REDLOCA
RED DE LOCALIZACIÓN Y PROBLEMAS AFINES

VIII International Workshop on Locational Analysis and Related Problems

Segovia, Spain, 27th – 29th September 2017

Territorial districting models for the reorganization of postal services

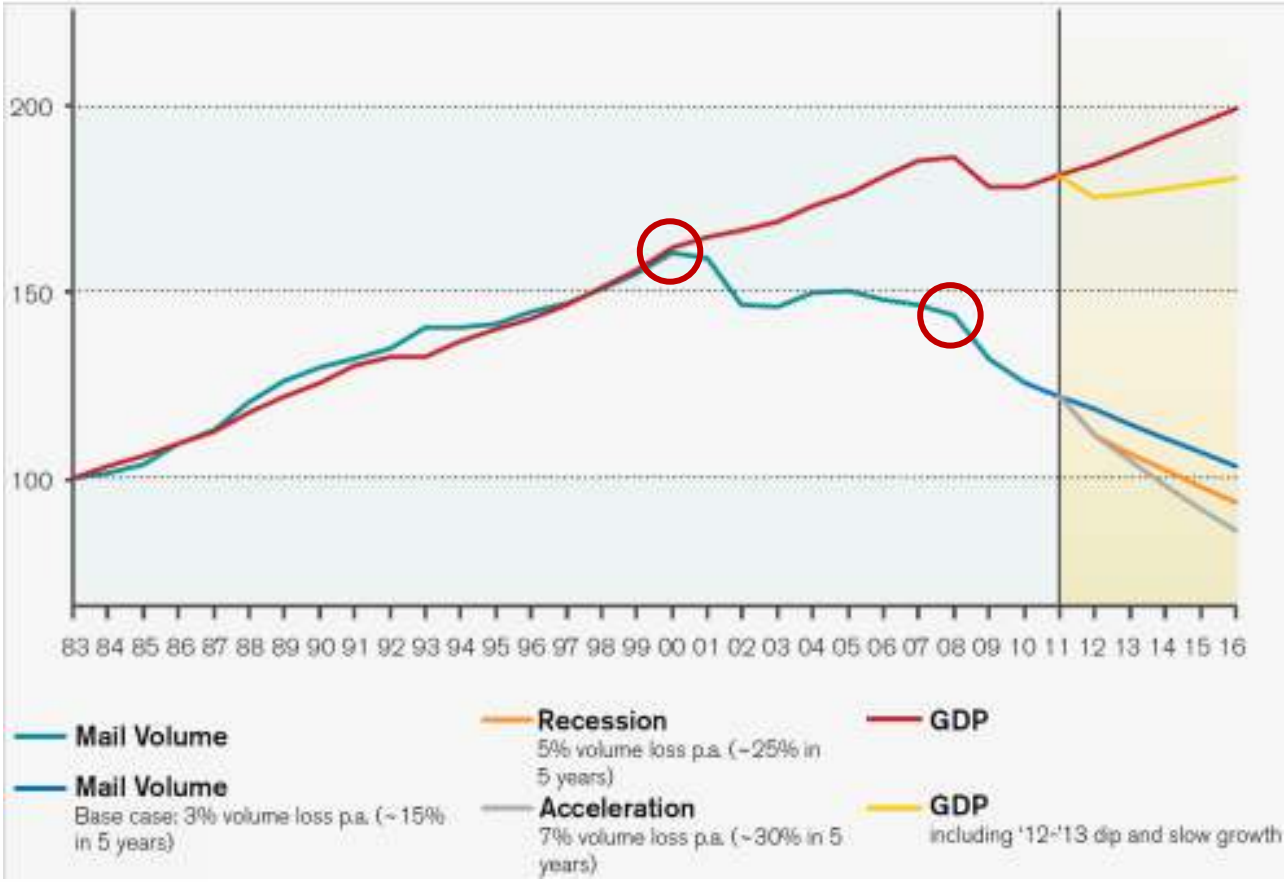
G. Bruno, M. Cavola, A. Diglio, C. Piccolo

Agenda

- *The context of the postal sector*
- *Problem description*
- *Mail Collection Problem: mathematical model and application*
- *Mail Delivery Problem: possible strategies and first steps*
- *Conclusions and further research*

E-substitution: Reduction of postal volumes

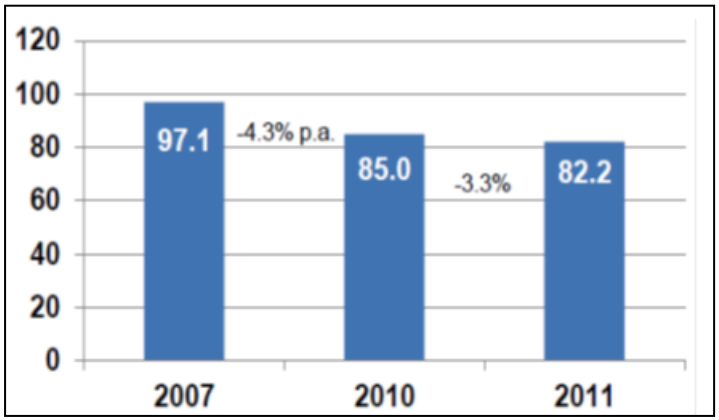
source: BCG (2012), Focus on the future. Building a new compelling position for posts.



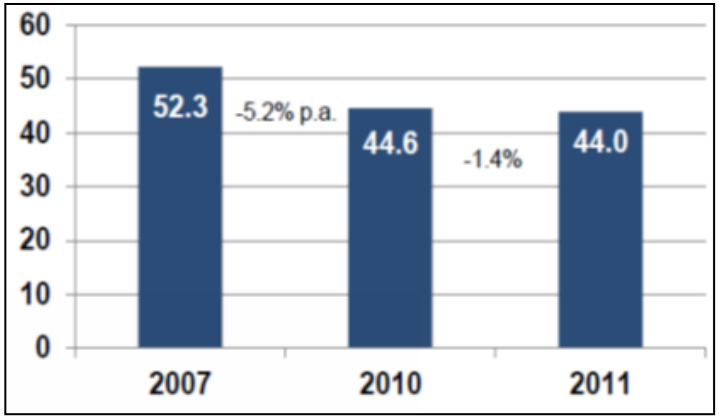
Effects of E-substitution

source: Main Development in the Postal Sector (WIK Consult, 2013)

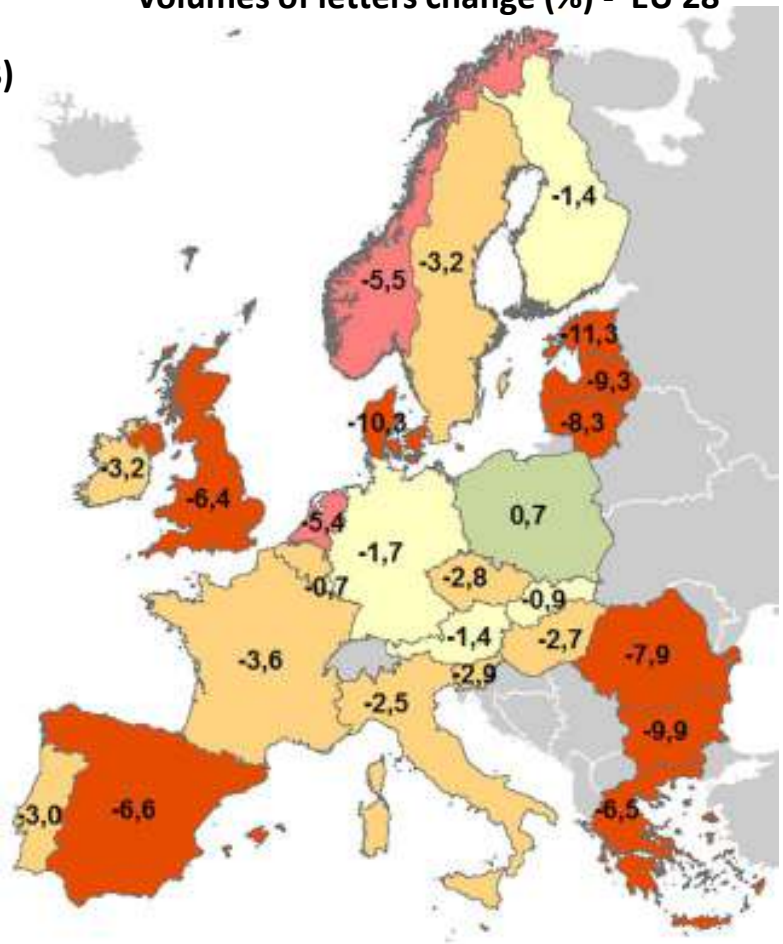
Volumes of letters (in billions) – EU 28



