CIRRELT

Centre interuniversitaire de recherche
sur les réseaux d'entreprise, la logistique et le transport

Interuniversity Research Centre
on Enterprise Networks, Logistics and Transportation

Reorganizing Postal Collection Operations in Urban Areas as a Result of Declining Mail Volumes A Case Study in Bologna

Giuseppe Bruno
Manuel Cavola
Antonio Diglio
Gilbert Laporte
Carmela Piccolo

April 2019

CIRRELT-2019-19

Bureaux de Montréal :
Université de Montréal
Pavillon André-Aisenstadt
C.P. 6128, succursale Centre-ville
Montréal (Québec)
Canada H3C 3J7
Téléphone : 514 343-7575
Télécopie : 514 343-7121

Bureaux de Québec :
Université Laval
Pavillon Palasis-Prince
2325, de la Terrasse, bureau 2642
Québec (Québec)
Canada G1V 0A6
Téléphone : 418 656-2073
Télécopie : 418 656-2624

www.cirrelt.ca

Reorganizing Postal Collection Operations in Urban Areas as a Result of Declining Mail Volumes – A Case Study in Bologna

Giuseppe Bruno[1], Manuel Cavola[1], Antonio Diglio[1], Gilbert Laporte[2], Carmela Piccolo[1,*]

[1] Department of Industrial Engineering (DII), Università degli Studi di Napoli Federico II, Piazzale Tecchio, 80 – 80125 Naples, Italy

[2] Interuniversity Research Centre on Enterprise Networks, Logistics and Transportation (CIRRELT) and Department of Management Sciences, HEC Montreal, 3000 Côte-Sainte-Catherine, Montréal, Canada H3T 2A7

Abstract. The impact of technological developments on consumer habits and behavior is endangering the classical model of postal services. The resulting fall in postal volumes generated by the substitution of traditional letter posts by electronic forms of communication has rendered the collection of postal items highly inefficient. In this context, our work deals with a real problem concerning the reorganization of the collection system of the Italian postal service provider, based on the reduction of the number of postboxes currently located in an urban area. To tackle the problem, we propose solving a mathematical programming model in order to reduce the number of postboxes and to create associated collection areas, i.e., clusters of postboxes to be assigned to operators. Considering the crucial role of postboxes as main access points of users to the postal network, equity is also taken into account. We also consider workload balance and shift duration requirements in the determination of the collection areas. Several computational experiments are conducted based on real data from the city of Bologna, in northern Italy. The resulting scenarios show the capability of the model to support the decision making process towards the redesigning of the postal collection system.

Keywords. Postal service, equity, districting, service accessibility.

Acknowledgment. This work was partially supported by the Natural Sciences and Engineering Research Council of Canada (NSERC) under grant 2015-06189. This support is gratefully acknowledged.

---

* Corresponding author: carmela.piccolo@unina.it

Dépôt légal – Bibliothèque et Archives nationales du Québec
Bibliothèque et Archives Canada, 2019

1. Introduction

Service organizations are experiencing several profound changes driven by the wide diffusion of information and communication technologies (ICTs), which have significantly modified customer behaviour and increased competitiveness. In particular, ICTs had a strong impact on organizational design and performance, thus constituting the main driver towards an overall reshaping of the traditional concept of service (Barrett, Davidson, Prabhu, & Vargo, 2015). In this context, public services are required to reach higher levels of efficiency and to adopt more flexible structures in order to better respond to unpredictable market changes (Phillips & Wright, 2009). We are interested in postal services, which have been affected by two significant trends: *e-substitution*, i.e., the progressive substitution of conventional letter mails by electronic forms of communication, and *e-commerce*, which have led to a significant growth of parcels volumes distribution against a crisis in the letter post segment (Hong & Wolak, 2008; Nikali, 2008). Indeed, in the 2002–2012 decade, the total traffic of letter post items has known an annual decrease of 2.0% at a global level and, starting from 2013, it has also gone down, with significant differences between countries, depending on their industrialization level and geographic position. In the same period, the annual growth of traffic of parcels has been 3.1%, with an increase of 6.4% in 2014–2015 (Universal Postal Union, 2015). This traffic currently accounts for more than 20% of the total income of postal providers, doubling its percentage share with respect to 2005. Such trends are expected to consolidate in the next few years and, consequently, the letter post segment is expected to lose its historical leading position as a major contributor to postal operators' revenues.

This transformation has also been accompanied by an evolution of the regulatory framework, which has promoted a gradual liberalization and globalization of the market. At the European level, the member states have been required to regulate postal markets with the goal of ensuring an efficient, reliable and good-quality service at affordable prices to citizens and enterprises (European Parliament and Council of European Union, 1998, 2002, 2008).

In this environment, postal companies have been and are still involved in reengineering processes aimed at innovating their organizational, logistic and technological systems, and at improving their overall operational performance (Cardenas, Dewulf, Beckers, Smet, & Vanelslander, 2017; Morganti, Seidel, Blanquart, Dablanc, & Lenz, 2014).

Our work focuses on a pilot study initiated by the main Italian Postal Service provider (Poste Italiane S.p.A), dealing with the reduction of postboxes located over the national territory and their partition in new *collection areas*, i.e. groups of postboxes to be assigned to single postmen for the daily operations (routing and letters pick-up). The problem is motivated by the fact that in the described context, the average daily amount of mail accumulated in each postbox is actually very low and consequently, the overall organization of the collection activities is highly inefficient. However, any reorganization decision cannot be taken by neglecting the nature of the service being considered, defined by the EU as a "universal service" (European Parliament and Council of European Union, 1998), meaning that it has to be accessible to all users, regardless of their geographic position.

In order to tackle this problem, we introduce a mathematical programming model and we also devise a constructive heuristic procedure. The proposed solution approach is applied to the real case study of the city of Bologna, with the aim of showing its ability to support the decision making process. The remainder of the paper is organized as follows. In Section 2, after a short description of a typical postal logistic system, we review the state-of-the-art of models and algorithms specifically devoted to postal applications. The formal description of the problem, the mathematical model and the proposed solution procedure are given in Section 3. Section 4 focuses on the description and solution of the case study. Conclusions follow in Section 5.

2. State of the art

Postal services are provided through a dedicated logistics network capable of performing all typical operations such as reception, collection, transportation, sorting, and delivery of postal items over a given territory (Figure 1). *Reception* is the phase in which users access facilities of the network in order to send postal items, while *collection* is the phase in which operators visit these facilities to collect the items and transfer them to departure sorting centers (DSCs), where they are clustered on the basis of their final destination. *Transportation* to arrival sorting centers (ASCs) is performed through different single or combined modes (airplanes, trains, vehicles), according to the volumes, the distances, and the delivery deadlines. At ASCs postal items are sorted and prepared for the final door-to-door distribution phase. All these activities must be completed within deadlines which depend on the specific services required by users.

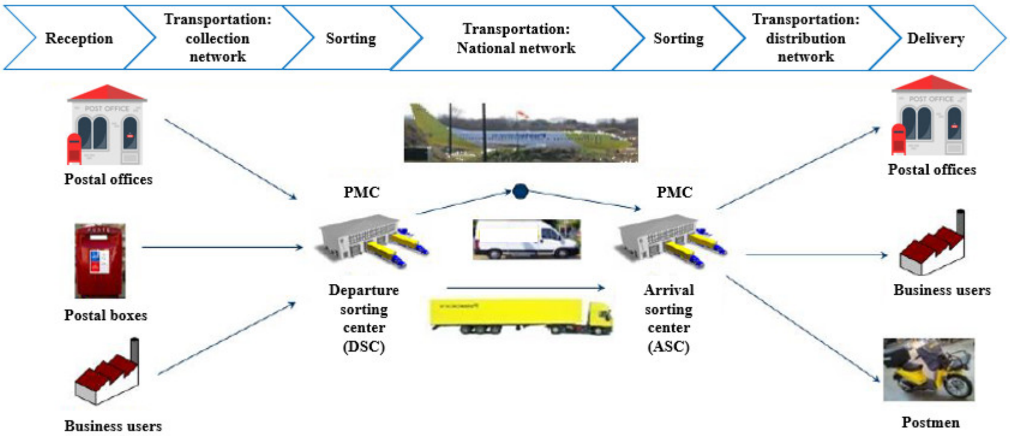


Figure 1. Representation of a postal logistics network.

