

1 **Introducing Competition in Urban Consolidation Centre freight allocation**  
2 **modelling**  
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1 **Abstract**

2 Urban consolidation center (UCC) represents in many cities the most chosen solution by the local  
3 governments to reduce the negative impacts of city freight distribution. In order to achieve successful results,  
4 it is important to consider also the perspective of carriers with respect to the choice of facility location and  
5 the evaluation of costs. Therefore, in this paper we propose a simple approach to investigate the problem of  
6 flow distribution and choice of UCCs locations in situations of competition or cooperation among freight  
7 operators. In the first part of the paper, after presenting a brief explanation of the concept UCC, an overview  
8 of UCCs critical success factors is provided. This paper considers the modeling of competitive behavior  
9 among freight transport carriers into the optimization of urban freight distribution centers considering their  
10 incoming and outgoing flows. Three different types of scenarios are developed in order to represent different  
11 market situations of monopoly and duopoly competition in Cournot and von Stackelberg equilibriums. The  
12 outcomes of the model in terms of optimal configuration of UCCs, optimal distribution of freight flows,  
13 overall costs of the system and costs of carriers seem to be influenced by phenomena of competition,  
14 particularly in situations where a new competitor attempts to enter the market.

15 *Key words:* City Freight Distribution; City Logistics; Urban Consolidation Centers; Competition; Game  
16 Theory;

17

## 1 **1. Introduction**

2 Urban freight transport plays a fundamental role in the sustainable development of urban regions. In order to  
3 cope with the steady growth of road freight transport that occurred during the last decades and to achieve  
4 more sustainable solutions, a series of initiatives including new regulations, infrastructure improvements and  
5 measures concerning sharing space and time have been adopted throughout the world (Muñuzuri et al.,  
6 2005). A particularly promising solution features Urban Consolidation Centers (UCCs): transshipment points  
7 usually situated in the proximity of a city center, where deliveries from logistic companies are consolidated  
8 and distributed. Usually the final delivery to shops is accomplished through electric vehicles. A series of  
9 additional logistics and retail services can be also provided at the UCC (Huschebeck and Allen, 2005).  
10 Often, the success of these experiments was determined by the level of involvement and the interaction  
11 between the private and public sector. The implementation of city logistics initiatives needs to make more  
12 explicit why conflicting objectives and interests, and in particular competition are very important while  
13 designing urban freight logistics systems (Larraneta et al., 1999; van Duin, 2012). This is the reason why  
14 phenomena like the cooperation or competition between companies (freight carriers, retailers) should be  
15 considered in the ex-ante evaluation of logistic initiatives, and, if possible included in the models (Anand et  
16 al., 2012). Particularly, it is important to consider this issue in the context of location of UCCs where  
17 different stakeholders including competing carriers are executing urban freight transport operations at the  
18 same location or city area. In reality, several forms of competition may occur and as a result of a particular  
19 form of competition, city distribution may lead to different equilibriums (Holguin-Veras et al., 2011). For  
20 example, freight operators may decide to install and operate their own UCC or share a facility to attain  
21 economies of scale. Situations of competition or collaboration among freight operators in urban areas have  
22 been explored in some routing studies where carriers compete against each other to obtain delivery services  
23 (van Duin et al., 2007) or participate in auction-based collaboration mechanisms (Song and Regan, 2003;  
24 Figliozzi et al., 2006).

25 In the same direction, the objective of this research is to include economic theory on market forms into the  
26 optimal location of UCCs and the distribution of flows. The central research question in our paper is the  
27 market entrance of competitors can affect the optimal configuration of city distribution, where the “optimal  
28 configuration” is intended as the combination of optimal location of UCCs and distribution of freight flows  
29 through them. While for a single freight distributor the solution might be rather straightforward, the  
30 introduction of one or more competitors complicates the problem as several forms of cooperation or  
31 competition can occur. This research grounds on the hypothesis that competition between two carriers can be  
32 modeled in a location model of UCCs. In this study we will investigate how the size and the number of  
33 UCCs and the flows are affected by the phenomena of Cournot and von Stackelberg competition. In parallel  
34 we will examine the changes of the total system costs and the consequences for the single transport  
35 operators.

36 The theoretical contribution of this paper consists of introducing competitive behavior among carriers into  
37 the problem of optimization of city freight distribution in order to reproduce more realistically the effects of  
38 competition on urban freight distribution. Furthermore, in order to test the reliability of our model, we  
39 investigate its sensitivity to logistic costs and warehousing costs to the location of UCC. The practical  
40 contribution of this study consists in providing a more realistic approach towards the optimal location  
41 problem and a good insight into the consequences of competition between carriers.

42 This paper is organized as follows. In Section 2, after a brief discussion about the critical factors behind the  
43 success (or failure) of UCC initiatives, we illustrate the ‘location-allocation’ model for UCCs. In Section 3  
44 we describe the extensions of the model in order to include competitive behavior phenomena among carriers.  
45 In Section 4, the model is applied to a case study of the city The Hague. In Section 5, we report and discuss  
46 the results of the analyses. In Section 6 we draw the conclusions about this study.