Revenues (in billions of euros) – EU 28

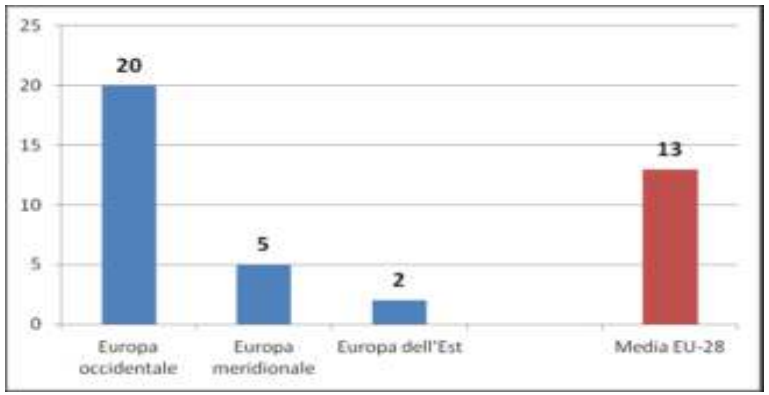


Volumes of letters change (%) - EU 28



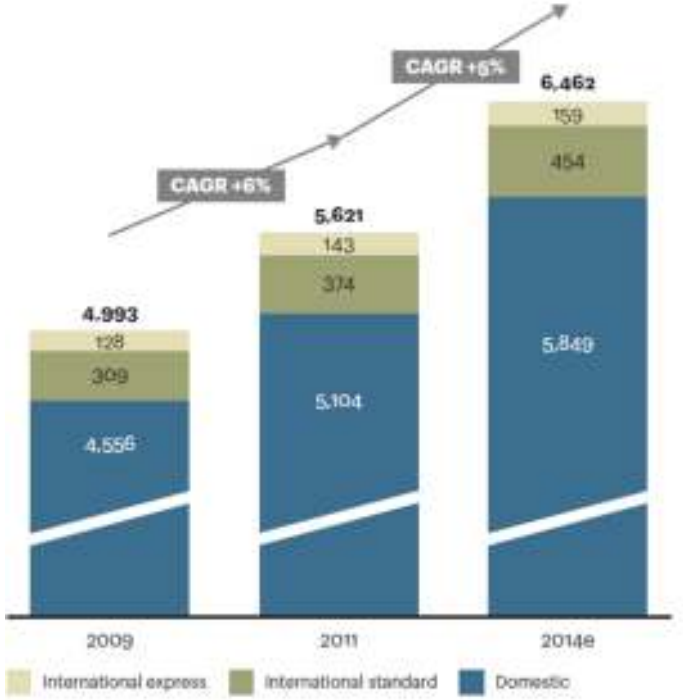
Effects of E-commerce

Volumes of parcels per inhabitant



Source: Main Development in the Postal Sector (WIK Consult, 2013)

Growth of volumes of parcels (in millions)



Source: Europe's CEP market: growth on new terms (ATKearney, 2012)

The aim of the project

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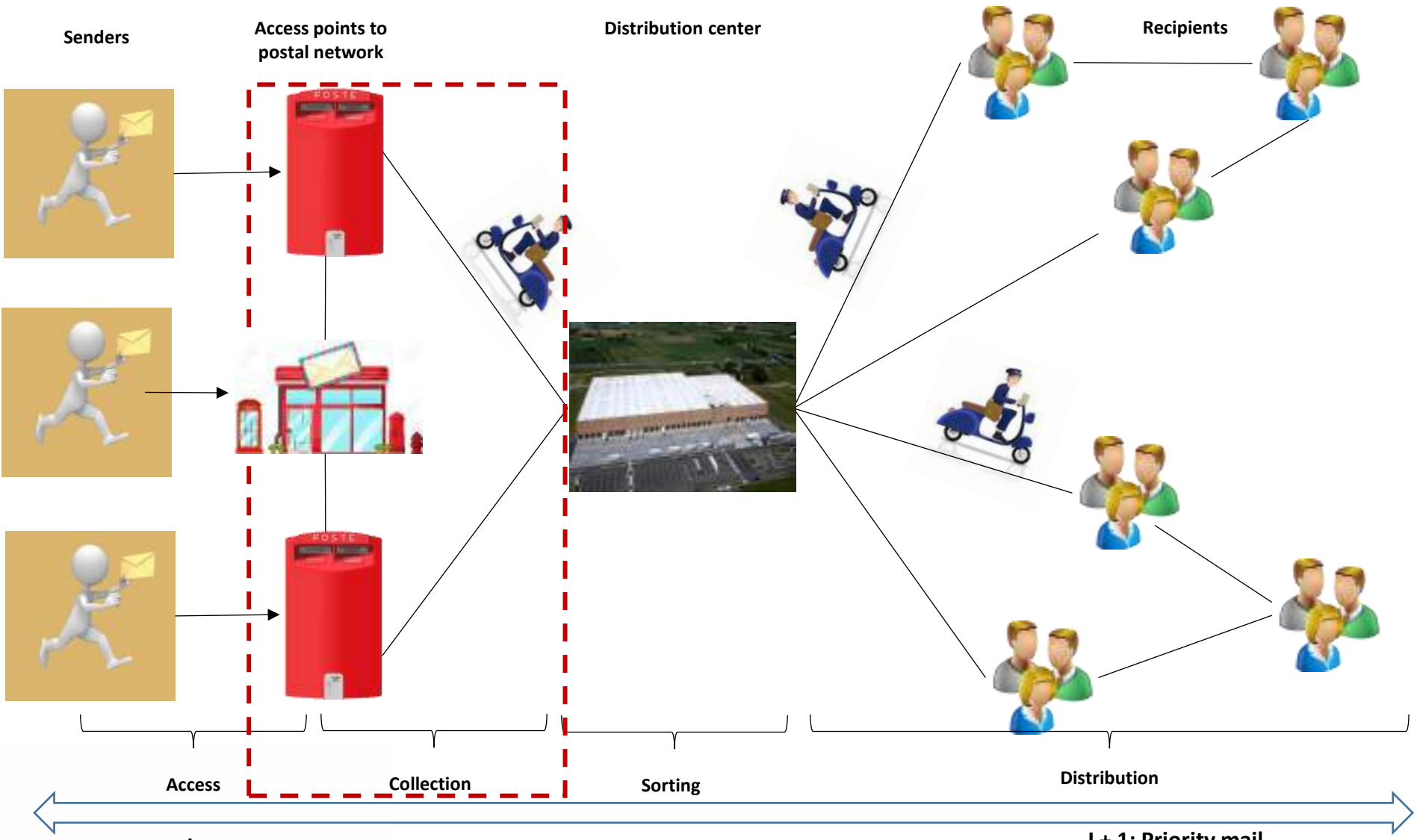
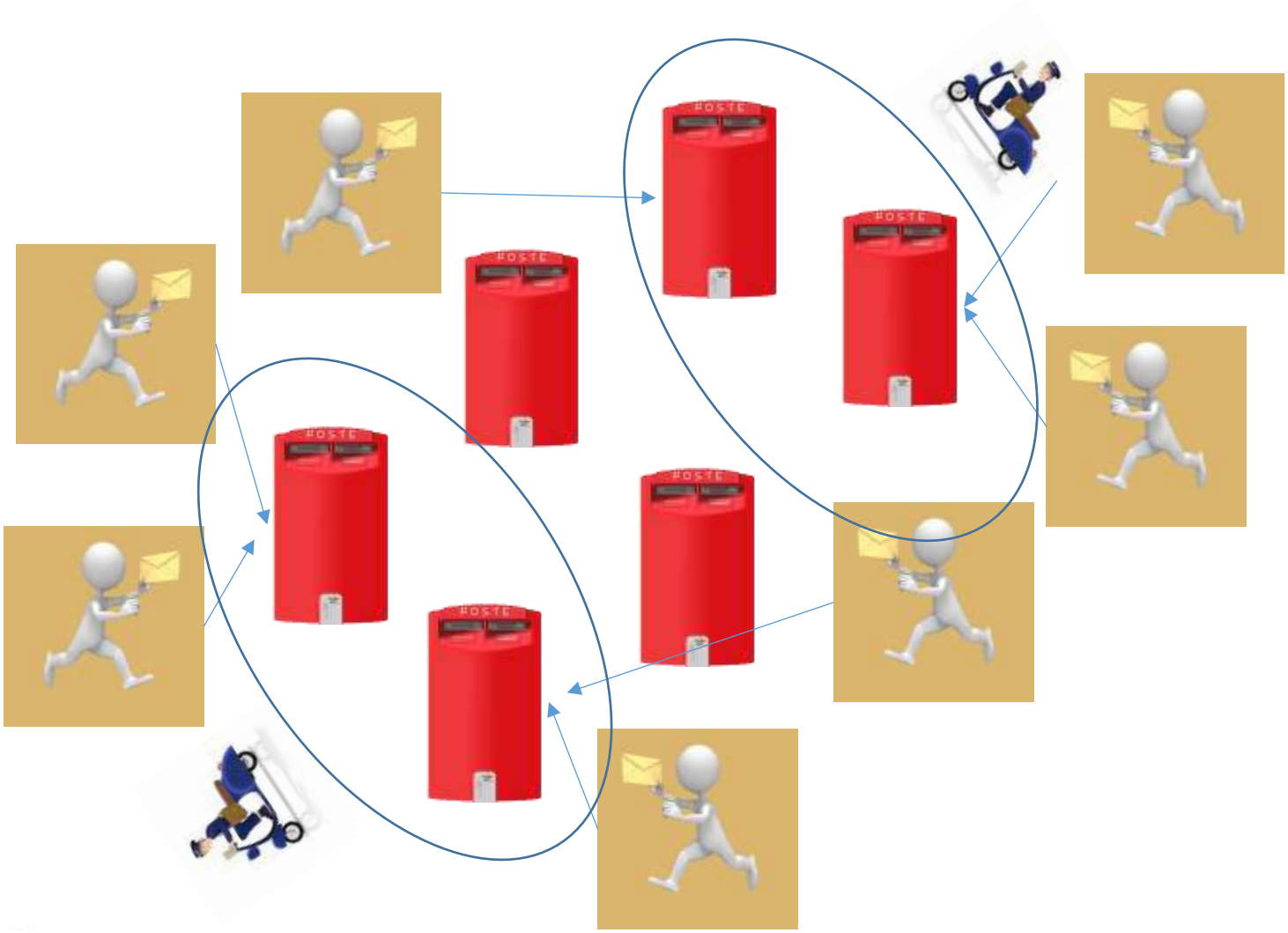
- ***Reorganization of the mail collection system through the reduction of the number of postal boxes***
- ***Simulation and comparison of mail delivery strategies***