The problems associated with the planning, organization and management of this complex system have stimulated a rich variety of models and algorithms. Regarding the *planning aspect*, a first proposal specifically focused on postal applications is due to Labbé and Laporte (1986) who solved the problem of locating postboxes with the aim of minimizing the total distance traveled by users and the routing cost associated with emptying the postboxes. More recently, Blagojević, Šelmić, Macura, and Šarac (2013) have developed a novel approach to locate the optimal number of postal units, based on the generation of fuzzy rules from numerical data.

Several studies have focused on the *scheduling problems* related to the personnel (Bard, 2004; Bard, Binici, & deSilva, 2003; Bard & Wan, 2008; Zhang, Chakravarthy, & Gu, 2009) and to the machines or equipment (Jarrah, Bard, & deSilva, 1992, 1994a, 1994b; Zhang & Bard, 2005) used to support operations at different levels.

Concerning the *transportation phase*, McWilliams and McBride (2012) have studied the parcel hubs scheduling problem, namely the scheduling of inbound trailers for the minimization of the timespan between unloading and loading docks. More recent contributions related to the inbound and outbound truck scheduling are those of Jarrah, Qi, and Bard (2014), Boysen, Fedtke, and Weidinger (2017) and Zenker and Boysen (2018).

Grünert and Sebastian (2000) provided an overview of the tactical problems encountered in the final *distribution phase*, while Irnich (2008) proposed mathematical formulations and solution methodologies for real-world postal problems arising in letter mail delivery. Algorithms for the integrated management of collection and distribution activities have been presented in the studies by Mitrović-Minić, Krishnamurti, and Laporte (2004), Jung, Lee, and Chun (2006) and Qu and Bard (2012). Abbatecola, Fanti, Mangini, and Ukovich (2016) have described a decision support system for the management of postal deliveries in an urban area based on a vehicle routing model. Rosenfield, Engelstein, and Feigenbaum (1992), Novaes and Graciolli (1999) and Novaes, de Cursi, and Graciolli (2000) considered continuous approximation models for the determination of the optimal size of service territories and of the total transportation cost (see also Franceschetti, Jabali, & Laporte, 2017 for an extensive review).

In this work, we focus on the reorganization of postal collection operations. To this end, we propose a mathematical model integrating two decision levels: location and districting. The location part of the model aims at identifying the set of postboxes to be kept active so as to ensure a good and equitable access to the users (Barbati & Bruno, 2018; Barbati & Piccolo, 2016; Marsh & Schilling, 1994; Talen & Anselin, 1998). In practice, a covering paradigm is applied in our model (García & Marín, 2015), as we ensure that a certain fraction of users is covered within a given accessibility distance by a postbox. The goal of the districting part is to group the located postboxes in a given number of areas to be visited by dedicated operators. In the existing literature, several studies resort to the use of districting models (Bruno, Genovese, & Piccolo, 2017; Kalcsics, 2015; Ricca, Scozzari, & Simeone, 2013) to cope with the strategic problem of designing pickup and delivery areas in distribution logistics (Galvão, Novaes, De Cursi, & Souza, 2006; Haugland, Ho, & Laporte, 2007; Jarrah & Bard, 2012; Lei, Laporte, & Guo, 2012; Lei, Laporte, Liu, & Zhang, 2015; Lei, Wang, & Laporte, 2016; Zhong, Hall, & Dessouky, 2007). Notably, in all the extant studies, the districting phase involves a set of points whose locations are fixed. In contrast, the introduction of location decisions concerning the points (i.e. postboxes) to be clustered represents a distinctive feature of our model.

Another valuable element of our study lies in the novelty of the application. Indeed, the problem of reconfiguring postal networks has been scarsely investigated. In particular, to the best of our knowledge, no paper explicitly deals with real problems concerning the closure of collecting facilities. Only Higgs and Langford (2013) have analysed the impact of post office closures on user accessibility in rural and urban areas after a Network Change Programme undertaken in Wales; but their contribution is limited to an ex-post spatial analysis. In this work, we introduce a mathematical programming model to support the decision maker in the reconfiguration of the network and in the reorganization of collection operations, with the aim of finding a trade-off solution between the need of reducing management costs and the need of preserving the users'accessibility to the provided service. The model is tested on real data related to the city of Bologna, in northern Italy, in order to show its capability to handle real-world instances and to provide meaningful managerial implications.

3. Formal problem description and mathematical model

The logistics network of Poste Italiane currently contains more than 50,000 postboxes spread throughout the national territory to provide users local access to the network and comply with the quality of service requirements (AGCOM, 2014). In recent years, the drastic drop in letter volumes has led to a general underutilization of such postboxes, thus making the current organization of the collection service unsustainable. Indeed, as long as a postbox is open, it has to be maintained and visited each day by an operator, thus impacting on the total operational cost. As a result, the postal provider is now evaluating the opportunity of reorganizing the collection system with the aim of reducing the number of existing postboxes and, hence, the number of operators devoted to collection activities. With this aim in mind, the following decisions should be made:

- the identification of the postboxes to be closed, at the strategic level;
- the definition of proper *collection areas*, i.e. groups of postboxes, to be visited by the same operator, at the tactical level.

When tackling this problem, specific constraints must be taken into account.
From a strategic point of view, the reduction of postboxes may yield a deterioration of users' accessibility. The universal nature of the postal service imposes that such decisions be made by preserving the access of users to the logistics network, according to the quality standards fixed by the regulatory authority. In the Italian case, two main criteria have to be considered: i) a *spatial criterion*, indicating maximum distances that users should cover in order to reach their closest postbox; ii) a *demographic criterion*, indicating the maximum number of inhabitants who have to be served by each postbox and then, the minimum desired number of postboxes (AGCOM, 2014). As concerns the first criterion, proper equity conditions on the distances to be covered by the users in the final configuration have been included in the model. In particular, we imposed that extra travel costs may be incurred only by those users located within a preset distance from their closest postbox, while the accessibility condition of the most disadvantaged users cannot be worsened any further. As concerns the *demographic criterion*, we did not include any explicit condition in the model regarding the minimum number of postboxes to be kept open. This choice is due to the fact that the relaxation of this criterion is currently under discussion in the context of a negotiation process between Poste Italiane and the national regulatory authority, as it is no longer considered a proper quality standard for service provision. Indeed, demographic conditions were originally introduced as a sort of capacity constraint to avoid the risk of having few access points in the network compared to the global demand, especially for densely populated areas. However, due to the decreasing trend characterizing the letter post segment, the daily demand has become negligible and the service can be substantially considered to be uncapacitated. This criterion has therefore become obsolete and its enforcement could yield a high proliferation of underutilized postboxes over the national territory, with a consequent damage for the postal providers, in terms of competitiveness.
From a tactical point of view, the definition of collection areas should be made by taking into account aspects related to the work shift duration. In particular, the workload assigned to each operator should be feasible in terms of duration of the tour performed to visit and empty the postboxes within its assigned collection area. Moreover, the workload balance of the operators should also be taken into account.
To model the problem, we consider a set I of nodes at which users are located, and a

set J of existing postboxes partitioned into a subset of *standard* postboxes, i.e. postboxes that can be removed, and a subset J_0 of *special* postboxes that need to be kept operational, being located close to post offices or to crucial locations such as hospitals and universities. We denote by d_{ij} the distance between nodes $i \in I$ and $j \in J$ and, assuming that each user patronizes the closest postbox, we adopt the minimum distance $d_i^{min} = \min_{j \in J}\{d_{ij}\}$ as a measure of the users'accessibility to the network. By fixing a given threshold distance $\overline{d}$, the set of users I may be partitioned into two subsets I' and $I \setminus I'$, which respectively include the users located further or closer than $\overline{d}$ from their nearest postbox. In order to take equity into account, we impose that the postboxes patronized by users in I' cannot be closed.
The proposed model aims at identifying the postboxes to be closed and at partitioning the remaining ones into a given number p of clusters, called *collection areas*, so as to optimize the workload of the operators and to preserve the accessibility of the worst served users. Our objective function is the minimization of a compactness measure of the created collection areas, since it is reasonable to assume that a more compact cluster of nodes most likely requires a lower routing time. It is important to stress that although compactness is widely acknowledged as a proxy measure of the travel times within a district (García-Ayala, González-Velarde, Ríos-Mercado, & Fernández, 2016; Kalcsics, 2015), it does not necessary lead to shorter routes. We provide in Appendix C the correlation obtained between the two measures in our computational experiments.
We use the following notation:

I	set of nodes where users are located, indexed by i;
J	set of nodes where postboxes are currently located, indexed by j;
$J_0 \subseteq J$	subset of special postboxes;
c_{jk}	distance between postboxes $j, k \in J$;
d_{ij}	distance between nodes $i \in I$ and $j \in J$;
d_i^{min}	distance between node $i \in I$ and its closest postbox $j \in J$ ($d_i^{min} = \min_{j \in J}\{d_{ij}\}$);
$\overline{d}$	equity distance;
I'	subset of users in the worst accessibility condition, i.e. further than $\overline{d}$ from their closest postbox ($I' = \{i \in I : d_i^{min} > \overline{d}\}$);
J_i'	subset of postboxes located within a distance $\overline{d}$ from node $i \in I$ ($J_i' = \{j \in J : d_{ij} \leq \overline{d}\}$);
$J^\star$	subset of postboxes patronized by disadvantaged users $i \in I'$ ($J^\star = \{j \in J : d_{ij} = d_i^{min}, i \in I'\}$);
p	number of collection areas to be created;

The decision variables are as follows:

y_j	binary variable equal to 1 if and only if postbox $j \in J$ remains open;
z_{jk}	binary variable equal to 1 if and only if postbox $j \in J$ is assigned to the postbox $k \in J$.

