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A new evaluation approach to City Logistics projects

A business-oriented Agent-Based model

By

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Declaration

I hereby declare that, the contents and organization of this dissertation constitute my own original work and does not compromise in any way the rights of third parties, including those relating to the security of personal data.

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The journey to completion of the PhD thesis is very rewarding, challenging and full of encounters with interesting and brilliant people. At the same time, self-doubt and uncertainties pay a visit every now and then and makes you question your research interests, methodologies and results.

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Abstract

Supplying goods to urban areas is a fundamental economic process because the majority of the world population lives and buys goods in cities. Freight distribution activities in urban areas account for roughly 40% of supply chain costs and 60% of supply chain CO2 emissions. Moreover, surging e-commerce trends shape the urban freight transportation arena, increasing its complexity and the pressure on private actors. Thus, urban freight transportation activities generate negative externalities, but are relevant to a great amount of enterprises that compose the economic and social fabric.

In this context, City Logistics (CL) emerged as a comprehensive concept driving solutions to reduce negative externalities while interfering as little as possible with private actors' operations and profitability. CL scholars and practitioners are facing several issues arising from e-commerce and population growth. In particular, logistics service providers are called to optimize their operations in order to increase the speed of delivery. At the same time however, CL is dealing with technological and systemic innovation that might enhance optimization capabilities and network usage.

As a response to the changing environment and within the mandate of CL paradigm, local authorities and private actors have invested on a wide range of initiatives. The variety of approaches adopted and stakeholders involved, at multiple governmental levels, are responsible for a mixed landscape of CL experiences across different regional contexts. Furthermore, despite their relatively large diffusion, CL initiatives often fail in taking up after a first pilot implementation, unable to reach paying customers after public subsidies are removed. Therefore, understanding the major business aspects that underline the reasons for adopting CL initiative by private stakeholders is key to a more long-term vision on CL implementation and assessment.

Previous research has given little attention to understanding the commercial and business aspects of CL projects before actually designing and implementing them, even though CL scholars have ascertained that evaluation methodologies need to encompass all aspects relevant issues for CL schemes. Several methodologies have been proposed since the inception of CL with the evaluation objective in mind. However, they fall short in different ways. For instance, qualitative

methods adopt a short-term feasibility approach to CL evaluation, and the subjective evaluation of quantitative outcomes may potentially influence the ranking between different alternatives. On the other hand, modelling techniques need high quality data to simulate traffic flows and consumers' demand, but fail short to address other important decision-making factors related to the business model of stakeholders. Research opportunities therefore lie in mixing the advantages of quantitative and qualitative approaches to include stakeholders in quantitative ex-ante evaluation of CL projects.

My thesis will try to answer to the following research questions.

- Research question 1:
  What is the state-of-art of CL projects modelling and evaluation methods/frameworks?
- Research question 2:
  How can an integrated qualitative-quantitative framework for CL evaluation be conceived?
- Research question 3:
  How can a new evaluation framework effectively integrate a business-oriented view of CL systems?

The first objective of this thesis is to highlight advantages and disadvantages of assessment methodologies with respect to the integration of the business motives of CL actors into non-project specific, a long-term view on CL project assessment. The second objective of this work is to define a theoretical framework for designing and assessing CL projects business models on a qualitative level. To this end, CL systems are here compared to business ecosystems, which are a network of interrelated business entities. In the framework, CL actors can play multiple roles, and their decisions are based on their objectives, information, and constraints. The business model of a business entity within the system is the set of the roles it plays, the business and operative relationships formed with other business entities, and the monetary and intangible values exchanged through these relationships.

New quantitative methods are needed for a more sound representation of the patterns emerging from the different behaviours of agents. Hence, the third objective is to build an agent-model proposal for modelling, simulating and ultimately evaluating CL projects business model. In agent-based modelling, each actor can be modelled as an agent possessing objectives and decision-making attributes.

Agents act autonomously and their interactions are defined formally by means of ontologies and model narratives built as a representation of real-life system.

Finally, an experiment design will be constructed to provide insights on an existing case study related to the introduction of automated parcel locker station. Two CL ecosystem configurations are modelled together in order to simulate the decision to adopt a new logistics service by potential customers. Then, the effect of the decision regarding the allocation of marketing and R&D budget is also evaluated. From the simulation runs, it becomes clear that the outcome for each ecosystem configuration in terms of profits and customers is strongly influenced by the decisions taken within the other configuration.

In summary, this thesis provides a first modelling and simulation tool for assessing the implications of business model decisions within specific CL business ecosystems. For instance, the strategic decision to adopt a service proposed by a CL company is associated with the evaluation of intangible benefits offered by such company. Moreover, the modelling tool highlights the links between such strategic decisions and the operative ones, such as vehicle routing or inventory policies. Therefore, it proves that qualitative approaches can be used to integrate all stakeholders, while quantitative modelling provide a simulation environment to test long-term effects of different scenarios. However, this study has some limitations. For instance, more strategic decisions should be included in the model to investigate endogeneity stemming from agents' actions. Furthermore, the implication on the business ecosystem of the value of information are not assessed. Finally, the scope of the computational experiment should be widened to include a performance evaluation phase, which would then lead to more decision-making by the agents. Further research is aimed at using the tools developed in the thesis to understand how to drive retailers to change their attitude towards CL by understanding and designing value proposition that might appeal to them. Moreover, the implications of the entrance of new CL players one traditional ones' business model need to be explored more deeply from the strategic perspective of power relations.

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Chapter 1

Introduction

1.1 City Logistics definition

Supplying goods to urban areas is a fundamental economic process because the majority of the world population lives and buys goods in cities, and it comprises the distribution related activities performed within the context of global supply chains. Such activities account for roughly 40% of supply chain costs and 60 % of supply chain CO2 emissions (Bohne and Ruesch, 2013; Roumboutsos, Kapros and Vanelslander, 2014). Moreover, surging e-commerce trends shape the urban freight transportation arena, increasing the amount of irrational purchases and therefore the number of commercial vehicles driving. Thus, urban freight transportation activities generates negative externalities in terms of CO2 emissions and traffic congestion, but are relevant to a great amount of enterprises that compose the economic and social fabric.

City Logistics emerged in the early 2000s as a comprehensive concept driving solutions aimed at solving negative externalities while interfering as little as possible with the private actors operations and profitability. City Logistics has been more recently defined by Taniguchi (2001) as:

"City logistics is the process of ***totally optimizing*** *the logistics and transport activities by* ***private companies*** *with support of advanced* ***information systems*** *in urban areas considering the traffic environment, the traffic congestion, the traffic safety and the energy savings within the framework of a market economy"*

Therefore, a dual objective is embedded in the very foundation of CL: improving the quality of life of citizens in terms of reduction of negative externalities, and improving the efficiency and profitability of urban logistics activities for private actors.

In the following sections, the recent trends and issues in the City Logistics arena will be outlined. Moreover, an analysis on the state-of-the art of the diffusion of City Logistics projects will be presented, in order to provide insights into the potentialities and difficulties encountered by CL efforts in achieving these objectives.

1.2 City Logistics: issues and trends

City Logistics is facing several issues that arise from e-commerce and population growth. In particular, logistics service providers serving the e-commerce industry are called to optimize their operations in order to increase the speed of delivery (Savelsbergh and Van Woensel, 2016), which has become a major value proposition for e-commerce customers (Ghajargar, Zenezini and Montanaro, 2016).

Own-account transportation still accounts for a large share of goods transported in urban areas. For instance, a survey on urban logistics practices performed by Nuzzolo, Crisalli and Comi (2011) for the city of Rome show that 69% of goods are transported by own-account companies. Own-account are typically small companies (retailers or wholesalers) with inefficient vehicles, less-than-optimal optimization skills and sometimes prone to illegal parking practices (Gatta and Marcucci, 2014).

At the same time however, city logistics is dealing with technological and systemic innovation that might enhance optimization capabilities and network usage. For instance, mobile enabled crowd-delivery (or crowd logistics) with private citizens (Mehmann, Frehe and Teuteberg, 2015; Punel and Stathopoulos, 2017) can increase the overall capacity of the network by exploiting unused space from private vehicles. International LSPs have enhanced their efficiency with vehicle technology and ICT optimization tools (Mena and Bourlakis, 2016). For instance, the installation of On-Board Units allows capturing the fuel consumption for better monitoring and improving the overall fuel efficiency. Data on the vehicle location in real-time feed vehicle routing algorithms. Such algorithms compute the most efficient route and most CEP companies have invested in smart mobile applications for their drivers (e.g. the SmartTruck system by DHL, ORION system by UPS).

At a system level, new delivery networks are trying to reshape the traditional hub-and-spoke network. Multi-Tier networks involve two consolidation and transhipment points (Crainic, 2008; Crainic *et al.*, 2010). First, goods and parcels are being consolidated and transhipped at a large distribution centre located at the outskirts, and then traditional commercial vehicles carry the goods to smaller terminals situated inside the city boundaries, closer to the delivery points. Then, goods are either transported with small electrical vehicles, or picked up directly by the goods' recipients. Pickup points and automated parcel locker station work in a similar manner (Dell'Amico and Hadjidimitriou, 2012; Morganti, Dablanc and Fortin, 2014). Moreover, companies may increase in the near their collaborative by sharing logistics infrastructure, thus enabling new business models for logistics service providers and companies (Matzler and Kathan, 2015). Sharing assets and capabilities may then result in increased consolidation and reduced number of freight trips (Savelsbergh and Van Woensel, 2016).

1.3 City Logistics projects[1]

Local authorities and private actors have focused their efforts on a wide scope of CL initiatives. Industry players have been using green vehicles or reshaping delivery time windows to increase their environmental efficiency and reduce the operational costs of urban delivery (Wygonik and Goodchild, 2011). Similarly, some municipalities have put in place, or are currently implementing, public policies to reduce the number of freight vehicles (Marcucci and Danielis, 2008). CL initiatives are usually directed towards two major objectives: goods consolidation and stakeholders' coordination (De Marco, Mangano and Zenezini, 2018). The variety of approaches adopted and stakeholders involved, at multiple governmental levels, are responsible for a mixed landscape of CL experiences across different regional contexts. In this section, I will outline a classification of CL measures and present an empirical analysis of a dataset of 70 European cities that have been piloting or rolling out a CL project, in order to understand the breadth of CL initiatives implemented and provide a state-of-the-art of the diffusion of CL initiatives across Europe.

The classification proposed includes 11 CL measures aggregated in three domains, namely Infrastructure, Regulation and Technology (Table 1). The detailed explanation on the methodological steps taken to build the classification is available in De Marco, Mangano and Zenezini (2018). In fact, this is a sub-set of the

[1] This section is based on the following paper: De Marco, A., Mangano, G. and Zenezini, G. (2018). Classification and Benchmark of City Logistics Measures: An Empirical Analysis. *International Journal of Logistics Research and Applications*, 21(1), pp. 1-19. doi:10.1080/13675567.2017.1353068.

potential CL measures that have been subject to evaluation via at least one assessment method, which are analysed in the literature section of this thesis.

Table 1 CL measures

Domain	CL Measure
Infrastructure	Urban consolidation centres (UCC)
	Curb side lay-by areas
	Micro consolidation centres
Regulation	Low emission zones
	Time Windows
	Road pricing
	Fiscal incentives
	Restrictions on vehicle weight and volume
	Off-hour deliveries
Technology	ICT Logistics platforms
	Adoption of low emission vehicles and alternative transportations

Infrastructure initiatives require the planning of new logistics infrastructure or the improvement of existing ones. Urban consolidation centres (UCC) are warehouses located in the outskirts of the city acting as a hub to consolidate goods and reduce the number of vehicle trips. UCC can generate potential operative and economic benefits to CL stakeholders, in terms of inventory control and new revenue generating services. However, UCCs often struggles with high set-up costs or limited attractiveness to logistics companies, given the fact that UCCs are not always able to handle a wide range of goods. Dedicated curb side (un)loading zones can be implemented by local authorities to avoid the problem of double-parking by trucks (Dablanc, 2009). The lack of lay-by areas is also considered one of the major problems that carriers face (Stathopoulos, Valeri and Marcucci, 2012). Micro-consolidation centres (MCC) are satellite terminals installed within the city boundaries acting as further consolidation and transhipment hubs, from heavy commercial vehicles to electric distribution vehicles (Crainic *et al.*, 2010). Micro-consolidation schemes they might be more profitable than UCCs, although for smaller goods (e.g. packages, mails, office supplies) (Janjevic, Kaminsky and Ndiaye, 2013).

Regulation measures comprise the limitation to the access of delivery vehicles, the imposition of fees to the entrance, or incentives to sustainable behaviours. Scholars have focused their attention to multiple restriction measures such as low emission zones (Carslaw and Beevers, 2002; Anderson, Allen and Browne, 2005), time windows (Quak and de Koster, 2007), restrictions on vehicle weight and volume (Behrends, Lindholm and Woxenius, 2008; Awasthi and Chauhan, 2012), load factor control (Teo, Taniguchi and Qureshi, 2014) or road pricing (Quak and Van Duin, 2010). These regulations aim at fostering sustainable behaviours form private actors, such as the use of low emission vehicles or improved vehicle loads with reduced freight vehicle trips. However, restrictive policies have to be carefully implemented so to not hinder freight operations (Ballantyne, Lindholm and Whiteing, 2013). Off-hour deliveries can relieve the nuisances generated by freight transportation, by shifting deliveries to less congested hours. This would also increase the efficiency of the delivery operations, due to lower and less uncertain journey times, but might have a negative impact on their overall cost given that resources need to be deployed outside of office hours. Hence, this solution might be feasible only with high volumes and strict collaboration between receiver and carrier (Holguín-Veras *et al.*, 2014).

Technology measures encapsulate the introduction of technology-based infrastructures in the urban freight transportation system. These include, for instance, ICT platforms connecting a system of sensors and other hardware deployed in the city to monitor and control the occupancy level of a particular area (e.g. parking sensors) or the access to the city centre (e.g.: cameras). These projects can improve carriers' operations (e.g. route and trip planning), by providing them with real-time information and value-added services. Advanced routing systems can exploit dynamic data to compute optimal delivery routes (Taniguchi and Shimamoto, 2004). Technology does not only refer to ICT platforms, but also to vehicle innovation. Different types of low-emission vehicles have been experimented for city logistics purposes, namely electric, hybrid or fuel cell vans (Nesterova *et al.*, 2013; Pelletier, Jabali and Laporte, 2014; Trip and Konings, 2014) or small electric distribution vehicles (Browne, Allen and Leonardi, 2011; Melo, Baptista and Costa, 2014). The investment required for a large uptake of low-emission vehicles is very high, and sometimes the benefits may be not enough to cover all initial expenses.

From an empirical analysis conducted on 70 European cities, it emerged that three types of measures are implemented in more than 50% of the panel, namely: Low Impact Vehicles, Urban Consolidation Centres and Low-Emission Zones. However, despite their relatively large diffusion, CL initiatives often fail to take up after a first pilot implementation, or lag at a low scale for years after their introduction. Sometimes, CL initiatives are kept alive only with public subsidies, and fail to reach out to paying customers after these subsidies are removed. Reasons for failure ranges from a lack of profitability, too many stakeholders involved or too complex schemes to be introduced (Van Rooijen, Guikink and Quak, 2017). If initiatives are implemented without a thorough exploration on the commercial and business attractiveness then private operators will not be willing to cooperate and invest their resources in the project (Cagliano *et al.*, 2016).

Chapter 2

Research Objective and Methodology

As seen in the previous chapter of this thesis, the underlying goal of CL initiatives should be twofold: first, to meet the highlighted public policy objectives of reducing negative externalities, and second to improve the efficiency of private actors that operates in a market economy and strive to improve their profitability.

However, previous research has given little attention to understanding the commercial and business aspects of CL projects before actually designing and implementing them, even though CL scholars have ascertained that evaluation methodologies need to encompass all aspects relevant issues for CL schemes (Leonardi *et al.*, 2014). Therefore, my thesis will try to answer to three research questions by stating them into research objectives, and associating those objectives with suitable methodological steps.

2.1 Research questions

2.1.1 Research question 1: what is the state-of-art of CL projects modelling and evaluation methods/frameworks?

CL scholars have used a wide variety of methodologies to solve mostly optimization problems with the goal of depicting the response of private actors to the introduction of public policies. Modelling CL can be quite useful to understand the impacts of selected policies, and therefore serves a second purpose of evaluating such policies. Other methodologies have been put forward in recent years with the evaluation objective in mind. Qualitative methods and quantitative methods that leverage on subjective evaluation by CL stakeholders (e.g. surveys or multi-criteria methods) can be quite useful in proposing different scenario and derive their acceptability by stakeholders (Allen, Browne and Cherrett, 2012; Stathopoulos, Valeri and Marcucci, 2012; Macharis, Milan and Verlinde, 2014).

2.1.2. Research question 2: how can an integrated qualitative-quantitative framework for CL evaluation be conceived?

Qualitative methodologies are able to evaluate effectively all stakeholders' objectives and decision-making criteria. However, such methods adopt a short-term feasibility approach to CL evaluation, and the subjective evaluation of quantitative outcomes may potentially influence the ranking between different alternatives. On the other hand, modelling techniques need high quality data to simulate traffic flows and consumers' demand, but fail short to address other important decision-making factors related to the business model of stakeholders. Opportunities for research in modelling and evaluating CL projects lie therefore in mixing the advantages of quantitative and qualitative approaches and in the necessity emerged recently to include stakeholders in ex-ante evaluation of CL projects (Lagorio, Pinto and Golini, 2016).

2.1.3 Research question 3: How can a new evaluation framework effectively integrate a business-oriented view of CL systems?

As previously mentioned, it is necessary to move beyond the traditional operational view of City Logistics to include the business aspects in the evaluation process. Only recently, there have been more efforts by CL scholars in exploring CL projects adopting a more business-oriented view, even though missing to understand the potential for commercial attractiveness of new CL innovations has been deemed one of the key ingredients in the failure of such innovations. The main reason is that there are significant challenges related to the application of business model concepts in CL. In fact, business modelling has proved to be of value for analysing a single firm's business environment rather than a network of stakeholders (Reuver, Bouwman and Haaker, 2013).

2.2 Research Objectives

As anticipated, it is possible to trace the roots of both the current inefficiencies of urban distribution activities and the barriers to the implementation of innovative projects in the heterogeneity of the involved stakeholders. In this context, more research is needed to address the main drivers that lead to long-term economic success of CL initiatives, in the face of the dynamics that arise from the distributed decision-making processes of the stakeholders that may unfold in different CL systems' setup. To this end, it is instrumental to take explicitly into account the business aspect of these decision-making processes as a major determinant for the long-term success of CL initiatives.

This thesis aims to answer the research questions outlined in the previous section by providing a qualitative and quantitative framework to assess CL projects, taking into consideration both business and operational factors and including all major stakeholders in the evaluation.

This overarching goal is further decomposed into research objectives. According to (Farrugia *et al.*, 2010), a research objective is "an active statement about how the study is going to answer the specific research question", and it defines a specific aim of the research. The research objectives (RO) of this thesis are as follows.

1. Categorize existing methodologies in terms of their assessment approach, the types of stakeholders involved, the variety of projects that have been evaluated with, and the impact areas explored. The purpose underlying this RO is to highlight advantages and disadvantages of assessment methodologies with respect to the integration of the business motives of CL actors into non-project specific, a long-term view on CL project assessment.

2. The business model concept can be of great help when it comes to assess the business decision-making criteria underlying the success or failure of a CL initiative. Hence, the second RO is to overcome the shortcomings of traditional business model concepts by building a new business model framework for CL concepts. This first part will compose the qualitative, theoretical framework that is needed to apply the concepts of business modelling to CL systems. Consequently, this RO is aimed at integrating a business-oriented view on CL assessment (i.e. RQ 3).
3. Incorporate links, behaviours and decisions of CL stakeholders. This sub-RO aims at building the formal relations that guide the interactions among CL stakeholders and drive the appearance of dynamics within the system. By following this RO, I aim to provide an answer to the conception of a qualitative-quantitative framework that includes a business-oriented view on CL systems (i.e. RQ 2 and 3).
4. Simulate different configuration of the CL system and evaluate their performance. Through this last RO I intend to come full circle to the notion of

integrating modelling with evaluation, by simulating different scenarios, calculate the impact on selected indicators and gain insights from the evaluation phase.

2.4 Research Methodology

The methodological steps outlined in the following sections aim to respond to the four ROs previously highlighted. In particular, a literature review is performed to answer to the first RO. Then, for the second RO a business ecosystem framework is presented, which will be implemented using an agent-based model approach to achieve the second and third RO. In fact, decisions, links and behaviours will be drafted in the theoretical framework, and later on formalized through a structured approach to agent-based modelling, provided by van Dam, Nikolic and Lukszo (2013). Finally, a case study implementation of the ABM proposal is presented with regard to the fourth RO.

2.4.1 Literature review

For the first RO, a literature review is performed on extant literature regarding CL projects assessment methodologies, in order to answer to the first research question above-mentioned.

In particular, the aim of the literature review proposed here is to provide insights into the ability of existing methods in taking into account the objectives of various stakeholder and especially those objectives referring to their business model. Moreover, existing literature will be addressed in terms of quantitative vs. qualitative methodologies, so to highlight advantages and disadvantages of both approaches.

The literature review presented in this thesis fulfils another purpose, namely to provide a research background to the next methodological steps. In particular, I will investigate the concept of Business Model (BM) and Agent-Based Modelling, focusing on their current applications to CL systems and highlighting the research gaps.

2.4.2 CL Business Ecosystem Framework

As anticipated, the purpose of this work is to overcome the shortcomings of the business model approach applied to CL systems. As a consequence, traditional business model concepts show some drawbacks with regard to their suitability to CL systems where a multitude of actors operate with various business motives.

To this end, CL systems are compared to business ecosystems, which are a network of interrelated business entities, characterized by value transfer and value co-creation mechanisms (Wang, Lai and Hsiao, 2015), operational transactions and interdependencies between business entities (Solaimani, Bouwman and Itälä, 2015). The decision-making processes by various stakeholders and the resulting dynamics and impacts on the CL system seem to fit with the outlined characteristics of business ecosystems. These decisions are based on their objectives, information, and constraints. The business model of a business entity within the system is then defined as the set of the roles it plays, the business and operative relationships formed with other business entities, and the monetary and intangible values exchanged through these relationships.

2.4.3 Agent-Based model implementation

The city logistics domain is characterized by a multitude of actors with different and often conflicting objectives, which drive their decision-making and contribute to shape a mixed environment. CL project evaluation has often failed to acknowledge this basic fact, and therefore new quantitative methods are needed for a more sound representation of the patterns emerging from the different behaviours of agents.

A branch of urban freight modelling that is gaining importance is represented by agent-based modelling, which might provide a feasible alternative to overcome the issue of stakeholders' interactions that is rarely taken into account in "traditional" traffic models. Moreover, Agent-based modelling shows great potential for capturing the changing distribution patterns in response to urban freight initiatives, with significantly less data required for the simulation. In agent-based modelling, each stakeholder can be modelled as an agent possessing objectives and decision-making attributes. Agents act autonomously and their interactions are defined formally by means of ontologies and model narratives built as a representation of real-life system.

The activity of an AB modeller resembles such configuration of the problem, as she starts with the observation of emerging patterns from the system; validate the objectives of the AB model at issue through literature or experts' feedbacks, and proceeds to propose solutions aided by computational experiments (Figure 1).

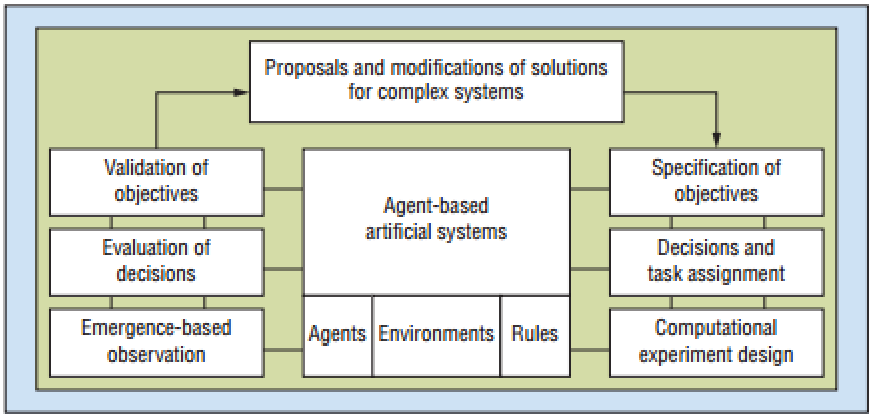

Figure 1 Complex systems, agent-based modelling and computational experiments. Source: (Mao and Wang, 2012)

2.4.4 Model simulation

The agent-based model implementation proposed in chapter 5 provides a generic proposal for a business-model oriented point of view on ABM for City Logistics. Hence, it identifies several value proposition and decisions that compose a City Logistics business ecosystem. In order to implement the ABM model proposal into a specific business ecosystem, the modeller needs to give a quantitative evaluation of the different components of the value proposition, the services offered and the pricing level of such services.

Thus, an experiment design will be constructed to provide insights on an existing case study. The case study application is built using real-life information from a company operating a network of automated parcel locker station in the Netherlands[2]. Parcel lockers are used by more and more companies, and they already show a variety of business models shaping the CL ecosystems[3]. As a matter of fact, some parcel lockers companies propose themselves as business entities that organize the last-mile delivery network, alternative thus to existing players such as express couriers. By doing so, they aim at optimizing such processes by consolidating freight from different actors. Hence, the impact of the decisions taken by the agent types in this ecosystem are likely to have an effect on other agents, such as express couriers and city planners (in terms of vehicle reduction).

[2] www.mypup.nl

[3] More information regarding this solution can be found in the papers of Morganti, Dablanc and Fortin (2014) and Iwan, Kijewska and Lemke (2016).

Such considerations make the parcel locker case extendable to other similar case studies, which are quite common in CL arena.

Parcel lockers installation is a very interesting case because it shows that technological innovations can reshape an ecosystem through the introduction of new actors and business relationships. Therefore, the computational experiment serves the purpose of providing a possible usage scenario for the ABM proposal, and the parcel locker case is well suited to provide new insights into the topic.

2.4.5 Data collection

For the theoretical framework, three case studies have been selected. The first depicts the parcel locker operator previously mentioned, whereas the other two show different business ecosystem configurations regarding the implementation of Urban Consolidation Centres (UCC). As will be clearer from the literature, UCCs compose the most studied set of CL project addressed via an assessment methodology. Hence, they have been chosen to highlight the insights provided by the new business model framework for CL business ecosystems.

For the computational experiment, I have selected the case study of parcel lockers implementation, for the reasons that were mentioned above.

Data on the case studies comes from secondary sources as well as first-hand information collected through interviews. Secondary sources ranges from scientific literature (Van Rooijen & Quak 2010; TRAILBLAZER, 2010; van Duin et al., 2016) to company reports and websites. Semi-structured interviews were performed with key people of the three companies, namely:

1. Parcel locker operators. For the MyPUP case, two interviews of 1-hour duration were conducted with the CEO and founder, the first at the company’s offices and the second via Skype. As the computational experiment required a second type of business ecosystem configuration, another 1-hour interview has been conducted with the head of product development of another company based in Belgium.
2. Binnenstadservice. One interview has been conducted with the CEO and founder at the Binnenstadservice office in Nijmegen, with a duration of 2 hours.
3. Bristol UCC. One interview on Skype has been conducted with a former employee of the company. This interview lasted for approximately 40 minutes.

The semi-structured interview tool is available in Appendix 1.

2.3 Thesis outline

In the following sections, I will outline the background that helped shape my research objective, with a focus on the research gap and opportunities stemming from the two research streams of evaluating and modelling CL systems.

The thesis is structured as follows.

In Chapter 3, I will present a literature review focused on analysing existing CL assessment methods through a structured approach, highlighting their advantages and disadvantages and identifying research gaps.

Chapter 4 presents the theoretical, role-based business ecosystem framework for CL business model evaluation.

In Chapter 5, I depict an agent-based model proposal for turning the theoretical framework in modelling terms, and paving the way for the computer experimentation through which it is possible to simulate the CL business. The computer experiment is depicted in chapter 6.

Finally, I will draw some conclusions and further research opportunities in chapter 7.

Chapter 3

Literature review

3.1 CL projects assessment methods [4]

As previously discussed, to overcome existing barriers to larger scale optimization of urban freight distribution activities requires properly developed and tested methodologies. Such methodologies should assess all aspects relevant to this context and aim at measuring and fostering long-term sustainability of urban freight distribution, both operational and economical (Balm *et al.*, 2014). The aim of this literature review is to review existing assessment methodologies to underline their advantages and disadvantages, along with possible research gaps. Some reviews already exist in the field of City Logistics (hereafter I will refer to City Logistics and urban freight as synonyms), such as the general reference taxonomy of CL based on 92 papers proposed by (Wolpert and Reuter, 2012). On the other hand, more specific reviews on assessment methods are proposed by (Ambrosini and Routhier, 2004), who studied objectives, methods and results of surveys carried out in this field, and (Anand, Quak, *et al.*, 2012), who provided a review of existing modelling efforts in city logistics. Danielis, Valeri and Rotaris (2015) provided the review more akin to the one proposed here, as they assess the evaluation methods for City Logistics projects. However, they only take into consideration the proceedings from the International City Logistics Conference, which is held every other year. Finally, Lagorio, Pinto and Golini (2016) presented a systematic literature review of City Logistics, finding that performance assessment is one of the most important topics in CL literature, accounting for roughly 30% of pub-

[4] This section is based on the following paper: Zenezini, G., and A. De Marco (2016). A Review of Methodologies to Assess Urban Freight Initiatives. *IFAC-Papers OnLine,* 49, no. 12. doi:10.1016/j.ifacol.2016.07.752.

lished papers. In this chapter, I propose a different perspective on the classification of existing literature, by looking at how different assessment methodologies take into consideration and evaluate several aspects of the multi-faceted topic that is City Logistics. Furthermore, I intend to propose future trends in the assessment of urban freight initiatives. The chapter is structured as follows: in Section 1, the review framework is presented. Then, the methodologies reviewed are presented in terms of their method in section 2, and their scope in section 3. Finally, discussions and conclusions are drawn in section 4.

3.1.1 Review Framework

Since the interest on urban freight distribution is recent, the review spans from 1999 to present days. The main databases of scientific refereed journals were searched, such as Google Scholar, Science Direct, SpringerLink or Scopus, as well as the proceedings from the main conferences in the field (e.g. The International City Logistics Conference). Initially, the review focused on field specific key words (and their combination), such as “city logistics”, “urban goods movement”, “urban freight transport”, “urban distribution”, and “urban logistics”. Then, the initial set of works was refined by selecting only those that present an evaluation framework, and 20 assessment methods presented in 61 papers were assembled (Table 2).

Table 2 Assessment methods and number of papers

Method	# of papers	Data type
Multi-criteria decision-making method (MCDM)	8	Quantitative
Quantitative case study	6	Quantitative
Agent-based modelling	5	Quantitative
Discrete-choice model	5	Quantitative
Vehicle Routing Problem (VRP)	5	Quantitative
4 step model	4	Quantitative
Case study	4	Qualitative
Multimethod assessment	4	Qualitative
Survey	3	Quantitative
Tour-based models	3	Quantitative
Business Model	2	Qualitative
Conceptual framework	2	Qualitative
Social Cost Benefit Analysis (SCBA)	2	Quantitative
Panel of indicators	2	Quantitative

Dynamic game theory	1	Quantitative
FREILOT	1	Quantitative
Lifecycle sustainability assessment (LCA)	1	Quantitative
Modelling quantitative economic equations	1	Quantitative
Overall Equipment Effectiveness (OEE)	1	Quantitative
Systems of Innovation	1	Qualitative

The review is constructed on two dimensions, namely the type of data used in the evaluation and the scope. Concerning the first dimension, evaluation methods differ significantly if they use quantitative or qualitative data. Quantitative methods make use of data retrieved from large-scale surveys, questionnaires or technical data to develop simulation model or scenario analysis. Qualitative approaches mainly comprise focus groups or interviews with stakeholders to identify decision-making criteria and evaluate possible alternatives or illustrate different point of views (Steckler *et al.*, 1992). As for the scope, existing assessment methodologies should cover at least one of three funding aspects of urban freight distribution systems. First, methodology can assess one of the private or public measures applicable to the urban freight transport system (Russo and Comi, 2011). Second, an assessment methodology should take into account the objectives of most of the stakeholders of urban freight distribution systems (Taniguchi and Tamagawa, 2005; Ballantyne, Lindholm and Whiteing, 2013). Third, assessment methodologies should explore the effect of the measures on at least one of six impact areas identified in the literature, namely environmental, economic, social, operational, customer and employee satisfaction (Patier and Browne, 2010). Two impact areas are also added to account for new development in CL assessment methods, namely Employee and Customer Satisfaction (De Assis Correia, De Oliveira and Guerra, 2012; Macharis, Milan and Verlinde, 2014).

