AN OPTIMIZATION METHODOLOGY FOR THE CONSOLIDATION OF URBAN FREIGHT BOXES

Elvezia M. Cepolina [(a)], Alessandro Farina [(b)]

[(a) (b)]Department of Civil and Industrial Engineering, University of Pisa, Italy

[(a)] elvezia.cepolina@dic.unipi.it, [(b)] alessandro.farina@dic.unipi.it

ABSTRACT
The paper refers to an innovative urban freight distribution scheme. Packages are firstly delivered to urban distribution centers (UDCs) on the border of urban areas. Packages should therefore be delivered from the UDC to receivers within the urban area. Each package is characterized by an address and dimensions. FURBOT boxes are consolidated in the UDC with these packages. Each box is addressed to a temporary unloading bay and it is delivered there by a FURBOT vehicle. A virtual key and the actual address of the box will be communicated to all the receivers, allowing them to collect their packages from the box in a given time window. The paper concerns a methodology for the box consolidation which minimizes the overall distance travelled by receivers, taking into account the box capacity and the maximum walking distance the receivers accept to collect their packages. A fuzzy k-means clustering algorithm has been adopted.

Keywords: LBL urban freight boxes, LBL freight consolidation, optimization

1. INTRODUCTION
This paper concerns freight distribution in urban areas. Freight is addressed to receivers that could be commercial activities or consumers.

As it concerns *freight directed to commercial activities*, its transport depends on the production system. The *decentralization of production* (e.g. importing the semi-finished products from countries with cheaper human resources to those with higher technology to assemble the final goods) gives an international nature to the freight transport. Moreover, the *increasing value of delivered products* requires rapid transportation because companies want to reduce the interest costs bound up in store and inventories. There is the need to *reduce store costs* since store areas in urban centers are expensive. In fact, the dimension of commercial activities in urban areas is small and often commercial activities have not a store area or if they have one, it is small. This leads to the Just-In-Time (JIT) delivery principle, which involves *more frequent delivery* of materials at the right time and at the right place in the production process.

As it concerns *freight directed to consumers*, this is the result of on-line shopping. E-commerce enables businesses to sell their products and services directly to the consumers without establishing a physical point of sale. While some products can be delivered digitally to households (for example, newspapers, airline tickets and music CDs), most products purchased online ultimately must be transported to the end-users in the physical world. The receivers are often single people, especially students and time-poor professionals, who purchase products online but are not normally at home at daytime to accept deliveries. An efficient, rapid and reliable delivery system is essential for gaining customer loyalty online and consequently obtaining profitability (Park and Regan 2004). Home delivery is therefore increasingly becoming a key element in e-commerce. The logistical requirements of supply chains that extend to each customer's address may stimulate greater complexity in distribution systems management, potentially causing higher costs in carriers' fleet operations. More frequent home-based local deliveries will likely add to traffic congestion and environmental problems in urban areas, making it more difficult for carriers to meet customer demands.

Nowadays, the trends of urban freight transport towards to deliver "Just-in-time" and "door-to-door". The operation of freight transport changes to have more trips but fewer loads in order to increase the efficiency differently. Without improvement, the transport costs will increase hugely to satisfy the current requirements. (Tseng et al. 2005). The impact of freight transport in urban centers is that, usually among the total urban traffic, 20-30% is composed of freight vehicles (Dablanc 2007; Cepolina et al. 2012). Freight vehicles are responsible for 30-50% of total emissions of PM10. Moreover, because the deliveries in urban areas consist on small quantity of freight to each receiver, the level of load is always very low and also several empty trips are performed. It is calculated that in Italy, the average load factor of 30% of vans in urban areas is less than 25%, of 50% of vans is less than 50% (Di Bugno et al. 2008).

These problems will become even more critical in the next future since on one hand urbanization will bring more consumers in urban areas; and on the other hand home deliveries will increase since e-commerce trend is growing despite the crisis. In Europe the total e-commerce revenue in 2012 was 305 billion euros and the 43% of the European population buys habitually on line products and services (Source: Eurostat). In Italy 12 million people were web shoppers in 2012. Between 2011 and 2012 we had a 15% increase in the number of online orders and this growth is expected to continue. In 2012, 35.5 million orders (services + products) have been done on the web (excluding train tickets, couponing and phone top-ups). Among orders, we are interested only in products because they need to be delivered as packages: these are 48.5% of the orders, equal to 17.2 million orders (source: osservatori.net). Each on-line order consists of 1.1-1.2 packages: in Italy therefore e-commerce moves 76000 packages each day. Although e-commerce still accounts for a very small market share compared to conventional retail business, the online shopping market is growing very fast.