The model is then formulated as follows:

$$\text{minimize} \quad \sum_{j\in J}\sum_{k\in J} c_{jk} z_{jk} \tag{1}$$

$$\text{subject to} \quad \sum_{j\in J'_i} y_j \geq 1 \qquad i \in I \setminus I' \tag{2}$$

$$y_j = 1 \qquad j \in J_0 \cup J^\star \tag{3}$$

$$z_{jk} \leq z_{kk} \qquad j,k \in J \tag{4}$$

$$\sum_{k\in J} z_{jk} = y_j \qquad j \in J \tag{5}$$

$$\sum_{k\in J} z_{kk} = p \tag{6}$$

$$(1-\beta)UBz_{kk} \leq \sum_{j\in J} c_{jk} z_{jk} \leq UB \qquad k \in J \tag{7}$$

$$y_j, z_{jk} \in \{0,1\} \qquad i \in I, j,k \in J. \tag{8}$$

The objective function (1) is defined as the total radial distance of the active postboxes $j \in J$ from their assigned cluster center $k \in J$, thus representing a compactness measure of the created collection areas. Constraints (2) guarantee that each user $i \in I \setminus I'$ has at least one postbox within the distance $\overline{d}$. Constraints (3) ensure that special postboxes, as well as postboxes patronized by users $i \in I'$, are kept open. Constraints (4)–(7) regulate the aggregation of active postboxes in collection areas. In particular, Constraints (4) impose that a postbox $j \in J$ can only be assigned to postboxes k selected as cluster centers ($z_{kk} = 1$). Constraints (5) impose that only active postboxes j are assigned to a single postbox $k \in J$. Constraint (6) fixes the number of cluster centers equal to p. Constraints (7) impose a balancing requirement on clusters, by setting a lower and an upper bound on the internal compactness. In particular, the lower bound is set as a maximum deviation β from the upper bound UB. Finally, Constraints (8) define the domain of the decision variables.

3.1. Solution methodology

The proposed mathematical model does not incorporate routing decisions and, hence, it lacks an explicit formulation of the workshift duration and workload balance constraints. Instead, it makes use of a proxy measure of the routing costs within each collection area, coinciding with the internal compactness or radial distance t_k associated to the single clusters k ($t_k = \sum_{j\in J} c_{jk} z_{jk}, k \in J$). For this reason, we adopt a decomposition strategy according to which we initially solve the model, and we then evaluate the actual routing costs by solving a Travelling Salesman Problem (TSP) within each cluster, to check their feasibility, in terms of duration.

In practice, we propose solving the problem by means of the constructive heuristic depicted in Figure 2, aimed at finding a scenario characterized by the minimum number of feasible clusters, i.e. having a collection time (CT) not exceeding a maximum workshift duration T beyond a given tolerance.

In a generic step of the solution procedure, we solve the model (1)–(8) for a specific setting of parameters $\overline{d}$, p and UB. We also set $\beta = 1.00$, as it makes the left hand side of the balancing constraint (7) inactive. If the model leads to infeasibility, we run it with an increased number of collection areas ($p \leftarrow p+1$), otherwise we solve a TSP within each collection area to compute the optimal length of the routes and then the collection times (CT_k) obtained by considering an average speed s and a unit time to collect items at each postbox v. If the maximum collection time ($\max_{k=1,\ldots,p}\{CT_k\}$) lies within the given duration T, included a given tolerance of 10%, we stop the procedure by setting $p = p^\star(\bar{d})$ and $UB = UB^\star(\bar{d})$. Otherwise, we run the model with a more stringent value of the upper bound UB. In particular, we set UB as 95% of the maximum compactness recorded in the obtained scenario ($UB \leftarrow 0.95 \times \max_{k=1,\ldots,p}\{t_k\}$).

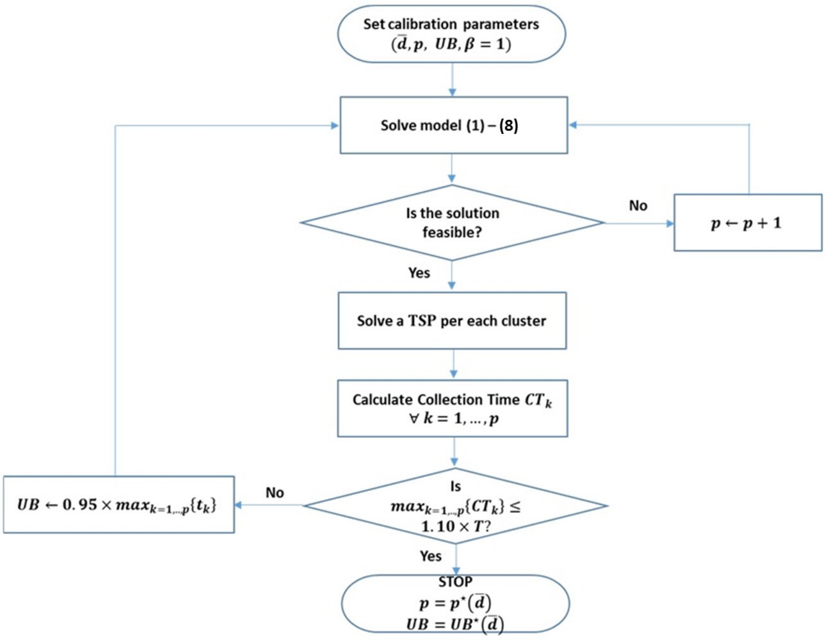


Figure 2. The proposed solution procedure.

In other words, according to our solution procedure, $p^\star(\bar{d})$ and $UB^\star(\bar{d})$ represent, respectively, the minimum number of collection areas to be activated and the maximum value of internal compactness to be set in order to have tours of feasible duration (not exceeding T).

Once a feasible solution has been obtained, a specific procedure is triggered to achieve workload balance. In particular, we solve model (1)–(8) with $p = p^\star(\bar{d})$ and $UB = UB^\star(\bar{d})$ by decreasing the parameter β. In fact, imposing a more stringent condition on the minimum compactness per cluster is expected to lead to a more homogeneous distribution of the collection times. Clearly, introducing the latter mechanism may yield infeasible instances since it enforces a lower deviation from the condition of perfect compactness balancing among the clusters. In these cases, the most balanced solution is the feasible solution corresponding to the highest value of β.

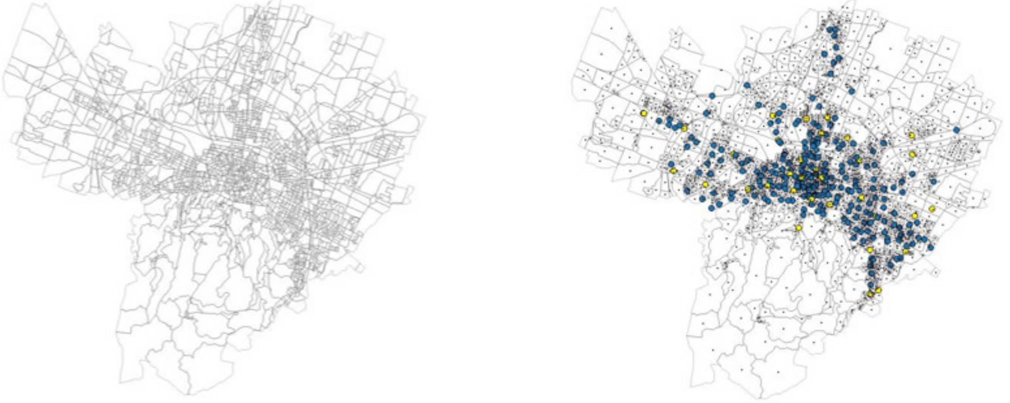
4. The Bologna case study

In this section, we report on the computational experiments performed to test the solution procedure proposed for the reorganization of the postal collection operations.