## 1 **2. The optimal location of Urban Consolidation Centers**

2 From a literature survey about the UCC issue, it is possible to identify several reasons behind the success or  
3 failure of UCCs initiatives (see Browne et al., 2005; van Duin et al., 2010; Allen et al., 2012; Browne et al.,  
4 2012). Some of them can be ascribed to strategic choices such as the location of the UCCs and the  
5 characteristics of the fleet; others concern the support from local authorities (subsidies), whereas other ones  
6 entail the planning process and the acceptance of these initiatives by carriers and the city population.

7 Briefly, we could identify the following critical factors:

- 8 • The location of the facilities that should not be too far from the served area;
- 9 • The vehicles in charge of deliveries should have adequate performance at reasonable costs;
- 10 • The support from municipalities through subsidies and regulations;
- 11 • The level of acceptance and cooperation among carriers, retailers and city inhabitants.

12 Issues related to the optimal location and the typology of used vehicles could be investigated through  
13 quantitative modeling or Operations Research. In particular, a wide range of location-allocation models (e.g.  
14 simple linear, single-stage, single-product, uncapacitated deterministic and non-linear probabilistic models)  
15 could be applied to identify the optimal configuration of flows and urban consolidation centers (Klose and  
16 Drexler, 2005). The location choice of urban distribution centers is typically associated with the category of  
17 Discrete Location Models where a finite number of candidate sites is chosen by minimizing the  
18 (predetermined) costs to serve demand (Taniguchi et al., 2001). Here the problem is formulated as a mixed-  
19 integer programming one where the decisions variables are the amount of goods transported through the  
20 UCCs and the UCCs themselves. If the number of candidates is low, the exact solution can be found with a  
21 Branch-and-Bound method.

22 Traditionally, the number of UCCs has been limited to a single facility located in the outskirts serving the  
23 city center and run by one freight operator. Nevertheless, given the large number of competing transport and  
24 logistics companies, more UCCs might be expected per urban region, especially when the urban region is  
25 large. Crainic et al.(2004)proposed an extension of the UCC scheme by introducing an additional stage of  
26 consolidation achieved with mini satellite platforms and city freighters (additional level of  
27 consolidation).The main rationale behind this development is to further reduce the volume of freight vehicles  
28 travelling within urban areas by means of better consolidation and coordination by means of small satellites  
29 (UCCs) without any function involving sorting and storage (cross docking) and with the support of ITS  
30 technologies to control and coordinate vehicles and operations. Moreover, by means of electric or alternative  
31 powered vehicles for the last part of deliveries the environmental impacts of urban freight transports to city  
32 inhabitants can be reduced even more. The authors address the issue of optimal location of satellite by means  
33 of a discrete location model where the objective function is given by the sum of the fixed costs of opening  
34 and operating the satellites and the transportation costs between external zones and satellites and between  
35 satellites and commercial zones. The interested reader may refer to Crainic et al. (2004) for a detailed  
36 explanation of the model.

37 A similar research has been recently presented by Muñuzuri et al. (2012) who investigated the optimal  
38 location of mini-hubs for urban deliveries in the city center of Sevilla (Spain). Mini-hubs are specified areas  
39 where vehicles can make deliveries and from where handcart or on-foot final deliveries can depart. In their  
40 paper they assume mini-hubs to be simple sections of curbs that do not require any investment or operational  
41 cost. There are also some methodological differences between the two abovementioned studies (Muñuzuri et  
42 al., 2012) such as: the absence of capacity restrictions of the mini-hubs; the single-allocation of freight flows  
43 between demand nodes and mini-hubs; the predetermined number of mini-hubs to be located, which is  
44 anyway considerably higher than potential candidate UCCs; the amount of freight transported to the mini-  
45 hubs is unknown and replaced by the heuristic approach of commercial densities.

### 1 3. Introduction of competing carriers in the location-allocation problem

2 One of the most important factors behind the success of UCC initiatives during the last years has been the  
3 degree of cooperation among carriers. In order to achieve larger load factors, economies of scale and a  
4 significant reduction of costs a sufficient number of carriers should join the project. Hence, during the  
5 planning phase it is important to consider important characteristics of the logistics sector like the presence of  
6 strong competition among carriers and also their high level of independence. In the approach introduced by  
7 Crainic et al. (2004) and Muñuzuri et al. (2012) no real interaction between stakeholders is taken into  
8 account. The objective of the local government (who wants to minimize the impacts of truck deliveries) is  
9 the only objective that is optimized and the carriers totally comply with this ‘centralized vision’. No  
10 distinction is made among the freight operators and demanded goods.