Cooperative freight systems are the ways which could be expected to solve urban freight transport problems. Cooperative freight systems integrate the resources of the cooperating companies to optimize the economic benefits. The main benefits of the techniques are (1) properly increasing delivery trip loads; (2) reducing unnecessary trips, as well as pollution and costs; (3) reducing service area overlaps; (4) increasing service quality and company profits (Tseng et al. 2005). Cooperative freight systems need logistic platforms (*UDC - Urban Distribution Centre*) close to the city centre, within the freight village area. The goods are reorganized in the freight village before being delivered to the urban areas. This system can reduce the required number of vehicles used for delivery and handling.

The paper concerns the delivery system from the UDC to the receivers in urban areas (i.e. the last mile distribution problem). The paper has been structured in the following way. The first section describe the FURBOT freight delivery system in urban areas and it describes alternative systems proposed in the literature. Afterwards, the FURBOT box characteristics are described. Then, the mathematical formulation of the clustering of packages in the boxes is provided and a fuzzy k-means clustering algorithm to solve it is presented. Finally, the application of the algorithm to a trial case study is exposed. Conclusions follow.

2. THE FURBOT FREIGHT TRANSPORT SYSTEM

The paper refers to the last mile delivery problem; the proposed transport system is based on the belief that pick-up points play an important role in the physical distribution of goods since they solve the problem of the receivers not being at home at the time of delivery and contribute in reducing the impact of freight transport on urban pollution and congestion. The concept of local pick-up points is described in Browne at al. (1997).

Freight is firstly delivered from the production/ consolidation sites to urban distribution centers (UDCs) on the border of urban areas. A set of packages should therefore be delivered every day from the UDC to receivers within the urban area. Each package is characterized by an address (consumer's home address or commercial activity address) and its dimensions.

Every day, in the UDC these packages are clustered, according to their addresses, in a given number of boxes (FURBOT boxes) and an unloading bay is assigned to each box, according to the addresses of the packages assigned to it. FURBOT boxes are then consolidated in the UDC with these packages. Each box is addressed to the unloading bay, resulting from the clustering process, in the urban area and it is delivered there by a FURBOT vehicle. A virtual key and the actual address of the box unloading bay will be communicated to all the receivers, allowing them to collect their packages from the box in a given time window. The paper concerns a methodology for clustering process which minimizes the overall distance travelled by receivers, taking into account the box capacity and the maximum walking distance the receivers accept to collect their packages.

The FURBOT vehicle is small in size and it is able to move two FURBOT boxes, it is ecologically friendly and allows the automatic unloading of the boxes in the bays. This operation saves time and operative costs related to personnel. Since the unloading bay is occupied by the box only if there is freight addressed to its location, also the land occupation is minimized and the bay can be allocated to different uses, like parking, when not required. The high loading factor of the FURBOT box will lead to a decrease in the number of trips for freight distribution in urban areas and its impact on pollution. A representation of the FURBOT vehicle is provided in figure 1

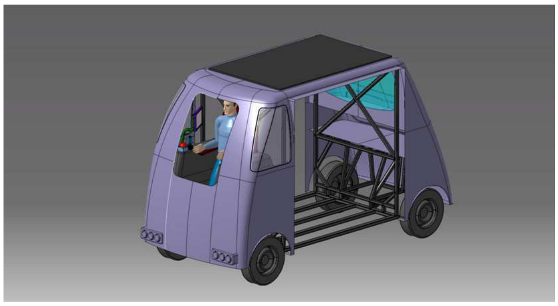

Figure 1: A Design of the FURBOT Vehicle

Some solutions, close to the FURBOT freight delivery system that adopt delivering to pick-up points, have been proposed in literature and will be shortly described in the following.

Packstation is a system that is meant to reduce the number of home deliveries, and it is destined to private customers and businesses. It has been introduced initially in Germany and afterwards developed also in Austria, Finland and Latvia. It is a service run by DHL Parcel Germany and it provides automated booths for self-service collection of parcels and oversize letters as well as self-service dispatch of parcels 24 hours a day, seven days a week. The structure is fixed, parcels can be accessed by customers through a touch screen. The pack station can be used for both: the delivery of packages to customers, who have a code to access their packages; and by customers to send their packages, avoiding queues at post offices. Using pack stations is free of charge both for private and business customers, however prior registration is required for collection of parcels.

A major market for pack station is the increasing number of people, who purchase products online but are not normally at home at daytime to accept deliveries, or who do not have the time to deposit parcels at the post office during normal opening hours.