We first describe the test data used. We then present and discuss the obtained results.

4.1. Test data

The solution procedure was applied to a real case study concerning the city of Bologna (371,217 inhabitants), located in the northern part of Italy. At this aim, we first discretized the location space into 2,333 territorial units, corresponding to the city census tracts (ISTAT, 2011), and we assumed that all users located in a census tract are concentrated in its centroid (Figure 3). We are conscious that any aggregation of demand points may introduce a bias error in the evaluation of users' accessibility, but "there is no agreement on how measure error" (Francis & Lowe, 2015) and hence on the best way to discretize a study region. Nevertheless, in Appendix A we provide a detailed analysis aimed at justifying the adopted aggregation, in terms of its representativeness of the real demand distribution. Figure 3b shows the current location of the 272 postboxes J, highlighting, in yellow, the positions of the special postboxes ($|J_0| = 36$). The distances d_{ij} between the centroids and the existing postboxes, and distances c_{jk} between pairs of postboxes, were determined as the shortest paths on the road network.



(a) Census tracts

(b) Centroids and postboxes locations

Figure 3. Data related to the case study of Bologna (provided by Poste Italiane)

.

The solution provided by the model highly depends on the calibration of the parameter $\overline{d}$, which contributes to the determination of the set I' of users to be preserved from the reallocation mechanism. In order to set appropriate values for $\overline{d}$, we first calculated the cumulative distribution of users' distances from their closest postboxes. In particular, considering the population a_i living in each census tract $i \in I$, we calculated the percentage of the total population A_{tot} having a distance from the closest postbox not exceeding a given $\overline{d}$ ($\alpha = F(d_i^{min} \leq \overline{d}) = \dfrac{1}{A_{tot}} \sum_{i \in I : d_i^{min} \leq \overline{d}} a_i$); see Figure 4.

This way, the equity distance $\overline{d}$ may be set according to the proportion $1 - \alpha$ of the population that the decision maker wants to preserve ($\overline{d} = F^{-1}(1-\alpha)$). In practice, in the case under analysis, for $\alpha = 1$, i.e., when no user is preserved and anyone is free to be reallocated, regardless of their current distance to the closest postbox ($I' = \emptyset$), we obtain a threshold distance of $\overline{d} = 5,626$ m; by decreasing the value of parameter α the distance $\overline{d}$ decreases as well. For $\alpha = 0$, i.e., when all users are preserved ($I' = I$), no reallocation is feasible. Table 1 reports the values of $\overline{d}$ obtained for several values of α, whereas Figure 5 shows how the partition of the demand nodes I in the subsets of *disadvantaged* users I' (in red) and *non-disadvantaged* users $I \setminus I'$ (in white) varies according to the value of α (and hence $\overline{d}$).

It is worth noting that the spatial criteria fixed by the Italian regulatory authority require that, in each municipality, at least the 75% of the total inhabitants be covered within a maximum distance of three km, 92.5% within five km and 97.5% within six km (AGCOM, 2014). Table 1 shows that for any value of α, the mechanism introduced in the model is definitely consistent and even more stringent with respect to the current requirements.

Although the above considerations are drawn with respect to the adopted aggregation rule, in Appendix B we show that they still hold when considering the real distribution of demand points.

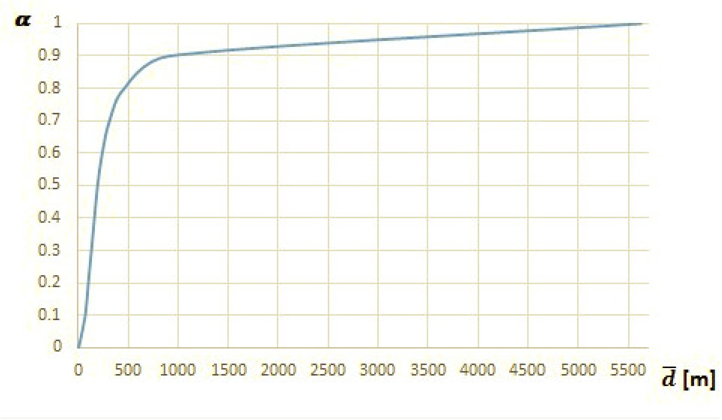


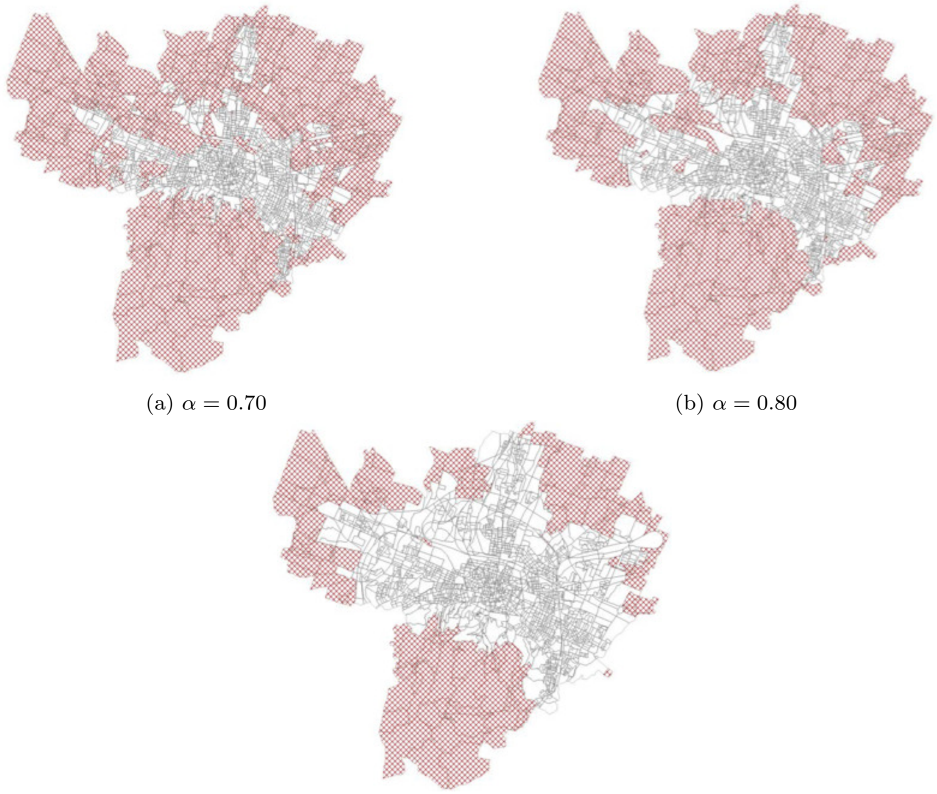
Figure 4. Distribution of the population by the distance from the closest postbox.

Table 1. Values of calibration parameter $\overline{d}$ selected for testing the model.

α	1.00	0.90	0.80	0.70	0.60	0.00
$\overline{d}[m]$	5625.50	913.15	461.59	313.27	240.59	4.15

The time to visit and empty all the postboxes within any area, indicated by Collection Time (CT) in the proposed solution procedure, was calculated by assuming a speed s of 10 km/h and a time v of 3.0 minutes to collect items at each postbox. Moreover, on the basis of an analysis conducted by Poste Italiane, the amount of time T dedicated to collection activities by each postman was fixed at 120 minutes.

In order to trigger our solution procedure, we need to set the values of the calibration parameters UB and p. The parameter UB imposes an upper bound on the compactness of the clusters to be created. Initially, we relax Constraints (7). Hence, these inequalities become active only after a feasible solution to our model has been found. The parameter p fixes the number of clusters. In order to make our solution procedure more efficient, we identify, for each value of α, a different initialization value $p_{min}(\alpha)$. In fact, according to the introduced notation, the minimum number n_{min} of postboxes to be located is equal to $|J_0| + |J^{\star}| + |\overline{J}|$, where $\overline{J}$ is the set of postboxes located in an optimal solution to a Set Covering Problem solved for users $i \in (I \setminus I')$, by setting a covering radius equal to $\overline{d}$. Hence, a lower bound L to the optimal tour



(a) $\alpha = 0.70$

(b) $\alpha = 0.80$

(c) $\alpha = 0.90$

Figure 5. Partitioning of the users into a set I' of disadvantaged users (red) and a set $I \setminus I'$ of non-disadvantaged users (white) by varying α

.

through these postboxes is given by $L = \sum_{j \in (J_0 \cup J^\star \cup \bar{J})} \min_{k \in J}\{c_{jk}\}$. Therefore, we can compute $p_{min}(\alpha) = (L/s + n_{min} \times v)/(1.10 \times T)$. The resulting values for $p_{min}(\alpha)$ are reported in Table 2.