Logistic system of a postal service provider



Mail collection: Problem description

Low volumes. High number of postal boxes. High inefficiency.



- ***Location***
- ***Allocation***
- ***Districting***

Hierarchical Facility Location Problems

- Çınar, Y., & Yaman, H. (2011). The vendor location problem. *Computers & Operations Research*, *38*(12), 1678-1695.
- Farahani, R. Z., Hekmatfar, M., Fahimnia, B., & Kazemzadeh, N. (2014). Hierarchical facility location problem: Models, classifications, techniques, and applications. *Computers & Industrial Engineering*, *68*, 104-117.
- Şahin, G., & Süral, H. (2007). A review of hierarchical facility location models. *Computers & Operations Research*, *34*(8), 2310-2331.
- Serra, D., & ReVelle, C. (1992). The PQ-Median problem: Location and districting of hierarchical facilities. Part II: Heuristic solution methods.
- Serra, D. (1996). The coherent covering location problem. *Papers in Regional Science*, *75*(1), 79-101.

Districting Problems

- 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.
- De Assis, L. S., Franca, P. M., & Usberti, F. L. (2014). A redistricting problem applied to meter reading in power distribution networks. *Computers & Operations Research*, *41*, 65-75.
- Kalcsics, J., Nickel, S., & Schröder, M. (2005). Towards a unified territorial design approach—Applications, algorithms and GIS integration. *Top*, *13*(1), 1-56.

Mathematical modelling: Notation and decision variables

Notation

I set of users, indexed by i, identified with the centroids of the census sections;

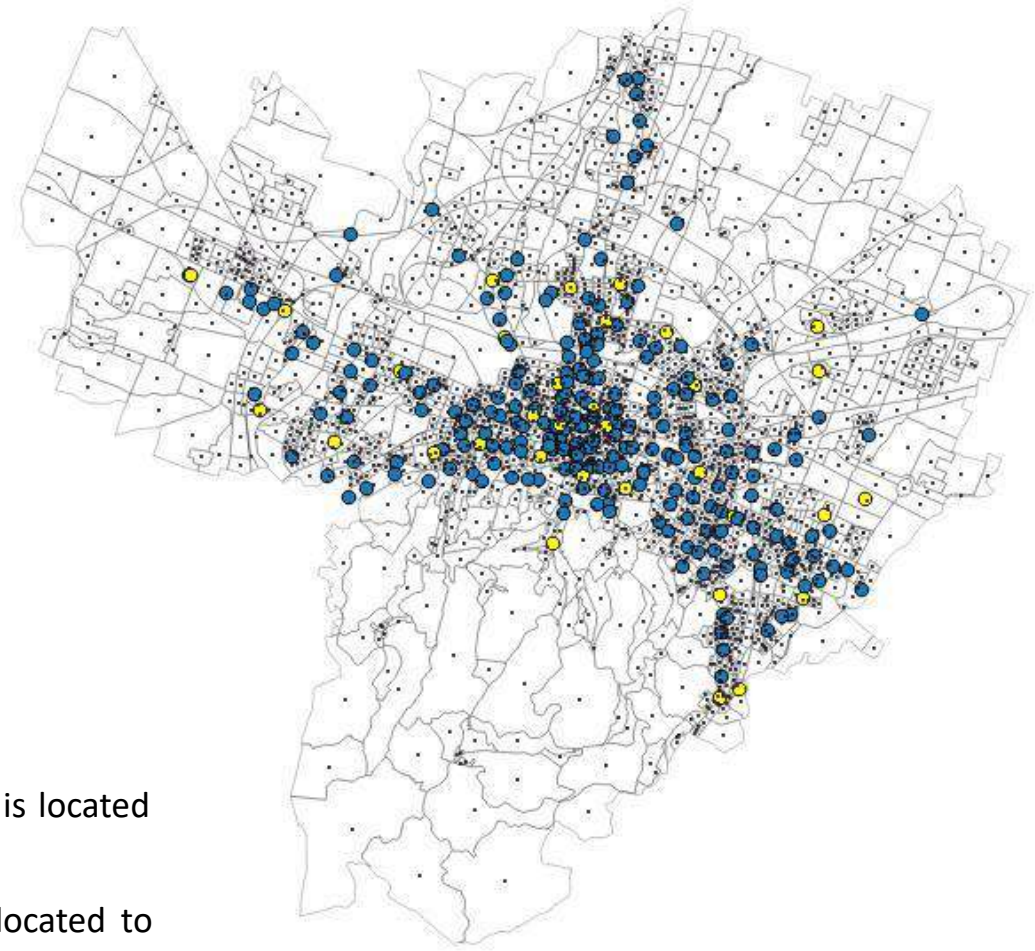
J set of current locations of postal boxes, indexed by j;

$J' \subset J$ set of current locations of postal boxes located at a postal office, indexed by j;

$$|\boldsymbol{I}| = \mathbf{2332};\ |\boldsymbol{J}| = \mathbf{272}$$

d_{ij} distance from user i to postal box j;

$d_{jj'}$ distance from postal box j to postal box j';



Decision variables

y_j binary variable equal to 1 if a postal box is located at j, 0 otherwise;