3.1.2 Data used in the assessment

3.1.2.1 Quantitative methods

Quantitative research methodologies are used to quantify a problem at issue by way of generating numerical data. These methods can be adopted to provide observed or simulated effects by using measurable data. In CL literature, quantitative methods includes structured surveys with closed questions, optimization algorithms and freight modelling techniques. Such methods mostly aim at simulating or evaluating the outcomes of a freight distribution system, in terms of vehicle flows, commodity flows, pollutant emissions, and monetary outcomes. These methods require, in most of the cases, a significant amount of various data in order to be validated and generate robust results. Freight modelling techniques have been for several years the focus of scientific works in the urban freight context. Ideally, freight demands models should build a strong behavioural foundation, incorporates freight and passenger interactions and should be capable of handling policy changes (Giuliano *et al.*, 2010). In particular, the last attribute is of paramount importance in urban contexts, in reason of the aforementioned issues generated by the freight activities. Anand, Quak, *et al.* (2012) state that efficiency is one of the most investigated aspects by city logistics modellers. Modelling approaches focus mainly on traffic flow and freight flows, as well as land use and location. Most of urban freight models are derived from more consolidated passenger flows models. For instance, the traditional four-step approach, which comprise trip generation, trip distribution, mode choice (often omitted) and traffic assignment (Hosoya, 2003), has been adopted by Muñuzuri *et al.* (2010) to simulate traffic flows in the city of Seville at peak hours, taking into account replenishment deliveries to local retailers and home deliveries. A strong assumption of this paper is that none of the trips made are multi-stop trips, since the authors only simulated flows in a narrow window of time. A further development by the same authors (Muñuzuri *et al.*, 2012) relaxed this assumption, introducing multi-stop routes, on the basis of retailers' location and the average distance travelled between stops. However, as Hunt and Stefan (2007) noted, the four-step approach still overlooks the strong tour-based nature of urban commercial flows. These authors adopted a tour-based model for simulating own account urban commercial flows, including service trips. This type of modelling approach is more detailed in the sense that it considers several features of the delivery trip, such as the purpose of the tour, the specific tour start time, and the characteristics of the stops on the tour (Nuzzolo, Crisalli and Comi, 2011). This level of detail of course is seen as an advantage of this approach, but it is in turn time and data intensive. A possible solution is to implement an aggregate approach (Chow, Yang and Regan, 2010). For the tour definition, probabilistic approaches are adopted to generate the choice of the next destination stop and to make the decision of whether return to the base (warehouse) or not on each tour.

Vehicle-Routing problems (VRP) comprise approaches aimed at optimizing the delivery route of CL commercial vehicles in terms of costs, number of trips, or environmental emissions. The VRP can be described as "the problem of designing optimal delivery or collection routes from one or several depots to a number of geographically scattered cities or customers, subject to side constraints" (Laporte, 1992). Real-time data from traffic can be used to improve the optimization given by the VRP problem in a dynamic traffic model (Taniguchi and Van Der Heijden, 2000). As a matter of fact, travel times in congested cities can be uncertain and VRP problems should take this into account (Ando and Taniguchi, 2006). Moreover, local regulations such as delivery time windows may impose some additional costs on carriers' operations and VRP problems are suited to evaluate the effect of

CL policies on carriers' costs (Muñuzuri *et al.,* 2013). At the same time, VRP techniques can be adopted to optimize both economic and environmental costs of the carriers' CL operations, so to take into account the trade-offs between costs, emissions, and service quality (Wygonik and Goodchild, 2011).

Several authors have adopted different assessment methods to evaluate specific case studies, exploiting the availability of data from stakeholders directly involved in a CL project. For instance, both Quak and de Koster (2007) and Browne and Gomez (2011) used VRP approaches to investigate the impact of time windows and other policies on receivers and logistics service providers respectively, by retrieving data from logistics service providers themselves. Assessing the potential demand for a CL project is a problem suited for a quantitative case study, as shown by Gruber, Kihm and Lenz (2014) and Correia, Oliveira and Guerra (2012). In fact, the former retrieve logistics data from a carrier and integrate them with findings from a survey to bike messengers, to evaluate the potential market and the willingness to adopt a delivery system with cargo bikes. The latter instead assess the potential demand generated by retailers for a UCC via a stated preference survey based on four attributes: costs, delivery service, and reliability and stock levels. Finally, the problem of assessing the financial and operative viability of a CL project is tackled with economic and environmental formulations within a quantitative case study. For instance, Arvidsson and Pazirandeh (2017) formulated a mobile depot scenario and compared it with the cost of conventional urban freight distribution using vans.

A branch of urban freight modelling that is gaining importance is represented by agent-based modelling, which might provide a feasible alternative to overcome the issue of stakeholders' interactions that is rarely taken into account in "traditional" traffic models. In agent-based modelling, each stakeholder can be modelled as an agent possessing objectives and decision-making attributes. Taniguchi and Tamagawa (2005) simulated traffic flows considering stakeholders' behaviours and objectives, adopting a genetic heuristic algorithm to model the vehicle routing problem (VRP) of minimizing cost with constraints. In (Wisetjindawat *et al.*, 2007), the stakeholders, namely retailers, wholesalers, manufacturers, suppliers, and carriers, interact with each other within an urban supply chain through information and material flows. A combined approach agent-based with vehicle routing has been proposed by Teo, Taniguchi and Qureshi (2012) and van Duin, van Kolck, Anand, Tavasszy, *et al.* (2012). Agent-based modelling shows great potential for capturing the changing distribution patterns in response to urban freight initiatives, with significantly less data required for the simulation. However, different interactions between agents have to be modelled according to the initiative that is the focus of the evaluation process (Knaak, Kruse and Page, 2006).

Some quantitative methods leverage on subjective evaluation by CL stakeholders to evaluate different alternatives. For instance, surveys are a suitable option for assessing stakeholders' responses to freight policies (see Allen, Browne and Cherrett (2012) for a review on surveys on urban freight transport). Anderson, Allen and Browne (2005) developed an evaluation framework composed of an assessment approach, aiming at defining the companies' response to policy measures through interviews, and a set of indicators retrieved from survey data. The evaluation is performed as a comparison between the actual scenario and the scenario constructed by applying the companies' responses to existing data depicting the actual operations. The selection of the policy measures is also part of the methodology, since changes in operations are directly assessed with the companies involved. Stated or revealed preference surveys in discrete choice models comprise a stream of CL literature that analyses qualitative data (i.e. choice of respondents) with quantitative methods such as multinomial logit models, in order to define a utility function for a category of stakeholders based on their preferences over a set of CL alternatives. Discrete-choice modelling methods have so far evaluated CL policies such as UCC (Marcucci and Danielis, 2008), off-hour deliveries (dell'Olio *et al.*, 2016; Marcucci and Gatta, 2017), or regulations such as parking policies and low emission zones (Filippi *et al.*, 2010; Marcucci, Gatta and Scaccia, 2015). Regulations are investigated from the perspectives of carriers (Filippi *et al.*, 2010; Marcucci, Gatta and Scaccia, 2015; Muñuzuri, Guadix, *et al.*, 2016) and UCCs and off-hour deliveries from the point of view of retailers (Marcucci and Danielis, 2008; dell'Olio *et al.*, 2016; Marcucci and Gatta, 2017). The main issue with these methods lies in the fact that evaluation attributes highly depend on the alternative at issue.

Contrary to discrete-choice modelling, in multi-criteria decision-making methods (MCDM) the attributes are more general in scope and only the evaluation by stakeholders depends, and rightly so, on the CL project subject to evaluation. The multi-stakeholders evaluation method (MAMCA) developed by (Macharis, De Witte and Ampe, 2009), has been emerging as a comprehensive tool for *ex-ante* evaluation of CL measures. Through this methodology, it is possible to identify the objectives of the different stakeholders involved and translate them into weighted criteria. Quantitative and qualitative key performance indicators (KPI) are then assigned to each criterion, allowing evaluating each alternative about a given criterion. As mentioned before, stakeholders have a large impact on the implementation of a project, and therefore including them in the decision making process can be a crucial element in the successful implementation of the measure. Other multi-criteria methods, such as Analytical Hierarchy Process (AHP) and Analytical Network Process (ANP), are used in the first place to define the objectives of CL planning, and in second place to evaluate alternatives. These methods involve different stakeholders in the evaluation process, but in a less explicit way than what happens with the MAMCA approach. Awasthi and Chauhan (2012) integrated these two goals adopting a combined approach with AHP for defining the objectives of CL planning and a TOPSIS algorithm for evaluating different scenarios against criteria highlighted with the AHP. The TOPSIS method is a technique for ranking alternatives by the level of similarity to an ideal solution, which maximizes the benefit criteria and minimizes the cost criteria. The AHP method do not allow for a dynamic modelling of the environment, since the elements that compose it are uncorrelated and influenced by a hierarchical structure (Meade and Sarkis, 1998). In response to this problem, the Analytical Network Process might represent a solution, since it depicts the dynamic relationships between decision attributes. However, I could find only one development of ANP in urban freight context, namely by Kaszubowski (2012). This is probably due to the complex framework that requires identifying several criteria and explicitly depicting their relationships.

Comprehensive methodologies that integrate the freight flows simulation with policy identification and urban freight planning scenarios are also available in literature (Filippi *et al.*, 2010). Some of the methods integrate qualitative aspects in a quantitative assessment framework. Patier and Browne (2010) developed a set of indicators pertaining to Economy, Social, Environmental and Logistics domains of the CL, and ranked the innovations based on a qualitative assessment given for each indicator on a three grade scale (0,1,2). Evaluation is based on a comparison between achieved results and target goals. This leaves questions over the level to which these goals are set and if this influences the evaluation. Cost-Benefit analysis (CBA) has been used to assess whether the benefits connected to a transport project exceed the costs and / or achieve an efficient use of resources (Suksri and Raicu, 2012). Social cost-benefit analysis (SCBA) is an extension of the traditional CBA used for transport projects appraisal, which includes non-market effects of decisions. SCBA methodology has been recently adopted for the STRAIGHTSOL project (Balm *et al.*, 2014). SCBA aims at giving a quantitative evaluation of all stakeholders' objectives, but several assumptions have to be made for treating non-quantifiable effects in the quantitative evaluation of the monetary value of the project.

3.1.2.2 Qualitative methods

Qualitative Research methods concern mostly exploratory, inductive research, where the goal is gain an understanding of underlying reasons and motivations.

In CL literature, some assessment methods are based on purely subjective evaluation by a panel of experts or selected stakeholders. These methods are mostly used to assess the transferability of innovation and best practices. Business model analysis (BMA) is a qualitative methodology developed in management research, showing a potential for investigating the feasibility of urban freight initiatives from a business-oriented perspective. BMA has been recently adopted to assess different urban freight initiatives within the STRAIGHTSOL assessment framework (STRAIGHTSOL, 2014). The methodology developed for the BESTFACT project comprises a multi-criteria assessment along four categories: innovation and feasibility, magnitude of impacts, information accessibility, and transferability. Each criterion is evaluated using a scoring system between 0 and 3, by three experts independently, and an average value is given to each innovation. In essence, these approaches show some relevance in terms of involving the stakeholders from the selection of the best policy measure to be adopted. However, they show some issues when treating quantitative information in the evaluation.

Finally, conceptual frameworks and qualitative case studies are developed to get insights on the implementation process of CL initiatives and on the organizational and operational changes connected to the implementation of new ways of delivering goods in urban areas (Gammelgaard, 2015). Conceptual framework can also be validated by means of case study, as in Harrington *et al.* (2016).

3.1.3 Scope of assessment

An assessment method can have a broader or more narrow scope, in terms of measures that it intends to assess, number and type of stakeholders included in the assessment process, and the category of potential impacts measured.

3.1.3.1 Measures

It is necessary to point out that the analysis of the scope cannot be performed without mentioning that the two types of method highlighted, namely quantitative and qualitative, do not always share the same underlying main objective. In fact, on the one hand most of the simulation and optimization models provide a general, modelling framework for simulating traffic flows by calibrating the parameters of the model according to the measure that is being evaluated (although information needed from stakeholders for calibrating the model could vary slightly according to the type of measures investigated). On the other hand, qualitative methods and quantitative methods that use subjective evaluation (e.g. MCDM, discrete-choice models) explicitly include the measure in the evaluation process, hence committing the whole process to that specific measure.

As a matter of fact, modelling techniques mostly investigate measures that intervene on organizational aspects of supply chains, such as consolidation and co-operation schemes (Boerkamps and Binsbergen, 1999; Muñuzuri *et al.*, 2010), or on measures having an effect on the overall logistics costs, such as low emission zones and road pricing (Nuzzolo, Crisalli and Comi, 2011).

Following the classification proposed in section 1.3., the following measures have been found in the reviewed papers:

Table 3 CL measures investigated

Measure	# of papers	%	First paper published
Urban Consolidation Centres	26	43%	1999
Micro-consolidation centres	11	18%	2004
ICT	11	18%	2000
Curb side lay-by areas	8	13%	2008
Time windows	8	13%	2005
Off-hour deliveries	8	13%	2008
Low emission vehicles	8	13%	2013
Restrictions on weight and volume	7	11%	2000
Road pricing	6	10%	2003
Low emission zones	4	7%	2005
Fiscal incentives	2	3%	2008

Infrastructure measures, namely consolidation schemes such as UCCs and MCCs and curb side parking, are by far the most investigated measure in urban freight literature. In fact, 45 infrastructure measures are assessed in at least one paper. UCCs in particular are the most analysed scheme. This is due to their great potential in bringing operational benefits to private stakeholders in terms of increase in inventory control (Browne *et al.*, 2005), and to the environment as well, because goods are consolidated and therefore fewer vehicles are needed for urban deliveries (although this positive outcome is still debated by scholars). Then, 35 CL Regulations such as time windows or road pricing and 19 technology measures such as ICT platforms and alternative vehicles are analysed.

Surprisingly enough, public policies are more likely to be investigated through quantitative modelling. In fact, a larger share of quantitative papers treat Regulations measure compared to the same share of qualitative papers (Table 4).

Table 4 CL domains and type of data used

CL domain	Qualitative methods	Quantitative methods
Infrastructure	85%	52%
Regulations	31%	44%
Technology	77%	21%

The reason for this gap can be traced down to the very nature of most of qualitative: the alternatives are assessed in a subjective way by stakeholders, who are not able to fully grasp the extent of the impact of policy changes on the urban context. Another reason might be related to the current implementation of such methods. These methods found their relevance for most of the recent large-scale European funded projects, which aimed at fostering knowledge sharing and involve all stakeholders in the process. Consequently, the focus might have been towards solutions that provide real operational and economic benefits for private operators, as opposed to public policies that might only increase the complexity of urban freight distribution. Concerning the other two CL domains, it is clear the qualitative papers are able to evaluate more measures, given the fact that they do not need to gather significant amount of data and provide mostly subjective judgement from the stakeholders.

3.1.3.2 Stakeholders

The last remark points out a complete opposite stance on the stakeholders' involvement in the assessment process. Qualitative methods, MCDM and discrete choice models have emerged in the context of urban freight distribution in the last years when the issue of including stakeholders' behaviour became more and more relevant. On the contrary, in the initial period of interest for city logistics the aim of scholars was directed towards freight modelling, since most of them came from transport modelling and operative research fields.

It comes with no surprise that stakeholders are taken into account almost only in some qualitative methods, MCDM and discrete choice models. As a matter of fact, all simulation and optimization based methods considered only carriers, with the exception related to the introduction of receivers (Hunt and Stefan, 2007). Moreover, surveys and methods to assess innovation transferability only take into account carriers, and sometimes citizens (Quak, Balm and Posthumus, 2014) or employees (Patier and Browne, 2010). On the contrary, three papers using agent-based modelling investigated a subset of at least four stakeholders among the most important ones of urban freight, namely shippers, receivers, carriers, citizens and public authorities.

In general, the most assessed stakeholders in CL are carriers, receivers and local authorities, as seen in table 5.

Table 5 Distribution of stakeholders among the selected papers

Stakeholder	# of papers	%	First paper published
Carriers	39	64%	2000
Receivers	29	48%	2007
Local authorities	25	41%	1999
Shippers	13	21%	2005
Citizens / final customers	13	21%	2005
Logistics service providers	9	15%	2003
Other operators	10	16%	2005
Vehicle manufacturers	3	5%	2012

3.1.3.3 Impacts

Finally, six types of impacts are identified, namely Economical, Environmental, Social, Customer and Employee satisfaction, and a last one that represents the effect of the measures on the level of service and the productivity indicators. Different terms have been assigned to the operational category of impacts, namely technical (Awasthi and Chahuan, 2012), transport (STRAIGHTSOL, 2014), logistics (Patier and Browne, 2010) or operational (Anderson et al. 2005).

It is clear from the analysis that the most analysed impact areas are economic, environmental and operational, as the first paper published for each of these areas dates back to before 2004 (Table 6).

Table 6 Impact areas and papers

Impact area	# of papers	%	First paper published
Economic	42	69%	2000
Environmental	39	64%	1999
Operational	34	56%	2004
Social	19	31%	2005
Customer satisfaction	10	20%	2008
Employee satisfaction	4	7%	2010

Moreover, qualitative papers cover a wider range of impacts. For instance, 50% of qualitative methods explore social issues in contrast with only 10% of quantitative papers. Employee and Customer satisfaction are virtually non-existent in quantitative papers. On the contrary, quantitative methods focus more on the operational aspects of City Logistics (Table 7).

Table 7 Distribution of impact areas among qualitative and quantitative papers

Impact area	Qualitative methods	Quantitative methods
Economic	75%	62%
Environmental	63%	66%
Operational	50%	62%
Social	50%	10%
Employee satisfaction	13%	0%
Customer satisfaction	28%	10%

It is also clear that qualitative methods cover a broader set of impacts than quantitative ones. In particular, the conceptual framework validated by the case study of Harrington *et al.* (2016), the BMC by (Quak, Balm and Posthumus, 2014) and the MAMCA papers cover 5 of the 6 impact areas. On the contrary, the more encompassing quantitative methods are the method by Patier and Browne (2010) and the SCBA by Kin *et al.* (2016) with 5 impact areas, the agent-based model by Taniguchi and Tamagawa (2005) and the quantitative case study by Arvidsson and Pazirandeh (2017) with 4 impact areas. It can be noted that all the previous methods take into account the objectives of stakeholders in the evaluation process, both directly as in case studies, surveys or multi-criteria methods, or indirectly as in agent-based models and BMC.

For each impact area, several indicators can be identified. A broad review of urban freight indicators is out of scope of this chapter. However, only by focusing on some papers that presented the most advanced development in this sense it is possible to get some insights on the variety of indicators and their use. Environmental indicators are represented by the reduction of CO2 and other pollutant emissions; operational indicators refer to, for instance, the level of service to customers, the number of stops, the number of deliveries, or the punctuality of pick up and delivery. Some papers provide a more detailed description of urban freight indicators. Patier and Browne (2010) identified 24 core indicators pertaining to 5 impact category: Economic indicators comprise investment costs, customers' satisfactions etc.; social indicators include working conditions and employment. Finally, The STRAIGHTSOL project covers all the main impacts with 31 indicators, such as cost per item or investment costs (Economic impact), employee satisfaction, attractiveness of urban environment or accessibility perceptions (Social and transport system impacts).

3.2 Business model

The notion of business model in literature will be tackled from the dual perspective of strategic and city logistics literature. The first perspective will enable to understand the basic elements of a business model and support the argument that business model is suitable for city logistics purpose. The second perspective instead will provide an overview of the extant efforts in traducing these concepts in CL domain and their shortcomings.

3.2.1 Business model in strategic literature

Business Modelling (BM) provides a framework to evaluate the potential economic value that an organization can create by selling a product or service (Afuah 2004). Moreover, it can be considered as the expression of how organizational variables are set, how a company structures its relationships with external stakeholders, and the consequences of this variables and relationships on the company economic and financial performance (Saebi and Foss, 2015). Johnson, Christensen and Kagermann (2008) consider four different components for a business model, namely customer value proposition, profit, key resources, and key process that together create a business model and deliver value. Value constitutes indeed the focal aspect of a business model, both in terms of value offered to customers and the share of that value retained by the company in financial terms (Barneto and

Ouvrard, 2015). Hence, in summary a business model includes the following components: a value proposition (Chesbrough, 2007); a revenue model adopted to gain a share of the value created (Amit and Zott, 2001); a value chain including key resources, key processes and key partners; and finally a cost structure.

To represent, describe, and analyse all the elements of a business model, several concepts are available in literature (Gordijn & Akkermans 2001; Hedman & Kalling 2003; Morris et al. 2005; Osterwalder & Pigneur 2010). Traditional business model concepts present some drawbacks. For instance, most BM concepts only give a somewhat static rendition of companies' business model, lacking the ability to depict the dynamic changes that occur at a firm level, and to describe how business model principles guide the decision-making of the stakeholders. Another major drawback of business model concepts is their focus on the architecture of the system, rather than on the dynamics that might emerge across the components of the system (Westerlund, Leminen and Rajahonka, 2014). This issue becomes even more relevant where the unit of analysis is not a single company but a network of enterprises, such as the case of CL systems.

3.2.2 Business model in CL literature

To this day, the business model approach has been seldom applied to CL project evaluation. Quak et al. (2014) evaluated the Bentobox solution (i.e. automated parcel lockers for B2C and B2B deliveries) with the Business Model Canvas (BMC) by Osterwalder & Pigneur (2010). The authors state that the BMC helps to show how changes in a CL system result in a better value proposition for customers as well as society as a whole. Moreover, a business case can be constructed using the BMC to define different scenario for the business model.

However, Posthumus et al. (2014) state that with the BMC it is difficult to assess the overall feasibility of a CL innovation taking into account the differences between stakeholders. Hence, they integrate this approach with an assessment on the degree to which CL initiatives have a market viability and an organizational fit. In particular, viability focuses on the customers' side of the BMC, trying to quantify the market size of a CL innovation and the willingness-to-pay of customers. Organizational fit instead measures the degree to which companies need to reshape their existing processes and capabilities after a CL innovation is implemented. Lastly, van Duin et al. (2016) devised a business model framework to assess the value creation processes generated by the relationships between CL stakeholders in Urban Consolidation Centres (UCC). However, there are significant challenges, related to the application of business model concepts in CL. In fact, business modelling has proved to be of value for analysing a single firm's business environment rather than a network of stakeholders (Reuver, Bouwman and Haaker, 2013).

3.3 Agent based modelling

Literature review on agent-based modelling is divided in two parts. First, a general outline of the ABM methodology is proposed, aiming at identifying the value of AB modelling technique and the major aspects that modellers need to focus on. Then, I will delve into the ABM literature applied to the city logistics field.

3.3.1 ABM approach

As previously mentioned, Agent-based modelling for instance focuses on modelling the behaviour of the entities composing a system, together with the interactions among them and the feedbacks they exchange with their environment. AB modelling was conceptualized and developed in order to solve some of the drawbacks that other software engineering approaches showed when modelling complex, distributed systems. In particular, these approaches fall short because the interactions between the entities of the system are too rigidly defined and because they lack the mechanisms for representing the system's organisational structure (Jennings, 2000). As a matter of fact, ABM is shown to be suitable to represent organizational complexities and the interdependencies among organizational design elements and decision-making (Rivkin and Siggelkow, 2003).

ABM modellers argue that unexpected patterns of behaviour in socio-economic complex systems emerge from modelling individual entities as autonomous agents with simple rules, behaviours and local interactions (Macy and Willer, 2002). Agents' behaviours are often non-linear and path-dependent (Bonabeau, 2002). At a system-level, the characteristics of the agents generate processes of self-organization, non-linearity and path dependence. The processes of emergence and self-organization are very important features of AB models, and they imply that some properties belong only to the system as a whole and not to its individual components (Grimm *et al.*, 2005).

AB modellers adopts a bottom up approach to define and represent a complex system, rather than identifying global variables ruling the system as a whole. Hence, there are three funding elements in each AB model:

- A set of agents, together with their attributes and behaviours
- A set of relationships and rules that drives agents' interaction
- The agents' environment

Macal and North (2010) propose a detailed representation of agent's properties:

- Agents are autonomous, as they can function independently from other agents and their environments, and are self-directed.
- Agents have boundaries and can be distinguished easily from other agents
- Agents have a state, representing the variables associated with their current situation. States are composed by a sub-set of the agent's attributes.
- Agents communicate and interact with other agents, and are able to react to the environment. They have protocols that guide these interactions. Interactions are heterogeneous and might generate network effect (Bonabeau, 2002).
- Agents have goals they aim to achieve. This leads them to evaluate the outcome of their actions towards their goals.
- Agents may be adaptive, when they have the ability to learn from experiences and adapt their behaviours accordingly.
- Agents can be reactive, when they only respond to changes in the environment, or proactive when they anticipate the possible state of the system and act accordingly. In both cases, they show problem solving capabilities necessary to achieve their goals (Jennings, 2000)

For each agent, the environment is represented by the component of the system that lies beyond its boundaries. Agents interact for instance with only a subset of other agents, named neighbours (Macal and North, 2010), but are affected by the states of the global system, which can constrain their behaviours (Macy and Willer, 2002; Macal and North, 2010).

3.3.2 Application of ABM to City Logistics

Scholars of City Logistics have only recently turned to ABM as a technique to model and simulate various aspects of the CL topic and as decision support tools for an *ex-ante* evaluation of CL measures and policies (Maggi and Vallino, 2016).

Taniguchi and Tamagawa (2005) integrated ABM with a genetic heuristic algorithm to model a vehicle routing problem (VRP) to minimize transportation and logistics cost with constraints. The authors simulated traffic flows considering stakeholders' behaviours and objectives, aiming at the evaluation of public measures (i.e. ban on commercial vehicles and tolling of urban expressway). A combined approach agent-based with vehicle routing to evaluate city logistics measures has also been proposed by (Teo, Taniguchi and Qureshi, 2012, 2014; van Duin *et al.*, 2012). In particular, Teo, Taniguchi and Qureshi (2012, 2014) include administrators, carriers, producers and customers to evaluate a road-pricing measures within an e-commerce delivery environment. These papers focus on the behaviour of freight carriers, retailers, public administrators, shippers and citizens, as well as other city logistics players such as UCC operators. CL agents mostly interact through flows of money and goods, and the model evaluates the introduction of the selected measures in terms of economic and environmental impact. Adaptive agents learning from previous experiences are modelled in (Tamagawa, Taniguchi and Yamada, 2010) using a Q-learning algorithm to compute the value function of an agent, namely the profit, including the expected values of the agent's future states and behaviours and a learning rate through which the agent adapts its behaviour. The decisions of agents in the previous models are mostly driven by costs and only basic transportation services are exchanged among them. van Heeswijk, Mes and Schutten (2016) adopts a similar approach, but also extend the formulation for the cost function of CL agents, and assign optimization problems to each agent, except for administrators and receivers. Moreover, the authors integrate operational decisions with strategic ones, such as cooperation and collaboration among agents. Finally, the agents in the work of Marcucci *et al.* (2017) are transport providers in charge of transporting the goods on behalf of shippers, retailers hiring third-party transportation services and own-account transport providers, which are retailers in charge of the transportation of their own goods. The objective of the model is slightly different from the previous ones, as it aims to simulate a participatory decision-making process where all stakeholders should reach a consensus on the most suitable CL policies. For this model, the decisions of the agents are strictly limited to the choice between different policy alternatives. This decision is made according to a utility function composed of the attributes of the different alternatives and their coefficients.

The interactions among actors of urban supply chains, regardless of the introduction of CL measures, are also modelled through AB modelling. (Wisetjindawat *et al.*, 2007), include retailers, wholesalers, manufacturers, suppliers, and carriers, interacting with each other within an urban supply chain through information and material flows. The model simulates the demand generation and commodity distribution flows by means of simple rules applied to the agents. However, this model still relies heavily on mathematical formulation and shows no link with some of the properties highlighted for AB models, such as emergence or self-organization. Roorda *et al.* (2010) propose a conceptual framework for modelling urban supply chains and introduce the concepts of business model changes of SC actors. Moreover, SC agents are modelled here in terms of the function or roles they play in the freight transportation system. In the framework built by the authors, business establishments are location agents that can either produce or sell commodities or provide services to other establishments, and may own resources; firms instead are an aggregation of business establishments, and take both business decisions and supply chain operational decisions.

Finally, a deeper, more theoretical exploration on the application of ABM into CL context is represented by the doctoral dissertation of Nilesh Anand (2015). The author provides the first structured and validated ontology of the CL domain, and implements an agent-based model depicting the behaviour of the stakeholders in a properly defined city logistics context (i.e. final customers, retailers, shippers, carriers and local authorities).

3.4 Final remarks

Section 3.1 of this chapter presents a structured representation of the literature, in order to identify advantages and disadvantages of existing assessment methods. Therefore, it aims at increasing the knowledge on the potentialities and drawbacks related to the process of assessing urban freight transport initiatives as a mean to achieve their long-term sustainability. The point of view of this literature review is that CL assessment methods should encompass the objectives of CL stakeholders in the evaluation, provide insights on different impact areas and should be used to evaluate a wide array of CL measures.

Hence, qualitative methodologies show less potential for estimating future trends or the effect of external changes on the system, since they are mainly developed for evaluating specific alternatives. Moreover, a potential weakness of these methods is related to the subjective evaluation of quantitative outcomes, which may potentially influence the ranking between different alternatives. On the other hand, quantitative models provide simulation frameworks for traffic flows and consumers' demand, and have more potential for the integration with changes in stakeholders' behaviours or the dynamic introduction in the system of new measures. However, simulation models usually need high quality of data for the development and validation.

Only some of the analysed methodologies propose sets of performance indicators to evaluate the overall success of an initiative. Moreover, we have found that there are no clear indications to be found in the papers reviewed for integration within an *ex-post* evaluation framework of the indicators, which are mostly identified and categorized for the *ex-ante* scenario evaluation. In this sense, it is argued here that a proper assessment methodology should make leverage on the indicators for the continuous monitoring of the performance of the measure implemented. However, a strong barrier hinders the development and use of such methodologies: the lack of detailed data available to public and private stakeholders.

Finally, the trend that has emerged in the reviewed literature shows that more efforts are put towards the involvement of all the stakeholders in the evaluation process, through methodologies such as agent-based modelling and MAMCA. More precisely, 2012 marks a year after which the relative importance of qualitative vs. quantitative methods switches towards qualitative methods. In fact, 26 out of 39 quantitative papers have been published before the end of 2012, whereas 17 of the 22 qualitative papers have been published after 2012 (Figure 1).

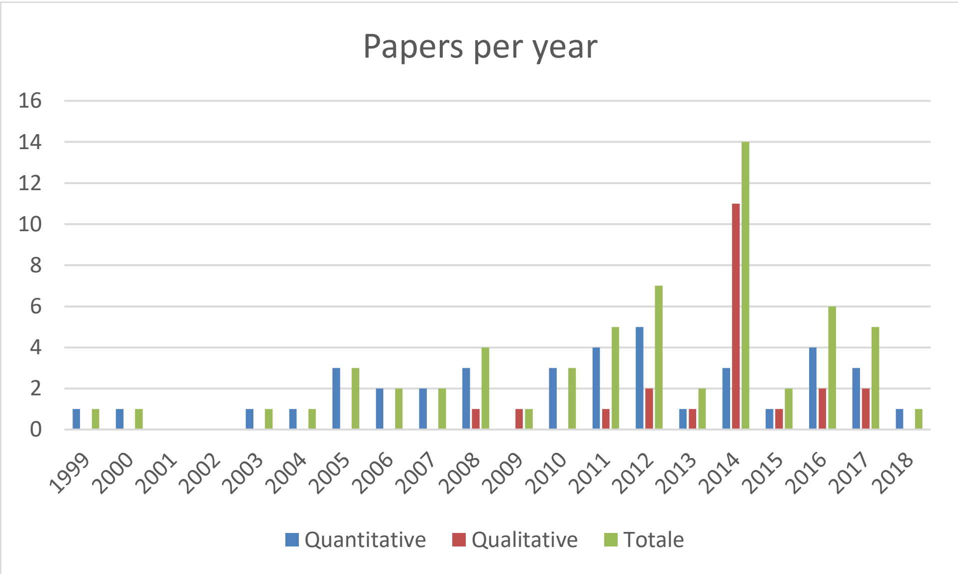

Figure 2 Papers per year, divided in qualitative and quantitative

This is considered a shift from the initial development that mainly opted for transport system modelling and scenario simulations based on quantitative data retrieved from survey and other secondary sources data. Future development in urban freight assessment, such as the interactive MAMCA, CL living labs or agent based modelling for decision-making, are currently deepening the debate on stakeholders' interaction and involvement.

From the literature, agent-based modelling has emerged as one of most promising quantitative methods to account for a comprehensive view of the CL issue within a simulation framework. ABM has been used in CL for a wide variety of purposes, from providing more fine-grained details on stakeholders' behaviours in optimization problems, to modelling the interactions among CL stakeholders and their decision-making processes and attributes. Hence, any effort in ABM for CL should consider these existing approaches.

Moreover, business-modelling approaches such as the BMC can provide an insight into the long-term economic feasibility of CL projects. However, more research is needed to bridge the research gap emerged in the literature. In particular, it has been found that with traditional Business Model approaches, it is not always easy to evaluate the overall feasibility by taking into account the perspective of different stakeholders, and that these approaches are better suited to assess a business model of a focal company rather than of a network of companies.

Chapter 4

A theoretical framework for CL business ecosystems[5]

The purpose of this chapter is to overcome the shortcomings of the business model approach applied to CL systems. Moreover, this chapter aims to overcome existing issues in business oriented dynamic assessment tool for CL, thus supporting the ability of researcher to gain insights of the potential for long term success of CL systems. In this chapter, the following research question will be answered:

How can we setup a business modelling approach to understand the dynamic decision making process of the CL stakeholders?

In order to give an answer to this question, CL systems are here compared to business ecosystems, which are a network of interrelated business entities, characterized by value transfer and value co-creation mechanisms (Wang et al. 2015), operational transactions and interdependencies between business entities (Solaimani et al. 2015).

The decision-making processes by various stakeholders and the resulting dynamics and impacts on the CL system seem to fit with the outlined characteristics of business ecosystems. Moreover, a role-based modelling approach is adopted to provide a business model representation of the CL business ecosystem able to

[5] Chapter based on the paper: Zenezini, Giovanni, Ron van Duin, Lorant Tavasszy, and Alberto De Marco. "Stakeholders' Roles for Business Modelling in a City Logistics Ecosystem: Towards a Conceptual Model." In 10th International City Logistics Conference. 14-16 June, Phuket, Thailand: Institute for City Logistics, 2017.

identify and explore the components of the system and their dynamics. In this ecosystem modelling framework, roles are defined as “an aggregation of common functions, including activities, decisions, and metrics” (Tian *et al.,* 2008). In this sense, while the role definition does not change, business entities make decisions in reaction to the changes in the ecosystem by taking on certain roles in the CL system. These decisions are based on their objectives, information, and constraints. The business model of a business entity within the system is then defined as the set of the roles it plays, the business and operative relationships formed with other business entities, and the monetary and intangible values exchanged through these relationships.