11 In order to answer the research question whether competition between urban distributors influence the  
12 optimal results for city distribution, we develop a simple extension of the two-tier logistic model including  
13 aspects derived from economic concepts of two non-cooperative games: Cournot Equilibrium and Von  
14 Stackelberg Equilibrium (Ekelund and Hébert, 1990). Game theory actually provides useful insights to  
15 analyze situations where competing actors are involved like the case of freight carriers in a supply chain. In  
16 our research three scenarios corresponding to different strategic interactions of stakeholders are developed.  
17 In our model, trucks, city freighters, costumer zones, external zones will mean the same as in the model of  
18 Crainic et al.(2004). The *Base Scenario* represents a situation of monopoly where no competition is present  
19 and only one carrier is considered. In the other two scenarios, the *Cournot Scenario* and *Von Stackelberg*  
20 *Scenario*, an additional carrier is introduced into the model so that a market form of duopoly is reproduced.  
21 A duopoly is a particular form of oligopoly where only two competitors are involved. The two competitors  
22 may jointly maximize their profits or act independently such that they reach a form of equilibrium where the  
23 situation is optimal for all the stakeholders in terms of maximum gain and cannot be improved.

24 The *Base Scenario* is modeled similarly to the original approach proposed in the two-tier logistic scheme by  
25 Crainic et al. (2004). These conditions where no distinction between carriers is made (and therefore no  
26 competition) may reflect the market form of monopoly. Under these circumstances, two sets of decision  
27 variables are identified:

28 1. Location variables  $y_s$  corresponding to 1 if the satellite is open and 0 otherwise,  $s \in \tilde{S}$  where  $\tilde{S}$  is the  
29 number of satellites.

30 2. Flow distribution variables  $f_{is}$  and  $f_{sk}$  representing respectively the quantity of goods being sent from the  
31 origins  $i$  to satellite  $s$  by trucks and the quantity of goods be distributed from the satellites  $s$  to the  
32 destinations  $k$  using city freighters;  $i \in \tilde{I}$  where  $\tilde{I}$  is the set of origins;  $k \in \tilde{K}$ , where  $\tilde{K}$  is the set of  
33 destinations.

34 Hence, the optimization program of the location-allocation model is formulated as follows:

$$35 \quad \text{Min } Z(y, f) = \sum_{s \in \tilde{S}} (y_s \cdot i_s + \sum_{i \in \tilde{I}} f_{is} [c_{is} + t_{is}] + \sum_{k \in \tilde{K}} c_{sk} \cdot f_{sk}) \quad (1)$$

$$36 \quad \text{s.t. } \sum_{i \in \tilde{I}} f_{is} = \sum_{k \in \tilde{K}} f_{sk} \quad \forall s \in \tilde{S} \quad (2)$$

$$37 \quad \sum_{i \in \tilde{I}} f_{is} \geq y_s \cdot k_{\min} \quad \forall s \in \tilde{S} \quad (3)$$

$$38 \quad \sum_{i \in \tilde{I}} f_{is} \leq y_s \cdot k_{\max} \quad \forall s \in \tilde{S} \quad (4)$$

$$39 \quad y_s \in \{0,1\} \quad \forall s \in \tilde{S} \quad (5)$$

$$40 \quad f_{is} \geq 0 \quad \forall i \in \tilde{I}, \quad \forall k \in \tilde{K}, \quad \forall s \in \tilde{S} \quad (6)$$

$$41 \quad f_{sk} \geq 0 \quad \forall i \in \tilde{I}, \quad \forall k \in \tilde{K}, \quad \forall s \in \tilde{S} \quad (7)$$

1  
2 Where  $c_{is}$  corresponds to the transportation cost parameter per unit transported (on annual basis) of trucks  
3 from the origins  $i$  to the satellites  $s$ ;  $c_{sk}$  corresponds to the transportation costs (on annual basis) of city  
4 freighters from the satellites  $s$  to the destinations  $k$ ;  $i_s$  corresponds to the installation costs (annualized) of the  
5 satellites facilities;  $t_{is}$  corresponds to the transshipment operation costs (on annual basis). Constraint (2)  
6 fixes that the total volume going in the town by the satellites should be equal to the total volume delivered  
7 from the satellites to the final destinations. Constraint (3) and (4) specify (lower/upper) capacity constraints  
8 for each satellite  $s$ . Constraints 5 and 6 specify whether a satellite is considered or not, and satisfying non-  
9 negative flows. The model can be solved through mixed-integer programming using the Branch-and-Bound  
10 method.

11 In the 'Cournot Equilibrium' two competitors produce homogenous products and they make their choices  
12 simultaneously. Furthermore we assume that they both have the same constant unit cost of production. This  
13 situation might occur when two firms (suppliers) operate as a cartel. While in the traditional economic  
14 studies the Cournot competition model is employed to determine the quantity produced by the two  
15 competitors, in our research the market shares are fixed and the two carriers just compete for the usage of  
16 UCCs. Hence, in the *Cournot Scenario*, we assume that the multi-objective optimization problem  
17 characterized by two stakeholders' cost functions, where each one has 50% of the market (demand), can be  
18 expressed as a single objective function given by the sum of the respective costs functions to be minimized.  
19 The demand for each zone is equally split between the two carriers and the same capacity constraints are  
20 applied to the satellites. The location-allocation problem can be solved in similar fashion to the Base  
21 Scenario, with the only difference that there are two costs functions corresponding to carriers' costs that are  
22 simultaneously minimized.