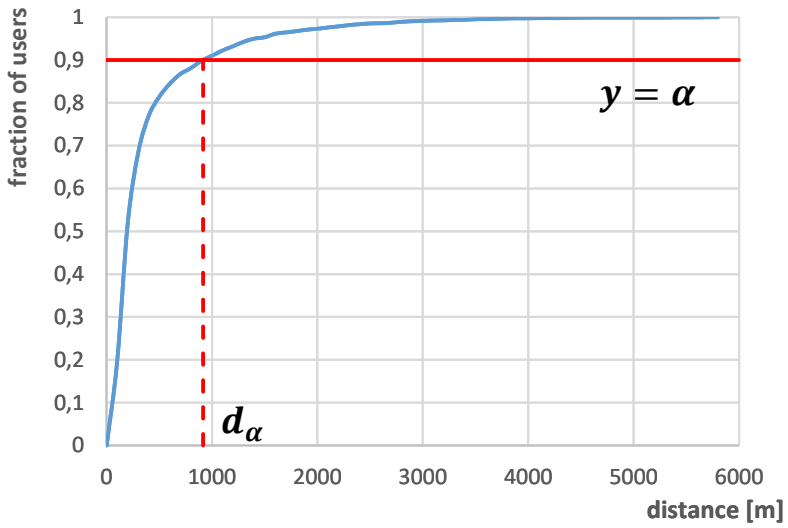
x_{ij} binary variable equal to 1 if user i is allocated to postal box j, 0 otherwise;

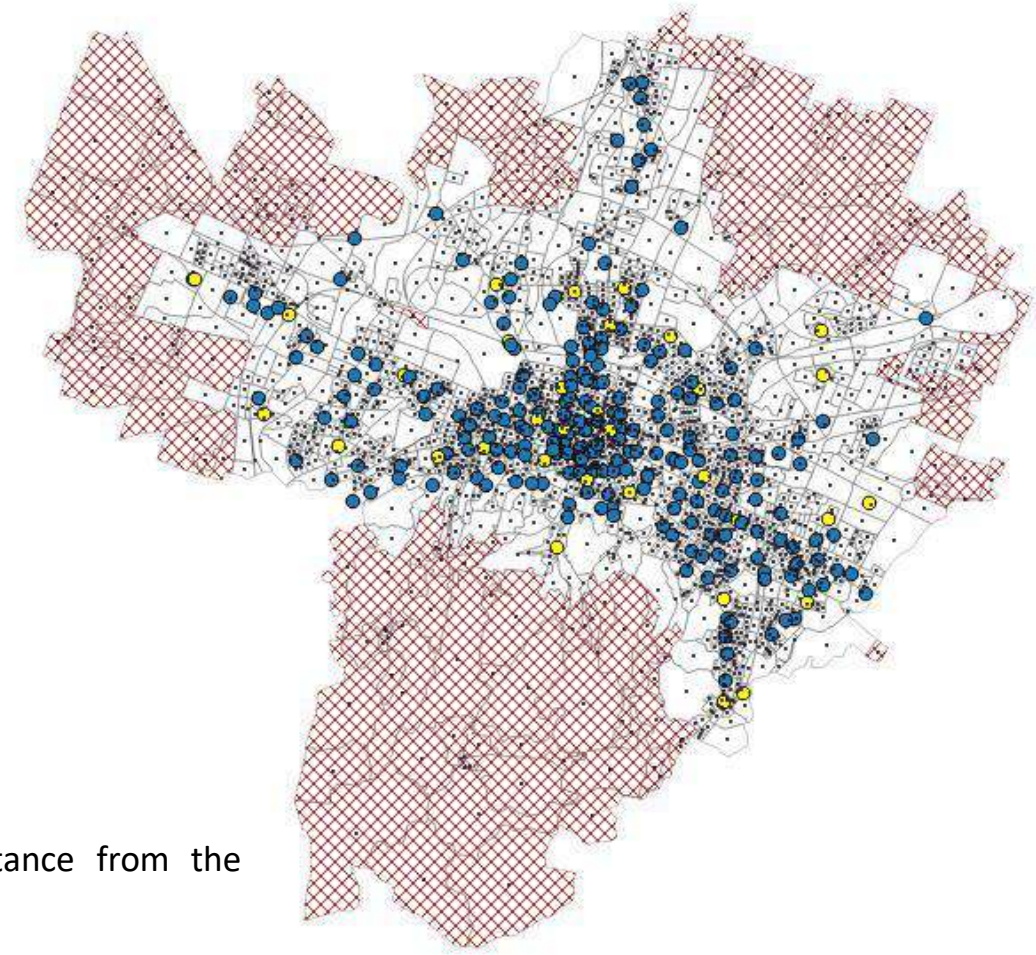
$z_{jj'}$ binary variable equale to 1 if postal box j is allocated to postal box j', 0 otherwise.

Mathematical modelling: accessibility measures

d_i^{min} cumulative distribution function

$$d_i^{min} = min_{j \in J}\{d_{ij}\}\ \forall i \in I$$





I_α set of users located within d_α distance from the closest postal box ($i \in I: d_i^{min} < d_\alpha$);

$I_{(1-\alpha)}$ set of users NOT located within d_α distance from the closest postal box ($i \in I: d_i^{min} \geq d_\alpha$)

Mathematical model

$$z = \sum_{j,j' \in J} d_{jj'} z_{jj'} \qquad Min! \qquad (1)$$

s.t.

$$\sum_{j \in J} x_{ij} = 1 \qquad \forall\, i \in I \qquad (2)$$

$$x_{ij} \leq y_j \qquad \forall\, i \in I, \forall\, j \in J \qquad (3)$$

$$\sum_{j \in J} d_{ij} * x_{ij} \leq d_i^{min} \qquad \forall\, i \in I_{(1-\alpha)} \qquad (4)$$

$$\sum_{k \in J_i} d_{ik} * x_{ik} + \left(M - d_{ij}\right) * y_j \leq M \qquad \forall\, i \in I_\alpha, \forall\, j \in J_i \qquad (5)$$

Location/Allocation

$$y_j = 1 \qquad \forall\, j \in J' \qquad (6)$$

$$\sum_{j' \in J} z_{jj'} = y_j \qquad \forall\, j \in J \qquad (7)$$

$$z_{jj'} \leq z_{j'j'} \qquad \forall\, j, j' \in J \qquad (8)$$

Districting

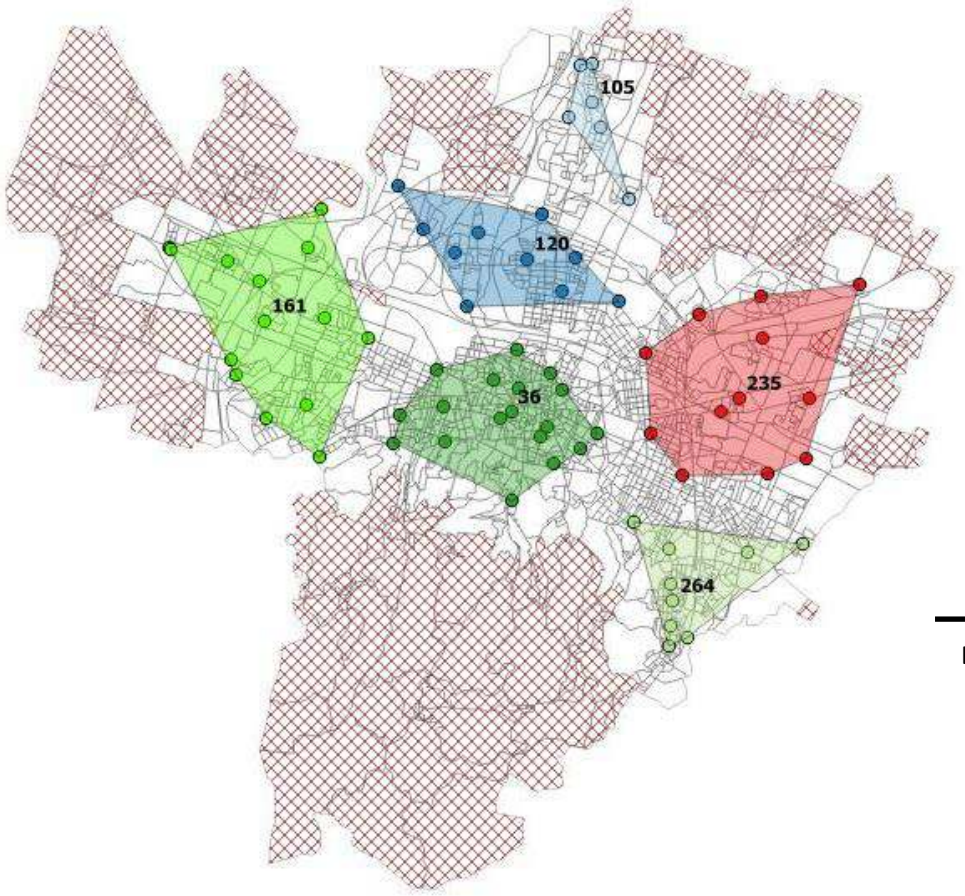
$$\sum_{j \in J} z_{jj} = k \qquad (9)$$