In order to show the contribution of the CL business model framework some existing CL concepts are illustrated and analysed under the lens of the framework, including cases of Urban Distribution Centre (van Duin *et al.*, 2016) and parcel lockers installation (Weltevreden, 2008).

The structure of the chapter is the following. First, in the next section the theoretical background for this chapter is reviewed. Then, the CL ecosystem business model framework is presented, and some CL concepts are depicted through its lens. Then, a process for the formalization required for the Agent Based Model implementation is shown, and finally implications are drawn.

4.1 Literature review

4.1.1 Business Ecosystems

Theoretical and practical frameworks for designing and assessing business models and decisions “assume that the strategic outcome can be defined independently of the reactions of other players” (Tian et al., 2008). However, a key challenge that is not completely dealt with the business model concept lies in characterizing the relationships among business entities, and understanding how decisions taken by one entity affect other interrelated entities (Tian *et al.*, 2008). In some sectors, companies intermingle to provide services, thus taking the form of business ecosystems (or network). The definition of network of interrelated companies as Business Ecosystems (BEC) stems from ecology, which depicts biological ecosystems as complex system of organisms and relationships amongst them (Battistella, Colucci and Nonino, 2013). Likewise, within business ecosystems “firms interact in complex ways, and the health and performance of each firm is dependent on the health and performance of the whole. Firms (….) are therefore simultaneously influenced by their internal capabilities and by their complex interactions with the rest of the ecosystem” (Iansiti and Levien, 2004). BECs are characterized by value transfer and value co-creation mechanisms (Wang, Lai and Hsiao, 2015), operational transactions and interdependencies between business entities (Solaimani, Bouwman and Itälä, 2015). Business entities (BE) composing a BEC can at the same time co-operate, to improve the growth of the business ecosystem, and compete for market shares (Battistella, Colucci and Nonino, 2013).

In the literature, several tools are available for modelling business ecosystems and analysing the impacts of different business decisions taken by the business entities operating within the business ecosystem. A dynamic approach to business ecosystem design and analysis is provided by the role-based modelling approach (Tian *et al.*, 2008; Ok *et al.*, 2013). In this ecosystem-modelling framework, business entities can play multiple roles and make decisions reacting to the changes in the ecosystem over time, and based on their objectives, information, and constraints.

4.1.2 Role-based networks and ecosystems

The concept of roles within a network of companies has been used in different research streams, such as closed-loop supply chains (Savaskan et al., 2004), supply network management (Harland and Knight, 2001) or the management of innovation (Story, O'Malley and Hart, 2011). The basic notion of roles underlines that companies perform different functions within a network of companies (Pohlen & Farris, 1992) and that an actor performs a specific role when necessary (Story, O'Malley and Hart, 2011). As a matter of fact, the overall network profit is affected by the organizational structure underlying the assignment of actors to the role played, taking into consideration that different actors are able to take on the same role. To this notion, most authors argue that, to some extent, it is possible to single out the actor most fit to perform a certain role, through either qualitative inquiry or mathematical estimation (Savaskan et al., 2004). Harland & Knight (2001) stress that it is necessary to understand and develop roles specific competences in order to be proactive in the network. The authors also argue that organization can adjust the role played in managing the network, and thus respond to factors that have an impact on their performance by taking on different roles.

Roles are defined as a bundle of different functions and activities, but since companies can perform similar functions the distinction between the roles can be somewhat blurred, and this could generate problems and conflicts between actors. In the proposed CL role-based business model framework, an effort is posed on overcoming this issue by sharpening the definitions of role so to create clear boundaries between them.

4.2 Role-based view of CL business ecosystems

The role-based approach to modelling CL as a business ecosystem seem to be suitable for our research objective for several reasons. First, it allows unpacking the CL system down to its main component and functions so to underline their relationship and the value creating mechanisms generated among them. This is done by embedding logistics activities and physical flows at the role level. Second, the evident separation between business entities and their functions (i.e. roles) enables a certain degree of freedom to design and assess different business model configuration where business entities play different roles and the same role can be played by several business entities alternatively. This further enhances the transferability of the ecosystem concept to the available city logistics projects and initiatives. Third, the inclusion of metrics to measure the performance of each role enables the modeller to incorporate the decision-making criteria of the business entities for role assignment purposes. As a matter of fact, decisions from Business Entities to take on a role and sign new logistics contracts take into account the operational aspects entailed with that specific role.

4.2.1 High-level concept

The proposed modelling framework is built for defining and structuring a wide range of business model configuration of roles and business entities in a CL system. The main pillars of this framework are Roles and Business Entities (BE). Roles are a composition of activities, decision, and metrics. To be more specific, Role *k* is defined as:

$$R_k = \{A_k, D_k, M_k\} \quad (1)$$

Where A_k, D_k and M_k are sub-sets of activities, decisions and metrics available in the ecosystem.

Business entities can play multiple roles inheriting the role's specific activities, decisions and metrics, but they also have entity-specific attributes and relationships. This allows BEs to compete or cooperate with other BEs based on their performance analysis of the roles they are playing.

Goods and services flow between BEs in return for revenues, since BEs own monetary resources, enter into logistics contracts and acquire services from other BEs. Then, the value exchanges of money, goods and services, as well as the intangible benefits (e.g. value proposition) are dependent on the role assignment, and are thus created (or co-created) and exchanged during the actual execution of the roles.

The business model of a business entity (BE) is identified with the set of roles the BE is playing and its relationship with other business entities, which are substantiated through value exchanges and logistics contracts. This will lead to the coexistence of different business models in the system, such as the case with multiple traditional LSPs operating for different customers in the same city. Hence, each CL business ecosystem consists of a set of BEs, Roles and assignment of BEs to the roles, and it represents only one possible configuration of the system's stakeholders and interactions.

A high-level depiction of the role-based view of CL is shown in Figure 3.

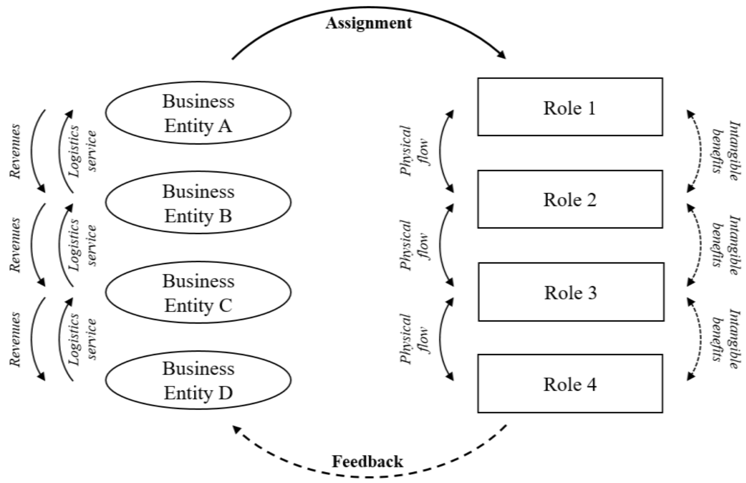

Figure 3 Roles, BEs and flows

In a business ecosystem, the interrelations between resources, activities, and decisions are fundamental. As anticipated, a BE performs activities and requires investment in resources to build a sustainable business model. The specific business model determines which BE takes certain decisions as well as the partnership model. These decisions have an impact on activity execution, and metrics are used to assess quantitatively the outcome of activity execution so to evaluate the role-playing performance (Table 8).

Table 8 Elements of the framework

Component	Definition	Properties
Resource	Resources are owned by the business entities and are necessary for the CL roles to be performed.	*Owner* *Unit cost* *Operational characteristics*
Activity	Activities are performed to offer a service, and they consume resources	*Resource usage*
Metric	KPI measuring a certain business object, namely activities, resources, value proposition exchange, business entity, ecosystem.	*Business object* *Value*
Decision	BEs make operative and economic decisions in the fulfilment of their roles, based on a set of constraints, variables, decision parameters.	*Objective* *Decision variable set* *Constraint set*
Service	Aggregation of activities that use resources and are characteristics of a role.	*Service attributes* *Activity set*
Value Proposition	Value proposition is a set of service offering characterized by different attributes that are valued by users by assigning weights to the attributes.	*Provider and user* *Logistics services* *Weights*

4.2.2 Role definition

The theoretical and practical underpinnings of the roles definition within a CL system are multiple.

The whole set of available roles must compose a physical representation of the overall logistics process of door-to-door delivery from the supplier to the receiver in urban areas. Each CL configuration thus comprises the following basic logistics services:

- Delivery of goods from suppliers to a distribution centre located in the outskirts;
- Goods consolidation through cross-docking goods from different suppliers, assignment to freight vehicle and delivery routes planning;
- City delivery with light commercial vehicles, which can be either traditional engines vehicles, electric or other environmentally sustainable vehicles

Two types of role are modelled: provider roles and user roles. Provider roles target customers with their services and value generation, and set cost and level of the service. User decides whether to adopt the logistics services by evaluating the potential benefits.

The boundaries between the roles have to be defined in a clear-cut way so to identify the most basic elements of a CL ecosystem that are still capable of providing value to the ecosystem and entice BEs to develop a sustainable business model around them.

New CL operators such as Urban Distribution Centres, green delivery operators, micro-consolidation centres or ICT logistics management platforms fit in the system as BEs that provide value added services to other BEs either by either improving role performance or creating new logistics value and business relationships. A detailed description of CL roles is shown in table 9.

Table 9 CL Business Ecosystem Roles

Role	Activities	Decisions	Tangible benefits	Intangible Benefits	Resources
Receiver	Ordering process Inventory management Inbound operations Payment for delivery Evaluation of level of service Evaluation of intangible benefits	Estimate demand and decide stock levels Inventory policy: EOQ, Frequency of delivery, time of delivery	Cost efficiency: reduce order cycle times and inventory levels (Moberg *et al.*, 2002; PLS Logistics, 2015) and transaction costs (Yamada *et al.*, 2011);	Product availability and right assortment (Booz-Allen Hamilton, 2003); Shorter lead times; Flexibility on delivery times (Vieira and Fransoo, 2015); Real time information on delivery time (Vieira and Fransoo, 2015);	Storage capacity Personnel EDI / PoS tools
User of goods consolidation and logistics service	Usage of logistics service Payment for logistics service Evaluation of level of service Evaluation of intangible benefits	Amount of service required Deciding which logistics and transportation service to subscribe; Adopting and maintaining a CL solution	Cost efficiency: reduce inventory levels and management cost (Moberg *et al.*, 2002; PLS Logistics, 2015); warehouse operations efficiency	Product availability and right assortment (Booz-Allen Hamilton, 2003); Shorter lead times; Focus on core business Reduction of total deliveries through freight consolidation;	Money
User of transportation services	Usage of transportation services Payment for transportation Evaluation of level of service	Selection of transport supplier: e.g. to 3PL for door-to-door, 3PL for long distance plus City Delivery for last mile, freight carrier for direct delivery Adopting and maintaining a CL solution	Reduce transportation costs Cost efficiency: handling/inventory, outbound operations, transaction costs (Yamada *et al.*, 2011);	Quick delivery; Quality and reliability of logistics service, including customer support (Vieira and Fransoo, 2015); Environmentally friendly delivery service (Veenstra, Zuidwijk and Van Asperen, 2012)	Money
City delivery	Delivery Tracking and monitoring Vehicle routing planning Green delivery Off-hour deliveries Waste recollection	Pricing scheme Vehicles purchase (environmentally friendly or not) Operative decisions on fleet allocation and routing Level of service provided	Payment for Delivery; Cost efficiency: loading/unloading operations (Punakivi and Tanskanen, 2002)	Brand recognition and improved customer relationship from direct contact with final customer Access to traffic information and other information on city status e.g. on loading bays availability (Vieira and Fransoo, 2015); Quality of life (e.g. less stress)	Cross-docking platform; Light commercial vehicles; Logistics personnel and trained drivers; ICT equipment

Goods consolidation and logistics service	Inbound operations Cross-docking Warehouse and inventory management Pre-retail services (packaging, labelling etc.) Inventory monitoring (Browne *et al.*, 2005) IT support	Pricing scheme Resource acquisition Marketing effort (Tian *et al.*, 2008) Level of service provided	Payment for pre-retail services; Payment for buffer storage; Sustainable source of revenues from long-term agreement with customers; Cost efficiency: handling/inventory management, outbound operations	Long-term business relations with customer, to increase revenues and assets maximization;	Urban Distribution Centres, including material handling equipment; Logistics personnel; Marketing personnel; ICT Equipment
Network coordination	Data collection and harmonization Data interface development Event management (e.g. traffic control) Platform operation and maintenance System update Marketing and communication Customer support	Pricing scheme Server acquisition Data quality control Customer service level Staff allocation and marketing effort	Payment from platform services	Competitive advantage through capacity building and customer relationships	Server Data ICT Platform Staff
Real estate development and management	Managing space	Introduce innovations (Posthumus *et al.*, 2014);	Increased revenues from rental fees and number of retailers	Attractive business environment	Rental space
Policy maker	Enforcement Collecting data Collecting freight related fees Evaluate level of service Evaluate intangible benefits	Policy selection Resource acquisition Choice of outsourcing data management services Adopting and maintaining a CL solution	Fees from freight policies	Reduction of the number of vehicles: decrease in emission and congestion level; more livable environment	Enforcing resources Data collecting resources

For instance, a traditional logistics service provider that normally provides logistics services to shippers and retailers will combine the roles of goods consolidation, pre-retail logistics service provider (e.g. packaging, labelling), city delivery, and either long distance transportation first hand or by outsourcing as a freight forwarder (i.e. user of transportation services) (PIT Logistics Consultancy, 2016).

4.3 Case studies

Three existing CL concepts are represented to provide insights into how the CL business model framework can be adopted. As previously mentioned, data and information for the case studies have been retrieved from the literature (Van Rooijen & Quak 2010; TRAILBLAZER, 2010; van Duin et al., 2016), company reports and interviews with the stakeholders involved.

4.3.1 Installation of Automated Parcel Lockers station

The example presented in this summary shows a case of a BE operating a network of parcel lockers located in the cities of Amsterdam and Nieuwegein (both in the Netherlands), namely MyPUP[6]. After signing up, customers make their online purchase and set the delivery address provided by the company (i.e. their distribution centre) and receive a code to open the box containing their package. Couriers then deliver goods to MyPUP's distribution centre on behalf of the shippers. Usually these companies guarantee for tight delivery schedules, as they offer same-day delivery (i.e. customers can pick up their purchase before 17). MyPup targets big employers as customers by installing parcel lockers inside major office buildings. The value proposition lies on the ground that if employees ship their items to an unmanned automated locker it will relieve the additional workload at the reception desk of the employer. On the operational side, MyPUP owns and operates its distribution centre as well as a vehicle fleet in Amsterdam. This is going to change soon as the company is planning to outsource all its city delivery operations to Van Straaten Post.

In this system configuration, MyPUP is acting not only as a cross-docking decoupling point at its distribution centre, but also as a receiver through the parcel lockers. It has to be noted that associating the role of receiver to the same company that provides the delivery service is consistent with the industry practice. In fact, the delivery process under the responsibility of express couriers ends as soon as the goods are correctly inserted in the parcel locker. MyPUP is therefore com-

[6] https://www.mypup.nl/en

peting with the same role as the Express Couriers by adding an additional consolidation point and introducing a new customer in the network, namely the employer. Express Couriers thus cease to act as user of city delivery services, since the delivery process under their responsibility ends at the MyPUP distribution centre (Table 10).

Table 10 Role assignment, MyPUP

Entity / **Role**	Express courier	City Freight carrier	UCC operator	Online retailer	Employer / Facility Manager	Final customer
Receiver			X			
User of goods consolidation				X	X	X
User of city delivery (CD) services			X			
City delivery (CD)		X	X			
Goods consolidation		X	X			
Network coordination	X		X			

It is clear in this case that all roles are being played by at least one BE, and that the new operator in the system adds complexity to the system by taking on multiple roles at once. Therefore, it is important to highlight the consequences of these role shifts at the BE level. For instance, MyPUP has to invest in parcel lockers and distribution centres. Employers become potential users of logistics services and are called to make a decision on the instalment of MyPUP parcel lockers in exchange for a monthly fee.

The interactions between BEs are also subjected to the perturbation brought by the new business model configuration. First, new freight delivery contracts have to be signed between MyPUP and Van Straaten Post. Second, MyPUP and the Express Couriers delivering goods on behalf of the shippers need to find some form of agreements as to the daily arrival time of the goods at the MyPUP distribution centres. As a matter of fact, MyPUP can provide same-day delivery only if Express Couriers are committed to deliver the parcels by 17:00. This kind of commitment can also be enforced if mutual benefits derive from the MyPUP service to both MyPUP and Express couriers. For instance, couriers might benefit as they disengage from the last leg of the delivery process which accounts for a large share of the total logistics cost. However, with the introduction of a new BE and new service the importance of the Network coordination role increases, and this increase is borne also by Express Couriers, who have to provide reliable and timely information on the vehicle arrival to MyPUP. Moreover, both Express Couriers and MyPUP need to integrate their ICT systems. These considerations are shown in Table 11. Figure 4 depicts the overview of MyPUP business model.

Table 11 Role shift in the MyPUP case

Role	**Business Entity (existing configuration)**	**Business Entity (new configuration)**	**Main changes**
Receiver	Employer / Facility Manager	UCC operator	Investment in parcel lockers
User of goods consolidation	Online retailer Final customer	Online retailer Final customer Employer / Facility Manager	Decision to adopt MyPUP service Monthly fee from Employer
User of CD services	Express courier	UCC operator	New freight delivery contracts are signed
City delivery	City freight carrier	UCC operator City freight carrier	
Goods consolidation	Express courier	UCC operator	Investment in distribution centres
Network coordination	Express courier	Express courier UCC operator	Commitment to punctuality Information sharing ICT systems integration

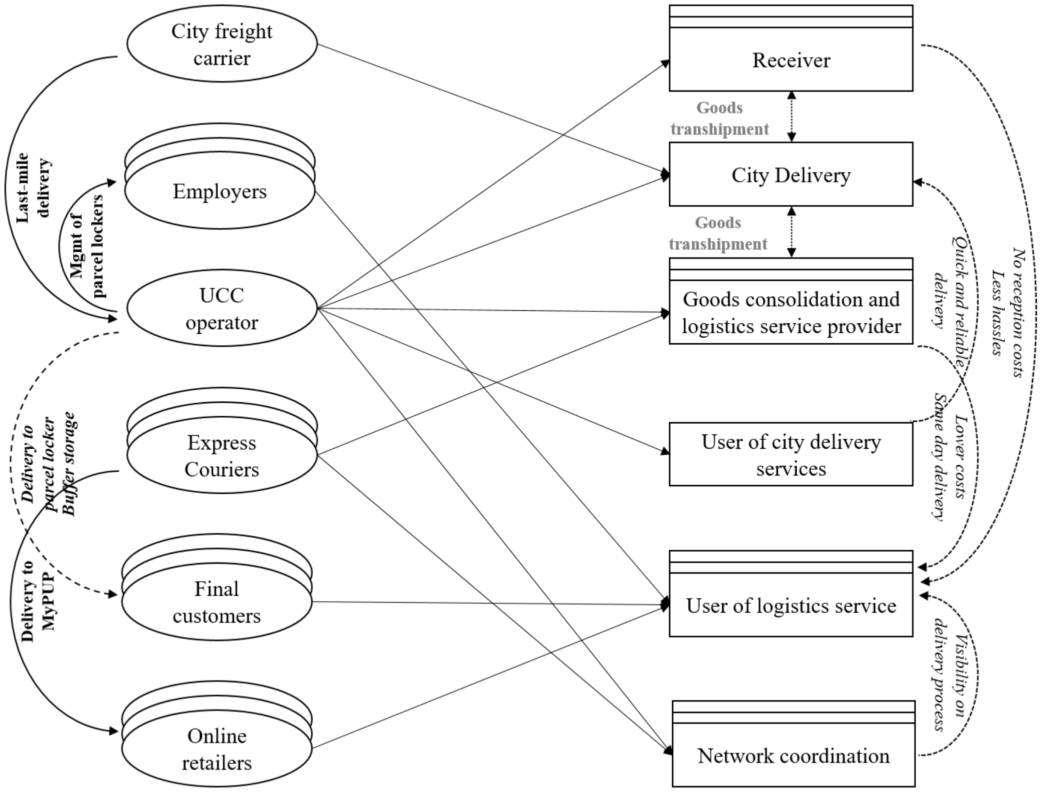

Figure 4 MyPUP ecosystem business model configuration

Three considerations can be drawn:

- MyPUP offers a service to a combination of users. In fact, it relieves the employer from the inbound operations and it delivers to the parcel lockers to generate "buffer storage" for the final customers. However, only employers pay for MyPUP services;
- The number of roles played by MyPUP increases the complexity of the systems, and reflects on all roles. In particular, Network coordination gains relevance as it is played by two BEs;
- There is no direct connection between MyPUP and the Express Couriers in terms of services and revenues. This can represent a potential shortcoming of the proposed business model since they have to jointly coordinate the logistics network;

At the physical network level where the roles interconnect and goods flow, the role-shift paradigm has its counterpart at the activity level. The major changes in this case take place within the roles of Receiver, User of goods consolidation and logistics services, and Network coordination.

4.3.2 Urban Consolidation Centres

4.3.2.1 Bristol UCC

This is a consolidation centre set up by the local city council and operated by DHL Exel, a subsidiary of DHL. The UCC consolidates goods destined to retailers in the Central Business District (CBD), and then it operates an electric vehicle fleet to deliver them at the shops in the CBD. Besides subsidies provided by the local city council, which accounts for 45% of operative costs, the revenue streams come from retailers and express couriers. However, even though these stakeholders pay the same delivery fee for the last-mile delivery (12 pound/pallet or 9.75 pound/cage), the logic behind the two revenue streams differs completely. In fact, for express couriers this represents a business-as-usual situation, where they outsource the last-mile delivery to a freight carrier. Local retailers instead pay the last-mile delivery service by the UCC as a “reimbursement” for the real service, which is the extra storage provided by the UCC associated with the flexibility of deliveries. The delivery fees are kept competitive to increase the attractiveness to the customers; this price competitiveness however could be put in jeopardy once subsidies are terminated.

The UCC operator obviously takes on the role of logistics service provider, integrating it with the city delivery role. Consequently, express couriers become user of city delivery services offered by this new BE. The local administration provides subsidies to the UCC and thus can be considered as a user of its services. This link is debatable since there are no actual logistics services exchanged; however, the UCC could bring intangible benefits that translates into a service to the local administration, under the form of a reduction in the number of freight vehicles in the city (Table 12).

Table 12 Role assignment, UCC Bristol

Entity **Role**	Express courier	UCC operator	Local retailer	Supplier	Local administration
Receiver			X		
User of goods consolidation			X	X	X
User of CD services	X		X		
City delivery		X			
Goods consolidation	X	X			
Network coordination	X	X			

In this case, therefore, the same network coordination mechanism applies. In addition, new freight contracts are signed, and the UCC operator has to invest in a vehicle fleet. This may lead to conflicts with the existing freight carriers. The business model of this UCC is relatively complex, as multiple stakeholders are involved in the revenue stream to the UCC operator. Table 13 and Figure 5 depict the major role shifts and the overall business model.

Table 13 Role shift in Bristol UCC

Role	**BE (existing configuration)**	**BE (new configuration)**	**Main changes**
Receiver	Local retailer	Local retailer	Less deliveries, less time for handling operations
User of goods consolidation	Supplier	Local retailer Supplier Local administration	Subsidies
User of CD services	Express courier	Express courier Local retailer	New freight delivery contracts Lower delivery fee Investment in vehicles
City delivery	City Freight carrier	UCC operator	
Goods consolidation	Express courier	UCC operator	Investment in distribution centres
Network coordination	Express courier	Express courier UCC operator	Commitment to punctuality More information sharing More data processing

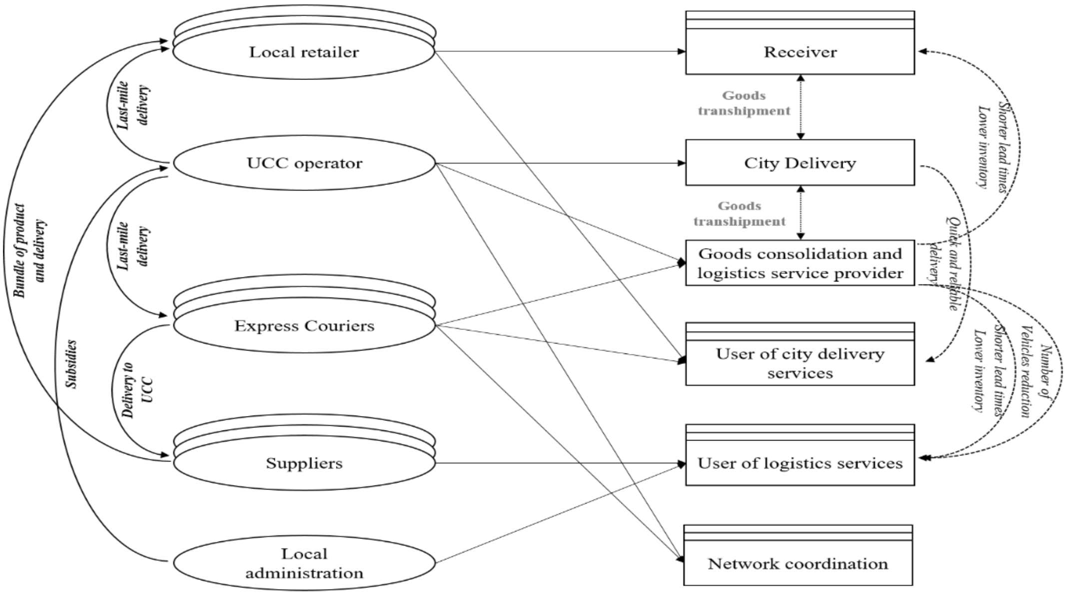

Figure 5 UCC Bristol ecosystem business model configuration

From a business model perspective, the link between the UCC operator and the Local Administration is rooted only in the intangible benefits that are potentially achievable rather than in an actual exchange of services. This shortcoming could be resolved if, theoretically, the UCC would commit to an annual objective of reduction in the number of vehicles. Moreover, there are some potential shortcomings on the local retailers' side. First, given the fact that they pay for the last-mile delivery on top of the delivery from the shipper to the UCC, they could maintain the same overall delivery cost only as they are able to renegotiate the delivery price to the UCC with shippers and express couriers. Second, while they benefit for goods consolidation at the UCC they do not pay for this service.

4.3.2.2 Binnenstadservice

Binnenstadservice is a company operating a network of urban consolidation centres in Dutch cities. It focuses on offering goods consolidation and other logistics services (e.g. delayed cross-docking, home deliveries, waste returns) to small local retailers. Retailer pay a basic membership cost between 30 to 50 euros per month, and an additional cost for the extra logistics services. The last-mile delivery is outsourced to freight carriers at 3.75 euro per stop. Moreover, Binnenstadservice aims to target shipper by offering them an ICT system integration package[7] that provides a single interface to receive real time Proof of Delivery

[7] https://www.mixmovematch.com

(POD) for all their shipments and enables them to combine shipments per geographical areas (Table 14).

Table 14 Binnenstadservice role assignment

Entity **Role**	Express courier	City Freight carrier	UCC operator	Local retailer	Supplier
Receiver				X	
User of goods consolidation				X	X
User of CD services			X		
City delivery		X			
Goods consolidation	X		X		
Network coordination	X		X		

Binnenstadservice acts as logistics service provider and organizes the last-mile delivery process, as in the MyPUP case. As in the previous UCC case, both Binnenstadservice and the express couriers perform the role of goods consolidation and logistics service provider. Finally, local retailers can take advantage of a decreased number of deliveries and a lower inventory, which are typical benefits of a receiver, by being proactive and shifting towards the role of logistics services' users. Moreover, Network coordination is a role where Binnenstadservice, together with an ICT partner, put considerable effort in order to offer a valuable service and provide intangible benefits to shippers. The main components of Binnenstadservice business model are shown in Table 15 and Figure 6.

Table 15 Role shift in Binnenstadservice

Role	**BE (existing configuration)**	**BE (new configuration)**	**Main changes**
Receiver	Local retailer	Local retailer	Less deliveries Lower inventory
User of goods consolidation	Supplier	Local retailer Supplier	Membership fee Extra value added services
User of CD services	Express courier	UCC operator	New freight delivery contracts
City delivery	City Freight carrier	City Freight carrier	
Goods consolidation	Express courier	UCC operator	Investment in distribution centres
Network coordination	Express courier	Express courier UCC operator	Systems integration More information sharing

			More data processing

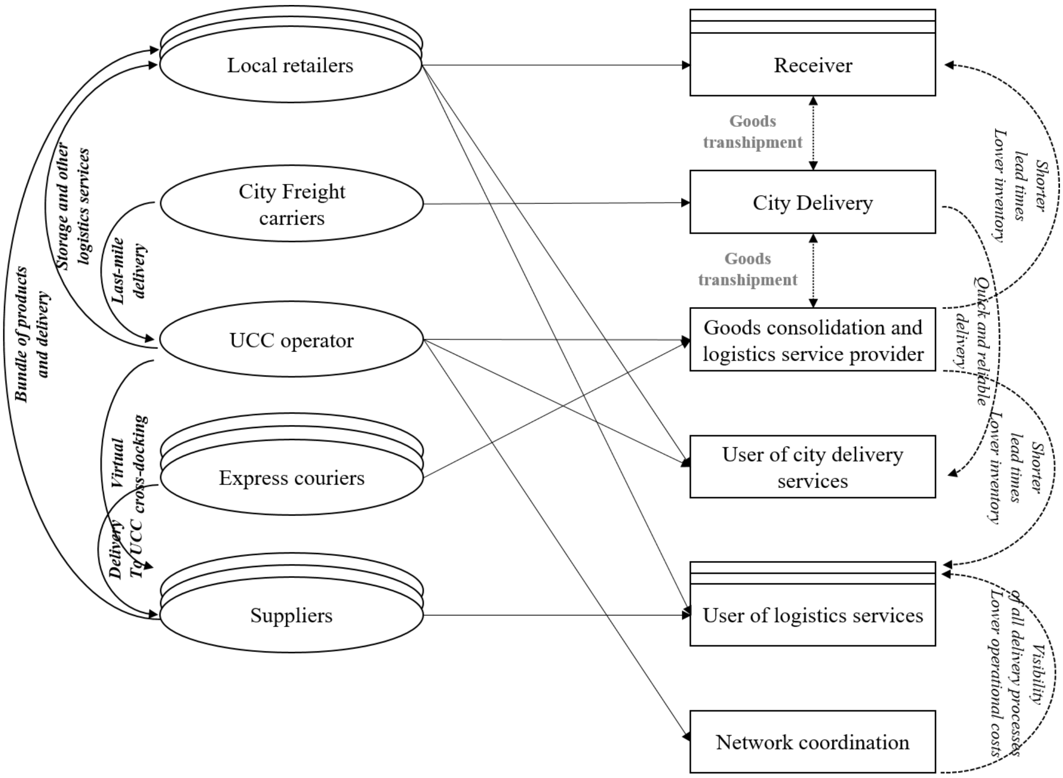

Figure 6 Binnenstadservice ecosystem business model configuration

4.4 Discussions

The previous cases represent different possible configurations for a CL systems new business model. MyPUP is one example of such new business models. The company takes advantage of the fact that it is not profitable for employers to act as receiver, since it is not rewarding for them and it generates hidden costs of in-bound operations. The key to become profitable and attractive towards employers is to evaluate correctly the value of the solution from the employers' point of view, and propose a service fee lower than that value. Furthermore, MyPUP becomes a logistics service provider, competing with larger firms. The decisive factor here instead is to improve the goods consolidation and logistics service provider role performance, and find a coordination mechanism with the express couriers in absence of a contractual agreement.

The Bristol UCC operator aims at financial sustainability by gaining revenue from multiple sources, including the couriers. However, there is no clear business model innovation and additional value provided to the couriers. Taking into account the door-to-door delivery process, the Bristol UCC acts as an additional decoupling point bearing operational costs without additional value to exchange for higher revenues. Moreover, the UCC operator performs the role of city delivery and offers the service to the local retailers, which have already paid for a part of the delivery process and are not always able to negotiate a reduction of delivery fees with shippers and couriers. Hence, acting as both logistics service provider and city delivery might not yield good sustainability of business model. Being valuable towards retailers and receiving revenues from them for this value might be the possible solution for a sustainable business model, as in the case of Binnenstadservice.

A very important role that each of the previous new BEs had to perform and develop skills and resources for is Network coordination. As previously mentioned, when the complexity and number of the linkages among BEs and roles increases Network coordination ensures that the delivery goes as smoothly as possible and different supply chains integrate seamlessly. On the operational side, it is often required that new BEs develop integrated ICT platform from scratch. Network coordination does not only help stakeholders to switch to the new business model, but could also provide additional value and constitute a profitable service, as in the case of Binnenstadservice.

4.5 Conclusions

The theoretical CL business ecosystem framework depicts the dynamics between the components of the system, namely the interrelations between BEs and Roles, in addition to portraying a snapshot of the architecture of the system. Furthermore, it creates links among decisions that are taken by different stakeholders and at different level of granularity of the system. In this sense, by using the CL business model framework it is possible to draw the implications of higher-level business decisions on the operational processes of a CL system. This linkage works both ways, as the decision from a Business Entity to take on a role and sign new logistics contracts should take into account the operational aspects entailed with that specific role.

From a practical point of view, a major contribution of the proposed CL ecosystem business model framework lies in the fact that it assesses the feasibility of a network configuration rather than a specific measure. One important advantage of this consideration is that it provides an evaluation tool able to go beyond the context in which the CL measure is implemented e.g. geographical are, demand and location of customers, revenue model, and operational model.