23 Von Stackelberg competition is characterized by the presence of one leader and one follower competing for  
24 the quantity. In this case, the leader knows a priori that the follower will observe his action and it decides his  
25 output first. Then, the follower can only observe the quantity set by the leader (assumption of perfect  
26 information) and reach the equilibrium. Von Stackelberg competition model describes well a situation where  
27 one firm has the advantage of moving before the other one. These circumstances may occur when the leader  
28 has a monopolistic position in the city distribution and a new competitor (follower) enters the market. In the  
29 *Von Stackelberg Scenario* we assume that the leader has 80% market share and we reproduce the equilibrium  
30 in the location-allocation model by means of a bi-level approach. The upper level optimization problem  
31 corresponds to the leader's problem and the lower level optimization problem corresponds to the follower's  
32 problem. So, the leader's costs function is first optimized to find its optimal solution and then, the follower's  
33 cost function is optimized as well in order to find the best possible solution given the available capacity of  
34 satellites left. This way, once again, it is possible to solve the location model through linear programming.

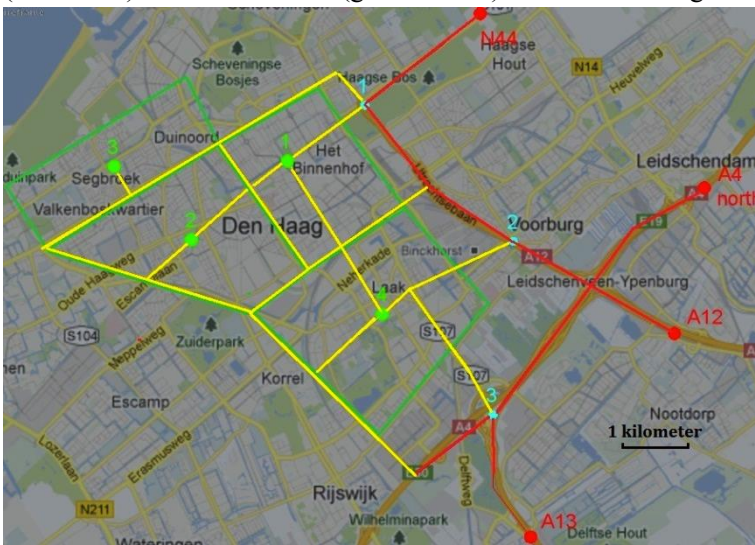
35 In order to simplify the location-allocation problem we applied some assumptions, which however do not  
36 compromise the aim of our study. First, only the problem of flows directed toward the city center has been  
37 considered and not vice versa. Second, the freight flows distribute following an All-or-Nothing assignment  
38 where travel times have been calculated by assuming simple average speeds (see Subsection 4.3).

#### 39 **4. Case Experiment in The Hague**

40 The theoretical models previously introduced are applied to the city of The Hague (the Netherlands). Part of  
41 the dataset (demand, costs of installation of facilities) have been derived from van Duin et al. (2010),  
42 whereas other inputs for the model such as characteristics of the vehicles and satellite and part of the logistic  
43 costs have been assumed based on other studies and experts' knowledge. In Subsection 4.1 the identification  
44 of the origins and destination and the development of a coarse road network are shortly described. In  
45 Subsection 4.2 the demand and supply are identified. The characteristics of satellites and vehicles are  
46 described in Subsection 4.3. The estimation of the costs is illustrated in Subsection 4.4. Finally the main  
47 assumptions made in the model are summarized in Subsection 4.5.

1 **4.1 Origins and destinations and road network in The Hague**

2 The origins in the case study are derived from the configuration of the main motorways serving the city of  
3 The Hague (A4, A12, A13, and N44). The destinations are identified with main commercial areas (North-  
4 East-West-South) determined by the existing road network. The corresponding centroids for both the origins  
5 (red nodes) and destinations (green nodes) are shown in Figure 1.



6 **Figure 1: Main origins and destinations in The Hague (adapted from GoogleMaps)**

7  
8 An abstracted road network has been identified through primary (red links) and secondary (yellow links)  
9 roads. Three potential locations for satellites (blue nodes) have been identified based on their proximity to  
10 both motorways and destination zones on the land availability for possible construction of the facilities.

11 **4.2 Demand and Supply**

12 In this study only aggregated demand data was available. Moreover, as no commodity-based data was  
13 provided, only one type of generic indistinct commodity is considered. Indeed, the exact type of goods is  
14 irrelevant for the scope of this study. Data about the demand are derived from a study conducted by van Duin  
15 et al. (2010) based on an enquiry by DHV (2008) where the equivalent annual demand of the city center of  
16 The Hague corresponded to 241,000 m<sup>3</sup> of goods. Having considered that in our study the served area entails  
17 also peripheral parts of the municipality characterized by lower commercial density, it is assumed that each  
18 zone equally has an average demand of 150,000 m<sup>3</sup> of goods per year, with a total demand of 600,000 m<sup>3</sup>.  
19 This assumption is derived from the fact that the four zones have approximately equal extension, but lower  
20 density than the (central) area studied by van Duin et al. (2010). The largest part of supply is coming from  
21 the motorways (A4, A12, A13) links and equally distributed among the three of them (180,000 m<sup>3</sup> each),  
22 since they represent the main traffic routes in the Randstad connecting The Hague with Amsterdam,  
23 Rotterdam, and Utrecht. The supply coming from the N44 corresponds only to 60,000 m<sup>3</sup> given its relatively  
24 lower importance. With the introduction of a second transport operator, the demand and supply are supposed  
25 to be equally distributed (50%-50%) in the *Cournot Scenario*, whereas 80%-20% in the *von Stackelberg*  
26 *Scenario*.