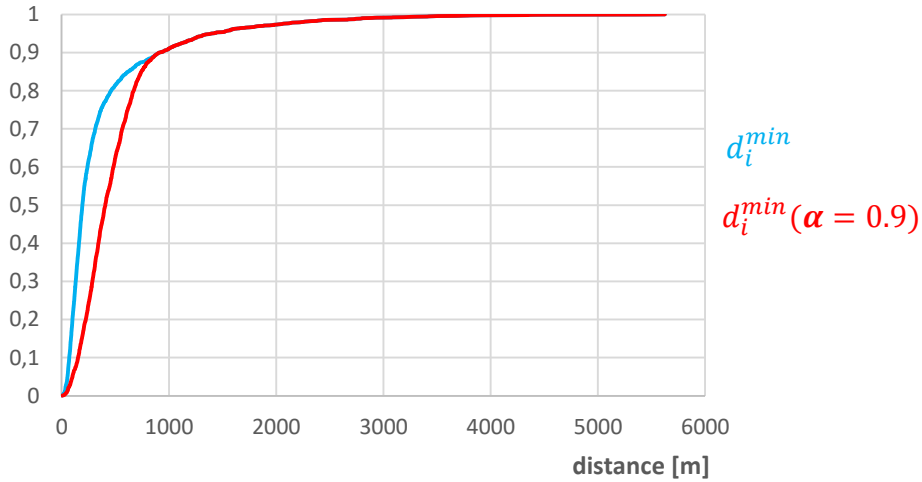
$$x_{ij} \in \{0,1\} \qquad \forall\, i \in I, \forall\, j \in J \qquad (10)$$

$$y_j, z_{jj'} \in \{0,1\} \qquad \forall\, j, j' \in J \qquad (11)$$

Computational experiments: an example of solution

$$\alpha = 0.9 \; d_\alpha = 914\, m \;\; k = 6$$

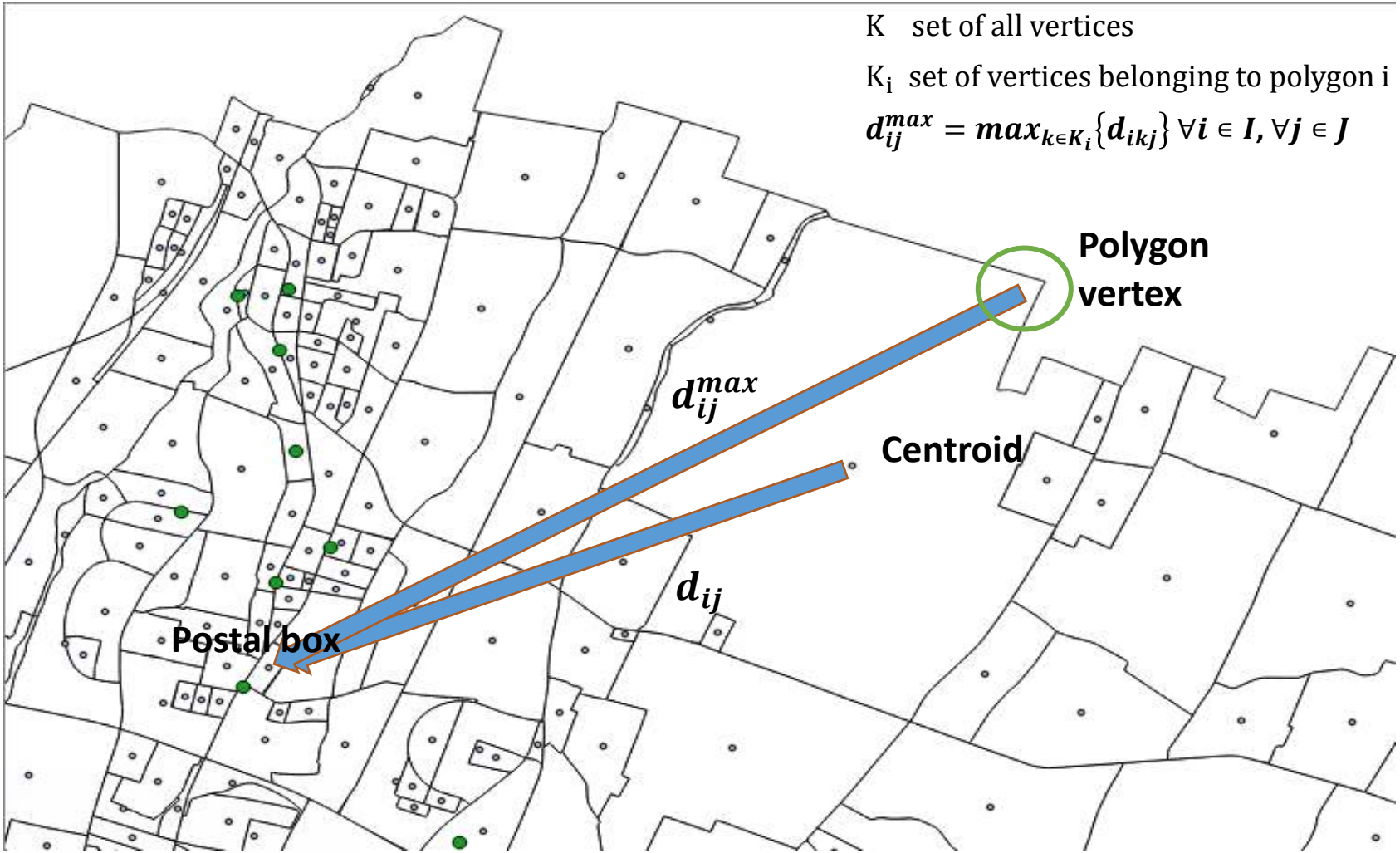




Initial Postal Boxes = 272
Current Postal Boxes = 69

District center	Number of postal boxes	Allocation cost [m]	Routing time [min]
36	18	18971,55	126,31
105	6	4055,11	49,82
120	10	12105,06	92,14
161	14	20144,17	122,83
235	12	16926,49	119,64
264	9	8539,26	76,53

Some refinements

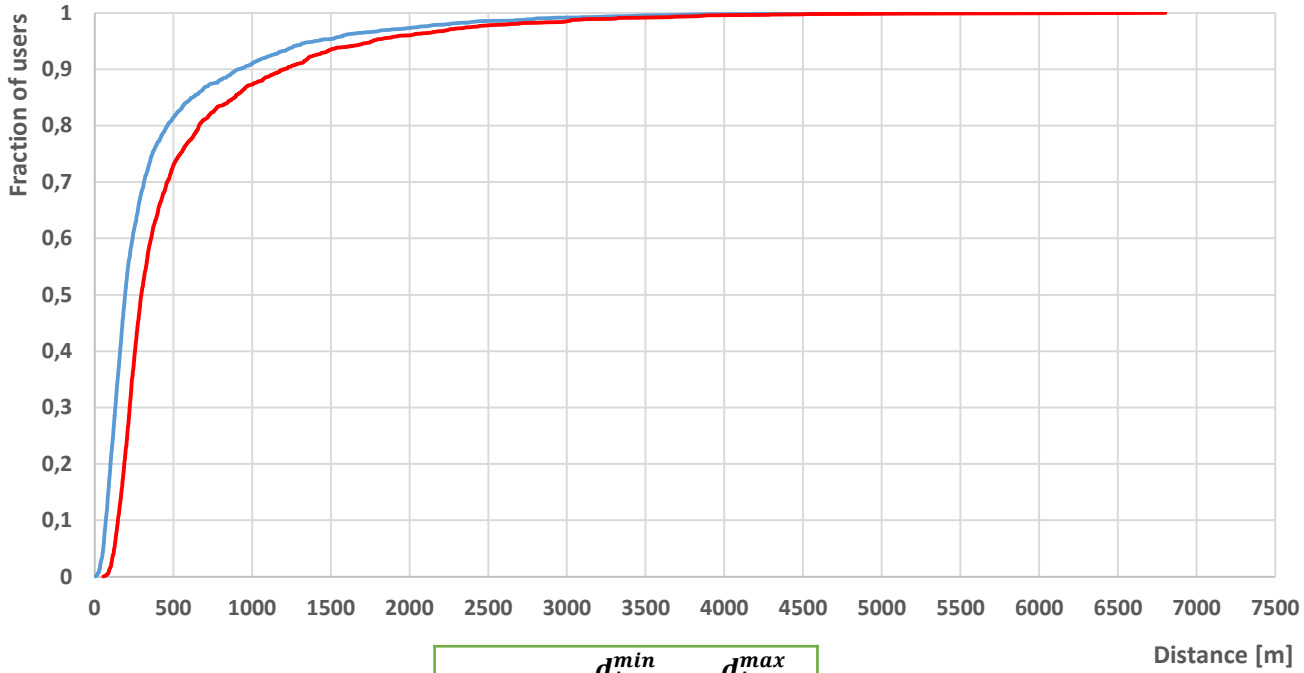


Accessibility considerations

d_i^{min} cumulative distribution function

$$d_i^{min} = min_{j \in J}\{d_{ij}\} \; \forall i \in I \quad \Rightarrow \quad j^* \quad \Rightarrow \quad d_i^{max} = max_{k \in K_i}\{d_{ikj^*}\} \; \forall i \in I$$