Finally, in order to activate the balancing mechanism in Constraints (7) we also set parameter $\beta = 0.20, 0.40$.

Table 2. Values of calibration parameter $p_{min}(\alpha)$.

α	1.00	0.90	0.80	0.70	0.60	0.00
$p_{min}(\alpha)$	2	3	5	6	8	9

The proposed solution procedure was coded in Python 3.6 and the TSPs were solved using the open source VRP Spreadsheet Solver (Erdoğan, 2017). The embedded model was optimally solved using CPLEX 12.8 for each value of α, with $\alpha = 1.00, 0.90, 0.80, 0.70, 0.60, 0.00$, within relatively small computing times (20 minutes on average).

4.2. Experimental results

We now show how the proposed methodology can be used to support the decision maker in the reorganization process of the collection activities.

We first analyse in detail the scenarios obtained by setting $\beta = 1.00$, i.e. when the workload balancing requirement is not explicitly considered. Even in this case, the solutions can represent interesting scenarios for the decision maker. Indeed, even if not balanced, the workshifts of the postmen will be characterized, on average, by a lower saturation degree, which could offer more flexibility in managing their daily tasks.

Table 3 summarizes all the scenarios obtained by setting $\beta = 1.00$ and by varying α. This table reports, for each value of α, the optimal number of created clusters $p^\star(\alpha)$, the total number of active postboxes ($n_{tot} = \sum_{j \in J} \sum_{k \in J} z_{jk}$) and the maximum collection time per cluster. As expected, a higher percentage of users to be preserved, in terms of the accessibility condition, results in a higher number of postboxes to be kept open; indeed, the number of postboxes increases by decreasing α. Similarly, the number of created clusters $p^\star(\alpha)$ increases when α decreases, passing from three for $\alpha = 1.00$ to 13 for $\alpha = 0.60$. This is reasonable since with a higher number of postboxes, more clusters have to be created in order to complete the tours within the time limit T. Interestingly, the solution with $\alpha = 0.00$ basically represents the ‘status quo’, because no user may be reallocated with such setting of calibration parameters and, hence, only four postboxes are closed.

Table 3. Characteristics of the produced scenarios ($\beta = 1.00$).

α	1.00	0.90	0.80	0.70	0.60	0.00
$p^\star(\alpha)$	3	6	8	10	11	13
n_{tot}	39	69	125	183	224	268
Max CT	131.52	126.31	130.51	131.80	131.93	131.46

Figure 6 shows the solution obtained by fixing $(\alpha, p^\star) = (0.90, 6)$. It can be seen that 203 postboxes out of 272 have been removed, while the remaining 69 are grouped into six clusters, depicted with different colours. In Table 4, each cluster k is characterized by its *number of postboxes* ($n_k = \sum_{j \in J} z_{jk}$), its internal *compactness*, i.e., the total radial distance of postboxes from their assigned cluster center ($t_k = \sum_{j \in J} c_{jk} z_{jk}$), and its *collection time* (CT_k), i.e., the time needed to visit and empty all its postboxes. It can be seen that the sizes of the six clusters are quite different, with a number of

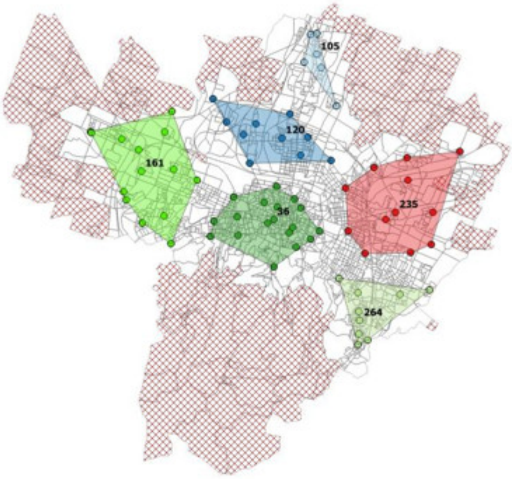


Figure 6. Scenario 1($\alpha = 0.90$; $p^\star = 6$) .

Table 4. Characteristics of scenario 1 ($\alpha = 0.90$; $p^\star = 6$).

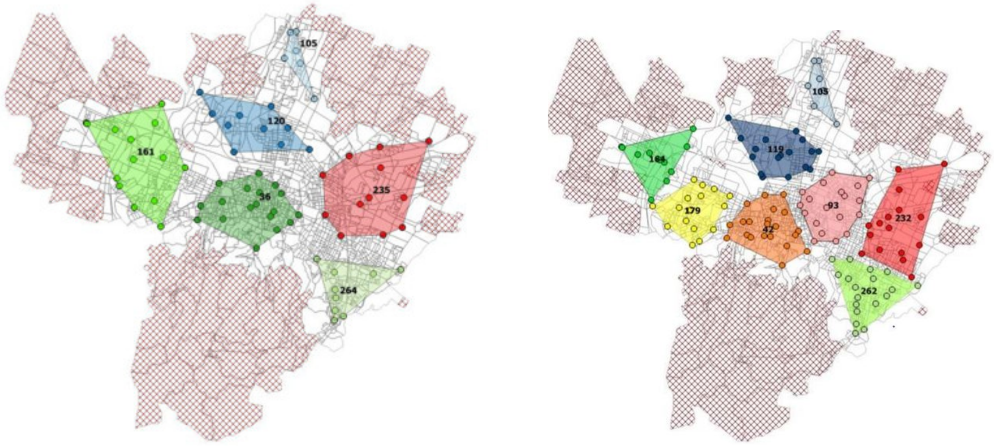
Cluster center	n_k	t_k [m]	CT_k [min]
36	18	18,971.55	126.31
105	6	4,055.11	49.82
120	10	12,105.06	92.14
161	14	20,144.17	122.83
235	12	16,926.49	119.64
264	9	8,539.26	76.53
Total	69	80,741.64	587.27
Average	11.50	13,456.94	97.88

postboxes ranging from nine to 18, and a collection time ranging from 50 minutes to almost two hours. It is interesting to analyse the effect of α on the solutions provided by the model. Figure 7 illustrates the solution obtained for $(\alpha, p^\star)$=(0.80, 8). When the constraints are more stringent, the number of postboxes increases from 69 to 125, and the resulting number of collection areas passes from six to eight. As reported in Table 5, a higher number of postboxes has a positive impact on accessibility as the average distance to the closest postboxes is within 429 m, about 100 m less than the average accessibility condition obtained with $\alpha = 0.90$. In order to illustrate how user accessibility is affected by the solution provided by the model, we show in Figure 8 the new distributions of minimum distances d_i^{min} yielded by the two scenarios. Of course, the distribution associated to the first scenario shows the same values as the initial distribution for $\alpha \geq 0.90$, which is consistent with the fact that the distance from the closest postbox does not change for the disadvantaged users; the same happens with $\alpha \geq 0.80$ for the second scenario. For the non-disadvantaged users, the average accessibility distance increases, as testified by the fact that the curves progressively move to the right by increasing α.

Table 5. Comparison between scenarios 1 and 2

α	$\bar{d}$	Number of postboxes	Average user accessibility distance [m]	Average objective function per cluster [m]	Minimum collection time [min]	Maximum collection time [min]	Average collection time [min]
0.80	461.90	125	428.94	15,236.88	84.43	130.51	109.88
0.90	913.50	69	529.60	13,456.94	49.83	126.32	97.88

From Table 5, it can be seen that the collection times in the single areas are not well



(a) Scenario 1 ($\alpha = 0.90, p^\star = 6$)

(b) Scenario 2 ($\alpha = 0.80, p^\star = 8$)

Figure 7. Maps of scenarios 1 and 2

.