Some challenges and limitations of the proposed framework are noteworthy and allow for further research on the issue. First, while the identification of roles metrics is quite straightforward when they are concerned with tangible objects such as services and resources, it is much more complex when intangible benefits are exchanged between roles and business entities. Then, the value of information is not properly assessed and information only serves as constraints to the role assignment procedure. Information exchange are important because they can both influence the performance of some roles up to the point that some assignment are not feasible. As a matter of fact, BEs require certain type of information to perform specific roles. However, the implications for the role assignment of the value of information are not assessed in this chapter and provide for an interesting further development.

Chapter 5

An agent-based model proposal for CL business ecosystems

As previously mentioned, the complexity in CL ecosystems stems from the objectives and decisions of different stakeholders, which use different sets of evaluation mechanisms and take different decisions when facing such complexity.

In this chapter, I will outline the methodological steps taken to conceptualize and formalize the theoretical framework proposed in the previous chapter. The objective is twofold. First, to formalize all the features of a CL business ecosystem in order to provide a more grounded approach to modelling the context at issue, moving the high-level conceptual tool. Second, to build an ontology to model and simulate various configuration of a CL business ecosystem, hence creating a reference model for future implementation.

The objective of the ABM for CL business ecosystems is to build on previous experiences and moving further on towards the dynamics of commercial and business interactions taking place in the real world. In this sense, this ABM proposal aims to provide a tool to evaluate the outcome of different CL initiatives, and the promoters of such initiatives in order to gain the trust of other stakeholders and involve them in the process can use this tool. As a matter of fact, different interactions between agents have to be modelled according to the initiative that is the focus of the evaluation process (Knaak, Kruse and Page, 2006).

Several guidelines or approaches to Agent-Based modelling exist in the literature. For my ABM proposal I adopted the approach given by van Dam, Nikolic and Lukszo (2013), which propose a sequence of methodological steps for the development of an ABM. Literature review and verification with CL experts and practitioners are used to retrieve information needed to complete the different steps of the procedure.

After a first section on ABM literature, the structure of this chapter follows the methodological steps outlined by van Dam, Nikolic and Lukszo (2013). These steps include problem statement and system identification, followed by concept and model formalization. Finally, guidelines for software implementation and model verification are outlined in section 5 and 6.

5.2 Problem Statement and System Identification

Agent-based model are usually built to tackle issues deriving from a lack of knowledge about the structure of a real-world system, its behaviour and the response to different stimuli and inputs. Two very important questions that we need to ask ourselves when building an ABM are i) "whose problem are we addressing?", and ii) "which actors are involved?"

In the following sections, I will outline the response to these two questions that guide the modeller in stating the problem and identifying the system at issue.

5.2.1 Problem Owner

As previously mentioned, many CL projects fail to scale up or fail altogether because actors involved in new business ventures and CL innovations have an inadequate grasp of the business motives of other ecosystem actors that engage in such innovations and are crucial to their success. Moreover, the subsequent dynamics that arise from business motives and interactions among "proposing" actors and other actors intensifies the complexity of the problem. In this context, promoters of CL innovations face the challenge of involving other stakeholders without a complete knowledge of the potential outcomes of such projects. Therefore, the major problem owner of the proposed ABM is the stakeholder, or group of stakeholders, that comes up with an idea of an innovative CL solution and intends to design it, plan it and implement it.

Such proposing stakeholders could be one of the many actors that operates in CL, either as providers, as users or as stakeholder affected by urban freight activities, such as local authorities or final customers. For instance, public authorities that intend to foster sustainable behaviours within the urban freight transportation systems through investment in logistical facilities or ICT platforms, while achieving a sound business case for such financial effort. Alternatively, new business ventures in urban logistics are shaping their business model or striving to scale up. Both private ventures and public administrations need to generate value for old and new customers of logistics services. At the same time, they operate within consolidated networks that are already exchanging values and logistics flows. Having a modelling framework to grasp such complexity is thus important for the long-term success of the identified problem owners.

In particular, I will focus the model on the parcel delivery sector, which amount to 70 billion € worldwide, it is a growing market with compounded annual growth rates of up to 17% in recent years (AT Kearney, 2013). Such growth, along with the emergence of new business models and innovation provides a case for studying the long-term effect of new configuration to the city logistics system.

5.2.2 Agents

Agents are defined as entities capable of autonomous behaviour, without any external direction guiding their responses to situations encountered. Agents' actions are taken to reach their internal goals (Macal and North, 2010). Agents need to be identifiable and have boundaries to separate them from other agents or objects inside their environment (Van Dyke Parunak, Savit and Riolo, 1998).

As highlighted in the literature, only few ABM papers are available in CL literature. Moreover, some of the agents identified in the literature are related to very specific CL measures that have proven to be out of date in today's economic system.

Table 16 CL agents in CL ABM papers

	Administrators	Shippers	Carriers	Final customers	Retailers	UCC operator	Expressway operators	Residents
(Taniguchi and Tamagawa, 2005; Tamagawa *et al.*, 2010)	X	X	X				X	X
(Teo et al., 2012; 2014)	X	X	X	X				
(van Duin *et al.*, 2012)	X		X		X	X		
(Anand, 2015)	X	X	X	X	X			

According to the objective of my research, the agents are the entities that compose the CL business ecosystem framework. Each of these entities possesses a specific set of resources, is characterized by a limited set of decisions, and pursue a business model by selling or acquiring logistics services, and entering into business partnerships with other entities. Such point of view creates new development regarding the decomposition of a city logistics system into its agents. Thus, by merging previous ABM knowledge and the business model perspective I will outline the definition of the agents in the CL business ecosystem ABM.

5.2.2.1 Express Couriers

Usually, in CL literature, transportation companies different in size, scope and business model are aggregated into one single stakeholder group. For this model, I make a distinction between express couriers and other freight transportation companies. The former group aggregates the global logistics players appointed by shippers to deliver parcels and other goods across countries and ultimately to the recipients located in urban areas. The main activities of express couriers are related to warehouse management, cross docking of shipments and allocation to trucks, as well as organizing the last-mile leg of the freight transportation journey through vehicle routing and fleet allocation algorithms. Such activities require large investment in warehouses, vehicle technology and ICT optimization tools to ensure a fast and seamless delivery process (Chung, Rho and Ko, 2009; Mena and Bourlakis, 2016).

5.2.2.2 Local freight transportation companies

At the urban level, express couriers in some cases outsource parcel delivery activities to small, local freight transportation companies. These companies are then reimbursed per each delivery stop they make. The major assets for these companies are the freight vehicles, which are sometimes branded according to the express courier contracting their services. Green delivery vehicles sometimes offer a valid solution for such companies, but the investment decisions are mostly a joint effort of transportation companies and their main customers, namely the express couriers. Freight companies incur mostly in transportation costs, including fixed costs (e.g. depreciation) and variable costs (e.g. drivers' salaries, cost of fuel). Variable costs moreover are dependent on the characteristics of the delivery tour (e.g. number of stops, length of the tour). As they are reimbursed per delivery stop, local freight companies usually strive to reach as many customers as possible during the working day.

5.2.2.3 Other city logistics players

Innovative CL business ventures are not always included in the list of stakeholders that ought to be involved in the modelling process. The business model perspective instead brings forth the inclusion of innovative CL service providers as proper agents of a CL business ecosystem. This type of agent aggregates new entities that have emerged in recent years, with a focus specifically on last-mile delivery related activities. These specialized CL players can be considered as competitors or partners of existing players such as express couriers (Ducret, 2014). The new players in the parcel delivery sector that will be the focus of this research are:

1. Operators of collection and delivery points, where customers can pick up their online orders and send parcels (Weltevreden, 2008);
2. Specialized urban delivery service providers such as urban consolidation centres (Browne *et al.*, 2005; Van Rooijen and Quak, 2010);
3. Last-mile delivery operators (Maes and Vanelslander, 2012);

The relevance of collection and delivery points is increasing in a context of e-commerce surge, which creates the necessity for reducing the uncertainty of the home delivery process and offering more dedicated delivery services to end consumers (Morganti, Dablanc and Fortin, 2014). First attempt delivery failure and rescheduling increase operative costs of express couriers, which turn to collection and delivery points to solve this problem effectively (Wu, Shao and Ng, 2015). In France, the 60 million parcel delivered to collection and delivery points accounted for between 10 and 20% of the total deliveries (Morganti, Dablanc and Fortin, 2014). According to a report by Apex Insights, the parcel lockers global markets amounts to $ 750 Million (Apex Insight, 2017), and one major independent operator such as InPost has already installed parcel lockers in almost 5000 location across 1100 cities (InPost, 2017). Moreover, what makes parcel lockers more interesting than pickup point operators is the variety of business and operational models present in the market. For instance, InPost is already a large independent operator licensing out parcel lockers to express couriers and e-retailers that want to offer a wide variety of delivery solutions to their customers; MyPUP (MyPUP, 2017) and Bringme (Bringme, 2017) instead sell their parcel lockers to large employers and real estate managers to reduce nuisances created by parcel deliveries at the reception desk. Conversely, pickup point operators mostly operate with the same business logic and even independent operators have been taken over by global express couriers. Hence, for the purpose of this research I will focus on independent parcel lockers network operators, which offer their services to other business entities.

A relatively large literature exists on Urban Consolidation Centre (UCCs). UCCs are warehouses located at the outskirts of the city, where goods from different shippers and handled by different couriers are consolidated, cross-docked, and then delivered to the final customer or retailer. The goal of UCCs is twofold. First, to reduce the number of vehicles, and second to offer value added services to retailers, shippers and couriers.

Last-mile delivery operators include companies operating fleet of green vehicles. Some of these players target both express couriers and final customers that need to transport small items within city boundaries, such as law firms sending envelopes or home deliveries for restaurants. Sometimes, greener deliver modes such as cargo bikes are the results of collaboration between global parcel delivery operators and innovative local carriers specialized in green deliveries (Maes and Vanelslander, 2012; Gruber, Kihm and Lenz, 2014; Schliwa *et al.*, 2015).

New CL players take on some activities of existing companies such as warehouse management or fleet allocation. Moreover, they have an interface with both the final customers and the express couriers. Thus, the most important role played by these new business entities is the network coordination. To this end, the goal of parcel lockers operator, UCC operators and other CL players alike, is to ensure a seamless, automated delivery process, to provide a user-friendly experience for the final customer without hindering the operations of express couriers.

5.2.2.4 Suppliers

Product manufacturers, wholesalers, distributors compose a group of business entities whose main activity in the urban logistics ecosystem is to supply the goods needed by final customers or retailers and organize the transportation of such goods. With regard to the latter role, suppliers are referred to as shippers in the city logistics literature. Shippers outsource logistics activities to third-party logistics providers (i.e. express couriers in the model) and often tend to form long-term collaboration with them. Shippers usually seek low-cost delivery, and high quality logistics services based on seamless pick-ups at the their premises in the first place and on receivers' satisfaction in the second place (Macharis, Milan and Verlinde, 2012).

5.2.2.5 Retailers

The role-based business model framework makes a distinction between business entities, which own resources and are decision-making entities, and the roles they play in the CL business ecosystem, which can change according to the profits made by BEs and other factors. Hence, I introduce a separation between retailers, which are business entities capable of economic decisions, and receivers, which is the role being played by retailers and other entities. Retailers purchase the goods from their suppliers according to their ordering policy, and sell the goods to the final customers. Retailers decide whether to adopt a new city logistics concept if they feel that it generates economic and intangible values for them (Balm *et al.*, 2014; Gammelgaard, Andersen and Aastrup, 2016; van Duin *et al.*, 2016).

Nuzzolo and Comi (2014) state that retailers choose the transportation type and the shipment size. Better stated, their major decision is whether to manage their own transportation service (i.e. own account operators), to outsource their delivery to a third-party carrier, or rather to let the shipper in charge of the outsourcing process. In the first case, they perform the role of city delivery, which involves purchasing and maintaining delivery vehicles, picking up their goods at the supplier's or distributor's distribution centre and carrying them to their urban premises. In the second case instead, they act as user of a logistics service (i.e. likewise the shippers) and in the third case they are only receivers. Some large retailers also possess distribution centres and have vertically integrated supply chains, as is the case of fast fashion retailers (Barnes *et al.*, 2006). These retailers then take also the role of goods consolidation and network coordinator in order to develop agile supply chains and provide quick responses to consumers' demand. However, the vast majority of retailers receive their orders from either a third-party carrier or a wholesaler (60% and 15% respectively according to Alho and de Abreu e Silva (2015). These retailers then take on the role of receivers in the CL business ecosystem, and do not have a say in the decision of the type of carrier or logistics service provider to use. However, retailers need to assign human resources to receive and check the quality of the goods.

Finally, when new CL concepts are introduced, receivers are called to take a proactive stance towards such innovation, which is substantiated with different levels of commitment:

- For the first level of commitment they need to change their delivery address to an urban distribution centre and connect to the track and trace system provided by the new city logistics provider (Song *et al.*, 2009; Heeswijk, Larsen and Larsen, 2017). This action requires a certain level of trust that the new solution will at least provide the same level of service as the traditional configuration.
- Subsequently, retailers can decide to purchase value-added logistics services in exchange for a fee (Marcucci and Danielis, 2008; Gammelgaard, Andersen and Aastrup, 2016). This step requires that the city logistics provider offer them significant tangible and intangible benefits.

5.2.2.6 Facility managers

Facility managers are employees in charge of managing large complex buildings such as office buildings, malls or large condominiums. They need to cope oftentimes with the increasing number of parcels being delivered at the desk reception. Reception of parcels requires time for receiving the goods and space for keeping them until the final recipient can pick them up. Therefore, some CL innovations target these managers by offering them solution for reducing the efforts spent doing this non-core activity. Moreover, some facility managers have stated that increasing the quality of life of employees or tenants is part of their job, and therefore a logistics solution that makes things easier for employees or tenants generates benefit for facility managers.

5.2.2.7 Final customers

Citizens participate directly in city logistics only when they purchase items in bricks-and-mortar shops or from e-tailers, and thus decide which type of logistics service to acquire. Hence, they are treated in the agent-based model only as final customers (Anand, van Duin and Tavasszy, 2014). Likewise retailers, final customers face the decision to entrust new CL players with their deliveries, and will choose a new service only if it provides the same level of service while adding new benefits at the same time.

5.2.2.8 Local authorities

Local authorities play a major role in city logistics systems, as they can impose regulation and incentivize more sustainable logistics. In the agent-based model, local authorities act as the administrator-agent, collecting multiple information and calculating KPIs on pollution level based on total truck-km travelled and other metrics (Anand, 2015). Moreover, the administrator-agent can implement regulations that might interfere with the normal business operations of private companies, and modify their cost factors (Borbon-Galvez, Dewulf and Vanelslander, 2015). Ideally, the administrator-agent calculates environmental and social KPIs based on all the truck movements from a new CL system configuration, and compares the results with a target value or the as-is situation. If the target value is not reached, it can dismiss the system configuration under evaluation. Moreover, as previously stated, some local administrations have committed resources to the introduction of UCC, and therefore will also act as users of a logistics service or even logistics service provider. Finally, public entities such as hospitals and universities are large procurer of goods, both in terms of supplies for their operations and goods purchased by employees. Such large volumes of goods generate many freight movements and have the potential to be optimized achieving direct benefits to the liveability of the surroundings, which contributes deeply to the very objectives of such public organizations (Balm *et al.*, 2015). In this role, facility managers of public organizations can foster the consolidation of freight through the uptake of new procurement policies or innovative logistics services.

5.2.2.9 CL Resources

As stated previously, agents are self-directed as they have their own rules and are reactive to the environment and other agents' actions. As such, some CL resources can be enumerated amongst the agents of the CL business ecosystem. Vehicles for instance have their own attributes, namely capacity, cost, and emissions, are loaded with parcels and move across the city following a specific routing. Moreover, they can calculate the amount of emissions and their speed based on traffic situation. Warehouses own floor space, handling capacity and cost, and geographical location. Cross docking is the main activity taking place in warehouses, and thus the total accrued cost for such activity are computed by this resource-agent. ICT systems are characterized by their capacity to handle and process data and their purchase cost. After receiving the request for data processing, ICT systems execute their activity and compute the total cost. Finally, reception spaces are needed by receivers to manage goods inbound. In a similar fashion, this agent receives the demand, evaluate the availability, execute the inbound of goods and then calculates the total cost.

Finally, amortization is a function of the cost for acquiring those resources, and is calculated by each resource-agent (Figure 7).

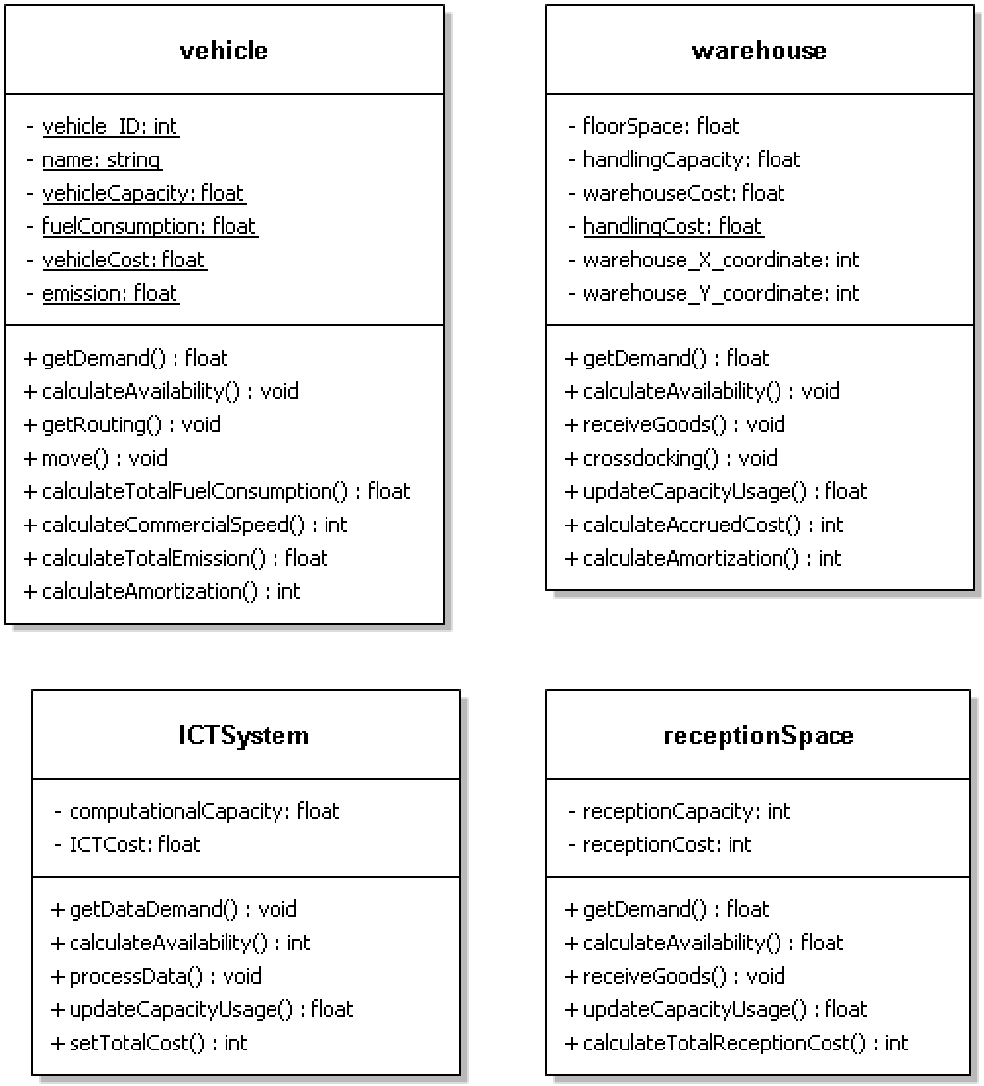

Figure 7 CL Resources

5.2.3 Environment

Environment represents everything that is not agents *per se* but can affect their actions (Guessoum and Briot, 1999; van Dam, Nikolic and Lukszo, 2013) and might provide some constraints to the ability of the agents to reach their goals (Macal and North, 2010). Environment is also shared by the agents and is the space where they interact (Bandini, Manzoni and Vizzari, 2009). Moreover, the actions of the agents can be triggered by specific properties of the environment (Klügl, 2016). The environment provides the physical structures typical of a road network where trucks move and agents deploy their business agreements through the CL physical model mentioned before. Roads and intersections constrain and guides the movement of the delivery trucks hence affecting the routing algorithm of the service providers and consequently their costs. Moreover, each retailer, employer and final consumer owns a set of coordinates in the grid where the agent is physically situated.

Agents perceive the changes in the environment and react to those perceived changes (Bandini, Manzoni and Vizzari, 2009). With this regard, dynamic environments have internal processes or rules that maintain some dynamics of the system, such as price fluctuations or physical processes (Weyns, Omicini and Odell, 2007). For instance, the CL environment generates the demand from consumers on a daily basis, and can include demand shocks and peaks (e.g. increase of demand on Christmas). In the CL business ecosystem, agents change the way they evaluate some Value Proposition based on the dynamics of the environment surrounding them, meaning that the perception of a CL innovation changes when more and more agents start adopting it. Moreover, relationships between agents are the result of interaction, and each agent can encounter a set of other agents and deliver the Value Proposition. In this context, the environment decides which agents are actually parts of the subset of potential users.

Moreover, the environment is both observable and accessible by the agents, and supports agents' perception and actions. As such, it can also collect data and provide valuable information that are elaborated by agents to decide their course of action (Martinez, Correia and Viegas, 2015). Furthermore, the environment may also embed some resources situated in a physical structure, which can be "perceived, modified, generated, or consumed by agents". (Weyns, Omicini and Odell, 2007). The availability of resources from the CL business ecosystem environment determines the ability of a business entity to play a specific role. In particular, new CL companies gain access to external funding from investors, which are not modelled explicitly. The user decides whether a new business entity can have access to a specific amount of monetary resources.

The role of the environment is also to include user's defined parameters to establish the cost of the interaction among the agents and the success of such interactions. In fact, the CL business ecosystem implies the generation, promotion and execution of logistics services. Thus, each provider-user encounter as well as each logistics contract signed has a cost. This cost is borne by the provider. Then, the execution of the service requires the execution of activities, which may incur in errors and failures. The percentage of failures is also a user's defined parameter assigned to the execution of service activities.

Some authors argue that other agents are also part of one agent's environment (Yang and Chandra, 2013; Koppl *et al.*, 2015; Caton, 2017). As a matter of fact, agents do not usually interact with all elements of the model but only with a subset of neighbouring agents (Macal and North, 2010). This point of view is adopted here to define different environments based on the size and type of entity (i.e. agent) operating in the system. In fact, companies in urban logistics, or supply chain, networks have different visibility of the whole network and therefore have the possibility to encounter different portions of that network. In fact, entrants usually need to cope with existing business networks and struggle to unchain the contractual and informal ties that the incumbents have formed with their potential users. Switching to new CL systems then brings stakeholders to bear hidden costs (e.g. opportunity costs) or direct costs related to signing new logistics contracts (e.g. transaction costs). Moreover, new business entities have to create awareness on their value proposition and overcome the risks of handing over the delivery process to an unknown entity.

Hence, one of the major constraint faced by CL innovative solutions regards the level of trust and collaboration embedded in the relationship between retailers, carriers, and shippers. Collaboration among receivers and carriers, including sharing information, flexibility and commitment, can increase the efficiency of the logistics service (Vieira and Fransoo, 2015). A long-standing collaboration leads to commitment among partners, improving the level of logistics service, and reducing order cycle times and inventory levels (Moberg *et al.*, 2002). As a consequence, some CL scholars argue that this variable can be negatively correlated with the uptake of new policies (Marcucci, Gatta and Scaccia, 2015).

On the contrary, the dynamics and history of the environment provide advantages and leverage for the innovation. These factors enable the uptake of CL innovations in the ecosystem. For instance, a buyer-supplier relationship may be affected by a significant total cost of ownership, and an entrant company could leverage on this to appeal to the buyer company. Similarly, new tangible and intangible benefits may be offered to logistics users, thus untying the existing contractual relationships.

Constraints and enablers present in the environment of a CL business ecosystem are outlined in table 17.

Table 17 Constraints and enablers for a role shift

Level of the ecosystem

	Business Entities	Roles
Constraints	Logistics contracts duration Transaction costs	Resources
Enablers	Total Cost of Ownership	Tangible and intangible benefits Profitability

Constraints defined here are embedded in the environment and are defined by the user before the computational experiment.

5.3 Concept formalization

The first step towards an ABM implementation requires an operationalization of the theoretical concepts underpinning the role-based view of CL ecosystems. Therefore, for an ABM implementation it is required that the modeller underlines and resolves the following aspects of the ecosystem.

First, it is necessary to outline the mechanisms related to the assignment of entities to roles, and the effects of the assignment on other entities and the system. Furthermore, the objectives and constraints that drives the decision-making processes of the entities induced by their role-playing need to be identified. Objectives are in a way a formal representation of the rationale underpinning the ecosystem. Moreover, by assigning a quantitative value to such objectives the parameters through which entities evaluate roles performance can be introduced.

To explain the propagation path of the decisions in the system, the influence links between the entities need to be described. Consequently, such influence links can be seen as a part of a network with entities as nodes with decision-making attributes and functions, receiving inputs from the system and from other nodes, and returning outputs to the network. These outputs are the results of the decisions taken, that is, the set of actions each entity can perform. These actions then set the role-based ecosystem in motion, triggering later decisions by other entities.

Furthermore, the constraints that restrict the adoption of a business model configuration by the stakeholders need to be underlined.

Establishing these aspects will result in a truthful, formal representation of the CL business model ecosystem that does not generate any ambiguity that might hinder its further implementation in a programming language or else its ability of being understood by other modellers and used in different contexts. Finally, I will formalize the concepts highlighted in the following sections with Unified Modelling Language (UML) data structure representation containing ad-hoc built formulation.

5.3.1 Role assignment

Role-playing by BEs entails that the entities first set the goals they want to achieve, and then continuously monitor the fitness of their role-playing performance towards those goals.

A role shift in the CL system configuration might happen for the following reasons. First, some roles are not profitable if taken on by certain BEs, and thus other BEs with better profitability seize the opportunity of delivering new services. BEs then need to improve the performance of a role in terms of level of service and therefore increase the tangible benefits delivered to other stakeholders in the network. Second, there may exist some latent benefits to offer to BEs not involved in the CL system so far. Such benefits create a market gap that is potentially filled by new CL players. Benefits are both tangible, when they can be calculated in financial terms, or intangible. Intangible benefits are delivered by BEs to the market through their role performance. Intangible benefits derive from the level of service, and therefore when a new BE is taking on a role played by another BE she needs to organize her resources to deliver at least the same level of service. Relationship between Business Entities is underlined by contracts, and entails transaction costs and opportunity costs that need to be taken into account when new configuration are setup.

However, BEs are constrained in their decision to play a role by the availability of resources that those roles require. However, entities can still acquire such resources if they are available on the market and they have enough monetary resources (i.e. budget). On the operational side, when a BE takes on a role, more resources are required to maintain the level of service, thus leading to higher costs. In case of a role of service provider, this equals to investing resources or deploying more personnel. In case of a User role, this means that an incremental payment for a new logistics service is due.

When a new BEs enters the market, inevitably, she will take on one or more existing roles and hence the number of role assignment will increase. This will require additional resources, the cost of which will be borne mostly by the entrant but partially by existing companies as well. Each change in the role assignment set entails additional complexity to the system and thus an increase in the effort of

Network Coordination is associated. If two BEs plays the same role, they can co-ordinate, compete or perform different activities belonging to the role.

Goods and services flow between BEs in return for revenues, since BEs own monetary resources, enter into logistics contracts and acquire services from other BEs. Then, the value exchanges of money, goods and services, as well as the intangible benefits (e.g. value proposition) are dependent on the role assignment, and are thus created (or co-created) and exchanged during the actual execution of the roles.

Entities can perform only a set of roles, as seen in Table 18. However, while CL systems most of the time consist of a subset of BEs, they need to comprise all the roles identified in the matrix.

Table 18 Role assignment matrix. X marks a potential entity-role assignment

Role / **Business Entity**	Receiver	User of logistics service	User of city delivery	City delivery	Logistics service provider	Network coordination
Express couriers		X	X	X	X	X
City Freight carriers				X		
Last-mile operators				X	X	X
UCC operators	X			X	X	X
Parcel locker operators	X		X	X	X	X
Suppliers		X	X	X		
Large retailers	X	X	X	X		
Local retailers	X	X	X			
Local authorities	X	X				X
ICT platform operators						X
Facility Managers	X	X				X
Final customers	X	X	X			

Entities that decide to become providers aim at delivering a value proposition including tangible and intangible benefits that are valued by their potential customers. Such value proposition is assembled as a bundle of logistics service with attributes such as price and service quality. User-entities then evaluate value proposition coming from different providers based on the relative importance they give to each attribute of the value proposition. Then, the level of attributes of the VP can be subject to negotiation among agents. If this evaluation yields positive outcomes and both the provider and the user agree on the terms of the VP a contractual relationship is established among them. To comply with the contractual agreements, the provider executes the logistics service and performance indicators are computed to check the level of compliance of the service agreements. Further decisions to maintain or opt out from the relationship are taken based on the outputs of the performance evaluation (Figure 8).

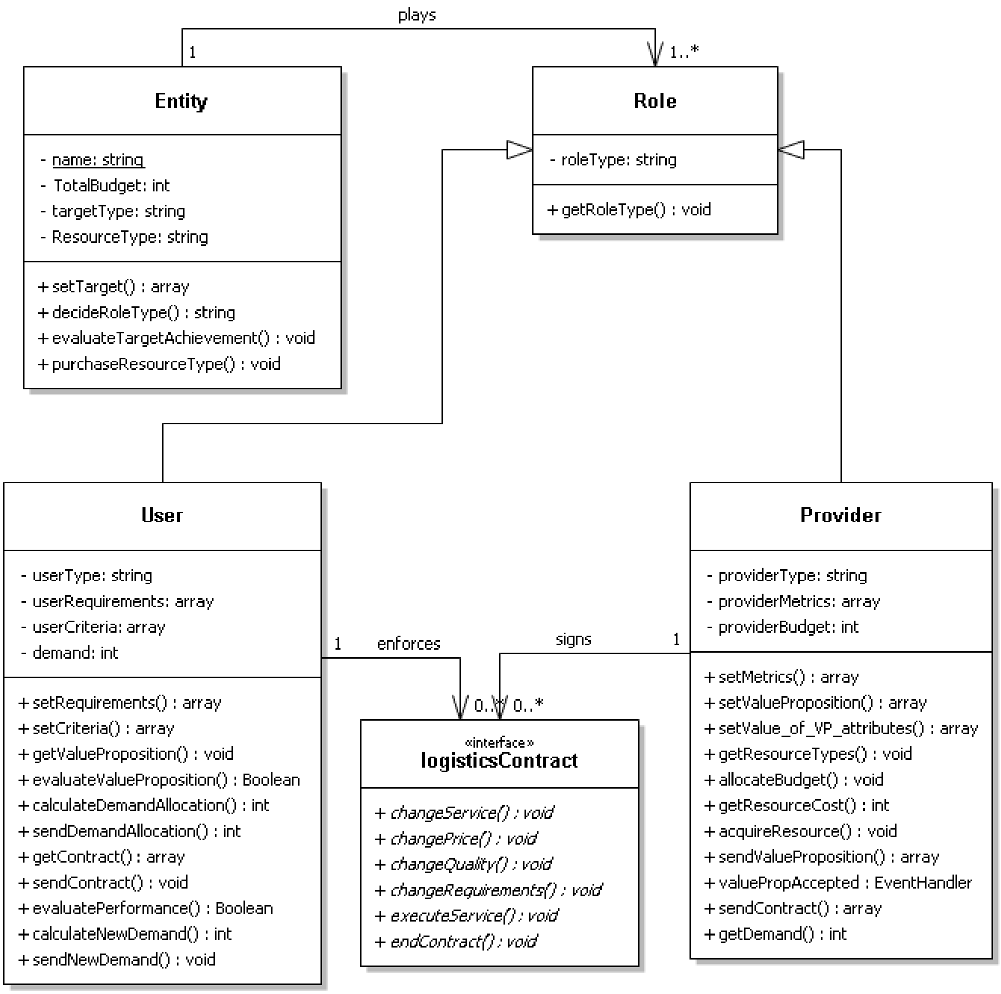

Figure 8 Role assignments, roles and logistics contracts

5.3.2 Agents' decision-making

Each role-entity assignment configuration implies an allocation of the decisions, which are embedded in roles, to the business entities. For instance, the decision to adopt a logistics services can be taken by both retailers and shippers if they act as user of logistics services. Moreover, a business entity makes different decisions based on the roles played, and therefore uses different decision-making attributes.

In the CL business ecosystem decisions are related to business and operational aspects of role execution. The first set of decisions has a longer time horizon, as they are medium to long term decisions which are not likely to be changed on the short term (Roorda *et al.*, 2010). Decisions are outlined in table 19.

Table 19 Business and operative decisions of CL roles

<table>
<tr><th>Role</th><th>Strategic Decisions</th><th>Operative decisions</th></tr>
<tr><td>Receiver</td><td>Adoption of logistics services
Evaluation of level of service
Evaluation of intangible benefits</td><td>Decide stock levels
Inventory policy: EOQ, Frequency of delivery, time of delivery</td></tr>
<tr><td>User of logistics services</td><td>Adoption of logistics services
Demand allocation (long-term)
Evaluation of level of service
Evaluation of intangible benefits</td><td>Demand allocation (short-term)</td></tr>
<tr><td>User of city delivery</td><td>Suppliers' selection
Evaluation of level of service
Evaluation of intangible benefits</td><td>Demand allocation (short-term)</td></tr>
<tr><td>City delivery</td><td rowspan="3">Value Proposition setting
Level of service provided
Pricing scheme
Budget allocation
Resource acquisition</td><td>Fleet allocation
Vehicle routing</td></tr>
<tr><td>Goods consolidation and logistics service</td><td>Fleet allocation
Vehicle routing
Demand allocation</td></tr>
<tr><td>Network coordination</td><td>Data quality control
Computational capacity allocation</td></tr>
</table>

A decision-making problem can be expressed with a typical linear programming formulation, where each decision shows the following elements: i) an objective, which could be either maximization or minimization of decision variables; ii) a set of variables; and iii) a set of constraints, which defines the domain of values for each variable.