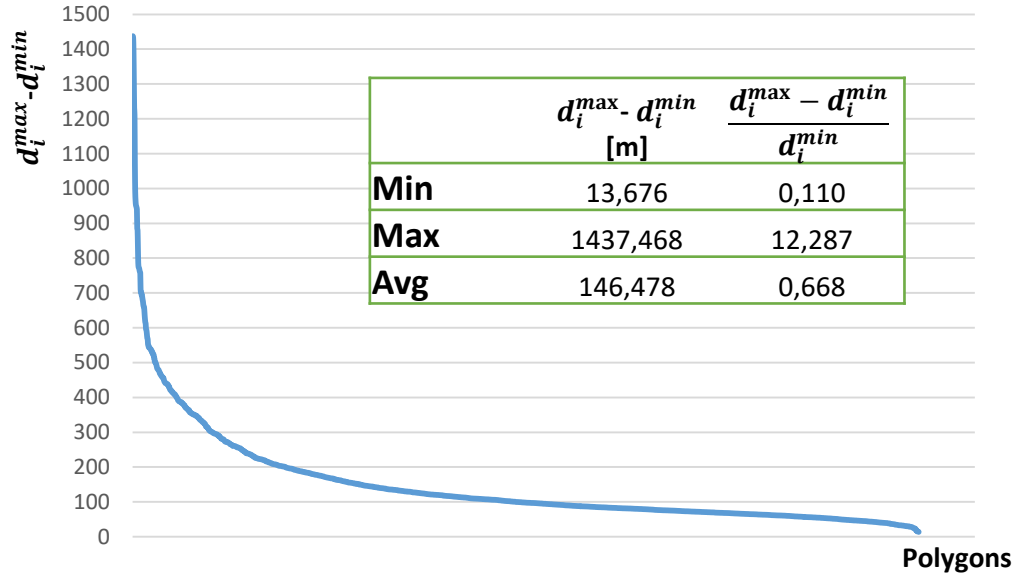
d_i^{max} cumulative distribution function



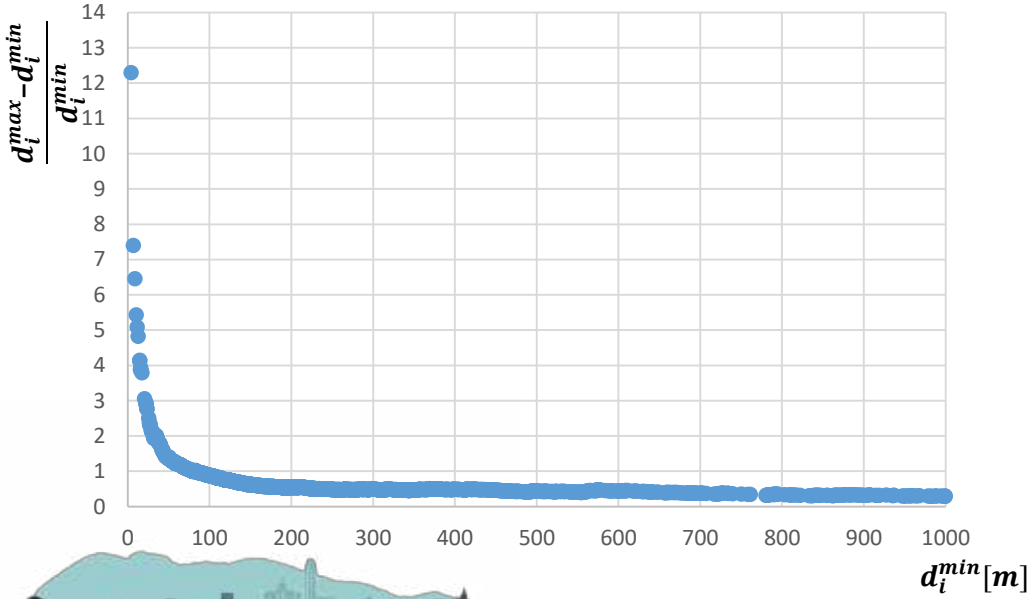
	d_i^{min}	d_i^{max}
Min	4,152	55,178
Max	5625,515	6801,782
Avg	380,575	527,061
Dv. Std	546,244	637,366

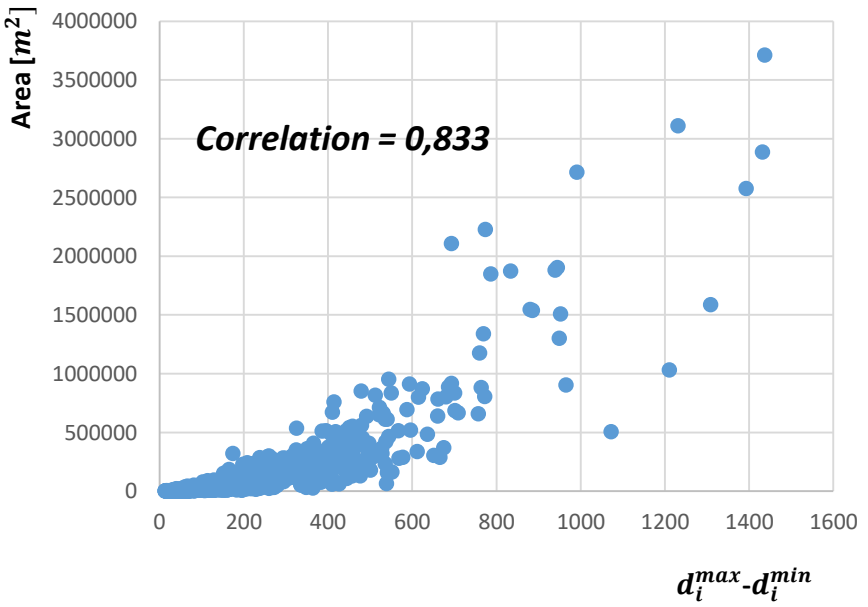
In 168 out of 2333 cases (7%), users should patronize a different facility