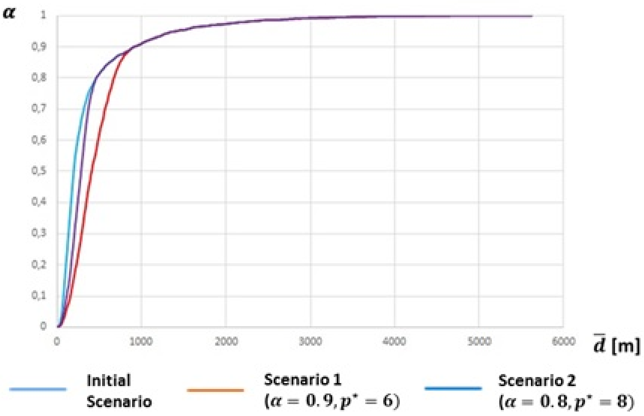
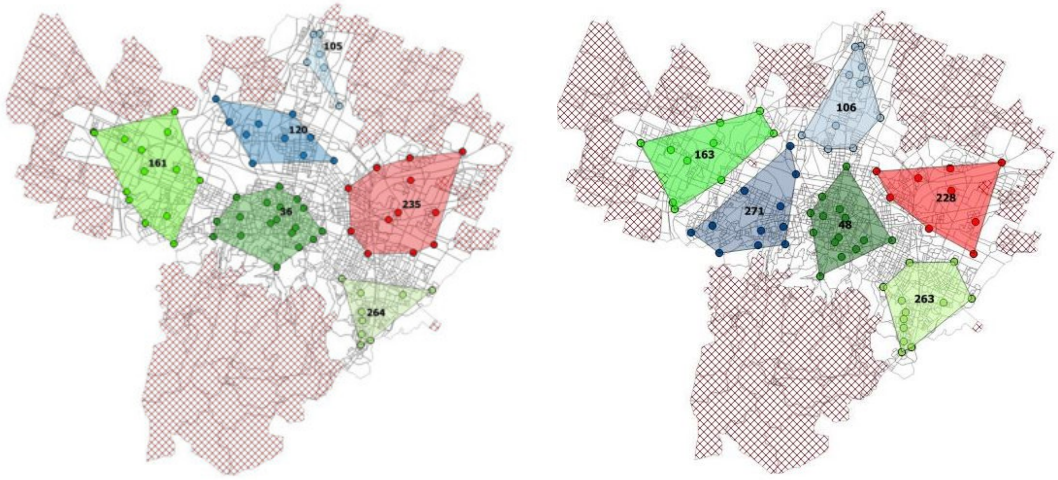


Figure 8. Comparison of the users accessibility measures for the three scenarios

balanced since there exists a significant gap between the minimum and maximum times under both scenarios. For this reason, according to the proposed solution procedure, we solve for each value of α the model (1)–(8) with $(p, UB) = (p^\star(\alpha), UB^\star(\alpha))$, by decreasing the value of the parameter β in order to show how the introduction of the constraint regulating the balance condition can help generate more balanced solutions. As an example, Figure 9b depicts the solution obtained with $(\alpha, p^\star, UB^\star) = (0.90, 6, 22000)$, by setting $\beta = 0.40$. Tables 6 highlight significant differences between the solutions. Despite very similar number of postboxes (69 vs. 68), the objective function increases by 6.23% (from 80,741.64 to 85,813.27 m). However, Scenario 3 is certainly more balanced in terms of estimated collection times, as reflected by the standard deviation values. Finally, Table 7 shows the minimum and maximum collection times in the produced scenarios.



(a) Scenario 1 ($\alpha = 0.90, p^\star = 6, \beta = 1.00$)

(b) Scenario 3 ($\alpha = 0.90, p^\star = 6, \beta = 0.40$)

Figure 9. Maps of scenarios 1 and 3

.

Table 6. Characteristics of scenarios 1 and 3

Cluster center	n_k	t_k $[m]$	CT_k $[min]$
36	18	18,971.55	126.31
105	6	4,055.11	49.82
120	10	12,105.06	92.14
161	14	20,144.17	122.83
235	12	16,926.49	119.64
264	9	8,539.26	76.53
Total	69	80,741.64	587.27
Average	11.5	13,456.94	97.88
St. dev.	4.18	6,349.38	30.67

(a) Scenario 1 ($\alpha = 0.90, p^\star = 6, \beta = 0.40$)

Cluster center	n_k	t_k $[m]$	CT_k $[min]$
48	14	13,822.80	110.70
106	11	13,586.33	91.50
163	11	16,736.72	105.86
228	9	13,267.51	101.45
263	12	13,262.46	92.93
271	11	15,137.55	102.48
Total	68	85,813.27	604.93
Average	11.33	14,302.21	100.82
St. dev.	1.63	1,379.72	7.42

(b) Scenario 3 ($\alpha = 0.90, p^\star = 6, \beta = 0.40$)

It can be observed that the gaps tend to to be reduced when a more stringent bound is applied. We conclude that the objective function actually works well as a proxy measure for the cluster collection times. It therefore constitutes an additional decision making lever on which to act in order to meet the workload balancing requirements without dramatically compromising the computational complexity of the problem.

Table 7. Minimum and maximum collection times [min] in the produced scenarios

	$\beta = 1.00$		$\beta = 0.40$		$\beta = 0.20$	
α	Min	Max	Min	Max	Min	Max
1.00	120.47	131.52	120.47	131.52	120.47	131.52
0.90	49.83	126.32	91.50	110. 70	93.30	100.47
0.80	84.43	130.51	85.26	127.98	101.14	119.40
0.70	60.13	131.80	88.36	131.06	99.29	130.63
0.60	105.71	131.94	106.95	129.79	108.30	128.41
0.00	94.46	131.46	105.86	131.93	108.29	131.93

5. Conclusions

Performance optimization has become a top priority for postal service providers as a means of guaranteeing a fast, timely and affordable service to users, and hence of achieving a large market share in an increasingly competitive environment. Throughout the world, the impact of technological developments on consumer habits and behavior is endangering the classical model of postal services. The resulting fall in postal volumes generated by the substitution of traditional letter post by electronic forms of communication has rendered the collection of postal items highly inefficient. In such a context, our work has addressed a real problem related to the reorganization of the collection system of the Italian postal service provider, based on the reduction of the number of postboxes currently located in an urban area. However, since postboxes are the main access points of users to the postal service, any reorganization decision should aim to avoid an uncontrolled worsening of their accessibility. In such a multi-objective context, it becomes important to develop a decision support system capable of handling several criteria. To this end, we have developed a mathematical programming model aimed at reducing the number of postboxes and at creating clusters of postboxes to be assigned to operators. The model was tested on the Bologna data, and several accessibility analyses and graphical visualizations were performed by using a GIS software. This has enabled us to provide a large set of scenarios that can support the decision making process.

Acknowledgement

This work was partially supported by the Canadian Natural Sciences and Engineering Research Council under grant 2015-06189. This support is gratefully acknowledged.

Disclosure statement

All the authors authors approve this version of the manuscript and declare that no part of this paper has published or submitted elsewhere. Furthermore, the authors state that no conflict of interest exits in the submission of this manuscript.

References

Abbatecola, L., Fanti, M. P., Mangini, A. M., & Ukovich, W. (2016). A decision support approach for postal delivery and waste collection services. *IEEE Transactions on Automation Science and Engineering*, *13*(4), 1458–1470.

AGCOM. (2014). *Public consultation on the criteria for the distribution of access points to the public postal network.* (Italian Authority for Communication Guarantees. URL: www.agcom.int [accessed on June 10, 2018])

Barbati, M., & Bruno, G. (2018). Exploring similarities in discrete facility location models with equality measures. *Geographical Analysis*, *50*(4), 378–396.

Barbati, M., & Piccolo, C. (2016). Equality measures properties for location problems. *Optimization Letters*, *10*(5), 903–920.

Bard, J. F. (2004). Staff scheduling in high volume service facilities with downgrading. *IIE Transactions*, *36*(10), 985–997.

Bard, J. F., Binici, C., & deSilva, A. H. (2003). Staff scheduling at the united states postal service. *Computers & Operations Research*, *30*(5), 745–771.

Bard, J. F., & Wan, L. (2008). Workforce design with movement restrictions between workstation groups. *Manufacturing & Service Operations Management*, *10*(1), 24–42.

Barrett, M., Davidson, E., Prabhu, J., & Vargo, S. L. (2015). Service innovation in the digital age: key contributions and future directions. *MIS Quarterly*, *39*(1), 135–154.

Blagojević, M., Šelmić, M., Macura, D., & Šarac, D. (2013). Determining the number of postal units in the network–fuzzy approach, serbia case study. *Expert Systems with Applications*, *40*(10), 4090–4095.

Boysen, N., Fedtke, S., & Weidinger, F. (2017). Truck scheduling in the postal service industry. *Transportation Science*, *51*(2), 723–736.

Bruno, G., Genovese, A., & Piccolo, C. (2017). Territorial amalgamation decisions in local government: Models and a case study from italy. *Socio-Economic Planning Sciences*, *57*, 61–72.

Cardenas, I. D., Dewulf, W., Beckers, J., Smet, C., & Vanelslander, T. (2017). The e-commerce parcel delivery market and the implications of home B2C deliveries vs pick-up points. *International Journal of Transport Economics*, *44*(2), 235–256.