Such formulation is apt for optimization problems with limited option. However, solving decision-making problems through optimization algorithms is not always best suited for decision variables that cannot be quantified easily. For instance, the decision to accept a logistics service proposal lies in the evaluation of the value proposition, which includes intangible benefits as well.

Several CL scholars have investigated CL agents' decisions and decision-making attributes, meaning the objectives that drive their decisions. For instance, the attitude of CL stakeholders towards different policy scenario has been investigated through different consolidated methods, such as discrete choice modelling with stated preference surveys, or Multi Criteria approaches. Therefore, from CL literature it is possible to get insights on CL agents' set of decisions and decision-making attributes.

Receivers usually look for flexibility in terms of size and frequency of deliveries, to enhance the effectiveness of their ordering policy (Nuzzolo and Comi, 2014; Muñuzuri, Onieva, *et al.*, 2016). Moreover, delivery time window is an important decision-making attribute as receivers try to settle with transport providers to receive the goods at most convenient time of the day, particularly when the store is not busy with customers (Patier and Browne, 2010; dell'Olio *et al.*, 2016; Marcucci and Gatta, 2017). In addition, receivers value a reliable delivery service in terms of punctuality, safety and security of the items sent. Moreover, some authors argue that reducing the logistics stock at the store in exchange for additional display stock is a value, especially since rent in city centres can be very high (De Assis Correia, De Oliveira and Guerra, 2012; dell'Olio *et al.*, 2016). Decisions-making criteria for receivers are listed in table 20. Carriers instead aim for parking time reduction, and operative costs (Muñuzuri, Onieva, *et al.*, 2016). From a carrier's point of view, the retailers' accessibility, average shipment's size and type of vehicles (in terms of size and engine) are major attributes for choice of routing.

Table 20 Decision-making criteria for receivers

Criteria	**Description**
Cost of delivery	The cost for delivering items in urban areas. However, this criteria applies only for shopkeepers who see the cost of delivery
Reliability and Trust	The carrier needs to provide a high quality service, complying with their service requirements and avoiding less than professional behaviour. For instance, it has been noted that a driver had once signed for the consignment in place of the shopkeeper. On-time delivery can be a factor of reliability only when it is precisely stated in the delivery contract.
Safety of the delivery	Receivers want the goods to arrive in good condition.
Traceability of the delivery process	Tracking and tracing the goods at every step. Visibility on the whole delivery process is key for having a trusted relationship with the shipper and the LSP. This criterion sometimes can be omitted when retailers are certain that they

	will receive goods each day at roughly the same time.
Sustainability	The delivery is performed with low-impact vehicles. All things equal, a low-emission delivery service appeals more than a traditional fuel one.
Delivery lead time	The time between the order to the supplier and the delivery. Lower delivery times increase the flexibility of the ordering process and may lead to reduced order cycle time and lower inventories. Usually retailers expect one-day or two-day delivery lead-time.
Flexibility	Flexibility in the time of delivery. Shops usually can accept goods delivered at any time during working hours, but a certain degree of flexibility in the time of delivery can help organizing the work and avoid receiving items during the busiest hours
Average shipment size reduction	Retailers prefer to receive small shipment because they can better check the delivery status and arrange the goods on the shelf.
Delivery frequency reduction	Lower number of freight vehicles reduces the nuisance to daily activities and might create a more attractive environment for citizens. This criterion is partially contrasting with the previous one.

For the proposed model, other criteria have to be taken into account. Given its business-oriented nature, criteria related to the relations among business partners have to be considered as well. Take the express couriers for instance. Such actors have invested in assets (warehouses and vehicles) and business relations with their city transportation suppliers, who make the final deliveries with branded vehicles. If a new entity would enter in the city delivery arena, this could mean less branded deliveries for the couriers and a strain in the relationships with their suppliers, which could even convert into a penalty payment for profit loss by the suppliers.

In the next three paragraphs, the three major decisions that actors take in CL business ecosystems are explained.

5.3.2.1 Adoption of a logistics service and demand allocation

In CL literature, the problem of selecting third-party logistics service provider or carriers is often overlooked. In the AB model proposed by (Anand, van Duin and Tavasszy, 2014), suppliers choose the carrier with the lowest price. This approach fails to take into account other important factors highlighted in the literature, such as the suppliers' maintenance costs, the service level, the risk of failure or the delivery time among others. These factors are outlined in table 21.

Table 21 Criteria for choosing a logistics service in a CL ecosystem

Decision	**Criteria**	**Description**
Outsource to last-mile transportation service.	Cost of delivery	The cost for delivering items in urban areas. Usually the cost is accrued per stop.
	Reliability and Trust	The carrier needs to provide a high quality service, complying with their service requirements and avoiding less than professional behaviour. For instance, a retailer has noted that a driver had once signed for the consignment in place of the shopkeeper. On-time delivery can be a factor of reliability only when it is precisely stated in the delivery contract. Successful pick-ups at the warehouse are also very important.
	Safety of the delivery	Receivers want the goods to arrive in good condition.
	Knowledge of urban area	Local freight carriers should have experience with the delivery area in order to improve the service
	Exclusivity	The possibility to have exclusive agreement with the city delivery operator so that the freight vehicles show the company's logo.
	Reach	The amount of final customers that the carrier can reach. This is a positive factor for lighter, low-impact freight vehicles, especially where local regulations preclude the entrance of traditional fuel vehicles to delimited areas of the city.
	Capacity	The delivery capacity of the supplier. This is important because LSP can opt for a lower number of suppliers to manage. This can be a negative factor for lighter freight vehicles (bicycles, city freighters etc.)
	Transaction costs	Committing to a supplier requires an investment in resources (e.g. vehicles, ICT integration). Moreover, transaction costs are based on procurement, ordering, and transactional activity costs (Dogan and Aydin, 2011).
	Sustainability	The delivery is performed with low-impact vehicles. All things equal, a low-emission delivery service appeals more than a traditional fuel one.
Adopt a logistics service	Service cost	Total logistics cost, including freight handling and transportation and other logistics

		services (Sheffi, Eskandari and Koutsopoulos, 1988)
	Delivery time	Lower delivery time increase the flexibility of the ordering process and may lead to reduced order cycle time and lower inventories
	Willingness to focus on continuous improvement	The potential for improving operations and keep up with the growth of the customer. This includes also the potential for an increase in the total output handled, which also decrease the risk of committing to a new provider.
	Reliability and Trust	Reliability can be defined in many ways e.g. % on time deliveries, % of errors etc. Successful pick-ups at the warehouse. Reliability is shown by providing a consistent record of performance over time.
	Flexibility	The service provider is able to guarantee a certain level of acceptance of last-minute changes, ability to handle special needs and emergencies, choose different modes and times of deliveries.
	Capacity	The total capacity of the logistics service provider. The capacity enhances the availability of the LSP to meet customer's demand and expectations, including the potential to respond to peak periods (e.g. Christmas) or disruption to the supply chain. Flexibility is also a function of the capacity.
	Stock reduction	Stock reduction can be one of the potential benefits offered by a new service
	Sustainability	The logistics service provider commits to reducing the emissions generated by her activities.
	Traceability of the delivery process	Visibility on the whole delivery process is key for having a trusted relationship and maintain control of the process
	Transaction costs	Committing to a supplier requires an investment in resources (e.g. vehicles, ICT integration). Moreover, transaction costs are based on procurement, ordering, and transactional activity costs (Dogan and Aydin, 2011).

The adoption of a logistics service comprises two problems. First, users have to choose a logistics company as their supplier (i.e. supplier selection problem). Second, they have to allocate a share of their total demand to that supplier.

In literature, supplier selection is treated with both quantitative and qualitative methods (De Boer, Labro and Morlacchi, 2001). Total cost of ownership (Degraeve, Labro and Roodhooft, 2000; Wouters, Anderson and Wynstra, 2005) in combination with statistical methods is used as a quantitative method, together with DEA and multi-objective programming (Weber, Current and Desai, 1998, 2000). In Linear-weighting models weights are assigned to criteria and then a single figure is computed for each supplier (Grando and Sianesi, 1996; de Boer, Wegen and Telgen, 1998); these models can be compensatory when a high score on one criteria can outweigh a low one on another, and non-compensatory if minimal requirements are needed for each criteria. To deal with the uncertainties linked with this decision, several methods have been proposed, such as AHP (Bhutta and Huq, 2002), Monte-Carlo simulation and other simulation model in general, and fuzzy sets theory (FST). Demand allocation and supplier selection can be optimized jointly, as envisioned by (De Boer, Labro and Morlacchi, 2001). In this sense, (Ruiz-Torres and Mahmoodi, 2006) propose to optimize a cost function including costs of supplier's failure, supplier maintenance costs and ordering costs. A dynamic programming approach to the solution of the two problems is proposed by (Mafakheri, Breton and Ghoniem, 2011), where the utility score of the supplier is used to build a utility function for order allocations called the total value of purchase (TVP). A more recent development in logistics outsourcing decisions comes from the application of transaction costs theory (Hobbs, 1996; Williamson, 2008). Outsourcing logistics activities is beneficial when this reduces transaction costs, which may refer to order processing, the use of logistics assets, and consolidation of overhead (Zacharia, Sanders and Nix, 2011). Transaction costs are expenses generated by activities such as identification of fair market prices, and the subsequent negotiation and economic exchange. This is true for innovative solutions in supply chain, for which decisions remain related to transaction costs and risks, given that alternative performance indicators and operational criteria are needed to assess new capabilities provided by supply chain innovations (Harrington *et al.*, 2016). By applying the theoretical framework of transaction costs economics, Rabinovich, Knemeyer and Mayer (2007) argue that companies will likely outsource to a focal logistics service provider if they only require standardized distribution processes. In fact, standardized activities do not require asset specificity and therefore customers will incur in lower transaction costs in terms of protecting their valuable assets. Moreover, lower uncertainties about the provider's performance decrease transaction costs connected to specifying in advance and continually adjusting to the provider's change in performance. The use of ICT infrastructure is instrumental in this regard to bring down transaction costs (Sodhi and Tang, 2014).

Traditional supplier selection methods apply when a set of suppliers with similar characteristics and offering the same service is there for the customer to choose. For instance, in supply chains, supplier selection techniques are used to outsource logistics activities to one or more of the large third-party logistics service providers operating in the market. In the business-model oriented CL ABM however, innovative companies devise new value proposition and offer different logistics services. Hence, a comparison between the "new" and the "business as usual" supplier is rather complicated, especially when there is no business as usual to compare to. To this end, the concept of value proposition is used here to guide the supplier selection decision performed by the user. In particular, users evaluate the value proposition of logistics providers, and if the evaluation phase returns positive results, the user then allocates a share of its total demand to that company. This share is assumed relatively low at the beginning and increasing in time. The reason behind this assumption lies in the fact that companies entering the market with innovative value proposition have to overcome the risk inherent to committing to the services of a supplier with little or no previous record. In addition, they have to prove that their solution is consistently and considerably better than the traditional ones, or else customers would just stay with the *status quo*.

The evaluation of a value proposition by customers is affected by "attention, cognition, goal alignment (Töytäri and Rajala, 2015)" and other factors the influence the decision-making process by customers. To quantify a value proposition, (Töytäri and Rajala, 2015) propose to link the elements of such VP to key performance indicators that the customer is seeking after. VP evaluation is then regarded likewise a qualification step for the supplier selection problem, where the supplier performance/attributes have to rank above a minimum threshold. This step is included to make sure to assess the VP against a target value dependent on the existing value proposition offered by incumbent companies. Moreover, innovative companies have to overcome the afore-mentioned risk of committing to them by providing a "premium" in terms of the desired service attributes. If the components of value proposition yield higher value than the target requirements then the user decides how much demand to allocate.

After evaluating the value proposition, the user must allocate the demand to the provider. However, since new logistics companies do not have a previous record they cannot really be compared to existing suppliers. Hence, we should look beyond those methods that use a comparison among suppliers to select the supplier and allocate the demand. In order to mitigate the risk issues connected to outsourcing to a new provider, order allocation can include the real problem derived from the potential loss of one supplier. Ruiz-Torres and Mahmoodi (2006) aim at minimizing the expected loss from supplier's failure, the costs of maintaining a supplier and the purchasing costs. The economic loss is represented by the percentage of demand that is not delivered. Each supplier has a parameter that represents the output flexibility in case other suppliers would fail. The model of Ruiz-Torres and Mahmoodi (2006) state that, let p_j and p_k be the probability of failure to delivery of supplier j and k respectively, $0<y(i)<1$ the flexibility parameter and a_i the allocated output to supplier *i*, *vQ* the economic loss for quantity Q not delivered, the expected loss cost is:

$$ELC\ \{j,k\} = (p_j p_k + p_j\,(1-p_k)(1-a_k^{y(k)}) + (1-p_j)p_k(1-a_j^{y(j)}))\ vQ \qquad (2)$$

Where $a_i^{y(i)}$ represent the total potential output from supplier *i*. If the number of suppliers increases than the expected loss costs decreases since the probability of failure also decreases. Suppliers' maintenance costs are linearly dependent with the number of suppliers, according to a fixed unit cost *b* of maintaining a supplier:

$$SCM_m = bm \qquad (3)$$

This model could be applied to the CL business ecosystem AB model by imposing a probability of failure to the existing suppliers = 0 and a positive probability to the new company. Higher flexibility could also be set for traditional suppliers.

More specifically to logistics literature, (Dullaert *et al.*, 2005) model the selection and quantity allocation among different transportation modes, taking into account four logistics characteristics. These are loading capacity, order and transportation costs, average lead-time and variance of lead-time. Service level and inventory carrying costs are invariant for the different transportation alternatives. The total logistics costs are a sum of total order costs, total transportation costs, total costs of cycle stock, total costs of inventory in-transit and total costs of safety stock. An evolutionary genetic algorithm procedure is used to reach the best solution heuristically, starting with a random assignment of the storage capacity of the receiver to the transportation alternatives, hence calculating the number of times an alternative is potentially used. Then, the solution is evaluated by computing the total annual logistics cost. More simply, demand allocation can be a function of the gap between the expected (target) requirements and the actual ones.

5.3.2.2 Resource allocation

In the CL business ecosystem, entities face the problem of allocating resources to maximize their objective. There are two types of resource allocation decision: allocating the budget and allocating operational resources. The first type has a strategic nature and it refers to the share of the monetary resources own by the entity that are spent in R&D and operational efforts or marketing. The latter type instead concerns the maximization of the usage of existing assets (e.g. warehouse, vehicles) that are taken with high frequency.

Resource allocation can be treated as an efficiency problem, where each additional money unit allocated to a specific activity increases total revenues by a marginal increase. Nevertheless, in the model proposed for instance by (Keh, Chu and Xu, 2005), allocating the total budget to marketing purposes is only an intermediate step towards the objective of efficiency and productivity. Companies therefore aim at minimizing marketing expenses to achieve the required level of efficiency. However, the same authors argues that productivity is negatively correlated with efficiency i.e. revenues are not always maximized when the efficient budget allocation is reached. One challenge that start-up companies have to face is the problem of allocating their scarce resources to operations and marketing. In particular, monetary resources can be allocated either to build up logistics capacity or to reach a wider customer base through commercial efforts (e.g. marketing, promotions, hiring commercial employees etc.). A common conception is that during the first stages of growth a start-up company allocate most of the budget on R&D activities and product development, whereas later on a shift occurs towards more marketing-oriented activities. A model on R&D and marketing allocation in start-up companies is proposed by Joglekar and Lévesque (2009). According to the authors, start-up companies want to maximize the valuation of their company so to gather more funding. Payoffs (i.e. revenues) from expenditures on R&D and marketing are function of the payoffs from the previous period and the productivity of the capital allocated to that activity, which is decreasing in time. For instance, the payoffs RD_t from R&D investments are calculated as follows:

$$RD_t = e_{RD,t} * g(RD_{t-1}) + p_{RD,t} * [r_t W_{t-1}]^{\alpha} \quad (4)$$

Where:

- $e_{RD,t}$ represent a time-variant coefficient that shows the variability over time of the evolution of R&D payoffs, which are a function of the payoffs from previous time steps
- $r_t W_{t-1}$ is the amount of budget available (W_{t-1}) allocated to R&D expenditures (r_t)
- $p_{RD,t}$ is a random, time-variant productivity parameter
- $0< \alpha<1$ is a coefficient for offering decreasing returns for R&D expenditures

Simulation results, from this model shows that an increase of the productivity and evolution parameters for marketing expenditures has positive effect on profits.

Concerning the budget allocation decision however, it has to be noted that given its strategic nature it can be considered as a managerial leverage to drive profits and sustainable advantage over competitors. As such, for a computational experiment based on the CL business ecosystem ABM this decision can be subject to a scenario analysis rather than being treated with an optimization problem continuously run by agents.

5.3.2.3 Other operative decisions

Operative decisions such as fleet allocation and vehicle routing (Hosoya, 2003; Ehmke and Mattfeld, 2012; Cattaruzza et al., 2015; Montoya-Torres, Muñoz-Villamizar and Vega-Mejía, 2016) as well as inventory policy (Anand, 2015; Li, Wang and Dai, 2016) are approximated with consolidated techniques available in CL literature. These techniques can be used by the modeller for a computational experiment on the CL business ecosystem ABM.

5.3.3 Value Proposition

Services are an aggregation of activities that require resources to be performed. As mentioned, Value Proposition is a set of offering based on the logistics services and the attributes related to such services (Figure 9). By designing a value proposition, companies are also able to understand their need for specific resources. Moreover, a VP is evaluated through a set of attributes, which are subject to metrics evaluation, and thus companies need to clearly have in mind what is the target they want to set for VP attributes.

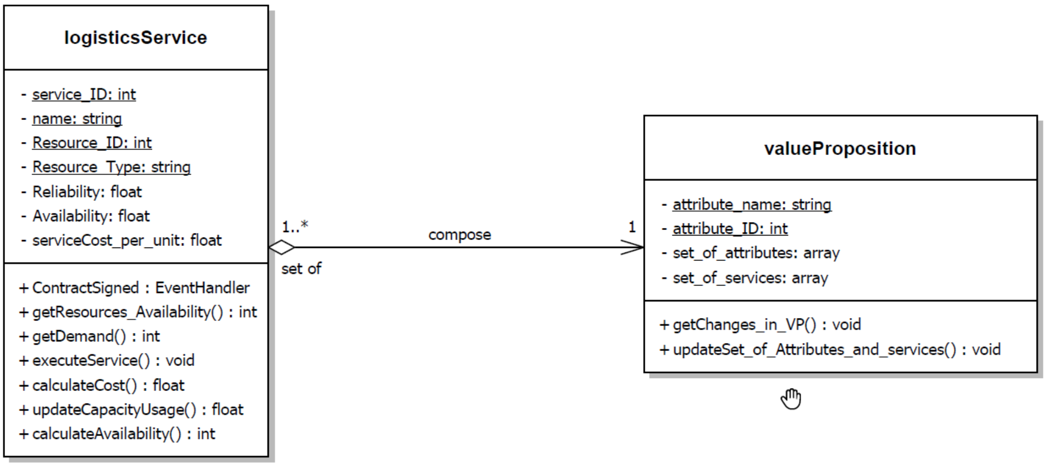

Figure 9 Service offering module

Value can consist in the aggregation of product/service attributes, image and relationship with the customer (Walters and Lancaster, 2000; Bose and Thomas, 2007). Consistently with (Zacharia, Sanders and Nix, 2011) the value proposition of a logistics provider offering last-mile and logistics services is composed of the following components:

- Price intended as the price per unit of service (e.g. parcel delivered or stored).
- Order cycle time, being the total lead-time from the order acceptance to the order fulfilment. For instance, for a third party logistics service that offer transhipment of goods at the LSP's distribution centre (DC) and organize the last-mile delivery, the order cycle time might include the acceptance of goods at the DC, inventory handling and last-mile transportation.
- Service quality, which is determined by several dimensions as highlighted in the literature.
- Scope of the service. This represents the features or functionalities of the service i.e. the breadth of the services offered. Scope is a key dimension in outsourcing relationships (Levina and Ross, 2003).
- Sustainability, in terms of reduction of pollutant emissions.
- Intangible benefits, including increased productivity and cost reduction (Chesbrough, 2007), availability and convenience, better, flexible and customized service or plain innovativeness and status from product superiority or design.

Cross-checking the findings from both service quality and city logistics literature (Zeithaml, Parasuraman and Berry, 1990; Cronin Jr and Taylor, 1992; Ghobadian, Speller and Jones, 1994; Franceschini and Rafele, 2000; Wygonik and Goodchild, 2011; Harrington *et al.*, 2016; Den Boer *et al.*, 2017), service quality can be narrowed down as the composition of different dimensions as perceived and sought after by customers. These are:

- Reliability, which addresses the ability to perform the activity as required. It is always evaluated in accordance to customers' expectations and the requirements stated in the contract signed by provider and user.
- Compliance, as in meeting regulations and agreement with the customer (e.g. time-window for the delivery).
- Flexibility, as the ability to adjust the service offer to meet specific needs of the customer.
- Credibility, as a measure of the trust instilled by the service company.

Service quality is approximated with a weighted sum of these dimensions. Reliability and compliance are directly dependent on the capability of the company to organize its resource to effectively comply with customers' expectations, but it is also influenced by constraints stemming from traffic, regulation and other hindrances. Taking into account a traditional third-party logistics service, customer and provider agree on the afore-mentioned order cycle time, and the delivery time window (if applicable), place and quantity.

The order requirements to be met are then set for each of the previous characteristics of the service, as per eq. (5).

$$\text{Requirements}_j = (\text{OrderCycleTime}_j, \text{TimeWindow}_j, \text{Place}_j, \text{Quantity}_i) \qquad (5)$$

The provider's ability to comply with those requirements depends on her internal capability, the external constraints to be faced as well as the intrinsic strictness of that request. Compliance of provider *i* to user's *j* request is as follows:

$$\text{Compliance}_{ij} = f\,(\text{Capabilities}_i, \text{Constraints}_i, \text{Requirements}_j) \qquad (6)$$

For methodological purposes, it is necessary to state that the Compliance dimension, while being formulated here through a analytical formulation, it is rather the outcome of resource allocation problems solved continuously by the agents.

Reliability was previously defined as the extent to which a company complies with the customers' expectations.

$$Reliability_{ij} = g\,(Compliance_{ij}) = \%\ \text{compliant requests} \quad (7)$$

This definition of reliability is consistent with the Reliability performance attribute of the SCOR model, stating that reliability is the % of perfect order fulfilled (Kowalkowski, 2011).

The overall value proposition is an aggregated function dependent on the four attributes of value highlighted.

$$VP_i = f\,(Price_i, OrderCycleTime_i, Quality_i, Scope_i, Sustainability_i, Intangible_i) \quad (8)$$

Evaluating the VP means giving a quantitative outcome as a weighted linear combination of the four attributes, calculated for each service. Following the previous reasoning, a value proposition is exchanged between logistics provider *i* and user *j*, is the aggregation of various offerings based on a logistics service, and is formulated as follows:

For *k* = 1…n services that are part of the value proposition delivered by provider *i* to user *j*

$$VP_{ij} = \sum^{n}_{k=1} \text{Value of Offering}_k \quad (9)$$

where:

$$\text{Value of Offering}_k = w(p)_{jk}\, P_{ik} + w(t)_{jk} T_{ik} + w(q)_{jk} Q_{ik} + w(s)_{jk} S_{ik} + w(sus)_{jk} Sus_{ik} + w(i)_{jk} I_{ik} \quad (10)$$

$$w(p)_{jk} + w(t)_{jk} + w(q)_{jk} + w(s)_{jk} + w(sus)_{jk} + w(i)_{jk} \quad (11)$$

P_{ik}, T_{ik}, Q_{ik} and S_{ik} are the four attributes of the service k included in the value proposition offered by provider i, whereas $w(p)_{jk}$, $w(t)_{jk}$, $w(q)_{jk}$, $w(s)_{jk}$, $w(sus)_{jk}$ and $w(i)_{jk}$ are the weights assigned to those attributes by user j.

5.3.4 Metrics

Metrics are assigned to the targets set by entities, which refer to their objectives. Primarily, entities need to achieve economic benefits from their relationships with other entities. Providers for instance need to make profit by selling their logistics services to users. Then they aim at maximizing other objectives, which are better represented by the intangible benefits created and exchanged during the execution of the roles. Metrics are relevant because performance measurement can steer the decisions of BEs. For instance, receivers can be tempted to become user of logistics as soon as the metrics they use to assess the logistics performance do not hit the established target.

A selection of metrics is performed via literature review, including both scientific papers and grey literature such as EU funded project reports (Shah and Singh, 2001; Nicolas, Pochet and Poimboeuf, 2003; Gunasekaran, Patel and McGaughey, 2004; Hamdan and Rogers, 2008; Toledo, 2011; Anand, Yang, *et al.*, 2012; Balm and Quak, 2012; McKinnon, 2015; Buldeo Rai *et al.*, 2017; Cagliano *et al.*, 2017). The decision to include reports was taken because additional information regarding the business model of CL case studies are available in project reports. This information is deemed relevant for the objective of the CL business ecosystem.

Table 22 Role metrics

Role	**Metrics**	
Provider	Profit	
	Return on investment	(Gain from investment – cost of investment) / Cost of investment Net profit / Invested assets
	Productivity of working capital	Total Sales / Working capital Cash turnover ratio[8]
	Number of customers	
	Customer satisfaction	

[8] The proportion of cash needed to generate sales: Total sales / Average cash balance (Richards and Laughlin, 1980)

	Efficiency	Shipping volume / production inputs (e.g. labour hours, space, equipment) (*warehousing efficiency*) Deliveries / fuel litre [9] (*fuel efficiency*) Deliveries / day / vehicle Loading rate (*routing and fleet efficiency*)
	Road network coverage	
	(Un)loading time	
	Employees satisfaction	
User of logistics services User of city delivery services	Total ownership cost	
	Reliability	On-time deliveries % successful deliveries
	Flexibility	% of delivery changes accepted by provider
	Receiver satisfaction	
	Employees satisfaction	
Receiver	(Un)loading time (Un)loading cost	
Policy maker	Emissions	CO2 emissions PM10 emissions NOx emissions
	Road congestion	Travel time index Average road speed

5.4 Model formalization

The model narrative is a funding part of the formalization, as it drafts the model behaviour, explaining “which agent does what, with whom and when?” (van Dam, Nikolic and Lukszo, 2013).

A more detailed description is provided in the next chapter for the case application.

[9] From Department for Transport (2005)

5.4.1 Flow of activities

The model narrative is divided into three phases: i) the first phase is the step where agents set their target and negotiate the logistics contract; ii) then, after having signed a logistics contract, the operative phase of service execution is performed; and finally, iii) agents evaluate the performance of the system by calculating the metrics and comparing them against the target ones.

As stated in chapter 2, this chapter aims at proposing a business-model oriented point of view on ABM for City Logistics. In fact, during the chapter I have identified several value proposition and decisions that compose a City Logistics business ecosystem. Then, to implement this proposal into a specific business ecosystem, the AB modeller would need to give a quantitative evaluation of the different components of the value proposition, the services offered and the pricing level of such services. Likewise, the flow chart of agents' activities needs to be fine-tuned according to the specific CL innovation and the resulting business ecosystem at issue. In particular, the operative phase and the metrics to be evaluated depend strongly on each case study peculiarity and management's objectives. Therefore, the flow of agent's activities provided in this paragraph is rooted in one of the case studies highlighted in chapter 4, namely MyPUP. However, even though there are some specificities to the case study proposed, the flow of activities of this case can be generalized to other cases where the business entity organizes the last-mile delivery network alternatively to existing players such as express couriers.

As mentioned, MyPUP operates automated parcel lockers inside office buildings, and organizes the last-mile delivery on behalf of the final customers and the shippers. Hence, it offers its services to facility managers and has to achieve operational efficiency by playing the role of logistics provider. Morever, express couriers may evaluate the performance of the parcel locker operator based on its reliability as logistics service provider. Since the parcel locker operator informally asks to couriers to deliver their items by 12 each day, it must also build a solid reputation of being reliable as a partner. This can be obtained by handling items in a short time so to avoid any hindrances to the courier's daily activities.

Figures 10 and 11 show the flow of activities involving all the actors of the MyPUP business ecosystem.

As anticipated, entities first make strategic decisions. They set their targets for role-playing, which are related to their objectives and decision-making criteria.

Entities that take on the role of provider need to design their value proposition in terms of price and service quality. Then, the first allocation of the budget in R&D and marketing should take place. In the case presented, the business entity sets a specific number of customers (i.e. market penetration) as their target, and thus will calculate the size and number of parcel lockers stations according to this target. This decision nonetheless ensues from both the target for market penetration and the budget allocated to R&D in terms of capacity building. Consequently, the size of the lockers station will also determine an estimation of the total costs.

Entities that are potential users of this service will receive the service offer and evaluate it according to the attributes values. If the values of the VP attributes perceived by the user are sufficiently close to the required ones, a negotiation can take place between the provider and the user. For instance, the provider could set a minimum threshold on the profit margin so to offer its service to more customers. When a contract is signed among the parties, the lockers are installed and the information is sent to final users who can now make use of the service of the locker operator and receives their parcels at the office.

Finally, in this phase other agents of the CL business ecosystem are involved, namely express couriers. In fact, the MyPUP solution involves them directly on the operational side, because after the installation of lockers they will deliver the parcels to the MyPUP consolidation centre. Hence, since these parcels were previously sent to the final customers express couriers will generate different routings and estimate the benefits of this solution in terms of saved vehicle-kilometres, fuel costs and emissions.

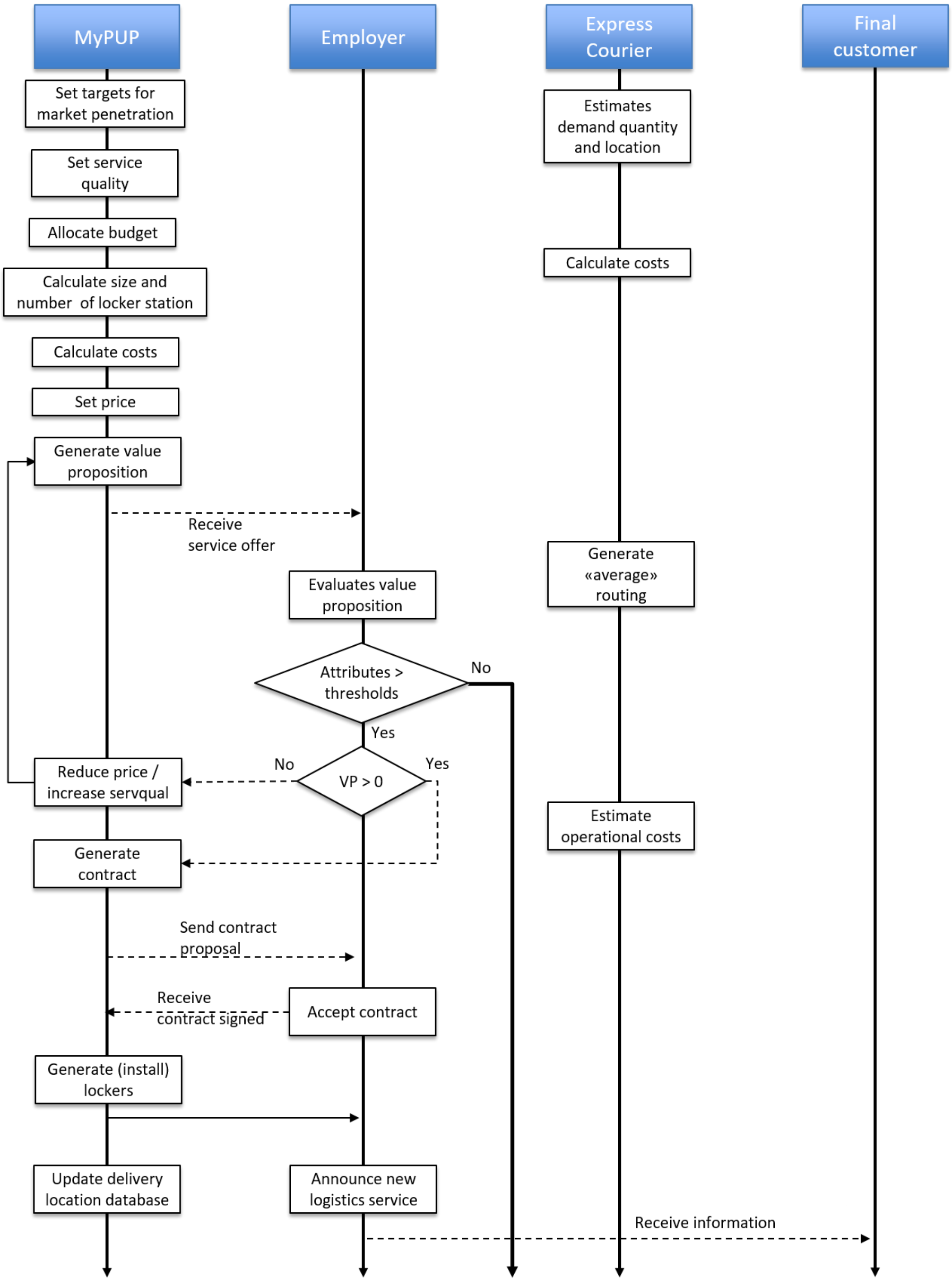

Figure 10 Strategic phases with value proposition negotiation among agents and performance evaluation-MyPUP case

The operative phase instead involves the flow of goods and information among the agents of the business ecosystem. When final customers buy goods online they decide the location of delivery, which can be either their home or their office. In case their employer has the MyPUP lockers installed, the location of delivery automatically updates to the MyPUP warehouse. Express couriers aggregate the information on delivery location from multiple customers and generate their daily routing. If the customer decided to have their parcels delivered at the office, the courier will integrate the MyPUP warehouse location in the vehicle routing. Then, if the next location on the vehicle routing is the MyPUP warehouse, MyPUP collects the parcel and organize its own routing sending the tour to its own transportation suppliers. The truck then delivers the parcel directly to a MyPUP parcel locker, and MyPUP transmits the information on the parcel's reception to the final customer. However, a same-day delivery can happen only if the couriers deliver the parcel before a specific cut-off time (12:00 in the real case). Otherwise, the parcels is stored in the warehouse and added to the routing of next day. The next location in the vehicle routing of the express courier's truck can alternatively be the office building of an employer without MyPUP or a final customer's home. In the first case, it is assumed that the delivery is accepted and the cost of reception is borne by the employer. In the second case, instead the recipient might not be at home hence generating the first attempt failure. The delivery is thus not successful and the parcel is carried back to the express courier for a second attempt, for which the final customer can decide the location.