Accessibility considerations

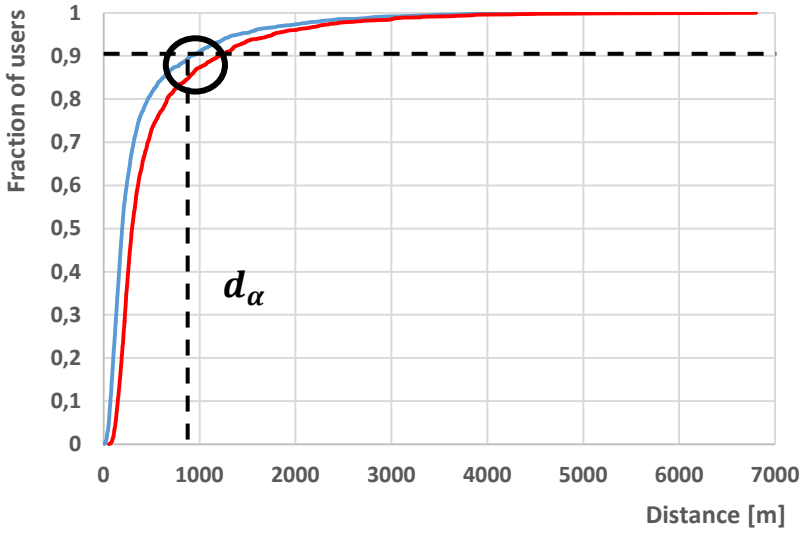


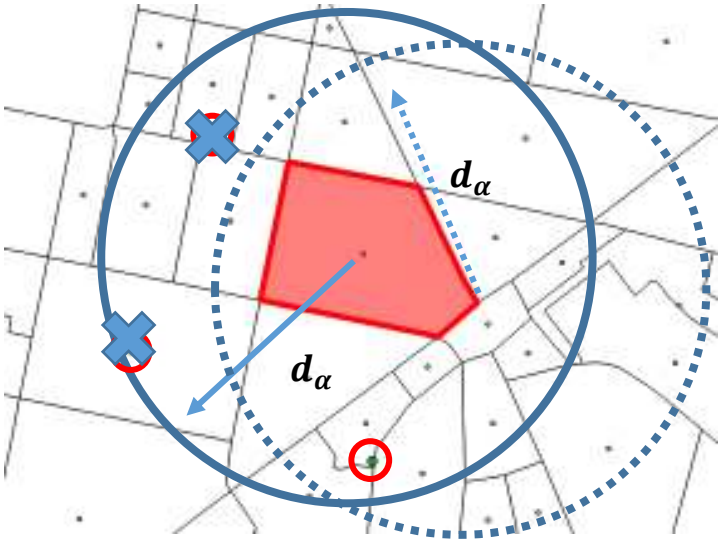
	d_i^{max}- d_i^{min} [m]	$\frac{d_i^{max} - d_i^{min}}{d_i^{min}}$
Min	13,676	0,110
Max	1437,468	12,287
Avg	146,478	0,668





Accessibility considerations

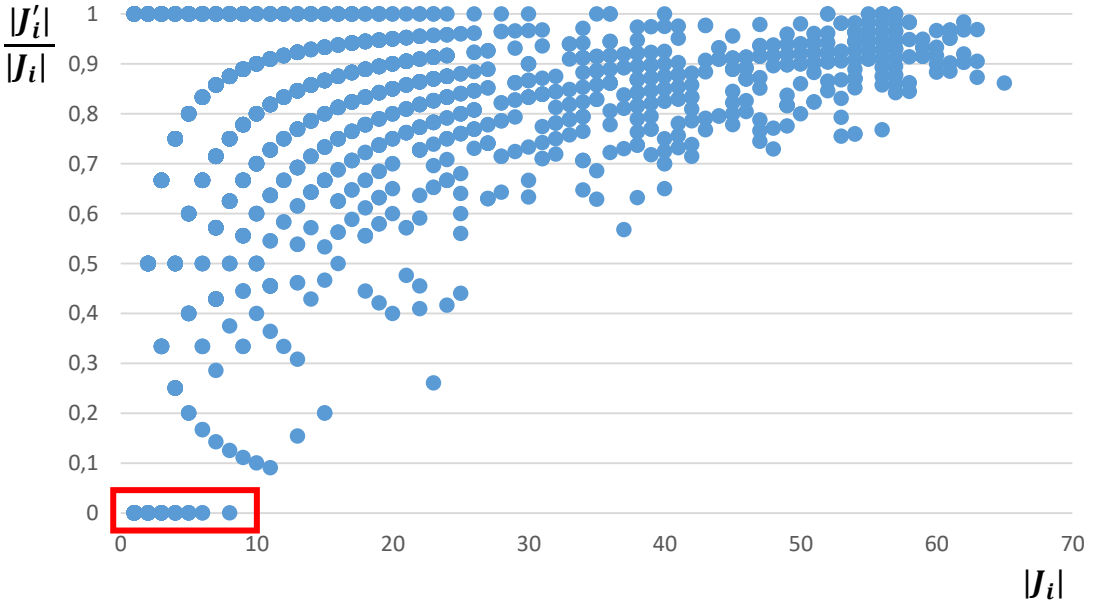




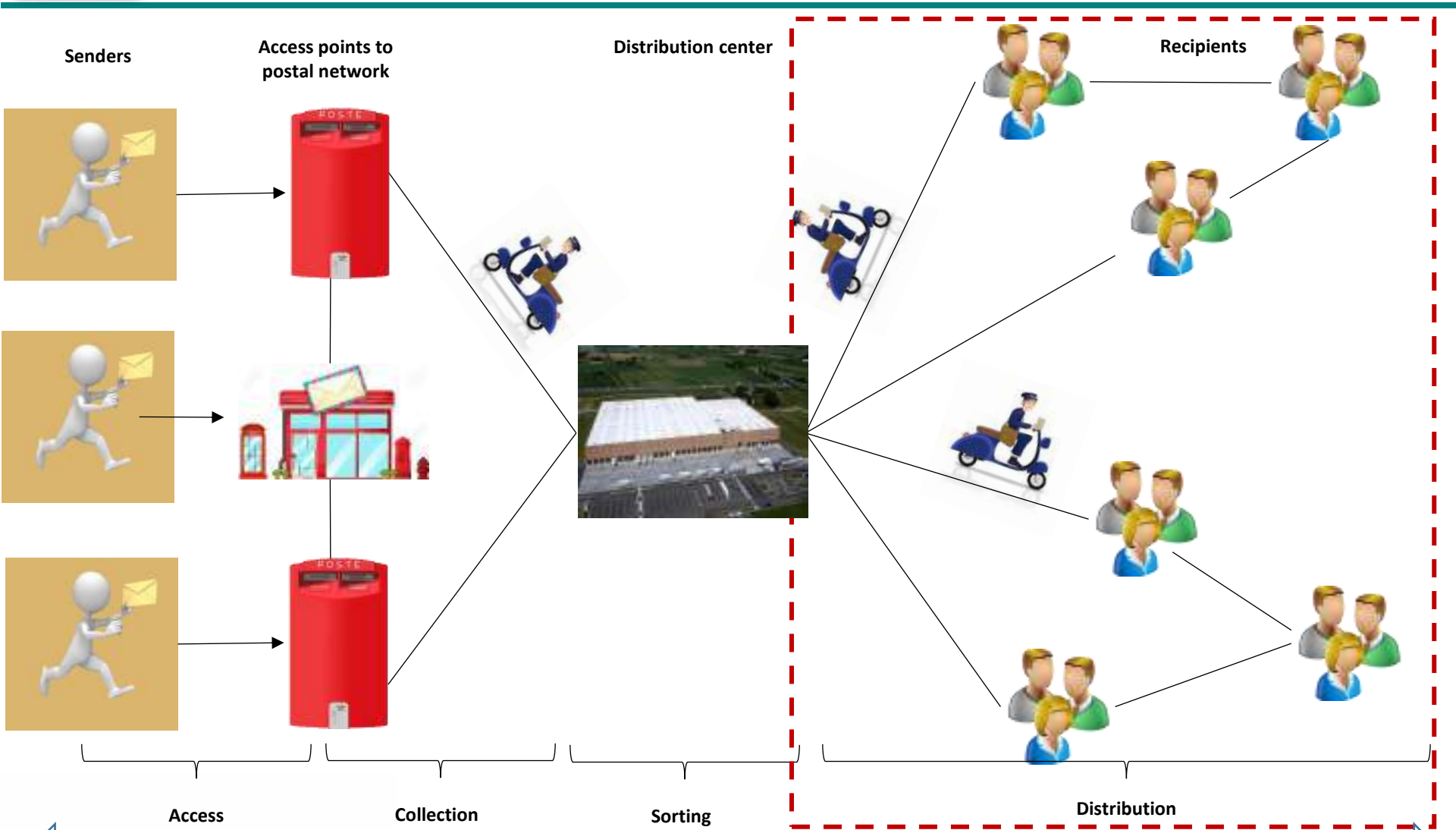
J_i set of facilities located within distance d_α from the centroid of polygon *i*
$(j \in J: d_{ij} \leq d_\alpha \; \forall \; i \in I)$

J_i' set of facilities located within distance d_α from the farthest vertex of polygon *i*
$(j \in J: d_{ij}^{max} \leq d_\alpha \; \forall \; i \in I)$

