastic delivery locations. *Transportation Research Part C*, 67:95–108, 2016.

[22] J.C. Molina, I. Eguia, J. Racero, and F. Guerrero. Multi-objective vehicle routing problem with cost and emission functions. *Procedia - Social and Behavioral Sciences*, 160:254–263, 2014.

[23] C.C. Murray and A.G. Chu. The flying sidekick traveling salesman problem: Optimization of drone-assisted parcel delivery. *Transportation Research Part C*, 54:86–109, 2015.

[24] C. Navarro, M. Roca-Riu, S. Furi, and M. Estrada. Designing new models for energy efficiency in urban freight transport for smart cities and its application to the Spanish case. *Transporation Research Procedia*, 12:314–324, 2016.

[25] P. K. Nguyen, T. G. Crainic, and M. Toulouse. Multi-trip pickup and delivery problem with time windows and synchronization. *Annals of Operations Research*, pages 1–36, 2016. doi: 10.1007/s10479-015-2001-7.

[26] NISSAN. Nissan and DHL test e-NV200 , 2014. URL `http://www.nissan-global.com/EN/NEWS/2013/_STORY/130712-01-e.html`. Last accessed: 20/10/2016.

[27] A. Osterwalder and Y. Pigneur. *Business model generation. A Handbook for visionaries, game changers, and challengers.* 2010.

[28] S.Y. Park, J.W. Kim, and D.H. Lee. Development of a market penetration forecasting model for hydrogen fuel cell vehicles considering

infrastructure and cost reduction effects. *Energy Policy*, 39:33073315, 2011.

[29] G. Perboli. GUEST-OR. linking lean business and OR. *Workshop of the 28th European Conference on Operation Research*, pages Poznan, Poland, 2016.

[30] G. Perboli and R. Gentile. GUEST. from lean startup to lean business. a manifesto. Webinar http://www.slideshare.net/GuidoPerboli/guest-manifesto, DAUIN - Politecnico di Torino, 2014.

[31] G. Perboli, R. Tadei, and D. Vigo. The two-echelon capacitated vehicle routing problem: models and math-based heuristics. *TRANSPORTATION SCIENCE*, 45:364–380, 2011.

[32] G. Perboli, A. De Marco, F. Perfetti, and M. Marone. A new taxonomy of smart city projects. *Transportation Research Procedia*, 3:470–478, 2014.

[33] G. Perboli, R. Tadei, and L. Gobbato. The multi-handler knapsack problem under uncertainty. *European journal of operational research*, 236:1000–1007, 2014. doi: 10.1016/j.ejor.2013.11.040.

[34] G. Perboli, M. Ghirardi, L. Gobbato, and F. Perfetti. Flights and their economic impact on the airport catchment area: an application to the italian tourist market. *Journal of Optimization Theory and Applications*, 164:1109–1133, 2015. doi: 10.1007/s10957-014-0613-8.

[35] G. Perboli, M. Rosano, and L. Gobbato. Decision support system for collaborative freight transportation management: a tool for mixing traditional and green logistics. In *ILS 2016 - 6th International Conference on Information Systems, Logistics and Supply Chai*, pages 1–8, 2016. URL https://www.scopus.com/inward/record.uri?eid=2-s2.0-84985961129&partnerID=40&md5=57cb600540a53fd8f616b9ad79351e5c.

[36] G. Perboli, M. Rosano, and L. Gobbato. Decision support system for collaborative freight transportation management: a tool for mixing traditional and green logistics. In *ILS 2016 Conference, Bordeaux, June 1-4* , 2016.

[37] C. Prins, P. Lacomme, and C. Prodhon. Order-first split-second methods for vehicle routing problems: A review. *Transportation Research Part C*, 40:179–200, 2014.

[38] E. B. Riehle. Cargo bikes as transportation vehicles for urban freight traffic. study on european business examples to estimate the parameters and potential for German cities. TU Dortmund University. Faculty of Spatial Planning. Synopsis, 2012.

[39] F. Russo and A. Comi. A classification of city logistics measures and connected impacts. *Procedia - Social and Behavioral Sciences*, 2:6355–6365, 2010.

[40] G. Schliwa, R. Armitage, S. Aziz, J. Evans, and J. Rhoades. Sustainable city logistics making cargo cycles viable for urban freight transport. *Research in Transportation Business & Management*, 2015.