27 **4.3 Vehicles and satellites characteristics**

28 Based on the same two-tier logistic system proposed by Crainic et al. (2004), deliveries are accomplished  
29 through the combination of (light) trucks and electric vans. Trucks delivering goods from the origins to the  
30 satellites travel at the average speed of 60 km/h (suitable to motorway standard performance in relatively  
31 congested traffic conditions), while electric vans in charge of the city distribution travel at the average speed  
32 of 30 km/h (typical average speed in urban areas including delivery). The capacity is assumed to be 18 m<sup>3</sup>  
33 for trucks and 7 m<sup>3</sup> for electric vans (Van Duin et al., 2010). Regarding the characteristics of satellites, the  
34 minimum capacity in order to be operative is set at 50,000 m<sup>3</sup> of handled goods per year while the maximum

1 capacity is set at 300,000 m<sup>3</sup> (Van Duin et al., 2010). The size of the facilities is assumed to be around 2,000  
2 m<sup>2</sup> considering that the urban location of these facilities, and the absence of added logistic services imply  
3 limited capacities.

#### 4 **4.4 Logistic Costs**

5 Although total logistic costs include a whole range of costs associated with logistics such as transportation,  
6 warehousing, inventory and administration costs, they can be divided into two main categories: transport and  
7 warehousing costs. Transport costs usually decrease with increasing shipping size, whereas warehousing  
8 costs grow. As the intent of our study is to investigating changes in the freight flows and satellite chosen  
9 deriving from competition phenomena rather than identifying a realistic solution of the location-allocation  
10 problem, a series of assumptions have been made. The investment costs of installation of new satellites are  
11 determined as a function of the following parameters: land, real estate and mobile material. Considering a  
12 depreciation period of 20 years and an interest rate of 5%, the annual cost of the investment amounts to  
13 201,846 €. The costs derived from the operation of satellites are given by the product of amount of goods  
14 transshipped (in m<sup>3</sup>) and the average handling cost of 0.8 €/m<sup>3</sup>. The transportation costs divide in truck and  
15 city freighter costs. These ones are respectively assumed to be 100 €/hrs and 30 €/hrs based on Crainic et al.  
16 (2004).

17 Regarding the interactions between different stakeholders the following simplifications have been made. In  
18 the *Base Scenario* the facilities belong to and are operated by a single freight operator who takes all the  
19 investment and operation costs. In the *Cournot Scenario*, the investment costs of a UCC are assumed equally  
20 split by the two companies, while the operating costs are proportional to the amount of freight handled. In  
21 the *von Stackelberg Scenario* investment costs are again equally divided even if the new entrant may manage  
22 a significant lower amount of goods (basically, the old monopolist allows the new entrant to share the  
23 facility, but at his own conditions). In case of Cournot and von Stackelberg equilibria, the installation costs  
24 have been equally split by carriers in case of ‘shared’ facility regardless of the share of goods handled by  
25 each carrier. The costs of purchasing city freighters have been initially neglected assuming a financial  
26 support from the municipality in the form of subsidy. Loads for both the trucks and city-freighters have been  
27 set to 100%, while in reality the average loads of trucks are lower. Adopting more realistic loading factors  
28 equal to 70%-80% increases the transport costs related to the usage of vehicles and determines a shift  
29 towards configurations characterized by smaller but more fine-meshed configuration of UCCs.

### 30 **5. Results of the introduction of competition into location-allocation models**

31 In this Section we discuss the results derived from the introduction of a second transport operator in the  
32 location-allocation problem. Changes in terms of preferred potential sites and freight flow distribution are  
33 described in Subsection 5.1. The effects of competition on the total and single operator costs are reported  
34 respectively in Subsections 5.2 and 5.3. In Subsection 5.4 we illustrate the influence of the last-mile costs on  
35 the outputs of our model.

#### 36 **5.1 UCCs optimal location and flow distribution**

37 In all the modeled scenarios the preferred sites in the optimal location of satellites are Satellites 1 and  
38 Satellite 3 (see Figure 2). While the solution of the location-allocation problem is not largely influenced by  
39 cooperation or competition phenomena among carriers, the distribution of flows is affected. For example, in  
40 the *Cournot Scenario* the two freight operators equally share facilities and flows are evenly allocated (see  
41 Figure 4(c)). In the *von Stackelberg Scenario* instead, the “former monopolist” operates mostly at Satellite 1  
42 and distributes only a minor part of the goods through Satellite 3, which is run together with the “new  
43 entrant” (see Figure 4(d)). It is also interesting to see that in case of unlimited capacity indicated as  
44 “Uncapacitated *Base Scenario*”, both Satellite 1 and Satellite 3 would still be used, but a larger part of goods  
45 would be distributed through Satellite 1: 420,000 m<sup>3</sup>, equal to 70% of the total (see Figure 4(b)).