In all cases, a certain degree of failure in the last-mile is allowed, from which a complaint from the customer ensue. Failure can derive from a delivery to MyPUP after the cut-off time, an unsuccessful pick-up from the express courier or a first-attempt failure due to the missing recipient. At the end of the cycle, the providers compute the numbers of complaints and the operative costs, final users instead update the percentage of unsuccessful deliveries and, finally, employers calculate the cost for receiving goods.

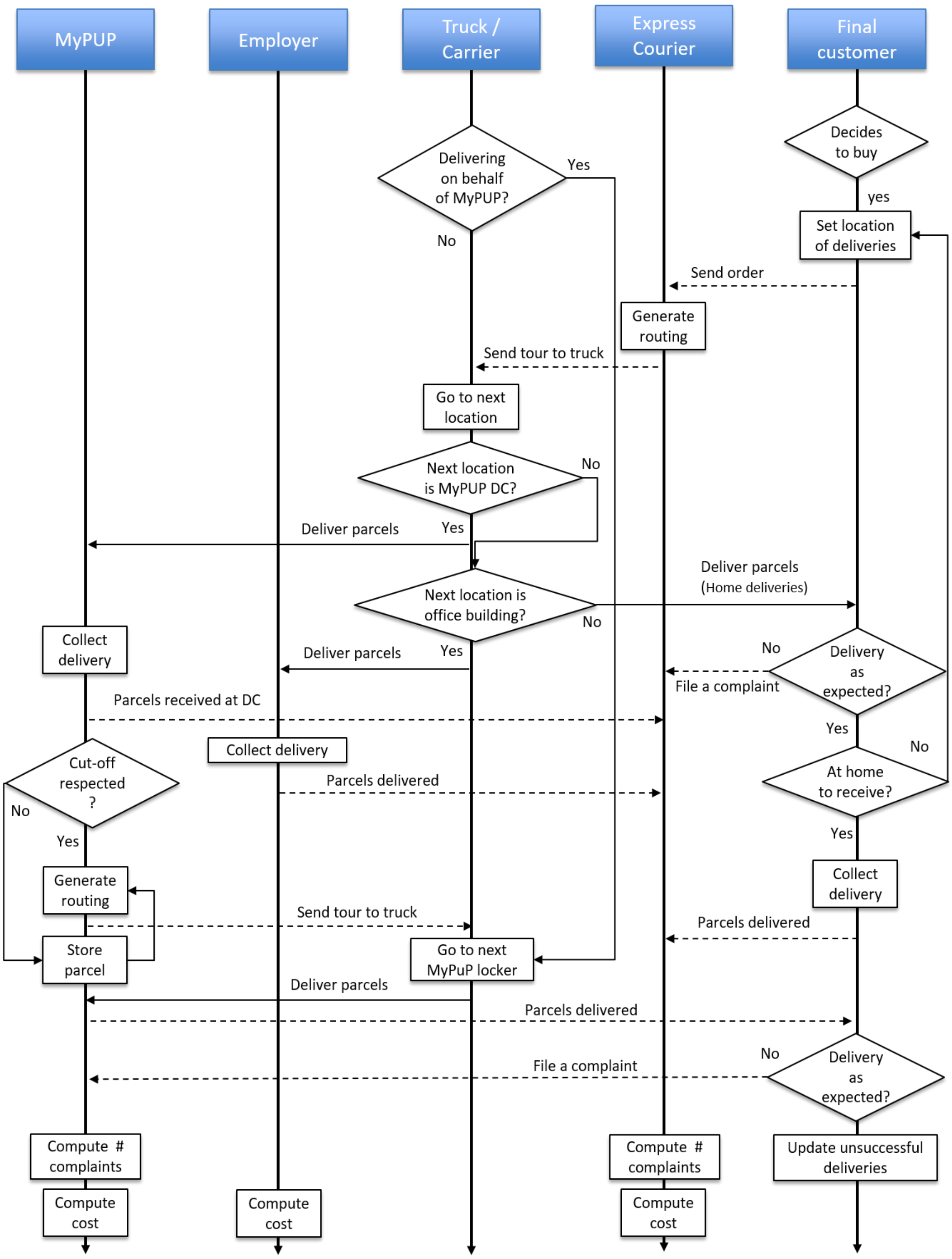

Figure 11 CL physical delivery model

The third phase of the CL business ecosystem ABM regards the performance evaluation. Each agent assesses the value of the metrics to be evaluated against the benchmark value. As anticipated, the benchmark value can be set either on the

AS-IS system configuration or an expected value that agents want to achieve. For user-agents, the latter might represent the expectation on the value proposition that the provider-agent need to fulfil in order to keep convincing the users to retain the service. For provider-agents instead the benchmark is usually set by the management and represents the target level of profit required to maintain competitiveness in the market.

For the MyPUP case, if final users and employers observe a positive result of the new system configuration in terms of intangible and tangible benefits, they might decide to increase their demand for the service. If demand increases, MyPUP need to calculate the availability of resources and even build new capacity if enough R&D budget is spared. On the contrary, if users are not satisfied with the level of service they might opt out of the contract. This event will only take place after a sufficient amount of time steps, to account for the length of the logistics contract agreed upon by the two parties (i.e. user and provider).

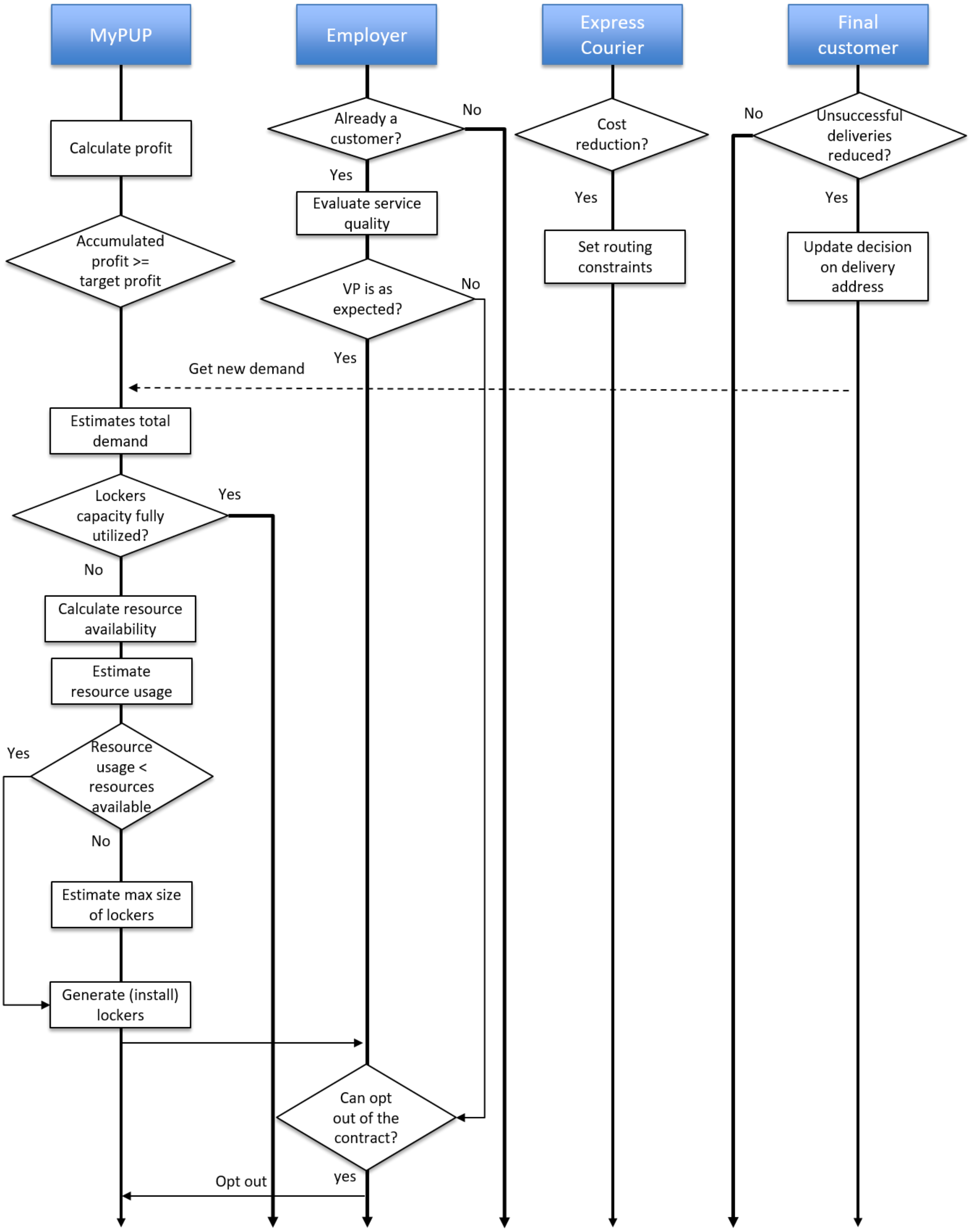

Figure 12 Performance evaluation phase

5.5 Software implementation

Software implementation will be performed using the NetLogo programming language and software (Anand, 2015). NetLogo is used for its simplicity and for its ability for rapid prototyping and developing proof-of-concept models. Moreover, NetLogo is a visual tool extremely suitable for interactive simulations, thus enabling the modeller to assess the functioning of the model and perform debugging on it (Niazi, 2017). The same author points out that NetLogo shows a high degree flexibility in terms using statistics and measurements. In fact, any variable that is of interest to the modeller can be added as a global variable and statistics can be generated based on single or multiple-run. This will be even clearer in the following chapter on model simulation. The coding of the simulation model presented in chapter 6 is available in Appendix 2.

5.6 Model verification

Verification of ABM often poses some challenges to modellers. ABM in fact are usually aimed at forecasting future behaviours of agents and systems, and therefore the traditional methods off fitting the model to existing data is often not possible. Moreover, even if the outcome of the model would resemble the real data, it would still be possible that agents reached that outcome by following a decision-making path than expected. The value of ABM lies exactly in the formal logic that define the behaviours of agents, who then act autonomously during the simulation.

(Walters and Lancaster, 2000; Bose and Thomas, 2007) designed a three-step procedure to verify a multi-agent model:

1. First verification during problem formulation and model building: The verification is built-in when the simulation is designed. To this end, the use of a theoretical framework provides a basic level of verification.
2. Verification during code generation.
3. Verification through empirical data, with the caveat that the same, identical dataset is not used for building the model and for verification.

The first verification step aims at achieving the conceptual model, or theoretical, validity of the model highlighted by Sargent (1998) and Richiardi *et al.* (2006). In particular, according to Sargent (1998), conceptual model validity is defined as "determining that the theories and assumptions underlying the conceptual model are correct and that the model representation of the problem entity is reasonable for the intended purpose of the model". To test conceptual model validity, tracing and tracking of agents is performed to verify that agents' behaviours and the implications of the theoretical assumptions are replicated by the model and to determine whether the model's logic is correct. According to Richiardi *et al.* (2006), theoretical concepts need to be further assessed in relation to their indicator to achieve operational validity. Operational validity can be achieved by testing the model output under extreme conditions, namely extreme values of the inputs.

Verification during code generation is related to computerized model validity or program's validity. Besides tracing agents' behaviour, another validation technique that can be used is to test the robustness of the model after some modifications in the technical architecture of the model (e.g. order of events when simultaneous actions are considered).

Regarding empirical validation, some authors argue that when new phenomena, such as the uptake of innovative CL projects, are observable but not easily quantifiable then empirical validation alone, might not always be the most appropriate choice for validation (Moss, 2008; Niazi, 2017). Hence, as previously mentioned, if only synthetic data are available the last validation stage can be carried out by performing a robustness analysis on the main assumptions and hypotheses regarding the performance indicators of the model.

5.7 Conclusions

The objective of this chapter was to develop a proposal for an agent-based modelling of a CL business ecosystem. Agent-based modelling has been already applied to the CL context, and this chapter provides a further improvement towards the capability of this modelling approach to understand the complexities of the urban logistics sector. The main assumption of this thesis is that such complexities arise from the business model of the entities that compose the system and their business links. Hence, the main elements of this agent-based model proposal originate from the theoretical framework depicting a CL system as a business ecosystem where the stakeholders are business entities that can play different roles in the ecosystem, generate and exchange value proposition and strive for profitability and increased benefits.

Hence, the agents of the model are represented by the business entities composing the CL business ecosystem. Agents' objectives and actions are then outlined according to their business model. The formalization of the agent-based concept requires an understanding of the mechanisms underlying the assignment of roles to entities, the decision-making processes of agents and the chain of activities linking agents together. Then, the guidelines for model verification are drafted for the computational experiment that will be objective of the next chapter.

Chapter 6

City logistics service provider business ecosystem simulation

6.1 Introduction

This chapter follows the proposal for an agent-based model built on the theoretical framework of a CL business ecosystem. The objective is twofold. First, to provide a computational experiment of a specific case study that is becoming one of the archetypes of CL innovations, namely the introduction of automated parcel locker stations. Second, to highlight the main steps required to implement the CL business ecosystem ABM into a simulation model, highlight the challenges connected to this task and the main results associated with it.

A case study on two different ecosystem configurations of the same innovation (i.e. automated parcel lockers stations installed in office buildings) is modelled using the NetLogo programming environment. Interviews with a CEO from one company and the Director of product design of a second company supported the development of the model mechanisms and the quantification of the value proposition of the two competing services.

This chapter is structured as follows. First, the model design and parameters are outlined. Then, a sensitivity analysis is performed to check the consistency of the criteria assigned to the agents for accepting or rejecting the value proposition. Then, the hypotheses to be tested during the computational experiment are drafted. The results of the simulation are presented in section 5, together with conclusions and further research in section 6.

6.2 Model design and parameters

The model aims to simulate two different business ecosystem configurations for the introduction of automated parcel locker stations in office buildings. For the first configuration, the locker operator only installs parcel lockers, and builds the managing ICT infrastructure. For the second one instead the locker operator consolidates goods at the warehouse on top of installing and managing the parcel lockers. Following the logic introduced in the CL business ecosystem framework, a parcel locker operator can take on the roles of network coordination and receiver through the automated lockers (i.e. first configuration) or also acquire the role of last-mile provider. Hence, it is assumed that the second configuration would require more resources and consequently offer a higher price to the customer.

As anticipated in previous chapters, the customers for this solution are represented by employers, or more specifically facility managers. Three types of employers are modelled here, namely small, medium and big entities according to the number of employees. Small companies have less than 50 employees, medium between 51 and 250, and big companies have more than 250 employees. Such companies differ in decision-making criteria as will become clearer later on.

After setup, the model simulation starts with service providers announcing the service offer to their potential customers, which then assess its value according to their subjective evaluation criteria.

The spread of the service proposal to potential customers is a function of the marketing action set up by the service provider. In fact, service providers have to approach potential customers and deliver their value propositions. From a modelling standpoint, this configures as a message sent by the service provider to a potential customer bearing a cost. Such cost is a reflection of how difficult it is to get in touch with a company. For instance, this could be represented by the human resources devoted to marketing, and the effort needed to contact each single customer. Providers can make a contact with the employer only once, and it is assumed that employers are reached by a provider and later on cannot be reached by a second provider. Hence, employers can be contacted by the "wrong" locker provider and therefore not choose any of the two providers.

If positively evaluated, customers choose the provider and the provider installs the parcel lockers. This decision will not change over time even if a better solution for the customer might be present in the system. This is because this is not cost-effective for an employer to look for other solutions, and thus the first solution to provide overall benefits will be chosen (technology lock in). On the contrary, a negative evaluation will end the evaluation process and no agreement will be signed between user and provider. However, users can change their minds if conditions change. For instance, a company may decide to care more about sustainability and therefore evaluate more positively the service offered by the locker operator with the consolidation. In this case, there will be no need for a second contact and the user will only re-evaluate the value proposition. At the end of the evaluation, actors evaluate their performance. In particular, providers calculate their costs and income and evaluate the profitability of the service.

6.2.1 Parameters

Table 23 shows the parameters of the model and the actor who owns those parameters. Data on infrastructure costs were collected through interviews with a parcel locker operator, data on marketing instead are a speculation based on the assumption made for the two configurations. The values for marketing cost are set so that realistically all employers are reached in a sufficient period of time, to avoid that a small share of the budget devoted to marketing is enough to reach all market in few simulation steps. Marketing cost is furthermore assumed to be related to the degree of innovation, and thus the marketing cost for provider 1 is half the same cost for provider 2. In other words, solution 1 is “easier” to understand and thus it can reach a wider market. Furthermore, more resources are necessary to organize last mile, thus the cost for each unit of capacity is higher for provider 2.

The ability of the Locker providers to reach the market depends on the marketing budget and therefore varies over time. The choice of increasing the budget during the simulation is left to the modeller. For instance, the marketing effort can be modelled by explicitly stating the share of the market that can be reached with the initial budget, and the cost for reaching one customer.

Table 23 Parameters of the model

Actor	**Parameter**	**Value**	**Description**
All locker operators	Initial Budget	Object of simulation	marketing and R&D expenses dry out the budget, profits increase it
	Initial Marketing budget	Object of simulation	Marketing spending is necessary to reach the customer
	r&dbudget	budget - marketingbudget	R&D budget is spent on increasing IT capacity to manage the infrastructure

	ITcapacity	r&dbudget / 1000 €	The higher the expenditure in r&d the higher the capacity of the infrastructure system to organize the delivery system.
	Cost of infra-structure	100 €/lockerstation	Cost for installing the locker station
	Cost of mainte-nance	50 €/lockerstation	Cost for locker maintenance
Locker operator (first configura-tion)	Marketing cost	2500 €	Cost incurred per each user reached
	Fixed cost	150 €/locker station	Overhead costs
Locker operator (second configu-ration)	area	100 m2	Size of the warehouse
	Handling area	area / 2	Floor space for storing the par-cels
	Parcel handled per m2	3	Parcels can be store in stacks
	Handling capaci-ty	Parcel handled per m2 *Handling area	
	Marketing cost	5000 €	Cost incurred per each user reached
	Cost of transpor-tation	10 €/lockerstation	Average cost incurred to deliver parcels at one locker station. This will change during the simulation
	Cost of handling	150 € / lock-erstation	Cost for handling parcels at the warehouse, computed for each locker
	Fixed cost	200 €/locker station	Overhead costs
Employer	Cost of handling	0.33 €/minute/parcel	Salary rate (€/minute) to handle parcels by locker operator's per-sonnel
	Handling time	5 minutes	Time to receive the parcel
	Handling cost	CHandling * THandling * employee per company * monthly demand per person	

The user evaluates the service offer by means of a multi-criteria assessment, including monetary and non-monetary aspects. That is, if the service does not provide a quantifiable cost reduction it can still provide intangible values to the user. The multi-criteria evaluation depends on the relative importance assigned to the different criteria, which is expressed as a subjective judgment by the user. Multi-criteria methods have already been used in transport problems, and are suit-able to the problem at issue. This particular case will happen even if the employer would have made contact with the provider with the more expensive solution.

This is due to the fact that is not cost-effective for an employer to look for an innovative solution and thus the first solution to provide cost benefit will be preferred.

A simple additive weighting (SAW) method is applied to evaluate the different alternatives (Afshari, Mojahed and Yusuff, 2010). Triantaphyllou and Mann (1989) state that SAW "gives the most acceptable results for the majority of single-dimensional problems" and is the most used multi-criteria methods for its simplicity (Şener *et al.*, 2005). The three alternatives are represented by i) Business-As-Usual (BAU), where no parcel lockers is installed, ii) first configuration with only parcel lockers management, and iii) second configuration with parcel lockers management and parcels consolidation. The alternatives are ranked using four criteria. The first criterion is the logistics cost for receiving parcels. For the first alternative, the total cost for receiving the parcels is computed based on the amount of time for receiving each parcel at the reception desk and the hourly cost of the reception personnel. For the other alternatives, the inbound cost incurred by a company installing a locker station will be equal to the service price. The logistics cost is evaluated on a per employee basis, to conform the evaluation for all companies' size. A second criterion is represented by the hassles connected with having to face the delivery process. This is determined with the amount of people external to the employer that are involved in this process, namely the sum of delivery persons coming in every month and the technicians visiting the locker station for the maintenance job. The third criterion is sustainability, which it is assumed to have the highest value for the second configuration. A fourth criterion is added to take into account the risk related to adopt an innovative solution ever tested before. This criterion is evaluated in relation with the width of the scope of the service. That means, the more comprehensive the solution in terms of services offered, the higher the gap from Business As Usual, the stronger the commitment required from the customer and therefore the riskier this commitment. Organizing the last-mile and consolidating goods is the more extensive solution among the three ones and therefore the more risky for customers.

Table 24 shows the formulation of the values that each alternative has for the different criteria. Hence, these values change according to the number of employees and the demand for parcels.

Table 24 Evaluation criteria for each employer

	Alternatives	Business as Usual (BAU)	Locker station	Locker station + consolidation
	Criteria	*A1*	*A2*	*A3*
C1	Cost	Inbound cost = (Monthly demand/employee) * Inbound cost per parcel	Monthly fee / # employee	Monthly fee / # employee
C2	Hassles from the delivery process	# delivery persons / month	(# delivery persons + technicians) / month	Technicians) / month
C3	Sustainability	Low	Low	High
C4	Risk	Low	Medium	High

6.2.2 Criteria weights and values

Small companies are less interested in consolidation value because they are less likely to face a lot of deliveries; they are also more risk averse because installing locker station require an investment which might be too large to sustain for them. Large companies instead care less about price but more for sustainability and consolidation, and are less risk averse. Medium companies are somewhat in the middle: if they receive few parcels, they will value price and will be risk averse, acting as small companies, and vice versa.

To calculate the values for each criterion and convert them for the multi-criteria method their value are computed and then converted into an ordinal scale signifying their relative values. A traditional Likert-scale 1-5 has been used to the task. To this end, thresholds need to be identified for criteria C1 and C2. For criteria C1, information from online retails reports is used (Ecommerce Foundation, 2017; Wallace, 2017). Data from these reports show that the average customer purchase online once a month. About one third of users instead buy goods online at least once a week, or four times a month; another around 40% orders once a month. On the two extremes of the online purchase spectrum, there are approximately 5-10% of users who order daily and a further 20% approximately who either never order online or does it once a year. Based on the assumptions made for the receiving cost at the reception desk, this translates into an ordinal scale calculated on the average monthly cost of receiving parcels. For criteria C2, it is assumed that one delivery person per day in average is still manageable by the company, whereas 5 represents a situation where having to deal with multiple persons entails a strain on daily operations. From the interviews with the locker provider, this criterion also refers to the fact that some employers would like to have to deal with only one delivery person, in order to trust this person with the freedom to enter the office buildings. This is especially true if express couriers should change the drivers very often.

Table 25 Conversion of values for SAW method

	Threshold	**Value**	**Goal**
C1	< 1 € / employee < 2 € / employee < 5 € / employee < 12 € / employee > 12 € / employee	5 = very high 4 = high 3 = medium 2 = low 1 = very low	Minimize
C2	1 delivery persons / day 2 delivery persons / day 3 delivery persons / day 4 delivery persons / day 5 delivery persons / day	5 = very high 4 = high 3 = medium 2 = low 1 = very low	Minimize

To assign the weights, companies are profiled based on their characteristics and size, as seen in table 26.

Table 26 Weights

Company	Type	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Rationale of the weights
		Price	*Consolidation*	*Sustainability*	*Risk*	
1	Small	0.8	0	0	0.2	Company with low demand of parcels. Only focused on price.
2		0.7	0.05	0.1	0.15	Company with low demand of parcels. Focused on price and slightly on sustainability. No interest in the value of consolidation, as it receives only one delivery person per day in average.
3		0.7	0.05	0.05	0.2	Same as previous company but less conscious of sustain-ability
4		0.6	0.1	0.15	0.15	Company with same demand as the previous two, but willing to spend more on innovation and more conscious of sustainability issues and the value of consolidation
5		0.5	0.2	0.15	0.15	Company with higher demand of parcels, hence keener on consolidation and less on price than previous ones.
6	Medium	0.7	0.1	0	0.2	Company with low demand of parcels. Only focused on price but might be more interested in consolidation given the larger demand from employees.
7		0.5	0.2	0.15	0.15	Same profile as company 5 but with slightly higher de-mand of parcels.
8		0.5	0.25	0.2	0.05	Interested in consolidation and sustainability.
9		0.45	0.25	0.1	0.2	Risk averse but more keen on consolidation than sustain-ability.
10		0.3	0.4	0.1	0.2	High demand, hence looking for consolidation.
11	Big	0.6	0.2	0.1	0.1	Low demand as company 6 but still bigger and hence more prone to adopt a consolidation service.
12		0.3	0.4	0.15	0.15	Similar demand as company 10, but more into sustaina-bility and less risk averse as it is a bigger company trying

					to improve its image to employees and external stake-holders
13	0.3	0.4	0.25	0.05	As previous company but more subject to sustainability issues.
14	0.2	0.5	0.2	0.1	Large demand and large company. Wants to organize last mile and to reduce the hassles connected to it.
15	0.25	0.45	0.15	0.15	As the previous company, but more risk averse.

Weights can change over time, based on the response of the system (i.e. the environment in ABM terminology). In particular, following a traditional view of the diffusion process, a solution becomes exponentially more appealing to increasing share of the population, as risk-averse employers will also adopt a widely used solution. Moreover, a large share of customers is keen on being seen as part of the majority, and will “fall in line” with a solution that is widely accepted by others like them. In multi-criteria terms, this translates into a threshold level above which an employer will modify the criterion risk so to reduce the barrier to adopt the service of one of the two providers.

For computing the weighted values for the alternatives, an indifference threshold of 0.05 has been chosen to identify the best alternative. Table 27 shows the results of the evaluation through the normalized decision matrix of the SAW procedure.

Table 27 Normalized decision matrix for alternatives ranking

NORMALIZED DECISION MATRIX

Company type	**Criteria**				**Weighted value**	**Best alternative**
1	Criterion 1	Criterion 2	Criterion 3	Criterion 4		***Alternative 1***
Alternative 1	1.00	1.00	0.20	1.00	***1.00***	
Alternative 2	0.40	1.00	0.20	0.60	***0.44***	
Alternative 3	0.20	0.60	1.00	0.20	***0.20***	
Criteria weights	*0.8*	*0*	*0*	*0.2*		
2	Criterion 1	Criterion 2	Criterion 3	Criterion 4		***Alternative 1***
Alternative 1	1.00	1.00	0.20	1.00	***0.92***	
Alternative 2	0.67	1.00	0.20	0.60	***0.63***	
Alternative 3	0.33	0.60	1.00	0.20	***0.39***	
Criteria weights	0.7	0.05	0.1	0.15		
3	Criterion 1	Criterion 2	Criterion 3	Criterion 4		***Alternative 1***
Alternative 1	1.00	1.00	0.20	1.00	***0.96***	
Alternative 2	0.67	1.00	0.20	0.60	***0.65***	
Alternative 3	0.33	0.60	1.00	0.20	***0.35***	
Criteria weights	0.7	0.05	0.05	0.2		
4	Criterion 1	Criterion 2	Criterion 3	Criterion 4		***Alternative 1***
Alternative 1	1.00	1.00	0.20	1.00	***0.88***	
Alternative 2	0.67	1.00	0.20	0.60	***0.62***	
Alternative 3	0.33	0.60	1.00	0.20	***0.44***	
Criteria weights	0.6	0.1	0.15	0.15		
5	Criterion 1	Criterion 2	Criterion 3	Criterion 4		***Alternative 2***

Alternative 1	0.50	1.00	0.20	1.00	***0.63***	
Alternative 2	1.00	1.00	0.20	0.60	***0.82***	
Alternative 3	0.50	0.75	1.00	0.20	***0.58***	
Criteria weights	0.5	0.2	0.15	0.15		
6	Criterion 1	Criterion 2	Criterion 3	Criterion 4		***Alternative 1***
Alternative 1	1.00	1.00	0.20	1.00	***1.00***	
Alternative 2	0.80	1.00	0.20	0.60	***0.78***	
Alternative 3	0.60	0.60	1.00	0.20	***0.52***	
Criteria weights	0.7	0.1	0	0.2		
7	Criterion 1	Criterion 2	Criterion 3	Criterion 4		***Alternative 2***
Alternative 1	0.75	1.00	0.20	1.00	***0.76***	
Alternative 2	1.00	1.00	0.20	0.60	***0.82***	
Alternative 3	0.75	1.00	1.00	0.20	***0.76***	
Criteria weights	0.5	0.2	0.15	0.15		
8	Criterion 1	Criterion 2	Criterion 3	Criterion 4		***Alternative 3***
Alternative 1	0.75	1.00	0.20	1.00	***0.72***	
Alternative 2	1.00	1.00	0.20	0.60	***0.82***	
Alternative 3	0.75	1.00	1.00	0.20	***0.84***	
Criteria weights	0.5	0.25	0.2	0.05		
9	Criterion 1	Criterion 2	Criterion 3	Criterion 4		***Alternative 2***
Alternative 1	0.75	1.00	0.20	1.00	***0.81***	
Alternative 2	1.00	1.00	0.20	0.60	***0.84***	
Alternative 3	0.75	1.00	1.00	0.20	***0.73***	
Criteria weights	0.45	0.25	0.1	0.2		
10	Criterion 1	Criterion 2	Criterion 3	Criterion 4		***Alternative 3***
Alternative 1	0.25	0.67	0.20	1.00	***0.56***	
Alternative 2	1.00	0.67	0.20	0.60	***0.71***	
Alternative 3	0.75	1.00	1.00	0.20	***0.77***	
Criteria weights	0.3	0.4	0.1	0.2		
11	Criterion 1	Criterion 2	Criterion 3	Criterion 4		***Alternative 1***
Alternative 1	1.00	1.00	0.20	1.00	***0.92***	
Alternative 2	1.00	1.00	0.20	0.60	***0.88***	
Alternative 3	1.00	0.75	1.00	0.20	***0.87***	
Criteria weights	0.6	0.2	0.1	0.1		
12	Criterion 1	Criterion 2	Criterion 3	Criterion 4		***Alternative 3***
Alternative 1	0.60	0.67	0.20	1.00	***0.63***	
Alternative 2	1.00	0.67	0.20	0.60	***0.69***	
Alternative 3	0.80	1.00	1.00	0.20	***0.82***	
Criteria weights	0.3	0.4	0.15	0.15		
13	Criterion 1	Criterion 2	Criterion 3	Criterion 4		***Alternative 3***
Alternative 1	0.60	0.67	0.20	1.00	***0.55***	
Alternative 2	1.00	0.67	0.20	0.60	***0.65***	

Alternative 3	0.80	1.00	1.00	0.20	***0.90***	
Criteria weights	0.3	0.4	0.25	0.05		
14	Criterion 1	Criterion 2	Criterion 3	Criterion 4		***Alternative 3***
Alternative 1	0.25	0.33	0.20	1.00	***0.36***	
Alternative 2	1.00	0.33	0.20	0.60	***0.47***	
Alternative 3	0.75	1.00	1.00	0.20	***0.87***	
Criteria weights	0.2	0.5	0.2	0.1		
15	Criterion 1	Criterion 2	Criterion 3	Criterion 4		***Alternative 3***
Alternative 1	0.25	0.33	0.20	1.00	***0.39***	
Alternative 2	1.00	0.33	0.20	0.60	***0.52***	
Alternative 3	0.75	1.00	1.00	0.20	***0.82***	
Criteria weights	0.25	0.45	0.15	0.15		

6.3 Sensitivity analysis

To validate the results of the evaluation phase and check the robustness of the model, a sensitivity analysis is performed on the criteria weights. The objective of the sensitivity analysis is to identify the change in criteria weights needed for diverging from the first ranking, assessing the impact of those changes on the final ranking of alternatives. This work can be performed by making pair-wise comparisons between two non-dominated alternatives, and observe the change in the criteria weights needed to reverse the total weighted value of those alternatives by a predetermined amount. Barron and Schmidt (1988) propose a least-square procedure that starts with an arbitrary set of attributes' weights, as in the experimental design proposed here. The least-square procedure applied on the weights assigned to the companies in the model shows that the evaluation results holds quite well after manipulating the criteria weights. As a matter of fact, only one company has an alternative set of weights that might change her decision, in particular from A3 to A2.

A sensitivity analysis has been performed on the random number generation embedded in the model. Hence, different values for random seed number to initiate the number generation are simulated. Results from this sensitivity analysis show that for different levels of random seed the outputs of the model do not vary significantly. The results of the sensitivity analyses are proposed in Appendix 3.

6.4 Model verification

As stated in paragraph 5.6, model verification is performed by means of agents' tracing and testing the behaviour of the model to the extreme conditions.