[41] J.D. Sterman. *Business Dynamics: systems thinking and modeling for a complex world.* McGraw Hill, 2000.

[42] J. Struben and J. D. Sterman. Transition challenges for alternative fuel vehicle and transportation systems. *Environment and Planning B: Planning and Design*, 35:1070–1097, 2008.

[43] R. Tadei, G. Perboli, N. Ricciardi, and M. M. Baldi. The capacitated transshipment location problem with stochastic handling utilities at the facilities. *International Transactions in Operational Research*, 19:789–807, 2012.

[44] R. Tadei, E. Fadda, L. Gobbato, G. Perboli, and M. Rosano. An ICT-based reference model for e-grocery in smart cities. *Lecture Notes in Computer Science*, 9704:22–31, 2016. doi: 10.1007/978-3-319-39595-1.

[45] T.T. Taefi, J. Kreutzfeldt, T. Held, and A. Fink. Supporting the adoption of electric vehicles in urban road freight transport a multi-criteria analysis of policy measures in germany. *Transportation Research Part A*, 91:61–79, 2016.

[46] E. Taniguchi. Concepts of city logistics for sustainable and liveable cities. *Procedia - Social and Behavioral Sciences*, 151:310–317, 2014.

[47] T. Vidal, T. G. Crainic, M. Gendreau, and C. Prins. Heuristics for multi-attribute vehicle routing problems: A survey and synthesis. *European Journal of Operational Research*, 231:1–21, 2013.

[48] J. Visser, T. Nemoto, and M. Browne. Home delivery and the impacts on urban freight transport: a review. *Procedia - Social and Behavioral Sciences*, 125(15-27), 2014.

A Business models of the main actors involved in the urban freight transportation system

A.1 Business model of the International courier

The main customers served by the International courier (see Figure 2 for the business model canvas) are differentiated in the following segments, each with own behaviours and needs to satisfy. Business-to-Business (B2B) segment consists of firms that use courier as a means for the movement of products in output from their logistic chain, which will represent the input for other customer firms. B2B segment also include the e-commerce involving the goods flows between e-retailers and between e-retailers and producers. Business-to-Consumer (B2C) segment consists of firms that produce goods direct to final consumers bypassing distribution chain, such as the e-stores or web sites service providers. Otherwise, the Consumer-to-Business (C2B) segment is strictly related to the reverse logistics. It represents the returning process of the products, which retrace back the supply chain for different reasons, such as disposal of waste, processing scraps or packaging, end user guarantee, dismantle or recycle end of life products or finally customer rejection, or order mismatch for new products. Individuals that require transportation of goods or documents for private needs, and online auction websites (e.g., eBay) are parts of the Consumer-to-Consumer (C2C) segment. Finally, the Intra-Business consists of firms that use courier services for linking different plants and warehouses. The value proposition that the International courier intends to offer them is mainly represented by "time sensitive" or "time critical" transportation services of different product categories. For their features of speed and reliability, these services are also called "express and overnight deliveries", because they must be performed in a smaller time window. For this reason, couriers provide more than a transportation service and a specific time defined as "transit time" [8]. Another component of the value proposition is the superior customer experience offered, due to the high added value of express deliveries. In fact, the customers obtain benefits deriving from the shipment efficiency, speed, reliability and security (e.g., through "tracking & tracing") of the services received. Another important benefit consists on the customization of pick up and delivery activities on last mile and of solution based on product types to be transported (e.g., fragile or perishable products). Referring to small and medium sized business customers, International courier proposes them other two types of value from the costs optimization and the sales market extension. First, firms through express deliveries are capable to realize JIT manufacturing, with the consequence reduction of inventory level and the optimization of the whole production process and costs. The last component of value proposition is strictly related to the customer strategy. In fact, time sensitive transportations, together with internationalization, enhance the catchment areas and create new business opportunities for firms. The main channels used to reach customers and communicate with them to deliver the value proposition are classifiable in direct and indirect channels. Web site and mobile applications represents the first contact points with the customers to raise the awareness of the services offered and to help them to evaluate several propositions. Retail stores are physical structures located throughout the territory to increase the customer proximity. Another type of channel related to marketing strategy is the brand identity, realized through the personalization of vehicles with the brand of the courier. These channels are generally owned by the company and allow to obtain an immediate awareness without intermediaries. Otherwise, the indirect channels are mainly partner-owned web sites used in e-commerce. Customer relationships are maintained through the availability of retail stores, web site, help desk and call centre, which provide to customers, both business and consumers, a direct support and assistance in all phases of the shipment process with high level of customer retention and loyalties. Lockers and in general the delivery machines located in urban areas, allow to establish an indirect relationship with the customers and provide them a self-service available 24 hours during the whole year. Moreover, in order to increase the strength of the customer relationships, the International courier also interplays with its customers through social initiatives and the creation of a community (e.g., the "UPS Foundation" [3]). The revenues streams that the International courier can obtain, derives from the sell of time sensitive delivery services to each customer segments, through the identified channels. The key resources required to make the business model work are the physical assets such as vehicle fleets and point-of-sales systems, the intangible assets as software and other information tools used to the optimal allocation of trips, licenses and partnerships and finally, human resources employed in the operations management and drivers. According to the analysis of the value chain, conducted by LUISS Business School and Associazione Italiana Corrieri Aerei Internazionali (AICAI) [8], the main activities that represent the core business of the International couriers are the process and operations management and the customer care. The first consists of the ordinary activities such as the route planning, intermodal transportation, customs clearance, pick ups and deliveries and also the monitoring of the whole process. The second refers to the activities for the customer relationship management and are strictly related to each steps of transportation process: pre and after sales support, but also during the transportation, with additional services such as tracing & tracking of parcels or proof of delivery. To support its business model, International courier creates partnerships and alliances with high strategic value. The main key partners are suppliers, subcontractors to outsourcing the activities on last mile, cargo operators and handling agents, logistic and commercial joint ventures with the aim to make business more efficient or to develop new models. Finally, another relevant partnership is created with local administrations in order to fulfil at government regulations and ensure the sustainability of parcel delivery in urban areas (e.g., the URBeLOG project [4]). To operate the business model, the main costs the International courier incurs are related to the key resources, as well as materials (e.g., fuel costs, packaging, consumables, etc.), personnel costs, handling fee, acquisition and maintenance of the vehicle fleets, equipment, structures and ICT system, operative costs such as governmental and auditors fees, but also subcontractor fees for the outsourcing of activities. Other costs consist in the marketing and advertising expenditures and also costs related to the risk management.