Erdoğan, G. (2017). An open source spreadsheet solver for vehicle routing problems. *Computers & Operations Research*, *84*, 62–72.

European Parliament and Council of European Union. (1998). *Directive 97/67/EC of the European Parliament and of the Council of 15 December 1997 on common rules for the development of the internal market of Community postal services and the improvement of quality of service.* (URL: www.eur-lex.europa.eu [accessed on June 10, 2018])

European Parliament and Council of European Union. (2002). *Directive 2002/39/EC of the European Parliament and of the Council of 10 June 2002 amending Directive 97/67/ec with regard to the further opening to competition of Community postal services.* (URL: www.eur-lex.europa.eu [accessed on June 10, 2018])

European Parliament and Council of European Union. (2008). *Directive 2008/6/ec of the European Parliament and of the Council of 20 February 2008 amending Directive 97/67/ec with regard to the full accomplishment of the internal market of Community postal services.* (URL: www.eur-lex.europa.eu [accessed on June 10, 2018])

Franceschetti, A., Jabali, O., & Laporte, G. (2017). Continuous approximation models in freight distribution management. *TOP*, *25*(3), 413–433.

Francis, R. L., & Lowe, T. J. (2015). Demand point aggregation for some basic location models. In G. Laporte, S. Nickel, & F. Saldanha da Gama (Eds.), *Location science* (pp. 487–506). Berlin: Springer.

Galvão, L. C., Novaes, A. G., De Cursi, J. S., & Souza, J. C. (2006). A multiplicatively-weighted Voronoi diagram approach to logistics districting. *Computers & Operations Research*, *33*(1), 93–114.

García, S., & Marín, A. (2015). Covering location problems. In G. Laporte, S. Nickel, & F. Saldanha da Gama (Eds.), *Location science* (pp. 93–114). Berlin: Springer.

García-Ayala, G., González-Velarde, J. L., Ríos-Mercado, R. Z., & Fernández, E. (2016). A novel model for arc territory design: promoting eulerian districts. *International Transactions in Operational Research*, *23*(3), 433-458.

Grünert, T., & Sebastian, H.-J. (2000). Planning models for long-haul operations of postal and express shipment companies. *European Journal of Operational Research*, *122*(2), 289–309.

Haugland, D., Ho, S. C., & Laporte, G. (2007). Designing delivery districts for the vehicle routing problem with stochastic demands. *European Journal of Operational Research*, *180*(3), 997–1010.

Higgs, G., & Langford, M. (2013). Investigating the validity of rural–urban distinctions in the impacts of changing service provision: The example of postal service reconfiguration in wales. *Geoforum*, *47*, 53–64.

Hong, S.-H., & Wolak, F. A. (2008). Relative prices and electronic substitution: Changes in household-level demand for postal delivery services from 1986 to 2004. *Journal of Econometrics*, *145*(1-2), 226–242.

Irnich, S. (2008). Solution of real-world postman problems. *European Journal of Operational Research*, *190*(1), 52–67.

ISTAT. (2011). *Dati del censimento generale della popolazione italiana (italian national census data).* (URL: www.istat.it [accessed on June 10, 2018])

Jarrah, A. I., & Bard, J. F. (2012). Large-scale pickup and delivery work area design. *Computers & Operations Research*, *39*(12), 3102–3118.

Jarrah, A. I., Bard, J. F., & deSilva, A. H. (1992). A heuristic for machine scheduling at general mail facilities. *European Journal of Operational Research*, *63*(2), 192–206.

Jarrah, A. I., Bard, J. F., & deSilva, A. H. (1994a). Equipment selection and machine scheduling in general mail facilities. *Management Science*, *40*(8), 1049–1068.

Jarrah, A. I., Bard, J. F., & deSilva, A. H. (1994b). Solving large-scale tour scheduling problems. *Management Science*, *40*(9), 1124–1144.

Jarrah, A. I., Qi, X., & Bard, J. F. (2014). The destination-loader-door assignment problem for automated package sorting centers. *Transportation Science*, *50*(4), 1314–1336.

Jung, H., Lee, K., & Chun, W. (2006). Integration of gis, gps, and optimization technologies for the effective control of parcel delivery service. *Computers & Industrial Engineering*, *51*(1), 154–162.

Kalcsics, J. (2015). Districting problems. In G. Laporte, S. Nickel, & F. Saldanha da Gama (Eds.), *Location science* (pp. 595–622). Berlin: Springer.

Labbé, M., & Laporte, G. (1986). Maximizing user convenience and postal service efficiency in post box location. *Belgian Journal of Operations Research, Statistics and Computer Science*, *26*, 21–35.

Lei, H., Laporte, G., & Guo, B. (2012). Districting for routing with stochastic customers. *EURO Journal on Transportation and Logistics*, *1*(1-2), 67-85.

Lei, H., Laporte, G., Liu, Y., & Zhang, T. (2015). Dynamic design of sales territories. *Computers & Operations Research*, *56*, 84-92.

Lei, H., Wang, R., & Laporte, G. (2016). Solving a multi-objective dynamic stochastic districting and routing problem with a co-evolutionary algorithm. *Computers & Operations Research*, *67*, 12-24.

Marsh, M. T., & Schilling, D. A. (1994). Equity measurement in facility location analysis: A review and framework. *European Journal of Operational Research*, *74*(1), 1–17.

McWilliams, D. L., & McBride, M. E. (2012). A beam search heuristics to solve the parcel hub scheduling problem. *Computers & Industrial Engineering*, *62*(4), 1080–1092.

Mitrović-Minić, S., Krishnamurti, R., & Laporte, G. (2004). Double-horizon based heuristics for the dynamic pickup and delivery problem with time windows. *Transportation Research Part B: Methodological*, *38*(8), 669–685.

Morganti, E., Seidel, S., Blanquart, C., Dablanc, L., & Lenz, B. (2014). The impact of e-commerce on final deliveries: Alternative parcel delivery services in France and Germany. *Transportation Research Procedia*, *4*, 178–190.

Nikali, H. (2008). Substitution of letter mail for different sender-receiver segments. In M. A. Crew & P. R. Kleindorfer (Eds.), *Competition and regulation in the postal and delivery sector* (pp. 89–106). Cheltenham: Edward Elgar Publishing.

Novaes, A. G., de Cursi, J. E. S., & Graciolli, O. D. (2000). A continuous approach to the design of physical distribution systems. *Computers & Operations Research*, *27*(9), 877–893.

Novaes, A. G., & Graciolli, O. D. (1999). Designing multi-vehicle delivery tours in a grid-cell format. *European Journal of Operational Research*, *119*(3), 613–634.

Phillips, P. A., & Wright, C. (2009). E-business's impact on organizational flexibility. *Journal of Business Research*, *62*(11), 1071–1080.

Qu, Y., & Bard, J. F. (2012). A grasp with adaptive large neighborhood search for pickup and delivery problems with transshipment. *Computers & Operations Research*, *39*(10), 2439–2456.

Ricca, F., Scozzari, A., & Simeone, B. (2013). Political districting: from classical models to recent approaches. *Annals of Operations Research*, *204*(1), 271–299.

Rosenfield, D. B., Engelstein, I., & Feigenbaum, D. (1992). An application of sizing service territories. *European Journal of Operational Research*, *63*(2), 164–172.

Talen, E., & Anselin, L. (1998). Assessing spatial equity: an evaluation of measures of accessibility to public playgrounds. *Environment and planning A*, *30*(4), 595–613.

Universal Postal Union. (2015). *Development of postal services in 2015.* (URL: www.upu.int [accessed on June 10, 2018])

Zenker, M., & Boysen, N. (2018). Dock sharing in cross-docking facilities of the postal service industry. *Journal of the Operational Research Society*, *69*, 1–16.

Zhang, X., & Bard, J. F. (2005). Equipment scheduling at mail processing and distribution centers. *IIE Transactions*, *37*(2), 175–187.

Zhang, X., Chakravarthy, A., & Gu, Q. (2009). Equipment scheduling problem under disruptions in mail processing and distribution centres. *Journal of the Operational Research Society*, *60*(5), 598–610.

Zhong, H., Hall, R. W., & Dessouky, M. (2007). Territory planning and vehicle dispatching with driver learning. *Transportation Science*, *41*(1), 74–89.