Concerning the former method, I verified that employers contacted by the locker provider that is their preferred alternative would actually accept the value proposition of such provider. Figure 13 shows a sample of agents taken into account for this verification method. In practical terms, first I ask the model to return the ID of small, medium and large employers; then, I trace one agent per each type and ask this agent to return the value of the variables showing its list of alternatives (i.e. 0 for no parcel locker installed, 1 for parcel locker provider 1 and 2 for parcel locker provider 2), the provider by which the agent has been contacted and ultimately the provider chosen. Results show that agents behave as supposed by the model's logic and implications. In particular, employers 407 and 442 are contacted by provider 1 and do not choose to have the lockers installed, as presupposed by their preferred alternatives.

```
Setup procedure

   "Small Employers:"[404 401 400 413 406 402 407 411 409
410 405 414 412 403 408]
    "Medium Employers:"[418 423 429 415 426 417 420 422 428
424 425 421 416 419 427]
    "Large Employers:"[436 434 432 442 433 435 439 440 443
438 441 437 444 430 431]
    "List of alternatives:"(employer 407): [0 1]
    "List of alternatives:"(employer 415): [1 2]
    "List of alternatives:"(employer 442): [0 1]

Go procedure
Time Step = 1

    "contacted by locker provider 1:"(employer 407): false
     "contacted by locker provider 1:"(employer 415): false
     "contacted by locker provider 1:"(employer 442): false
     "Market untouched"45
     "Lockerprovider:"(employer 407): 0
     "readytoinstall?"(employer 407): false
     "Lockerprovider:"(employer 415): 0
     "readytoinstall?"(employer 415): false
     "Lockerprovider:"(employer 442): 0
     "readytoinstall?"(employer 442): false

......
```

```
Time step = 10
      "contacted by locker provider 1:"(employer 407): true
      "contacted by locker provider 1:"(employer 415): false
      "contacted by locker provider 1:"(employer 442): false
      "Lockerprovider:"(employer 407): 0
      "readytoinstall?"(employer 407): false
      "Lockerprovider:"(employer 415): 0
      "readytoinstall?"(employer 415): false
      "Lockerprovider:"(employer 442): 0
      "readytoinstall?"(employer 442): false
……
Time step = 19

      "contacted by locker provider 1:"(employer 407): true
      "contacted by locker provider 1:"(employer 415): false
      "contacted by locker provider 1:"(employer 442): true
      "Lockerprovider:"(employer 407): 0
      "readytoinstall?"(employer 407): false
      "Lockerprovider:"(employer 415): 0
      "readytoinstall?"(employer 415): false
      "Lockerprovider:"(employer 442): 0
      "readytoinstall?"(employer 442): false
……
Time step = 20

      "contacted by locker provider 1:"(employer 407): true
      "contacted by locker provider 1:"(employer 415): true
      "contacted by locker provider 1:"(employer 442): true
```

```
"Market untouched"13

"Lockerprovider:"(employer 407): 0

"readytoinstall?"(employer 407): false

"Lockerprovider:"(employer 415): 1

"readytoinstall?"(employer 415): true

"Lockerprovider:"(employer 442): 0

"readytoinstall?"(employer 442): false
```

Then, the model is tested at the extreme conditions. For instance, let us suppose that both providers allocate each 25’000 € of the budget to marketing purpose. Hence, during the first time step they would contact already a significant number of potential customers. However, this aggressive strategy would leave them with not enough budget in the next step if no customers decide to install the lockers and thus no profits are accrued. As a matter of fact, during the simulation run both locker providers made contact with 3 potential customers, but only parcel locker provider 1 signed a contract, and therefore this provider could continue to contact customers in the following time steps. Please see Appendix 3 for the screenshots of the simulation runs.

A third verification step is performed during code generation, and it involves modifying the internal structure of the model, namely inverting the order by which the model asks the two providers to contact customers. In fact, in the baseline simulation the model would first ask provider 1 and then provider 2. Appendix 3 also shows that changing the order does not affect significantly the outputs of the model.

6.5 Hypotheses testing

By modelling the two solutions together, I aim to test the effectiveness of the value proposition of different competing CL system configurations. The basic assumption is that the more appealing configuration is actually the most innovative one and therefore is more costly in terms of operations but also more expensive in marketing due to the difficulty of sending the message to customers.

Hence, the levers of the model are the initial budget of the two providers and the share of that budget for marketing purposes. What happens if I manipulate the marketing budget to reach more customers? Should I “gamble” by increasing the marketing budget to raise more customers when I have received few positive responses or wait for the profit to accumulate? The risk is to wipe out the budget without finding a customer.

6.6 Simulation results

Some interesting results emerge from simulating different scenario of the two parameters initial budget and marketing budget, for an initial population of 45 employers. These results are shown in table 28.

Table 28 Simulation scenarios

		Base case	Scenario 1	Scenario 1 bis	Scenario 2	Scenario 2 bis	Scenario 3	Scenario 3 bis	Scenario 4
Marketing Budget	Provider 1	2,500 €	5,000 €	5,000 €	2,500 €	2,500 €	5,000 €	5,000 €	2,500 €
	Provider 2	5,000 €	5,000 €	5,000 €	10,000 €	10,000 €	10,000 €	10,000 €	5,000 €
Initial Budget	Provider 1	30,000 €	30,000 €	20,000 €	30,000 €	20,000 €	30,000 €	20,000 €	20,000 €
	Provider 2	30,000 €	30,000 €	30,000 €	30,000 €	30,000 €	30,000 €	30,000 €	30,000 €
Months to reach all employers		31	23	29	33	30	23	27	30
Employers contacted by	Provider 1	28	25	25	30	27	34	33	26
	Provider 2	15	17	15	13	17	10	12	19
	Both providers	2	3	5	2	1	1	0	0
Customers	Provider 1	16	13	15	16	15	20	18	13
	%	36%	29%	33%	36%	33%	44%	40%	29%
	Provider 2	6	11	9	7	8	4	4	9
	%	13%	24%	20%	16%	18%	9%	9%	20%
	TOTAL	22	24	24	23	23	24	22	22
	%	49%	53%	53%	51%	51%	53%	49%	49%

For instance, decreasing the initial budget for provider 1 to 20’000 € results into three customers churning from provider 2 to provider 1. Moreover, provider 2 will accrue higher profits given the higher margin. Doubling the marketing budget of provider 2 instead does not change the outcome for provider 1 significantly. Moreover, scenario 2bis shows that provider 1 would lose only one customer should her initial budget be equal to 20’000 €. Hence, it seems that doubling provider 2’s marketing budget would not generate any improvement in her ability to attract customers, even though it would maximize the marketing effort by reducing the number of contacts that needs to be made to sign a contract.

Some counterintuitive results are drawn instead from increasing the marketing budget of provider 1. In fact, else equal, this turns into a lower penetration of the market as well as an improvement of the second provider in the same regard. Even more striking is the fact that by reducing the initial budget provider 1 can restore her ability to attract customers, rather than the contrary. The reason for this behaviour probably stems from the size of the market compared to the marketing efforts of the providers as well as their attractiveness. Given the initial setting of employers’ population, provider 1 is able to contact a larger share of the market in few initial ticks. This has two consequences. First, if provider 1 is not able to gather additional funding she would wipe out her budget in the first months, thus not being able to sustain the marketing effort. Second, the market still to be touched will quickly shrink, and therefore provider 2, who still has marketing budget left further on during the simulation period, can maximize the effect of the marketing action. In practice, by increasing the marketing budget effort in the first steps provider 1 chooses to anticipate the effect of her marketing effort, but ends up losing too much ground further on because provider 2 is able to sustain her marketing effort. This is possible also because the margin for each installation is higher for provider 2 than for provider 1.

Some of these results may be influenced by the decisions taken by the simulation software (NetLogo), which cannot ask the two providers to simultaneously contact the potential customers. Hence, one provider will always contact first. For some population size in fact, acting first has a positive result on the ability to attract customers, and vice-versa.

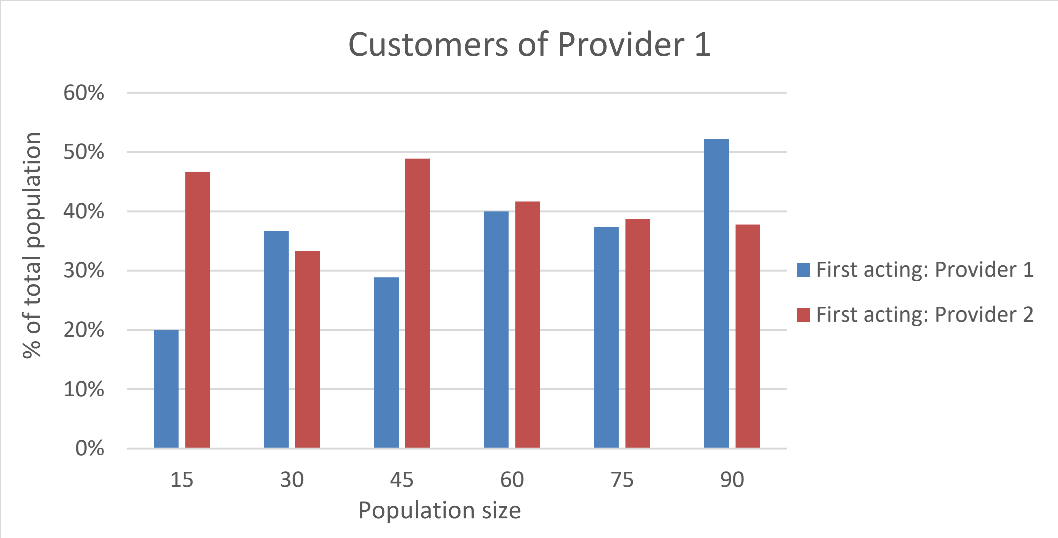

Figure 13 Customers of provider 1, depending on size of population and first acting

In particular, Figure 13 shows that provider 1 reaches more customers when she is first acting only with population size of 30 and 90 employers. On the contrary, she can significantly increase her customer base when provider 2 is acting first with a population size of 45 employers.

In conclusion, increasing the marketing budget does not always yield better results in terms of attracting customers, and this is related to which provider is acting first and the size of the market. An experiment has been run to prove this point and provide more insights into the effect of the parameters initial population, initial budget and marketing budget of the two providers on the number of customers reached. In particular, the ranges of the parameters are as follows:

Table 29 Parameter settings for the run experiment

Parameter	**Range**
Initial Market	15-90
Marketing budget provider 1	2500-10000 €
Marketing budget provider 2	5000-15000 €
Initial Budget provider 1	20000-30000 €
Initial budget provider 2	20000-30000€

One simulation run has been performed for each setting of the parameters, generating 1440 total runs. Figure 14 shows that only for selected initial population of employers the average market size reached by provider 1 increases with the marketing budget.

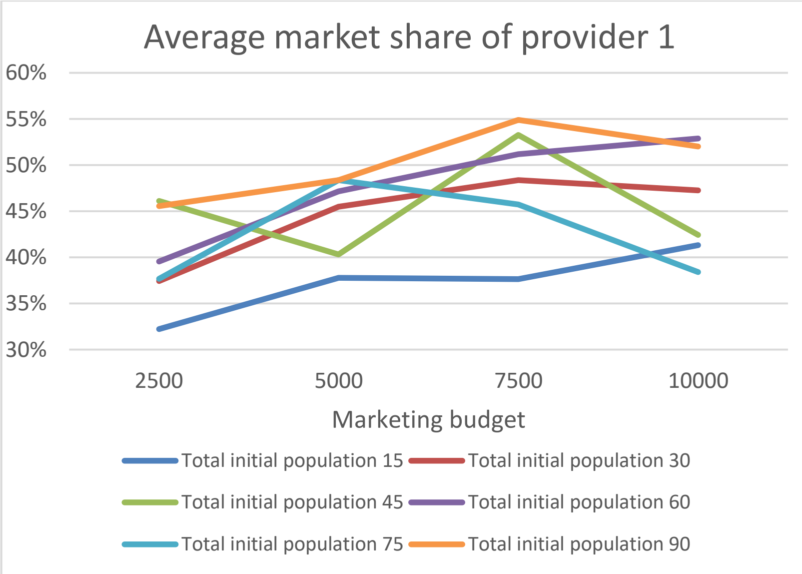

Figure 14 Market share of provider 1 with different levels of marketing budget and different initial population size

For population size equals to 75 the market share of provider 1 decreases with marketing spending. For a population of 45 moreover, the average market share is lower with a marketing budget of 10’000 € than with a marketing budget of 2’500 €.

The effect of marketing action by Provider 1 is also affected by the marketing spending of provider 2, even though with counterintuitive results as anticipated. In particular, provider 1 would reach higher share of the market with an increasing marketing spending by provider 2, in case of market sizes of 15, 45 (with some decline passing from 5’000€ to 10’000€) and 90 (Figure 15).

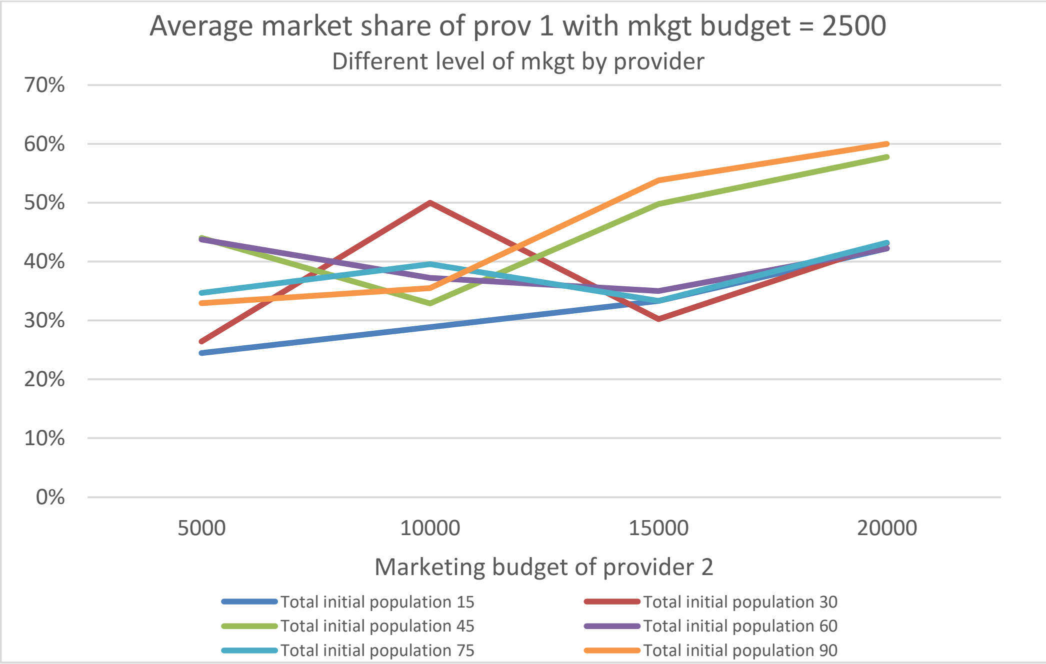

Figure 15 Market share of provider 1 with different levels of marketing budget by provider 2 and different initial population size

If we take into account the imitation criterion, the success of provider 1 would be only slightly improved. In particular, only one big "archetypical" company would change the decision to provider 1 when at least 15% of the market has adopted the solution. For a market share higher than 50% another archetypical medium company will switch to provider 2.

From the experiment, provider 1 reaches at least 50% of a total market of 60 employers in 336 simulation runs out of 720. Results show that provider 1 has a higher initial budget than provider 2 in 180 runs as opposed to 81 runs where she has a lower budget than provider 2. Moreover, for about a third of the total simulation runs provider 1 reaches at least 50% of the market with a lower marketing budget. Hence, in more than one third of the simulation runs (i.e. 36.25%) provider 1 can reach 50% of the market with either a lower initial or marketing budget than provider 2.

Provider 2 instead never reaches 50% of the market share, given the parameters settings range and cost factors. However, she can reach 15% of the market share and hence change the decision of one archetypical big company. For an initial population of 60 this is possible in 195 runs out of 720 (27%). However, in our simulation provider 2 is not able to fully exploit this effect because some of the companies that might change the decision have been contacted already by provider 1.

These results further confirm that it may be counterproductive to increase marketing spending as well as the overall budget, and that a decision from one provider affects the success of the other provider.

Another experiment has been conducted on profits, with the same range of parameters. Figure 16 shows the profits of the two providers depending on the size of the market and their marketing spending. It appears that provider 2 achieves lower profits in addition to lower market share.

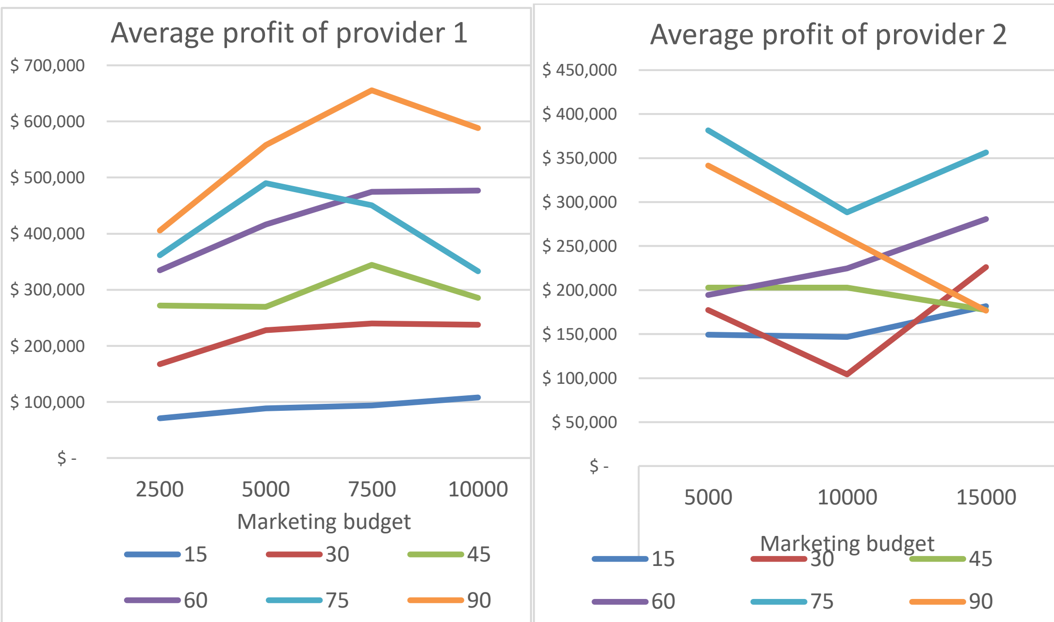

Figure 16 Average profits of the two providers

Moreover, the trends highlighted for the profits resembles the ones seen for the market share, meaning that profits follow quite linearly the market share. Hence, even with higher profit margin on each locker sold, Provider 2 is not able to overcome its lower market share and has lower profit ultimately. Profits for provider 2 do not seem to follow any particular pattern, as they are either rising or declining for all marketing spending and initial market. For instance, profits accrued with an initial population of 90 are at the lowest with the highest marketing spending. Instead, if we take into account the same marketing effort by the two providers, namely 5’000 € and 10’000 €, profits appear to be more comparable. In this case, profits increase for provider 1 with marketing spending for all population but 75. For provider 2 instead, profits increase with marketing spending for initial population of 15, 45 and 60. It can be stated thus that the profits of provider 2 in this experiment can at best follow the profits of provider 1, and at worst the lack of market share turns into declining profits given the higher cost of operations (Figure 17).

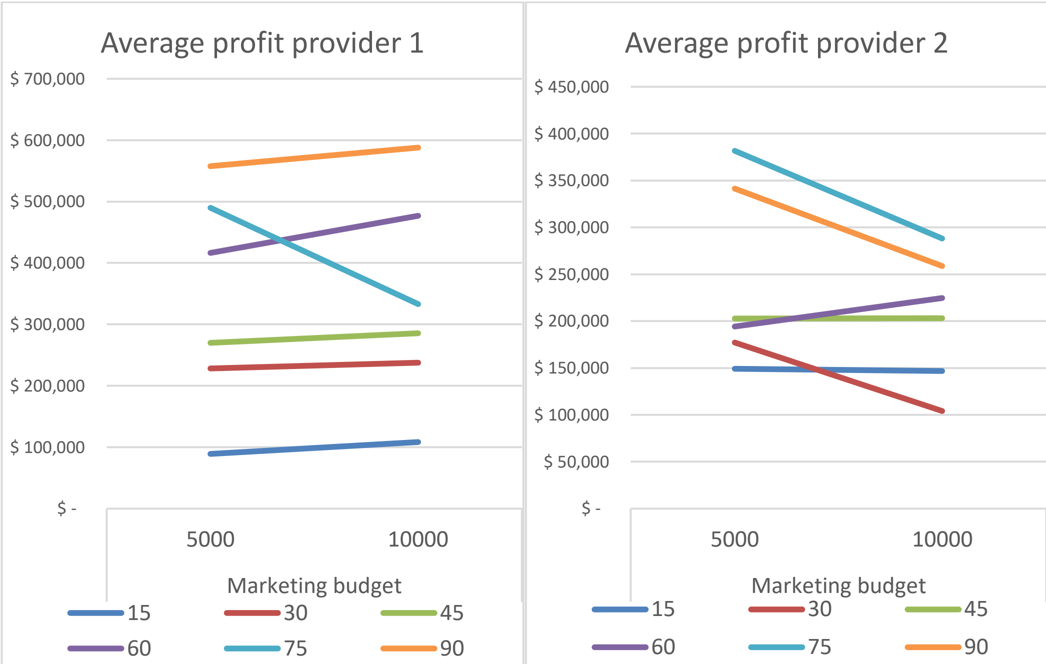

Figure 17 Average profit of provider 1 and 2

However, to compare fully the profits with market share it is necessary to apply normalization to the profits, as these are evidently influenced by the size of the market (Figure 18). Hence, the average profit per initial customers is used to check for correlation between market share and profits.

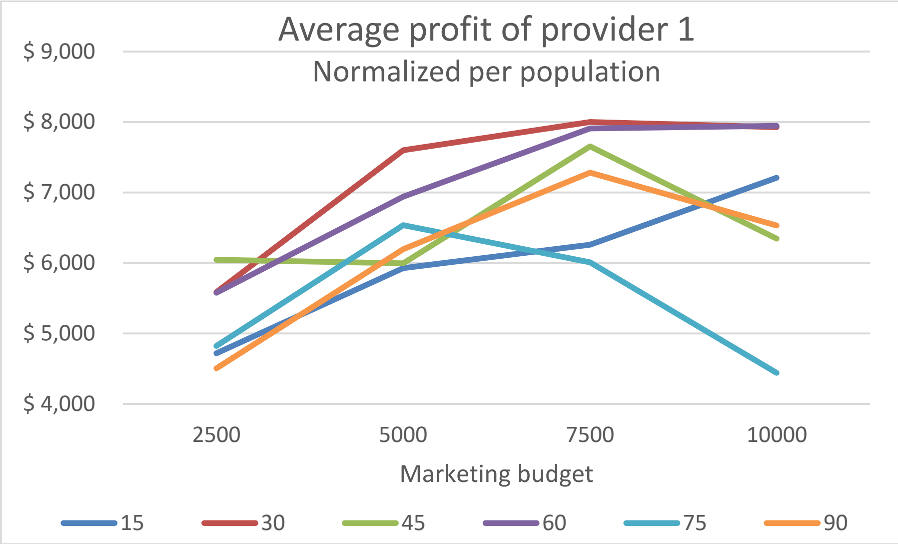

Figure 18 Average profit of provider 1 - Normalized per population size

We can see that the maximization of the profit per initial customer for all marketing budgets does not take place with the highest market share (i.e. with population of 30 customers). Similarly, we can find one of the lowest profit per customer corresponding to the highest market share (i.e. with population of 90 customers). Figure 19 shows in detail for an initial population of 30 that increasing market share does not guarantee a maximization of profits for provider 1.

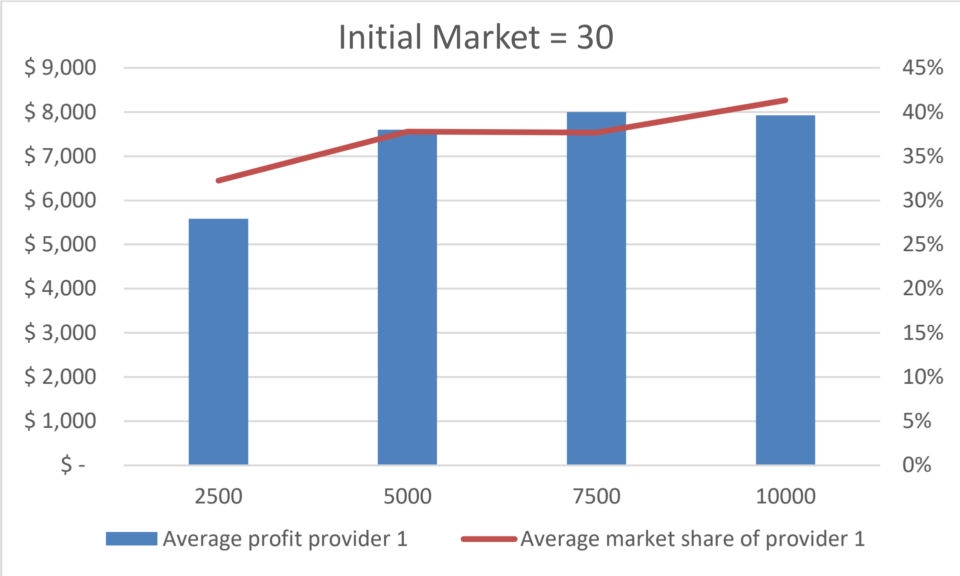

Figure 19 Profit and market share trends for initial market = 30

6.7 Conclusions

Two configurations are modelled together and their value proposition and cost factors are designed. Then, fifteen archetypical customer companies are characterized and their weights assumed based on the characterization. An assessment of the value proposition is performed through four decision-making criteria, identifying the ranking of the alternative ecosystem configurations. A model is constructed using NetLogo software to check for the impact of the population size, the initial budget of the service providers and the share of that budget spent on marketing action. Results show that in some cases a higher marketing spending, or total budget, would turn into smaller market share reached and consequently lower profits. This counterintuitive result originates from the fact that a higher spending dries out the budget for one provider, making it impossible to contact other customers and thus leaving the completely "untouched" market to the other provider. Hence, it is clear that the outcome for each provider is strongly influenced by the decisions taken by the other providers. Moreover, these combined effects show different patterns depending on the size of the market. Finally, based on the model mechanisms and cost factor, the provider with the higher profit margin would find it difficult to overcome a higher marketing effort required to convince customers to adopt her solution, which is the most comprehensive ecosystem configuration.

Chapter 7

Conclusions, limitations and further research

This thesis provides for an innovative take on the evaluation and modelling of City Logistics projects and innovations. The objective is twofold. First, to include both business and operational aspects into the modelling and evaluating process. Second, to exploit the advantages of qualitative and quantitative methods and thus creating a comprehensive tool for project evaluation, which can be used for both designing and assessing the CL project at a system-level. I intend to convey these two founding objectives by rooting them in three research questions.

Through the first research question (RQ), I aim to assess the state-of-art of existing frameworks used to model and evaluate CL projects. The sub-objective underlying the first research question is to explore potentialities and drawbacks of CL projects assessment methods as a mean to achieve CL long-term sustainability. In order to evaluate long-term sustainability, assessment methods should encompass various aspects of CL and include more stakeholders in the evaluation. Qualitative methodologies are usually able to achieve this objective, but may lack in representing long-term effects of CL projects. Quantitative methodologies on the other hand allow simulating the outcomes of a project on the long run, but are usually based on few operational variables and take the perspective of few stakeholders. From the literature review performed, a research gap emerges for new research to mix the advantages of quantitative and qualitative approaches and include stakeholders in ex-ante evaluation of CL projects.

Hence, the second RQ inquiries how to conceive an integrated qualitative-quantitative framework for CL evaluation. To this end, the methodological approach of this thesis integrates a qualitative conceptual framework built ad-hoc and a quantitative modelling approach. From the literature, agent-based modelling has emerged as one of most promising quantitative methods to account for a comprehensive view of the CL issue within a simulation framework. Therefore, an agent-based model is proposed to formalize the concepts expressed with the qualitative framework, so to provide a structured approach to quantitative modelling.

On the other hand, Business Model (BM) approaches can be insightful for qualitatively evaluate CL long-term sustainability. Hence, it appears to be well suited to respond to the first part of RQ 2 (the qualitative framework) and to RQ 3, which explores the ways to adopt a business-oriented view of CL systems in an effective manner. However, traditional BM approaches do not always take into account the perspectives of different stakeholders and are better suited to assess a business model of a focal company rather than of a network of companies. Hence, the theoretical framework presented in chapter 4 tries to respond to the following sub-objective related to the third RQ:

How can we setup a business modelling approach to understand the dynamic decision making process of the CL stakeholders?

To solve this issue, CL is compared to a business ecosystem where business and operational links are created among entities. Entities pursuit their business model objectives by playing different roles in the ecosystem. Relationships are formed on the basis of the value proposition exchanged between CL users and providers.

As above-mentioned, the quantitative agent-based modelling proposal intends to formalize the qualitative conceptual framework. Hence, its main elements are:

- Agents, which are composed by the business entities of the CL business ecosystem
- Agents’ decisions, both operational and strategic
- The value proposition
- The metrics used to evaluate the performance of the role-playing
- The mechanisms driving the actions of the agents in the ecosystem

The model simulation of chapter 6 provides insights into a specific case study that has become relevant in city logistics, namely the parcel locker operator. The model enables to assess the profitability of the solution by assigning a business model to all stakeholders involved. The model is designed on a service offering and evaluation basis, where service providers bear costs to reach customers and deliver their value proposition, which is then assessed using multiple criteria. Two different configurations of the same innovation are modelled, according to the specifics emerged during interviews with the administrators of two parcel locker companies. The main strategic levers for the success of the business model are the initial budget and the share of the budget allocated to the marketing effort, which enables the two providers to reach their customers.

The main value of this new approach to CL assessment and evaluation resides in the fact that different system configuration of similar innovations can be modelled together by taking into account all the stakeholders involved. The ability of Agent-Based Modelling to provide dynamic simulation of the interactions among the stakeholders may thus truly unlock more possibilities to evaluate the implications of multiple, simultaneous business and operative decisions of CL projects initiator. In my opinion, this is a considerable step toward a more realistic, and holistic, outlook on CL innovations, which are often competing in turbulent markets with fierce competitors and strict customers' needs. For instance, the simulation model, although a simple and preliminary one, showed that two competing solutions for parcel locker implementations targeting the same customer segments would have to shape different value proposition and possibly modify their strategies according to the system outcomes that are influenced by the decisions of the competitor. Existing assessment methodologies, even business-oriented ones such as the Business Model Canvas, are missing this implication because they are mostly focused on static assessment of stakeholders individually and not systemically. Moreover, existing methodologies fail to take into account some important decisions taken by CL initiatives such as marketing ones.

In conclusion, this thesis provides a first modelling and simulation tool for assessing the implications of business model decisions within specific CL business ecosystems. The qualitative-quantitative approach to CL evaluation and modelling provides a suitable response to the shortcoming highlighted in the literature. Moreover, it creates a funding reference for CL project evaluation with business-oriented point of view, and therefore it can be used by CL project promoters to understand the dynamics between the actors and assess whether their innovation can be successful on the long-term. Therefore, it proves that qualitative approaches can be used to integrate all stakeholders, while quantitative modelling provides a simulation environment to test long-term effects of different scenarios.

This study has some limitations. For instance, more strategic decisions should be added at the role level to investigate endogeneity in the model. For example, decision to change a role might be triggered by the failure of an entity to make profit, or also by other conditions such as an entity not maximizing other objectives. It is quite complicated and far-fetched from reality to include a multi-layered decision such as this into an agent-based model, and this will be part of further research efforts. Furthermore, the implications on the business ecosystem of the value of information are not assessed. Access to valuable information can serve as a constraint suffered by an entrant company in playing a role in the ecosystem. In fact, information exchanges can affect the performance so much that some assignments are not feasible. Concerning the computational experiment, the scope of the model should be expanded to include a performance evaluation phase, which would lead to more decision-making by the agents. This last phase would validate the business model mechanisms outlined in the thesis, and increase the endogeneity of the model.

In retrospective, I hope that this thesis will spark more interest from scholars aiming to delve deeper into the complex business ecosystem of City Logistics, and its theoretical and practical modelling approaches will be adopted and improved by academics and practitioners to evaluate new CL initiatives. Moreover, the underlying assumption of this work is that a long-term vision on CL evaluation and planning is fundamental. To do so, scholars should foster a better grasp on business relationships and motives of CL stakeholders. Therefore, further research is aimed at using the tools developed in the thesis to understand how to drive retailers to change their attitude towards CL by understanding and designing value proposition that might appeal to them. In this context, large-scale survey on retailers' preferences can be beneficial to give quantification to the decision-making attributes. Furthermore, the implications of the entrance of new CL players for more traditional ones (e.g. Express couriers) need to be explored more deeply from a strategic perspective of business decisions and power relations, and also from the perspective of an agent-based, case study driven computational experiment. Hence, further research can be directed towards more quantitative case studies with agent-based modelling. With this regard, further testing of the model mechanisms and cost factors with providers is needed, even though the weights and the ranking of the alternatives seem consistent after the sensitivity analysis. In further expansion of the scope of the model the users of the service will evaluate the performance of the service and decide whether to continue with the same demand, increase the demand or even opt out of the contract (only if the contract is expired). Moreover, the model will be refined by adding other behaviours by the agents. For instance, it would be interesting to include a more dynamic evaluation of the alternatives due to getting in contact with an innovative solution that was previously unknown.

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Appendices

Appendix 1: Questions to CL stakeholders

Binnenstadservice and UCC Bristol

OPERATIONS

1. Is the urban distribution center owned and operated by your company?
2. Do you plan to outsource completely the delivery process?
3. Do you think operations at the distribution centre could benefit from economies of scale significantly?

STRATEGY

4. Do you think of your company as a “network coorindator”, offering the middleware platform that is needed to operate the system besides being a full-fledged, city logistics operator?
5. Is the effort for integrating and coordinating the delivery process shared by other LSP or is it totally borne by your company? Do you need to integrate to the courier’s system or do you build your own system?
6. Are there any contractual obligations between your company and the logistics service providers?

OFFERING

1. How do you make money?
2. What are your most important costs?
3. Do you provide an additional tracking and tracing interface for the customer?
4. Do you think the LSP will benefit from using your warehouse? Is it a problem for them to not use their own vehicle in the city delivery?