A.2 Business model of the Traditional subcontractor

As discussed in the Section 4, International couriers of transportation and parcel delivery industry outsource pick ups, deliveries and transportation activities in the last mile segment to subcontractors couriers (see Figure 3 for the business model canvas), representing for them the main customer segment to whom they offer a value proposition, consisting of last mile parcel deliveries. Outsourcing generates value for above mentioned customer, through several benefits in terms of more efficiency and flexibility, due to the better management of activities in urban areas with consequence respect of demand peak and specially qualitative and temporal constraints imposed by the time sensitive deliveries. Other advantages for the International courier are the widest geographical coverage, the costs reduction, the possibility to focus on its core activities (e.g., multimodal and intermodal transport or customer care), the access to specialized resources and know-how (e.g., about territorial knowledge) and finally benefits from learning economies. Traditional subcontractor firms reach their customers through commercial agreements and tenders, which represent actually the best practices. Thus, subcontractors establish with customer segment a relationship maintained by a constant information exchange along all transportation activities (e.g., tracking services and feedback), permitting the co-creation of the value for final user. The main revenue stream for Traditional subcontractors consists of the incoming that they received from customers after the sale of last mile parcel delivery services. The key resources required to make the business model work are the physical assets such as vehicle fleets, mainly vans customized with the customer brand, warehouses, and human resources as driver and employees responsible of the parcel handling and warehouse management. The key activities included in the core business of Traditional subcontractors are the optimal management of transportation services as well as the planning of trips and dispatchers to achieve high service levels in the parcel delivery in fulfilment of time line constrain. After receiving parcels at the hub, the Traditional subcontractor makes a check on the accuracy and integrity of packages, as well as the related information and bar codes, along conveyors called "sorters". Then, parcels are assigned to a driver according to zoning criteria, and then they are ready for the shipment [36]. An important key activity is also the management of anomalies such as returns for data errors or residuals because receivers are not at home. Notice that nowadays, there is a considerably impact of the deliveries that failed at first-time (approximately 12% of all deliveries) [48]. Another key activity is related to the coordination with the International courier customer. The interplay between these two actors is important for the success of multimodality and the correct fulfilment of parcel deliveries, with the consequent satisfaction of final users. A key partnership is established with the suppliers of strategic assets above mentioned, particularly with vehicle dealers and leasing companies, but also with drivers. The cost structure consists of expenses related to acquisition, maintaining and fuelling the vehicle fleet, equipment and materials, warehouses, personnel costs and penalties, which incur due to the breaching of contractual terms.