If a customer wishes to pick up a delivery at a pack station, he just has to specify the identifier number of the pack station (e.g. pack station 124) where he desires to collect the package. Number and location of a pack station can be looked up online prior to receiving a delivery. If a parcel or letter is addressed to a pack station, it is delivered directly to the specified booth. If the destination is full, the parcel is diverted to the nearest booth with free compartments or to the nearest post office. It is also diverted to the post office if it is too large to fit into the compartments.

Since January 2004, DHL has offered in-house pack stations for large businesses. This service is especially attractive for businesses whose employees frequently receive private parcels at their work address.

Loading and unloading of a pack station is performed manually by an operator. A representation of the pack station is provided in figure 2.

Figure 2: A Pack Station

The BentoBox has been developed within the project CityLog (www.city-log.eu). It is composed of a fixed docking station, and six removable modular trolleys. Trolleys are consolidated at the UDC. A representation of a BentoBox is provided in figure 3.

The six trolleys have been made with different arrangements of compartments to allow the reception of several types of parcels. From a 1m79 height, 75 cm width and 63 cm depth, each trolley weighs about 50 kg. Accommodating 6 trolleys, the docking station has a touchscreen HMI to allow clients to retrieve their packages. A GRPS connection ensures the transmission of information with the central computer. For a 500 kg weight, the docking station measures 5m20 (width) x 82cm (depth) x 1m84 (height).

A new loading unit has been proposed within the project CityLog to accommodate the trolleys: it is a small cubic container, with a side of 2.1 metres and provided with retractile legs, in order to allow automatic loading and unloading, as shown in figure 4.


Figure 3: The BentoBox.

Figure 4: The Load Unit. BentoBoxes are Placed Here

The BentoBox trolleys are loaded into the loading unit in the UDC and unloaded at the docking station. At the UDC three loading units are accommodated into a freight bus to perform the penetration trip in the urban area. The freight bus on one side is smaller than a truck and on the other side is big enough to reduce the number of circulating freight vehicles. At some specific places around the oldest part of the city, the unit is unloaded from the freight bus and loaded into a light vehicle, called delivery van, to perform the last part of the trip. Thanks to the loading unit facilities, the transshipment is performed without the need of any building or special facility, but, as shown in figures 5 and 6, only some road space is needed.

The BentoBox by now has not been applied yet on the field as a facility for wide scale urban freight delivery. It has been tested only within the project CityLog, to three trial case studies: Berlin city centre, a major retail in Lyon, and Torino Lingotto.

The main differences between Packstation, BentoBox and the FURBOT delivery systems are herewith summarized.

1. The number and the localizations of the FURBOT boxes are not fixed in the urban area and they depend on the current daily freight transport demand. The impact of the FURBOT boxes on the land occupation is therefore minimized, as the boxes are only where they are required. Conversely, the number and the localizations of the Bentobox docking stations and of the Packstations are fixed for a given urban area and do not depend on the current freight demand.
2. The consolidation of the FURBOT box and of the Bentobox trolleys are performed in the UDC, therefore operative costs are minimized. Conversely the consolidation of the Packstation is performed manually in loco by an operator that transfers packages from a van,

temporarily parked on the road, to the Packstation.

3. The unloading of the FURBOT box in the temporary unloading bay is automatic. The unloading of the Bentobox unloading unit is again automatic but the BentoBox trolleys should be manually moved from the unloading unit to the docking station.
4. In the FURBOT delivery systems, packages are addressed to the receiver's addresses (home address or commercial activity address) and receivers are informed about the actual location of their packages only after the FURBOT box consolidation. Conversely, in the Packstation and in the Betobox systems, packages are addressed to fixed bays (Bentobox docking station locations and the Packstation locations), according with the receiver requests. In these last two cases the clustering of packages in the boxes does not take place whilst it is a critical issue in the FURBOT delivery system and this paper focuses on it.

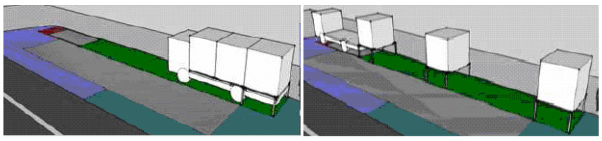

Figure 5: Using its Air Suspension, the Freight Bus Unloads the Loading Units

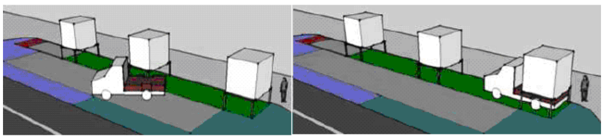

Figure 6: The Delivery Van Uses its Actuators to Load a Load Unit.