$|J_i'| \leq |J_i| \; \forall \; i \in I$



Logistic system of a postal service provider



Creation of the instance and preliminary notation

Notation

I set of recipients identified with house numbers

J set of streets where house numbers are located

$$|I| = 40953;\ |J| = 1756$$

p_i population located at house number *i*

P_j population located at street *j*

l_j lenght of street *j*

α_i probability that users located at *i* receive ordinary mail

β_i probability that users located at i receive priority mail

Mail delivery: Regulatory framework

Types of products delivered:

- Ordinary Mail
- Priority Mail
- Registered mail
- Legal proceedings
- Insured mail
- Massive mail (only for businesses)
- National/International parcels

Biweekly delivery model on alternate days

Quality objectives: J+1 (Priority

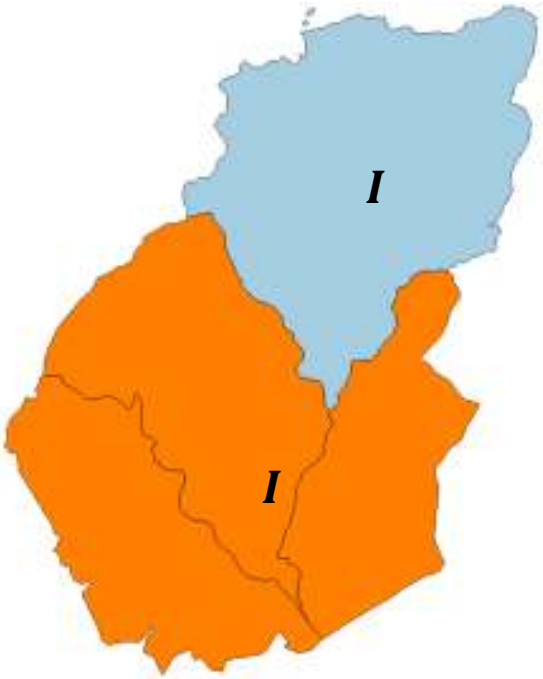
Priority Mail on a daily basis
Ordinary Mail on alternate days

Delivery strategies – Scenario 1

	MON	TUE	WED	THU	FRY
1	O_A	O_B	O_A	O_B	O_A
2	P_I	P_I	P_I	P_I	P_I

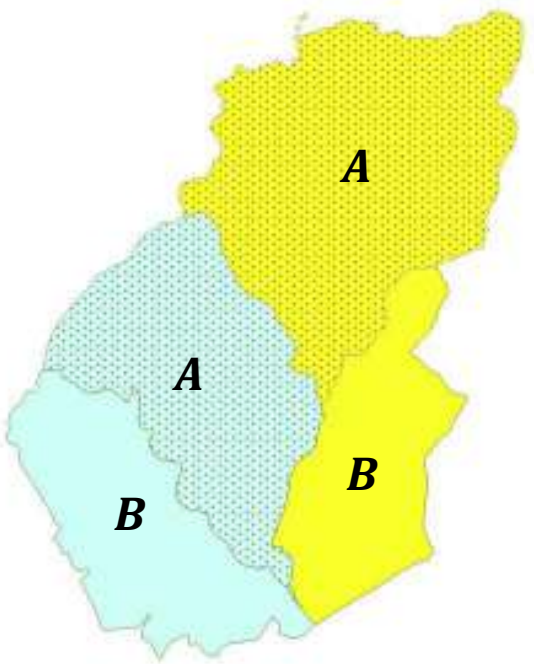
Ordinary mail districting

Priority mail districting



Delivery strategy – Scenario 2

	MON	TUE	WED	THU	FRY
1	$(0/P)_A + P_B$	$P_A + (0/P)_B$	$(0/P)_A + P_B$	$P_A + (0/P)_B$	$(0/P)_A + P_B$



Priority Mail

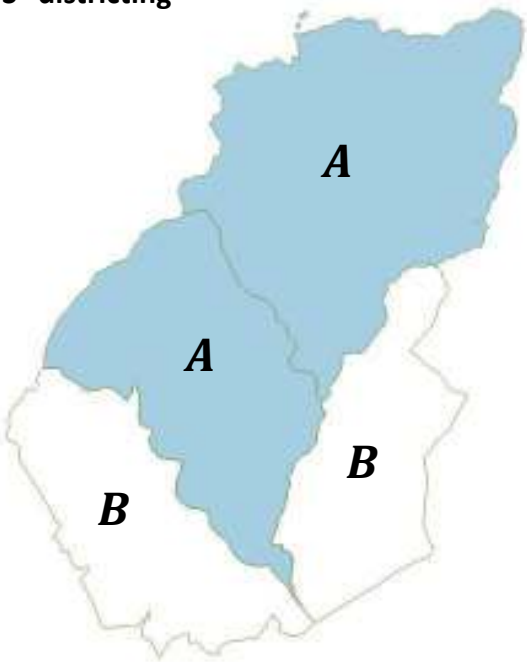
Priority and Ordinary Mail

Delivery strategy – Scenario 3

	MON	TUE	WED	THU	FRY
«Non Plus» Postman	$(0/P)_A$	$(0/P)_B$	$(0/P)_A$	$(0/P)_B$	$(0/P)_A$
«Plus» Postman	P_B	P_A	P_B	P_A	P_B

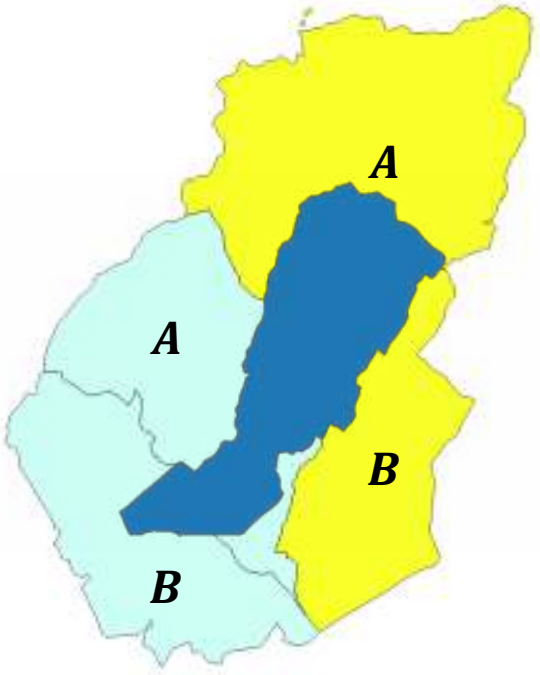
"NON PLUS" districting

"PLUS" districting



Delivery strategy – Scenario 4

	MON	TUE	WED	THU	FRY
Baricentric Zone	*O/P*	*O/P*	*O/P*	*O/P*	*O/P*
Non Baricentric Zone	Scenario 1 o 2 o 3	Scenario 1 o 2 o 3	Scenario 1 o 2 o 3	Scenario 1 o 2 o 3	Scenario 1 o 2 o 3



Non baricentric zones

Baricentric zone

Mail delivery strategies: a comparison

Strategies	Approach (Ordinary vs. Priority Districting)	Operators vs. Type of Mail	Competence Area	Driver
1	Separate (Single level districting)	Dedicated	Ordinary: 1 District (A+B) Prioriry: 1 District	Ordinary Mail Volumes in zone A [B] Priority Mail Volumes per district
2	Integrate (Multi level distrcting)	Not dedicated	1 District (A+B)	Ordinary and Priority Mail Volumes in A [B] + Priority Mail Volumes B [A]
3	Integrate (Multi level districting)	Non Plus: Not dedicated Plus: Dedicated	Non Plus: 1 District (A+B) Plus: 1 District (not covered zones)	Ordinary and Priority in A [B] Priority per district
4	Integrate (Multi level districting)	Non Baricentric: NA Baricetric: Not dedicated	NA 1 District	NA Priority Mail Volumes

Conclusions and further research

- ***The problem of reorganizing the collection system of a postal service provider has been addressed;***
- ***A mathematical model aiming at defining both the postal boxes to be preserved and proper collection areas has been proposed and implemented;***
- ***Some considerations on users' accessibility measures have been highlighted;***
- ***Some strategies for mail delivery have been showed***

Further research

- ***Enlarge computational experiments and test the developed model on different case studies characterized by different users and facilities' distribution and geographic characteristics;***
- ***Testing the model using taking into account the new accessibility measures defined;***
- ***Developing mathematical models for simulating the different delivery strategies proposed;***
- ***Building a real instance for testing and comparing the delivery models to be developed***

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Thanks for your attention!

Any questions? Comments?

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