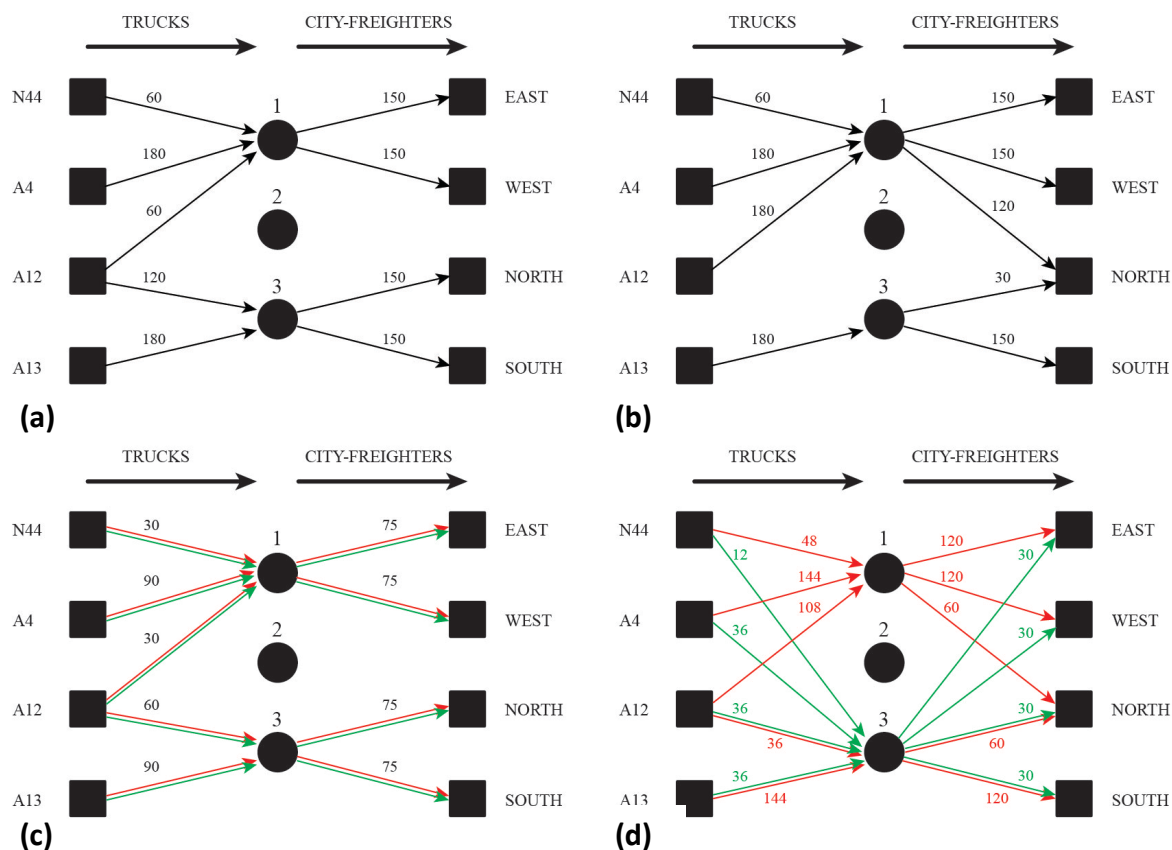


Figure 2: (a) location of satellites and configuration of flows in the Base Scenario; (b) location of satellites and configuration of flows in the Uncapacitated Base Scenario; (c) location of satellites and configuration of flows in the Cournot Scenario; (d) location of satellites and configuration of flows in the von Stackelberg Scenario.

## 5.2 Changes of the total system costs

The results from the experiment reported in Table 1 show that competition leads to inefficiency from a network-wide perspective. Indeed, the *Base Scenario* and *Uncapacitated Base Scenario* are characterized by the lowest total annual system costs thanks to a more efficient distribution of flows, whereas the *Von Stackelberg Scenario* is the one with the highest cost (total costs increased by 1,1%) due to an increase of the second competitor's costs. In the *Cournot Scenario* total costs are unchanged. The total costs for the investment and operation of new facilities are constant in all the scenarios (although in the reality some scale economies may apply when the facilities grow) and it accounts for about 65% of the total costs. Regarding the transport costs, typically truck operations represent 41-43% of the total transport costs, except for the *Uncapacitated Base Scenario*, where they reach 47% of the costs thanks to the significant reduction of freight transport costs by 16%. Von Stackelberg equilibrium determines a slight increase of transport costs.