A.3 Business model of the Green subcontractor

The increasing awareness about environmental problems related to the transportation and the intent to make it more sustainable has led to the development of new business models for a more conscious and optimized management of the parcel delivery on last mile segment. Examples are new firms that propose business model similar to those traditional, but they also consider the environmental impact of their activities, through the use of green vehicles such as bikes and cargo bikes (see Figure 4 for the related business model canvas). The customer segments are identifiable principally in the International couriers that outsourcing last mile operations, but also B2B and B2C segments for the intercity and intracity postal services. The value proposition offered by Green subcontractors consists in cycle-logistics services capable to overcome complexities that involve parcel delivery in urban areas. These are for example mobility restrictions (e.g., LTZ areas), inadequate or insufficiently available infrastructure (e.g., limited usability of loading and unloading zones), and they penalize the competitiveness of Traditional subcontractors. Cycle-logistics provide to the customer several sources of gain creators and pain relievers, as speed, punctuality and flexible service, because bikes are more performing in city traffic, interoperability between traditional road vehicles and bikes and finally, cost reductions but with an high quality level. This last factor is another important component of value proposition. In fact, the better management of parcel delivery on last mile, and the decrease of some expenditures (e.g., fuel, insurance, parking fine, etc.) lead a costs optimization. Green subcontractors offer to their customer segments the possibility of delivering small sized parcels, between 0 to 3 kg or until 6 kg. Finally, another value proposition for customer segments, it is given by the green image and green credentials required for the creation of a sustainable supply chain. Green subcontractors reach their customers through web sites that represent the first type of channel to increase the awareness and knowledge of services, but also through media and interviews published in magazine specialized on transportation and environmental issues. As Traditional subcontractor, also the green ones establish with customer segments a relationship maintained by a constant information exchange along all transportation activities (e.g., tracking services, feedback, and information about CO2 savings). The main revenue stream for Green subcontractors firms consists of the incoming that receive from customers for the sale of last mile parcel delivery services and cycle-logistics, revenues from

CO_2 savings and the carbon credits trading and also fees and royalties from affiliates. The key resources required to make the business model work are the physical assets such as very low environmental vehicle (bike and cargo bike), warehouses, sports and agile human resources as bikers, from which performance depend the service quality and punctuality. Due to the simplicity of this business model, it is affected by a high repeatability, and for this reason important key resources are intangible assets such as partnership, but mainly ICT tools and software for the optimization of operations management [36]. The key activities underlying the business model are the same of the Traditional subcontractors. Actually, Green subcontractors are generally start-up, thus fund raising is an important activity necessary for the future development of their business model. A key partnership has been established with technical partners, investors, sponsors, who are all important for give supports in several field to improve the business model. Other key partners are bikers and above all local administration. To operate their business model, the main costs the Green subcontractors incur are related to the key resources, as well as vehicles, equipment (e.g., bag customized for parcel transportation), consumables, information technologies, personnel costs, warehouses, but also marketing and advertising expenditures.

B Operating Costs per Kilometre of the different vehicles

Cost item	Benchmark value [€]	Technical life cycle [years]	Annual cost [€]	Commercial Speed [km/h]	Total km [km]	OCK [€/km]
			Purchasing cost of vehicle			
Advance payment	5000.00	5	1000.00	35	25000	0.0400
Lease fees and other insurance	11820.00	5	2364.00	35	25000	0.0946
Stamp duty	16.00	5	3.20	35	25000	0.0001
VAT 22%	3703.92	5	740.78	35	25000	0.0296
Total purchasing cost of vehicle	20539.92		4107.98			**0.1643**
			Vehicle taxes			
IPT	319.00	5	63.80	35	25000	0.0026
DMV costs and PRA	100.00	5	20.00	35	25000	0.0008
Stamp duty	208.98		208.98	35	25000	0.0084
Total vehicle taxes	627.98		292.78			**0.0117**
			Insurance			
Average truck liability insurance costs			2680.33	35	25000	0.1072
Total insurance cost						**0.1072**
			Maintenance and repair costs			
Maintenance and repair costs						0.0573
Total maintenance and repair costs						**0.0573**
			Tyres costs			
Average tyres costs			311.15	35	25000	0.0124
Average tyres costs						**0.0124**
			Personnel costs			
Personnel costs			56000.00	35	25000	2.2400
Total personnel costs						**2.2400**
			Vehicle fuelling			
		Price per litre [€/l]	**Consumption** [€/100km]	**Commercial Speed** [km/h]	**Total km** [km]	**Cost per Kilometre** [€/km]
Average manufacturing price	0.5375	0.072	35	25000	0.0387	
Average production tax		1.0069	0.072	35	25000	0.0725
Total vehicle fuelling costs						**0.0112**
				TOTAL OCK	€/km	**2.7042**