Appendix A. Evaluation of the aggregation error

In this appendix, we discuss in more detail the discretization approach applied to our case study. We chose to use census tracts as basic units since they represent the lowest aggregation level adopted for statistical purposes by the Italian Statistical Institute (ISTAT). The analysis of the available census data reveals that, on average, almost 160 inhabitants populate each tract and there are fewer than 500 in 96% of the cases (ISTAT, 2011). This indicates that the proposed discretization does not yield a very coarse representation of the total demand since we avoid massive aggregation of users in the extracted centroids. Clearly, considering the distribution of the real user locations (e.g. private residences, house numbers) would have been an alternative and more precise approach. However, this would have easily rendered the problem intractable because of the very large number of points to be considered (40,955).

Of course, replacing Demand Points (DPs) with Aggregate Demand Points (ADPs) produces an intrinsic error that can be measured in different and alternative ways. Among the indicators listed by Francis & Lowe, 2015, we refer here to the so called Distance Difference Error (DDE). In order to calculate such indicator, we denote by H the set of house numbers in Bologna ($|H| = 40{,}955$), by H_i the subset of house numbers located in a generic census tract with its centroid in $i \in I$ ($H = \cup_{i \in I} H_i$) and by l_{hj} the distance between nodes $h \in H$ and $j \in J$. Moreover, we define by $j_h^\star$ and $j_i^\star$ the closest postboxes to nodes $h \in H$ and $i \in I$, respectively. Then, the DDE is computed as difference between the distances of each DP $h \in H$ and the related ADP $i \in I$ from their closest postboxes (DDE=$d_{ij_i^\star} - l_{hj_h^\star}, \forall i \in I, h \in H_i$). A DDE equal to zero indicates that ADPs and DPs are identical. The results obtained (see Figure A2) show that in 95% of the cases (38,907 out of 40,955) the DDE is very low, ranging between

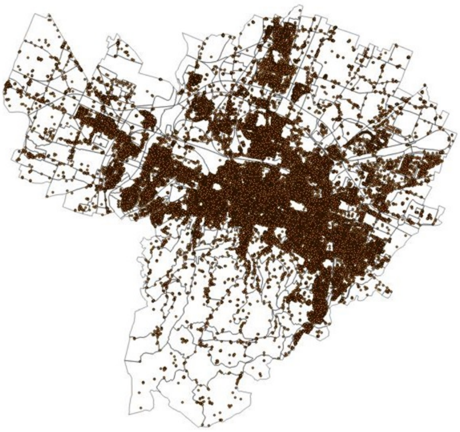


Figure A1. House numbers locations in Bologna

-112.37 m and 145.00 m. The extreme cases, i.e. those with the highest absolute values of DDE, belong to the more peripheral tracts. However, their real impact on the solution of the model is actually rather limited. In fact, given the location mechanism we want to implement, the more peripheral census tracts always correspond to the most disadvantaged users. Therefore, since their closest postboxes will remain active, the real error we make in these cases is due only to those house numbers whose closest postbox is different from that of the centroid ($h \in H_i : j^\star_h \neq j^\star_i, \forall i \in I$). Figure A3 depicts the percentage of house numbers having a different closest postbox with respect to their census tract centroid. Our analysis shows that with some rare exceptions, this percentage is rather small, and often equal to zero, in the non-central areas. For instance, for $\alpha = 0.9$, only 190 out of 1,344 house numbers belonging to tracts $i \in I'$ have a different closest postbox. This result implies that the magnitude of the DDE in the outer tracts is small in practice. Hence, based on the above findings, we consider the proposed discretization to be suitable for our problem.

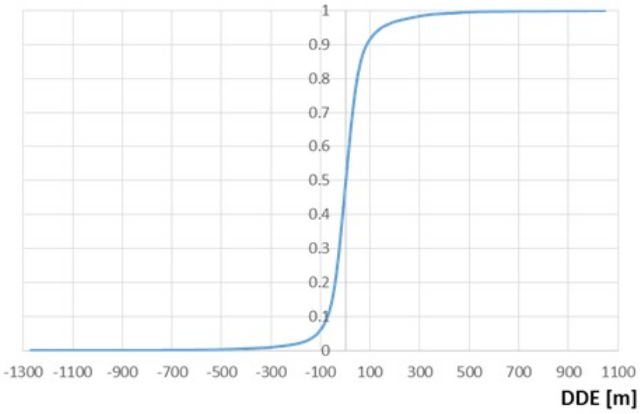


Figure A2. Distribution of DDE by the fraction of house numbers

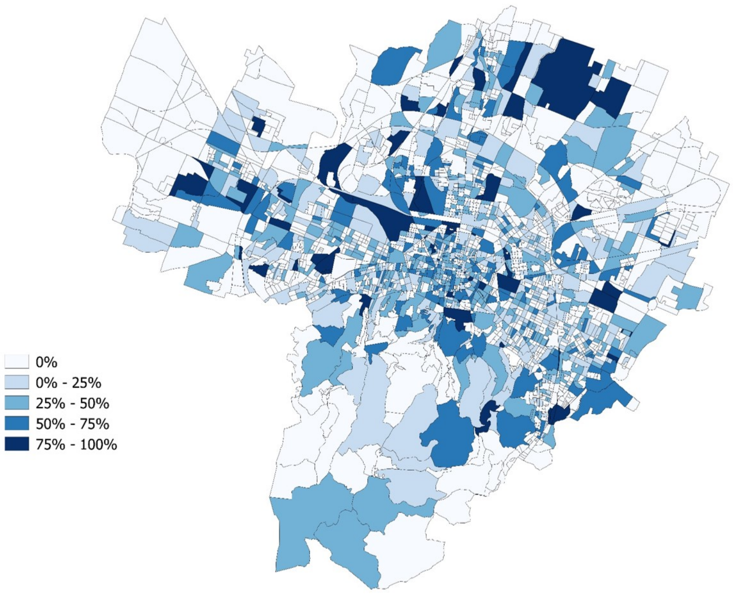


Figure A3. Percentage of house numbers presenting a different closest postbox

.

Appendix B. Accessibility considerations with real demand points

In this appendix we show that the accessibility considerations proposed still hold when considering the distribution of real demand points (i.e house numbers).

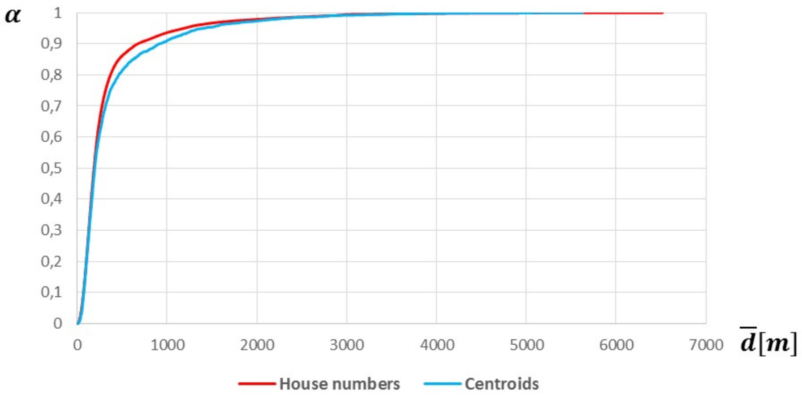


Figure B1. Distribution of the population, in terms of house numbers (red) and centroids (blue), by the distance from the closest postbox.

.

From the above figure it is possible to conclude that: i) the spatial criteria set by the regulatory authority are effectively respected for all users in Bologna; ii) since the two curves are almost overlapping, the accessibility values resulting from the proposed aggregation are consistent with the actual distribution of demand points. Again, this allows us to consider census tract centroids as a suitable representation of our problem.

Appendix C. Correlation between clusters compactness and collection times

In this appendix we show the correlation between the proxy measure of the travel times adopted in our model (i.e. clusters compactness), and the collection times.

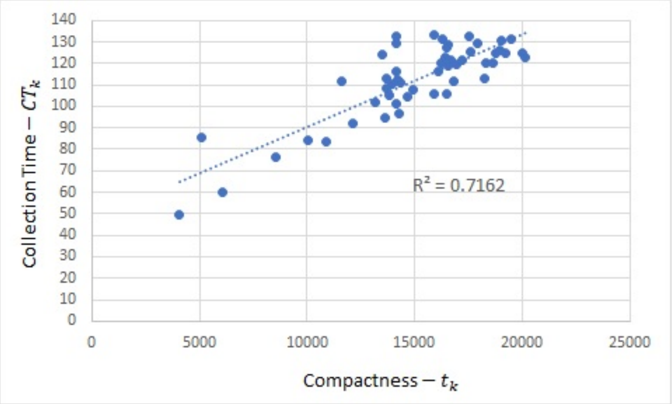


Figure C1. Correlation between clusters compactness and collection times

.