Table 1: Total costs composition for different scenario

	Base	Uncapacitated Base	Cournot	vonStackelberg
Total costs (per year)	1,366,946	1,338,946	1,366,946	1,382,596
Cost (euro per m <sup>3</sup> )	2,27	2,23	2,27	2,31
Satellite costs (%)	64	66	64	63
Transport costs (%)	36	34	36	37
Trucking costs (%)	43	47	43	42
City-freighter costs (%)	57	53	57	58

### 1 5.3 Changes in freight carriers' costs

2 It clearly emerges from Table 2 that costs for single freight carriers may vary considerably according to the  
3 presence of additional competitors that can result in different kinds of equilibriums. For example, while the  
4 occurrence of Cournot equilibrium does not affect the respective costs of the two carriers (strongly  
5 dependent on the assumptions), costs may vary significantly in quantity and composition according to the  
6 von Stackelberg equilibrium. Indeed, the original monopolist can have little gains (decrease of total costs by  
7  $0.07 \text{ €/m}^3$ ) determined by a combination of a reduction in satellite, transport and city freighter costs and an  
8 increase in truck costs.

9 **Table 2: Comparison of costs for freight carriers in the different scenarios**

	Base	Cournot		vonStackelberg	
	monopolist	c1 (50%)	c2 (50%)	leader (80%)	follower (20%)
<b>total costs (euro/m3)</b>	2.28	2.28	2.28	2.21	2.69
<b>satellite costs (euro/m3)</b>	1.47	1.47	1.47	1.43	1.64
<b>transport costs (euro/m3)</b>	0.81	0.81	0.81	0.78	1.05
<b>trucks (euro/m3)</b>	0.33	0.33	0.33	0.35	0.35
<b>city freighters (euro/m3)</b>	0.48	0.48	0.48	0.43	0.71

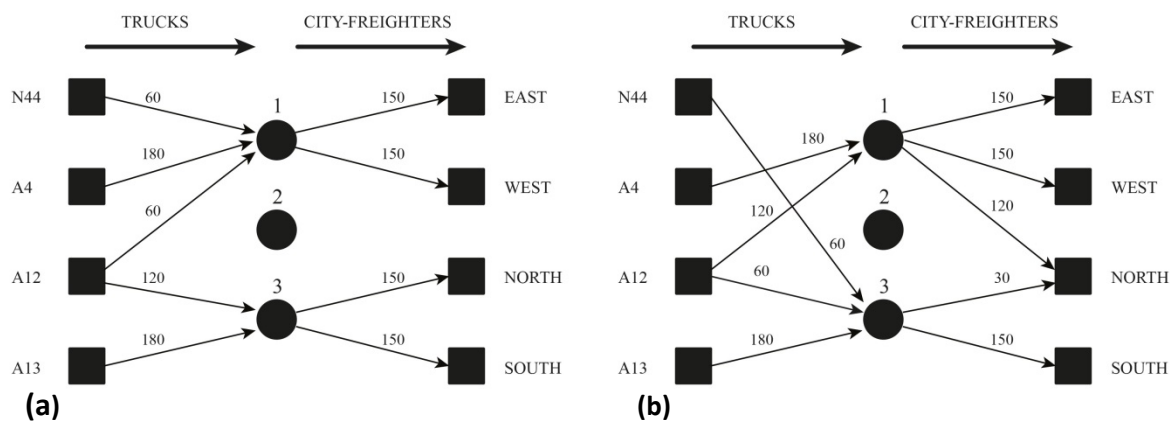
10 On the contrary, the new entrant is affected by a large increase in costs (by  $0.48 \text{ €/m}^3$ ) mostly determined by  
11 unfavorable conditions for satellite operations ( $+0.21 \text{ €/m}^3$ ) and a non-optimal location of facilities ( $+0.23$   
12  $\text{€/m}^3$  in “city freighter” costs). Indeed, the optimal facilities (Satellite 1) have been already used by the old  
13 monopolist.

### 14 5.4 Sensitivity to last-mile costs

15 Running the city-freighter service to accomplish the last part of the delivery, often referred as the last-mile,  
16 represents an important aspect to be considered in practice when making preliminary evaluations of UCC  
17 initiatives. Indeed, depending on several factors such as technical characteristics of the fleet, offered  
18 services, number of costumers and financial support from local authorities, the resulting transportation costs  
19 may considerably vary and reach up to a substantial part of the total delivery cost.

20 In order to test the sensitivity of our model to changes of the last-mile transportation costs we propose two  
21 alternative scenarios characterized by respectively an increase by a factor of 2 and decrease by a factor of 0.5  
22 of city-freighters' running costs in the Base Scenario. Our intent is not to identify the more correct scenario,  
23 but rather investigate how the costs of the last leg of the distribution chain affect our model in terms of  
24 chosen satellites and optimized freight flows.

25 As shown in Figure 3, the increase of operating costs of city freighters leads to minor changes only in the  
26 distribution of freight flows, whereas the facilities chosen remain Satellite 1 and Satellite 3. The decrease of  
27 operating costs does not produce any change. These results suggest that costs related to city freighters do not  
28 play a critical role in our model and that the choice of the UCC location and distribution of freight flow is  
29 mostly affected by the costs of running trucks towards the UCCs and the installation and operating costs of  
30 the UCCs. As a consequence, the “UCC issue” would be affected mainly by the interactions among carriers  
31 in investing and operating the new distribution facilities. It should be noted though, that the limited number  
32 of competitors and potential facilities could have reduced the sensitivity of the model.