3. THE FURBOT BOX

The FURBOT box footprint has the euro-pallet dimension (120 cm long and 80 cm wide). The FURBOT box is 170 cm high. The bottom part of the box has the euro-pallet design in order to be operated with the standard movement and handling tools (loader forks, etc).

We have 2 typologies of FURBOT boxes: LBL (Less than full Box Load) and FBL (Full Box Load). We define FBL box as a box that contains packages for only one receiver while LBL box is a box that contains packages for several receivers. The FBL box can accommodate an euro pallet. In the paper we focus only on LBL boxes.

The internal space of LBL boxes is divided into modular parcels. Each parcel can accommodate packages for a given receiver. The box is accessible by receivers from two sides, and it is divided in two parts through a vertical set. This configuration on one hand allows storing a much greater number of packages, and on the other hand it allows the box to be accessed by two persons simultaneously. The two sides of the box are identical. The design of the FURBOT LBL box is provided in figure 7. The box capacity is equal to 1.102 m^3. There are three standard parcels:

- Type A: 0.0783 m^3, i.e. 56x37x46 cm
- Type B: 0.0426 m^3, i.e. 36x37x32 cm
- Type C: 0.0275 m^3, i.e. 46.5x37x13 cm

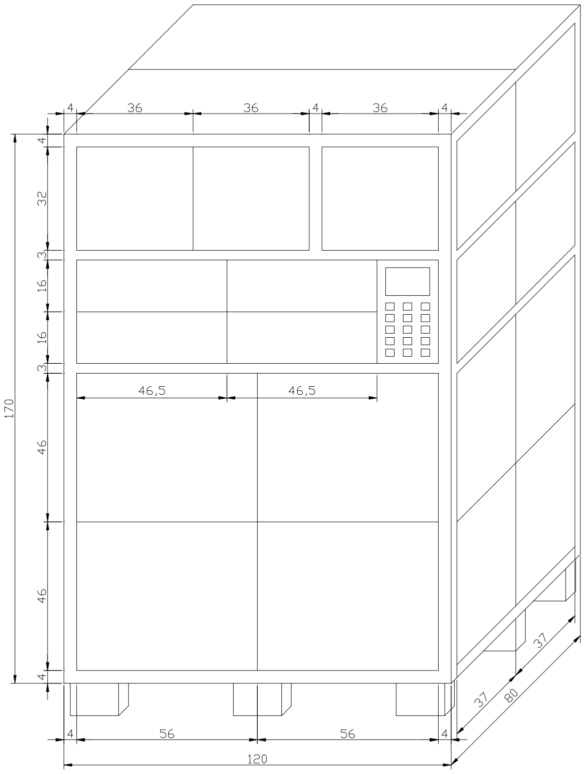

Figure 7: The Design of the FURBOT LBL Box

However, since internal sets are removable, parcels of different dimensions could be configured.

The standard parcel dimensions have been assessed according the dimensions of packages commonly delivered to commercial activities and consumers (e-commerce). Surveys on the field have been performed.

4. THE PACKAGES CLUSTERING IN THE FURBOT BOXES AND ITS MATHEMATICAL FORMULATION

The problem we face is the daily clustering of the packages at the UDC into a given number of LBL boxes. To each cluster, and therefore to each LBL box, an address is assigned, which is the "centre" position of the addresses of the packages within the cluster. Among all the possible clusters we select the ones that minimize the distances the receivers have to walk to collect their packages (and therefore the distances from the addresses of the packages to the cluster centre). The cluster centre will be the unloading bay of the box.

We have other constraints to our problem, one is related to the box capacity and another is related to the maximum distance the receivers can walk (in order to collect their packages in the box). In the literature one of the optimization problems closer to the problem we face is the k-means clustering problem with size constraints (Zhu et al. 2010).

Simple k-means clustering is a method of cluster analysis which aims to partition *n* observations into *k* clusters in which each observation belongs to the cluster with the nearest mean. The problem is computationally difficult (NP-hard); however, there are efficient heuristic algorithms that are commonly employed and converge quickly to a local optimum.

The simple k-means clustering does not work properly as we have a constraint on both the box capacity and the maximum allowed walking distance. Actually the simple k-means clustering always assigns each object to the closest box and therefore when some boxes have reached their capacity, the remaining objects must be assigned to other boxes, which may entail far more than the maximum walking distance allowed.