MyPUP

OPERATIONS

1. Is the urban distribution center owned and operated by MyPUP?
2. Do you plan to outsource completely your operations?
3. Do you think operations at the myPUP distribution centre could benefit from economies of scale significantly?

4. Are the parcel lockers owned or leased by MyPUP?

STRATEGY

5. What were the strategic underpinning of the decision to operate a MyPUP distribution centre? Could the system work using the existing networks of the logistics service providers?
6. Do you think of MyPUP as a "system integrator", offering mostly the middleware platform that is needed to operate the system? Or as a full-fledged, operational city logistics operator?
7. Is the effort for integrating and coordinating the delivery process shared by other LSP or is it totally borne by MyPUP? Do you need to integrate to the courier's system or do you build your own system?
8. Are there any contractual obligations between MyPUP and the logistics service providers?

OFFERING

9. Do you provide an additional tracking and tracing interface for the customer?
10. Do you think that you are offering a sort of "buffer storage" service for the final customer? And that the final customer could pay a small fee for it?
11. Do you think the LSP will benefit from MyPUP? Is it a problem for them to not use their own vehicle in the city delivery?

Bringme

OPERATIONS

1. Can I use Bringme only if the webshop I am buying from has the delivery option?
2. How does the carrier comply when he has to deliver to a Bringme box? Is it enough for them to read the Bringme text string before of the name of the consignee?
3. Is the effort for integrating and coordinating the delivery process shared by other LSP or is it totally borne by Bringme?
4. Do you need to have access to the courier's information and delivery system or do you build your own system?
5. Do you generate the same QR code for the courier and for the customer?
6. Other companies such as MyPUP operate distribution centers where they receive and handle the parcels and apply a new label on the package. Did you ever think of following the same path? Does the system work better by using the existing networks of different express couriers?

7. Is your operational model followed by other companies?

BUSINESS MODEL AND OFFERING

8. Do you think of Bringme as a “system integrator”, offering mostly the middleware platform that is needed to operate the system?
9. Do you think that you are offering a sort of “buffer storage” service for the final customer?
10. Do you receive a fee from the final customer for offering the service?
11. Do you provide an additional tracking and tracing interface for the customer?
12. Are the parcel lockers owned or leased by Bringme?
13. What is the most important cost factor for Bringme?
14. Are there any contractual obligations between Bringme and the logistics service providers?
15. Who is responsible when some issues with the delivery occur?
16. Do you think that express couriers will benefit from Bringme?
17. Do you think Bringme can build a successful relationship with express couriers because they will keep using their own vehicles and manage their own routing?
18. Are there any major barriers to the implementation of Bringme boxes? E.g. user friendliness of the system, special permits to install the lockers, resistances from the express couriers etc.

Appendix 2: Simulation model coding

The code appended here does not include the definition of the patches, intersections and roads.

```
globals

[


  phase

;; decides what phase the model is in, selling,ordering,creating-tours and moving

  daycounter

;; counts days the model is running. 1 selling phase per day

  TotalMarket

;; total unreached market. It decreases when more emplyers become customers

  servTab

;; table for evaluating the value proposition; keys are the alternatives, values are their weighted values from the SAW Multicriteria evaluation

  evaluation-list


]

;; breeds all agentsets


breed[lockeroperators lockeroperator]

breed[employers employer]

breed[lockers locker]


lockeroperators-own[

  consolidating?    ;; True = Parcel Locker provider 2 False = Parcel Locker provider 1
```

```
  ITcapacity        ;; IT capacity of locker operator
  area               ;; locker operator size of ware-
house
  handlingarea      ;; floorspace for storing parcels
  unitsperarea      ;; parcels per storage area
  Hcapacity         ;; capacity of handling parcels at
the warehouse
  budget            ;; total budget divided in market-
ing budget and R&D budget
  marketingbudget
  r&dbudget
  market            ;; Serviceable obtainable market,
as the potential reachable market based on the budget
and capacity
  Mcost             ;; marketing cost of reaching one
employer
  price             ;; price based on the profitmargin
as a % on top of cost
  estimated-demand  ;; estimated demand by people
  income            ;; total income
  cost              ;; total cost
  CInventory        ;; InventoryCost
  CTransport        ;; transportation costs
  CHandling         ;; handling cost per unit of time
per parcel
  cost-per-locker   ;; average cost per locker station
  marketingcost     ;; total marketing cost spent
  installationcost  ;; cost per installing the lockers
  THandling         ;; time for receiving a parcel
  Cmaintenance      ;; Lockeroperator incurs in cost of
maintenance after a predetermined period of time
  Cinfrastructure   ;; cost of installing a locker
  counter
  profit
```

```
]

lockers-own[
  dimension          ;; capacity in terms of parcels
  availability       ;; parcels that can be stored
  available?         ;; is the locker available to store
alll parcels for that delivery? true = yes false = no
  usage              ;; # of parcels currently stored in
the locker.
]

employers-own[
  employeelist       ;; list of employees
  #employees          ;; total number of employees (peo-
ple)
  employertype       ;; small, medium, big
  monthlydemand       ;; total monthly demand by employ-
ees
  personmonthlydemand  ;; total demand by each employee
in terms of parcels
  inboundtime        ;; time for receiving a parcel
  Cinbound             ;; inbound cost per unit of time
per parcel
  inboundcost         ;; total inbound cost. Variable is
fixed after parcel locker installed
  lockercost         ;; total cost of installed lockers
  profit             ;; inboundcost - lockercost
  contacted?         ;; if the employer has been reached
by the lockeroperator
  readytoinstall?    ;; value proposition evaluation is
positive and ready for lockers to be installed
  lockerinstalled?  ;; is a parcel locker station in-
stalled in the building? true = yes false = no
```

```
  contactedby_1      ;; need to know which operator has
reached the employer in order to make the evaluation. 1
is the lockeroperator wuthout consolidation
  contactedby_2      ;; locker operator with consolida-
tion
  contactedby_both   ;; if both lockeroperators contact
an employer at the same time step
  lockerprovider     ;; every employer can have max one
provider. 1 for the lockeroperator without consolidai-
ton and 2 for locker with consolidation

]

to setup           ;; sets up world
  ca
  hubnet-reset                      ;; move to startup
in the end
  random-seed 7                     ;; adds random seed
to create runs that are replicative
  file-close
  file-open "Output.txt"
  setup-globals                     ;; setup global var-
iables
  setup-employers                   ;; creates and sets
variables of employers
  setup-lockeroperators             ;; creates and sets
variables of parcel locker operators
  reset-ticks
end

                                              ;; create
initials for globals
  set phase "evaluating"                       ;; first
phase is evaluating the value proposition
```

```
  set servtab table:make                      ;; initi-
tate the table with the preferred alternative for each
employer
  set TotalMarket 15
end



to setup-employers             ;; employers are created
on intersection. We differentiate between small, medium
and big companies
                               ;; setup n-of employers
with same number of employees or random within range
  random-seed                                         7
;; sets randoms-seed to replicate runs and keep employ-
ers in same place
  ask n-of 15 intersections with [outercity? = false] [
    sprout-employers 1[
      set shape "house"
      set                    size                     2
;; small compay, small house
      set #employees 25                          ;; av-
erage within the range 0-50 employees.
      set employertype "small"
      set   personmonthlydemand   random   0   -   20
;; parcels per month.
      set inboundtime 5                    ;; 5 minutes
to receive the parcels at thee reception desk and check
it
      set Cinbound 0.33                     ;; cost per
minute of the resource (e.g. receptionist) that re-
ceives the parcel.
      set monthlydemand #employees * personmonthlyde-
mand    ;; need to calculate the cost to evaluate the
benefit of the locker
```

```
      set inboundcost monthlydemand * inboundtime * Cinbound      ;; calculate the total cost for receiving parcels
      set lockerinstalled?  false
      set contacted?  false
      set contactedby_1 false
      set contactedby_2 false
      set contactedby_both false
      set readytoinstall? false               ;; variable to state that the employer has evaluated positively the Value Proposition
    ]
    set employerhere?  true
  ]

  ask n-of 15 intersections with [outercity? = false] [
    sprout-employers 1[
      set shape "house"
      set size 4 ;; medium compay, medium house
      set #employees 150                  ;; average within the range 50-250 employees
      set employertype "medium"
      set personmonthlydemand random 0 - 20 ;; parcels per month.
      set inboundtime 5                ;; 5 minutes to recceive the parcels at thee reception desk and check it
      set Cinbound 0.33                 ;; cost per minute of the resource (e.g. receptionist) that receives the parcel.
      set monthlydemand #employees * personmonthlydemand   ;; need to calculate the cost to evaluate the benefit of the locker
```

```
      set  inboundcost  monthlydemand  *  inboundtime  *
Cinbound      ;; calculate the total cost for receiving
parcels
      set lockerinstalled?  false
      set contacted?  false
      set contactedby_1 false
      set contactedby_2 false
      set contactedby_both false
      set readytoinstall? false
    ]
    set employerhere?  true
  ]

   ask n-of 15 intersections with [outercity? = false]
[
    sprout-employers 1[
      set shape "house"
      set                    size                      8
;; big company, big house
      set #employees 750                             ;; av-
erage within the range 250-1250 employees
      set employertype "big"
      set   personmonthlydemand   random   0   -   20
;; parcels per month.
      set inboundtime 5                        ;; 5 minutes
to  recceive  the  parcels  at  thee  reception  desk  and
check it
      set Cinbound 0.33                         ;; cost per
minute  of  the  resource  (e.g.  receptionist)  that  re-
ceives the parcel.
      set  monthlydemand  #employees  *  personmonthlyde-
mand    ;;  need  to  calculate  the  cost  to  evaluate  the
benefit of the locker
```

```
      set inboundcost monthlydemand * inboundtime *
Cinbound      ;; calculate the total cost for receiving
parcels
      set lockerinstalled?  false
      set contacted?  false
      set contactedby_1 false
      set contactedby_2 false
      set contactedby_both false
      set readytoinstall? false
    ]
    set employerhere?  true
  ]

  write "small employers:" print [who] of employers
with [employertype = "small"]
  write "medium employers:" print [who] of employers
with [employertype = "medium"]
  write "big employers:" print [who] of employers with
[employertype = "big"]

end



to setup-lockeroperators

  random-seed                                        7
;; sets randoms-seed to replicate runs and keep lock-
eroperators in same place
  create-lockeroperators              1              [
;; creates first operator at an intersection
    set consolidating?  false
    set shape "box"
```

```
    set size 6
    setxy                    -45                    -46
;;places lockeroperator in bottom left hand corner
    set                 budget                 200000
;; marketing and R&D expenses dry out the budget, prof-
its increase it
    set             marketingbudget              50000
;; initiate marketing budget
    set    r&dbudget    budget    -    marketingbudget
;; initiate r&dbudget
    set ITcapacity  r&dbudget / 10000
    set Mcost 10000
    let fixed-cost 200
    set Cinfrastructure 100
    set price (1 + (profitmargin / 100)) * fixed-cost
;;  sets  price  for  parcel  operator.  no  handling  and
transportation
  ]

  create-lockeroperators              1              [
;; creates second operator at an intersection
    set consolidating?  true
    set shape "box"
    set size 6
    setxy                     45                     46
;;places lockeroperator in top right hand corner
    set area 100
    set handlingarea area / 2
    set unitsperarea 3
    set Hcapacity   unitsperarea * area
    set                 budget                 300000
;; marketing and R&D expenses dry out the budget, prof-
its increase it
    set             marketingbudget              50000
;; initiate marketing budget
```

```
    set r&dbudget budget - marketingbudget
;; initiate r&dbudget
    set ITcapacity r&dbudget / 10000
;; the higher the expenditure in r&d the higher the ca-
pacity of the infrastructure system to organize the de-
livery system
    set Mcost 10000
    set CHandling 1 / 3 ;;
salary rate (€/minute) to handle parcels: Hourly rate =
20 €
    set Thandling 5
;; 5 minutes to handle parcels
    set Ctransport 10
    set Cinfrastructure 100
    let handlingcost 200
;; the cost for handling the parcels for each locker.
    let fixed-cost 200
    set price (fixed-cost + handlingcost + Ctransport)
* (1 + (profitmargin / 100))
    set cost-per-locker handlingcost + fixed-cost +
Ctransport
  ]

  write "Bringme:" print [who] of lockeroperators with
[consolidating? = false]
  write "MyPUP:" print [who] of lockeroperators with
[consolidating? = true]
end

  ;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
  ;;;;;;;;;;;;; GO PROCEDURES ;;;;;;;;;;;;;;;;
  ;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

to go
```

```
    ;;Next part is to divide days into ticks and phase.
In every day there are phases, evaluating and negotiat-
ing the value proposition ->
  ;;installing the lockers  -> ordering online --> cre-
ating tours->moving. IF every phase is completed (if
necessary) the next day begins.
  ;; First 4 phases are all in 1 tick each, moving
phase of trucks takes as many ticks as necessary (mov-
ing in the night principle)


  ;cf:when
 ;cf:case   [any?   employers   with   [contacted?   =
true]][reset-ticks]
  ;cf:case       [phase       =       "evaluating"][
;; in this phase, employers evaluate the offer from
parcel locker operators.
  if TotalMarket > 0 [
    contact-customers


    write "Total Market ="
    print TotalMarket
    write "Employers contacted="
    print count employers with [contacted? = true]


    tick
  ]
    ;evaluate
;; If everyone has evaluated the day is over and people
will get the chance to order
  ;]
 ; cf:case [phase = "installing"][install]
  ;cf:else [
    ;calculate-profit-and-budgets
    ;set daycounter daycounter + 1
```

```
    ;output-print daycounter
    ;reset-ticks
  ;]

end

to                                    contact-customers
;; each lockeroperator contact a share of the total em-
ployer market.

  ask lockeroperators with [consolidating? = false] [
;; need to keep track of the locker operator number.
This is the locker operator without consolidation

    set market round min (list ITcapacity (market-
ingbudget / Mcost) count employers with [contacted? =
false])
    ;; set the potential market to be reached in each
step. It depends on the marketing budget and the IT ca-
pacity to manage the parcels at that given moment

    ask n-of market employers with [contacted? = false]
[             ;; until all employers are reached the
locker operator will try to get in touch with them.
      set              contactedby_1              true
;; We need to make sure that an employer already
reached by a lockeroperator does not change its con-
tacted status
    ]

    set marketingcost count employers with [contact-
edby_1 = true or contactedby_both = true] * Mcost
```

```
    ;; calculate marketing cost only if the employer is
actually reached and not the total market.
    show market
    show marketingcost
  ]

  ask lockeroperators with [consolidating? = true] [
;; locker operator with consolidation
    set market round min (list Hcapacity ITcapacity
(marketingbudget / Mcost) count employers with [con-
tacted? = false])
    ;; The market  depends on the marketing budget and
the capacity to handle the parcels at that given mo-
ment, as well as the IT capacaity to manage parcels.

    ask n-of market employers with [contacted? = false]
[
      set contactedby_2 true
    ]

    set marketingcost count employers with [contact-
edby_2 = true or contactedby_both = true] * Mcost

    show market
    show marketingcost
  ]

  ask employers [                ;; it is important to
know which lockeroperator has contacted which employer,
in order to make them evaluate the right value proposi-
tion

    if contactedby_1 = true or contactedby_2 = true [
      set contacted? true
```

```
    ]

    if contactedby_1 = true AND contactedby_2 = true [
;; if the employer is reached by both locker operators
then we need to keep track
      set contactedby_both true
      set              contactedby_1              false
;; to avoid confusion. Each employer can have only one
contact status
      set contactedby_2 false
    ]

    set TotalMarket 45 - count employers with [contact-
ed? = true]

    cf:when
    cf:case [contactedby_1]   [show contactedby_1 print
"contacted by 1"]
    cf:case [contactedby_2]   [show contactedby_2 print
"contacted by 2"]
    cf:case  [contactedby_both][show  contactedby_both
print "contacted by both"]
    cf:else                      [show contacted? print
"Not contacted"]

  ]

end

to evaluate

  ask employers with [employertype = "small" AND con-
tactedby_both = true] [                ;; we start with
```

```
small employers. Both operators can compete only if they reach

;; the employer at the same time step.
    set evaluation-list (list 0 0 0 0 1)
    let newlist sublist evaluation-list 0 (count employers with [contactedby_both = true]) ;; we take only the values assigned to the employers that were actually contacted by both locker.
    ask lockeroperators [
;; lockeroperators compute the evaluation table
      while [length newlist > 0] [
      table:put servtab [who] of myself first newlist
;; keys are the who employer, value their preferred alternative. Add one value at a time
      set evaluation-list remove 0 newlist
      ]
      write "employers:" print table:keys servtab
      write "preferred alternative:" print table:values servtab

      foreach table:keys servtab [
        if table:get servtab [who] of myself > 0 [
;; set ready to install to all employers with a preferred alternative
          set readytoinstall? true
;; different than Business as Usual
        ]
      ]

      cf:when
      cf:case [table:get servtab [who] of myself = 1] [set lockerprovider 1]   ;; if the first lockeroperator is the preferred alternative for that employer than the evaluation is positive
```

```
      cf:case [table:get servtab [who] of myself = 2]
[set lockerprovider 2]
      cf:else []
    ]
  ]


  ask employers with [employertype = "small" AND con-
tactedby_1 = true] [                  ;; we start with
small employers.
    let newlist sublist evaluation-list 0 count employ-
ers with [contactedby_1 = true] ;; we take only the
values assigned to the employers that are contacted by
both locker
    ask          lockeroperator          357          [
;; lockeroperators compute the evaluation table
      while [length newlist > 0] [
      table:put servtab [who] of myself first newlist
;; keys are the who employer, value their preferred al-
ternative
      set evaluation-list remove 0 newlist
      ]
      write "employers:" print table:keys servtab
      write "preferred alternative:" print table:values
servtab


      foreach table:keys servtab [
        if table:get servtab [who] of myself = 1 [
;; set ready to install to all employers with a pre-
ferred alternative
          set           readytoinstall?           true
;; different than Business as Usual
          set lockerprovider 1             ;; if the
first lockeroperator is the preferred alternative than
the employer will choose the provider
        ]
      ]
```

```
    ]
  ]

  ask employers with [employertype = "small" AND con-
tactedby_2 = true] [                    ;; we start with
small employers.
    let newlist sublist evaluation-list 0 (count em-
ployers with [contactedby_2 = true]) ;; we take only
the values assigned to the employers that are contacted
by both locker
    ask          lockeroperator          358          [
;; lockeroperators compute the evaluation table
      while [length newlist > 0] [
      table:put servtab [who] of myself first newlist
;; keys are the who employer, value their preferred al-
ternative
      set evaluation-list remove 0 newlist
      ]
      write "employers:" print table:keys servtab
      write "preferred alternative:" print table:values
servtab

      foreach table:keys servtab [
        if table:get servtab [who] of myself = 2 [
;; set ready to install to all employers with a pre-
ferred alternative
          set           readytoinstall?           true
;; different than Business as Usual
          set lockerprovider 2              ;; if the
first lockeroperator is the preferred alternative than
the employer will choose the provider
        ]
      ]
    ]
  ]
```

```
  if count employers with [readytoinstall? = true] > 0
[
    set phase "installing"
  ]

end

to install
  create-lockers count employers with [readytoinstall?
= true] [
    set dimension #employees * personmonthlydemand / 30
;; Size in terms of parcels that can be stored. This is
the total demand at any given time. For simplicity, we
assume that customers collect their items once a day.
    set available? true              ;; initially the
locker station is available. This will change during
the operational phase
    set lockerinstalled? true
  ]

  ask lockeroperators [
    set installationcost count employers with [readyto-
install? = true] * Cinfrastructure
    every daycounter / 30 [
      set Cmaintenance 100
    ]
  ]
  ;; need to assign the lockers to the right employ-
er!!!
  ask employers [if lockerinstalled? = true [set shape
"box"]]        ;; visual representation if employer has
locker installed.
```

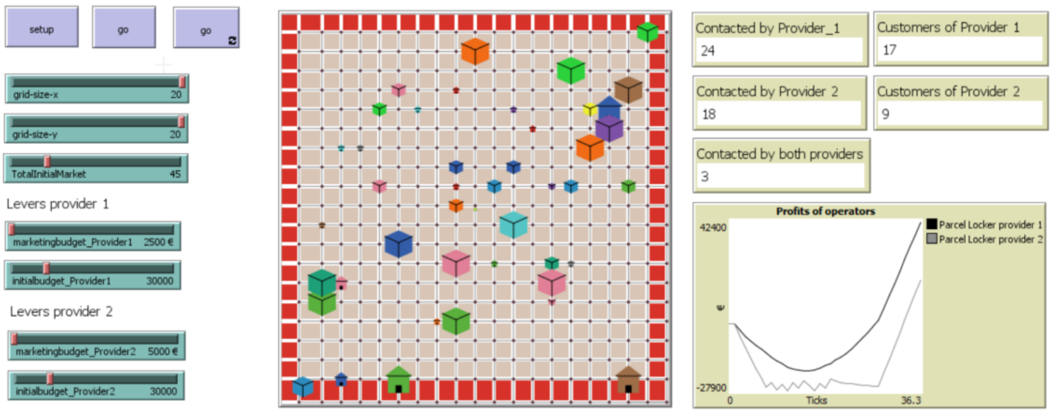
```
  write "Number of lockers:" print count lockers

end



to calculate-profit-and-budgets
  ask lockeroperators [
    set income count employers with [lockerinstalled? =
true] * price                              ;; does it cal-
culate the different price for the two locker opera-
tors??
    set cost marketingcost + (installationcost + cost-
per-locker) * count lockers + Cmaintenance
    set profit income - cost
    set budget budget + profit
    set marketingbudget marketingbudget + ( daycounter
* ((budget / 2 - 500) / 1095))
    set r&dbudget budget - marketingbudget
  ]

  write "Income:"
  show income
  write "Cost"
  show cost
  write "budget"
  show budget
end
```

Appendix 3 Sensitivity and verification of the model

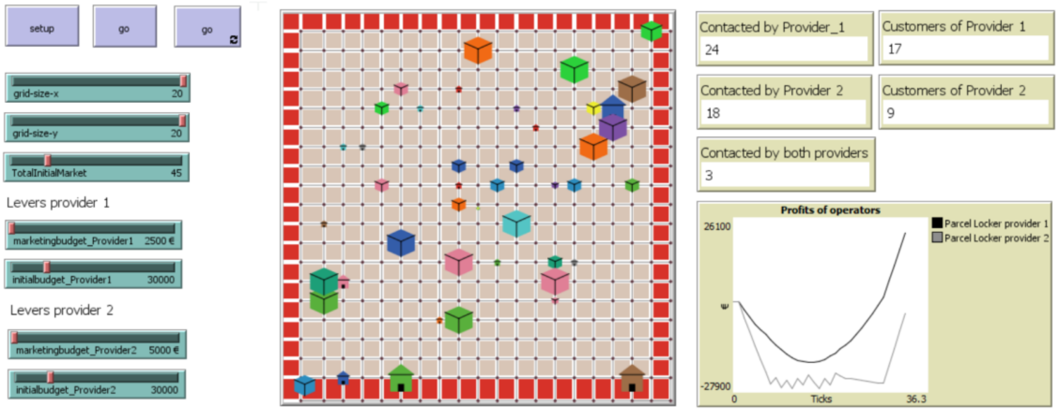
First, the results of the sensitivity to the random seed number are shown. Then, the sensitivity on the criteria weights is presented. Finally the results of the second and third verification steps are presented.

Random Seed = 7

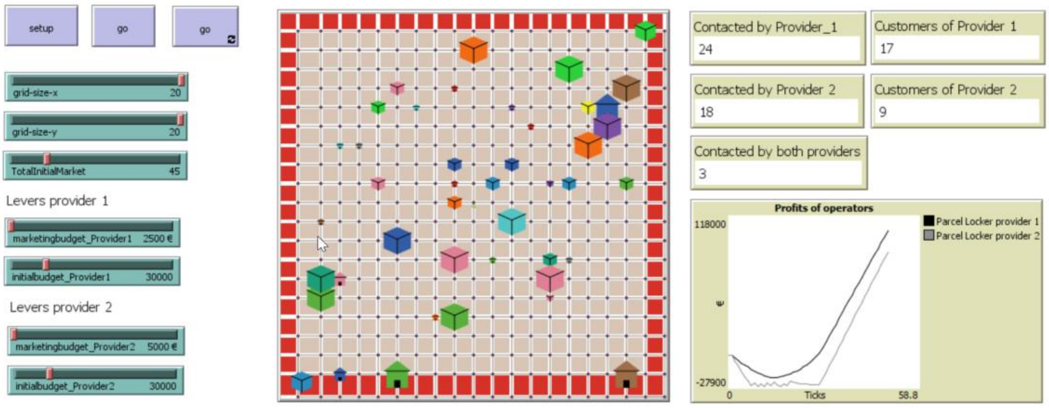
Random Seed = 3



Random Seed = 15



Random Seed = 25

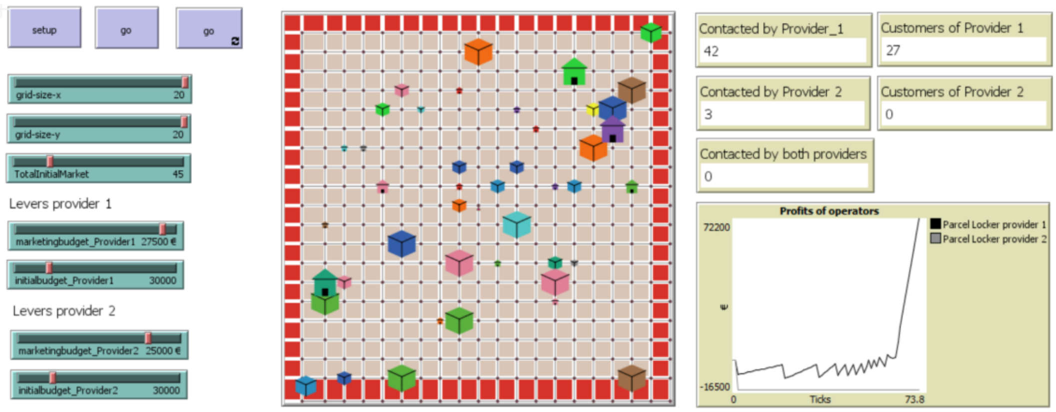


The following table shows the results of the procedure to assess the sensitivity of the evaluation action depending on the weights of the criteria.

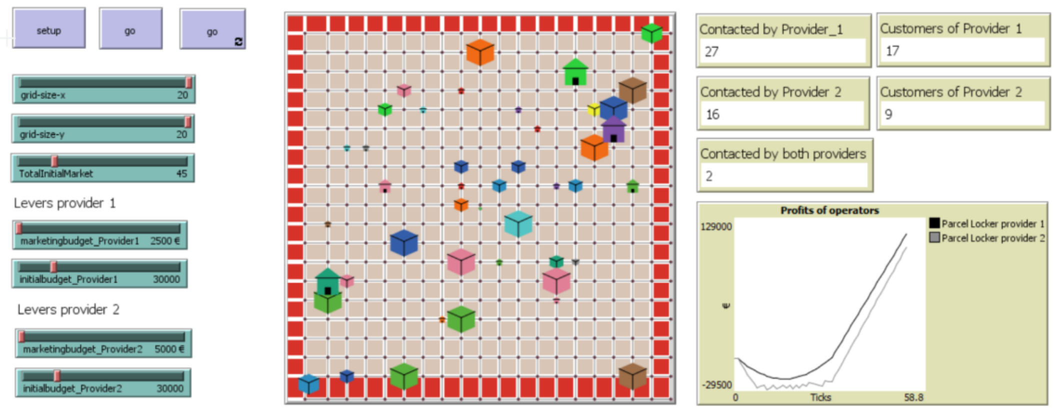
Company number	**Criterion 1**	**Criterion 2**	**Criterion 3**	**Criterion 4**	**Value of alternative**	**Alternative set of weights**				
7							**Criterion 1**	**Criterion 2**	**Criterion 3**	**Criterion 4**
Alternative 1	0.5	1	0.2	1	0.63	Alternative 3 is better than alternative 2 by 0.05	-0.01	0.28	0.78	-0.05
Alternative 2	1	1	0.2	0.6	0.82	Alternative 1 is better than alternative 2 by 0.05	-0.10	0.34	0.29	0.47
Alternative 3	0.75	1	1	0.2	0.76	*Negative weights are not feasible, hence there are no set of weights that can change the outcome of the decision.*				
8										
Alternative 1	0.5	1	0.2	1	0.59	Alternative 1 is better than alternative 3 by 0.05	0.60	0.35	-0.25	0.29
Alternative 2	1	1	0.2	0.6	0.82	Alternative 2 is better than alternative 3 by 0.05	0.61	0.25	0.07	0.07
Alternative 3	0.75	1	1	0.2	0.84	***With the second set of weights the outcome of the decision can change to alternative 2. This set of weights is admissible.***				
9										
Alternative 1	0.5	1	0.2	1	0.70	Alternative 1 is better than alternative 2 by 0.05	-0.06	0.29	0.14	0.63
Alternative 2	1	1	0.2	0.6	0.84	Alternative 3 is better than alternative 2 by 0.05	0.04	0.39	0.63	-0.05
Alternative 3	0.75	1	1	0.2	0.73	*Negative weights are not feasible, hence there are no set of weights that can change the outcome of the decision.*				

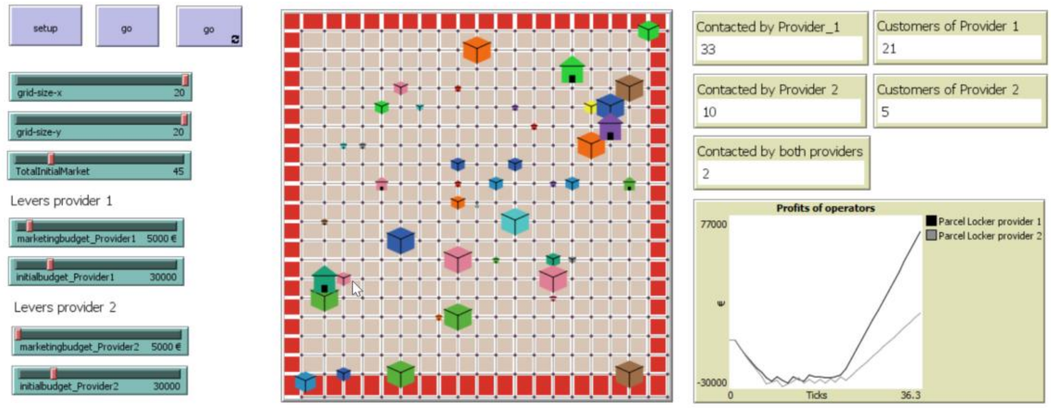
11										
Alternative 1	0.6	1	0.2	1	0.68	Alternative 1 is better than alternative 2 by 0.05	-0.14	0.39	0.29	0.45
Alternative 2	1	1	0.2	0.6	0.88	Alternative 3 is better than alternative 2 by 0.05	0.04	0.09	0.82	0.05
Alternative 3	0.8	0.75	1	0.2	0.75	*Negative weights are not feasible, hence the first alternative set of weights can not change the otcome of the decision. Alternative 3 can be preferred over alternative 2 only with a switch between Price and Sustainability.*				

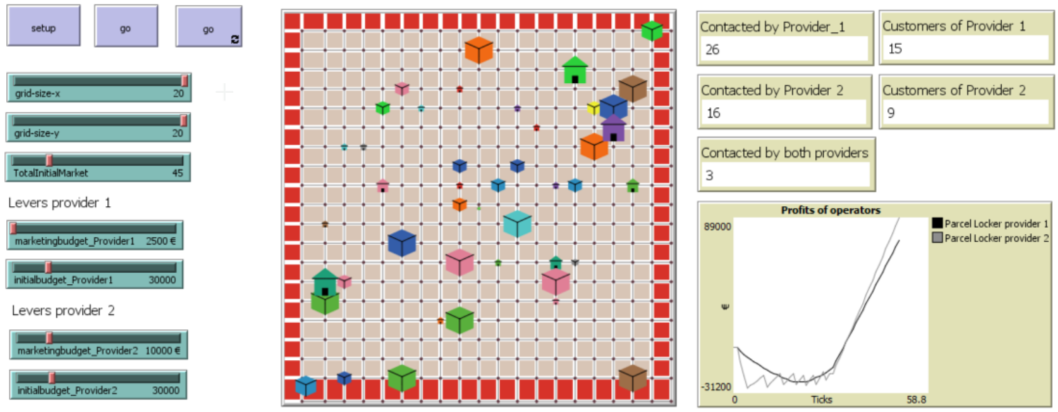
The following figures show the model behaviour at the extreme conditions. The first figure shows the simulation at the first time step, the second one instead shows the end of the simulation.



Finally, the last figures of this appendix show the model behaviour under a different model architecture and parameter settings.




setup
go
go
grid-size-x 20
grid-size-y 20
TotalInitialMarket 45
Levers provider 1
marketingbudget_Provider1 5000 €
initialbudget_Provider1 30000
Levers provider 2
marketingbudget_Provider2 5000 €
initialbudget_Provider2 30000
Contacted by Provider_1
33
Customers of Provider 1
21
Contacted by Provider 2
10
Customers of Provider 2
5
Contacted by both providers
2
Profits of operators
77000
-30000
0
Ticks
36.3
Parcel Locker provider 1
Parcel Locker provider 2


setup
go
go
grid-size-x 20
grid-size-y 20
TotalInitialMarket 45
Levers provider 1
marketingbudget_Provider1 2500 €
initialbudget_Provider1 30000
Levers provider 2
marketingbudget_Provider2 10000 €
initialbudget_Provider2 30000
Contacted by Provider_1
26
Customers of Provider 1
15
Contacted by Provider 2
16
Customers of Provider 2
9
Contacted by both providers
3
Profits of operators
89000
-31200
0
Ticks
58.8
Parcel Locker provider 1
Parcel Locker provider 2