1  
2 **Figure 3: (a) location of satellites and configuration of flows with decreased city-freighters' running costs (b) location of satellites**  
3 **and configuration of flows with increased city-freighters' running costs**

4 We would like to point out that in our modeling approach we only considered in-bound freight flows. Empty  
5 travel typically accounts for about 20% of truck traffic in urban areas (Strauss-Wieder et al., 1989) and about  
6 30-40% in intercity freight traffic (Holguín-Veras and Thorson, 2003). As the trucking costs show the  
7 highest sensitivity, we believe that integration of empty truck modeling could be a direction for further  
8 research with respect to different competition in the inter-city freight distribution rather than in the last mile  
9 distribution as it already happens in the base scenario.

## 10 **6. Conclusions and recommendations**

11 In this paper we shed light on competitive behavior phenomena among freight operators in the evaluation of  
12 optimal configuration of UCCs, the flows over the network and the costs. In particular, it emerged from a  
13 literature survey about UCCs how the importance of competition-cooperation phenomena among different  
14 freight distributors determines the success of such kind of initiative. Hence, we included basic interactions  
15 among freight operators in the "traditional" location-allocation model in order to reproduce the Cournot and  
16 von Stackelberg equilibria. The model was applied to a case study of The Hague to investigate changes in  
17 the optimal configuration of UCCs, optimal distribution of freight flows, overall costs of the system and  
18 costs of carriers.

19 In this study we reproduced in a simplified way two different market situations: the Cournot equilibrium and  
20 the von Stackelberg equilibrium that respectively represent a situation with equal competitors and a situation  
21 of competition between a market leader and a new entrant. The results show that cooperative games can lead  
22 to different outcomes through variations in the number and size of satellites, and the distribution of freight  
23 flows. Indeed, although the chosen facilities seem to be constant, the volumes and the routes of goods  
24 directed from the external zones to the commercial zones are different. In the *Cournot Scenario* the outputs  
25 are equal to the original *Base Scenario*, mainly due to the assumptions of equal shares and costs for the two  
26 operators. In the *von Stackelberg Scenario* it is possible to see relevant changes in the patterns, especially for  
27 the new entrant that is able to achieve only a sub-optimal configuration dependent on the choice of the  
28 leader. In order to provide a more complete overview of the model, changes in the last-mile costs,  
29 particularly the city-freighters' transportation costs, have also been tested. The fact that only minor changes  
30 in the optimal configuration are determined by this factor suggests that the ways UCCs are managed among  
31 competing carriers can considerably affect the final results. Hence, a particular focus need to be paid to  
32 possible deals among competing carriers' about ways of (co)investing and (co)operating UCCs.

33 Regarding the total system costs, as expected the scenario characterized by lowest costs is the one without  
34 any capacity constraint for the size of facility (*Uncapacitated Base Scenario*). While a situation of Cournot  
35 competition did not determine significant changes of the overall costs of the system, the von Stackelberg  
36 competition determined a slight increase. This result suggests that from the perspective of public authorities  
37 (who are interested in the final cost of the service and impacts on city livability) a situation of monopoly or

1 'regulated' competition might be preferred over a situation of competition characterized by the entrance of  
2 numerous carriers in the market. Given the public good characteristics and the high fixed costs of the UCC  
3 this seems plausible. Finally, it is interesting to look at the changes of costs for single carriers determined by  
4 the introduction of competitive dynamics. It is shown that in Cournot equilibrium no relevant changes occur  
5 as both the competitors have equal power and they reach their optimal configuration in the city distribution,  
6 however, in the von Stackelberg equilibrium a gap between the two stakeholders' costs arises.  
7 This study represents an extension of the previous work by Crainic et al. (2004) and Muñuzuri et al. (2012)  
8 who proposed a computational approach to optimize last-mile freight distribution initiatives by means of  
9 satellites and mini-hubs. The introduction of interactions among competitors in the UCCs location-allocation  
10 model can provide policy makers with an additional understanding of carriers' perspective, and if further  
11 developed, it could allow more meaningful considerations about the setup of UCCs. Indeed, the outcomes  
12 show that situations characterized by the presence of two equal competing carriers (oligopoly) can still lead  
13 to optimal configurations, whereas situations of strong disparity among the two competitors (von Stackelberg  
14 equilibrium) can determine suboptimal configurations. Moreover, the results of the experiment suggest that a  
15 further increase in the number of competitors could lead to a lower efficiency of the system. For this reason,  
16 a situation of monopoly regulated by local authorities (*Base Scenario*) appears as a valuable solution, as it  
17 seems to minimize the overall costs of the system. However, policy makers may decide to avoid this market  
18 situation since the monopolist could decide to raise prices at his own discretion. Introducing competition  
19 phenomena in the location-allocation model seems to be solid and rather practical approach to evaluate  
20 organizational features and financial issues of UCCs initiatives. Following this work, further studies are  
21 recommended on: increased number of carriers and candidates UCCs, broader and more detailed networks,  
22 and increased level of complexity in the interaction among carriers.  
23

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26

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