Table 1: Operating Costs per Kilometre related to the fossil fuelled vehicle

Cost item	**Benchmark value** [€]	**Technical life cycle** [years]	**Annual cost** [€]	**Commercial Speed** [km/h]	**Total km** [km]	**OCK** [€/km]
Purchasing cost of vehicle						
Advance payment	5000.00	5	1000.00	35	25000	0.0400
Lease fees and other insurance	13740.00	5	2748.00	35	25000	0.1099
Stamp duty	16.00	5	3.20	35	25000	0.0001
VAT 22%	4126.32	5	825.26	35	25000	0.0330
Total purchasing cost of vehicle	22882.32		4575.46			**0.1831**
Vehicle taxes						
IPT	319.00	5	63.80	35	25000	0.0026
DMV costs and PRA	100.00	5	20.00	35	25000	0.0008
Stamp duty	170.28		170.28	35	25000	0.0017
Total vehicle taxes	627.98		292.78			**0.0102**
Insurance						
Average truck liability insurance costs			2680.33	35	25000	0.1072
Total insurance cost						**0.1072**
Maintenance and repair costs						
Maintenance and repair costs						0.0625
Total maintenance and repair costs						**0.0625**
Tyres costs						
Average tyres costs			311.15	35	25000	0.0124
Average tyres costs						**0.0124**
Personnel costs						
Personnel costs			56000.00	35	25000	2.2400
Total personnel costs						**2.2400**
Vehicle fuelling						
		Price per litre [€/l]	**Consumption** [€/100km]	**Commercial Speed** [km/h]	**Total km** [km]	**Cost per Kilometre** [€/km]
Average manufacturing price	0.5593	0.048	35	25000	0.0268	
Average production tax		0.8763	0.048	35	25000	0.0421
Total vehicle fuelling costs						**0.0689**
				TOTAL OCK	€/km	**2.6843**

Table 2: Operating Costs per Kilometre related to the diesel fuelled vehicle

Cost item	Benchmark value [€]	Technical life cycle [years]	Annual cost [€]	Commercial Speed [km/h]	Total km [km]	OCK [€/km]
Purchasing cost of vehicle						
Advance payment	5000.00	5	1000.00	35	25000	0.0400
Lease fees and other insurance	21756.00	5	4351.20	35	25000	0.1740
Battery rental fee	4320.00	5	864.00	35	25000	0.0346
Stamp duty	16.00	5	3.20	35	25000	0.0001
VAT 22%	6840.24	5	1368.05	35	25000	0.0547
Total purchasing cost of vehicle	37932.24		7586.45			**0.3035**
Vehicle taxes						
IPT	319.00	5	63.80	35	25000	0.0026
DMV costs and PRA	100.00	5	20.00	35	25000	0.0008
Stamp duty	-		-			-
Total vehicle taxes	419.00		83.80			**0.0034**
Insurance						
Average truck liability insurance costs			932.50	35	25000	0.0373
Total insurance cost						**0.0373**
Maintenance and repair costs						
Maintenance and repair costs						0.0540
Total maintenance and repair costs						**0.0540**
Tyres costs						
Average tyres costs			230.92	35	25000	0.0092
Average tyres costs						**0.0092**
Personnel costs						
Personnel costs			56000.00	35	25000	2.2400
Total personnel costs						**2.2400**
Vehicle fuelling						
		Average price of electricity [€/kWh]	**Consumption** [kWh/km]	**Commercial Speed** [km/h]	**Total km** [km]	**Cost per Kilometre** [€/km]
Average price of electricity	0.0672	0.1650	35	25000	0.0111	
Total vehicle fuelling costs						**0.0111**
				TOTAL OCK	€/km	**2.6584**

Table 3: Operating Costs per Kilometre related to the electric vehicle