As a result, fuzzy k-means clustering has been adopted. In fuzzy clustering, each item has a degree of membership to each cluster (u_{ij} is the degree of membership of item *i* to cluster *j*), rather than belonging completely to only one cluster. The degree of membership of item *i* to cluster *j* is inversely proportional to the distance of the item *i* to the centre of cluster *j* .

The fuzzy clustering can be formalized as follows:

$$\min \ f = \sum_{i=1}^{N} \sum_{j=1}^{nLBL} u_{ij}^{m} \left\| x_i - c_j \right\|^2 \tag{1}$$

Where:
x_i = address of package *i*,
c_j = position of the centre of cluster *j*,
m = parameter of fuzziness,
N = number of receivers,
nLBL = number of LBL boxes (i.e. number of clusters).

In the faced problem the independent variables are the degrees of membership u_{ij}: we need to assess the u_{ij} values that minimize the cost function. To solve the problem, an iterative algorithm has been adopted.

As starting point, the initial values for the degrees of membership $u_{ij}^{(0)}$ of the item *i* to the cluster *j* at the 0 iteration (initialization step) have been assessed assuming the positions of the cluster centers uniformly distributed in the area.

At the generic *k* iteration, the degrees of membership $u_{ij}^{(k)}$ and the positions $c_j^{(k)}$ of cluster centers are updated according to eq. 2 and 3 (Klawonn and Hoeppner 2006; Hoeppner and Klawonn 2008).

$$c_j^{(k)} = \frac{\sum_{i=1}^{N} u_{ij}^{(k-1)^m} \cdot x_i}{\sum_{i=1}^{N} u_{ij}^{(k-1)^m}} \tag{2}$$

$$u_{ij}^{(k)} = \frac{1}{\sum_{b=1}^{nLBL} \left(\frac{\left\| x_i - c^{(k)}{}_j \right\|}{\left\| x_i - c^{(k)}{}_b \right\|} \right)^{\frac{2}{m-1}}} \tag{3}$$

At each iteration k, the algorithm updates a matrix $\mathbf{U}^{(k)}$ whose columns refer to the clusters, whose rows refer to the items and whose generic element is $u_{ij}^{(k)}$.

The fuzzy clustering algorithm stops when for each item *i* and for each cluster *j* the degree of membership is no longer updated relevantly from an iteration to the following:

$$\max_{\forall i,j} \left| u_{ij}^{(k)} - u_{ij}^{(k-1)} \right| < \varepsilon \tag{4}$$

The fuzzy clustering algorithm does not provide a problem solution since it does not provide clusters but a matrix **U**. Moreover constraints have not yet been taken into account in the algorithm.

A distance matrix **D** is now assessed. The columns refer to the clusters and the rows refer to the items. The generic element d_{ij} is the distance of the item *i* from the center of cluster *j*, c_j .

For each element *ij* in the **D** matrix whose value d_{ij} exceeds 450m (maximum allowed walking distance), the related element in the **U** matrix (u_{ij}) is set equal to 0. A new matrix **U*** is therefore assessed and it satisfies the constraint (eq. 5) on the maximum distance.

New values for c_j are assessed, according to equation 2 and **U***.

$$\max_{i,j} \left\| x_i - c_j \right\| < 450 \text{ m} \tag{5}$$

Clusters should be now assessed from **U***. The item *i* with the highest u_{ij}^* is assigned to cluster *j* if cluster *j* has enough space (and then eq. 6 is satisfied) :

$$\sum_{p=1}^{N} w_p y_{pj} \le K_j \tag{6}$$

Where:

$$y_{pj} = \begin{cases} 1 \text{ if the item } p \text{ has been assigned to the box } j \\ 0 \text{ otherwise} \end{cases}$$

w_p = volume of the item *p*,
K_j = capacity of the box *j* = 1.102 m^3

If the constraint is satisfied, the $\mathbf{U}^*$ matrix is modified: u_{ij}^{**}=1 and u_{iz}^{**} = 0 $\forall z \neq j$.

If the constraint is not satisfied, u_{ij}^{**} is set equal to 0. The resulting $\mathbf{U}^{**}$ matrix satisfies also the capacity constraints.

If the elements u_{ij}^{**}= 0 or u_{ij}^{**}=1, the clusters are definitely assessed.

If there is a row *i* for which u_{ij}^{**}= 0 $\forall j$ (this means that there is not space for item *i* in any of the boxes that satisfy the maximum distance constraint) it is necessary to modify the clusters already assessed.

We need to remove an item *q* from a box *b* and to substitute it with the item *i*. *b* are all the boxes for which $u_{ib}^{*} > 0$, i.e. which respect the distance constraints. Among these *b* boxes, the box *bb* and the item *q* are selected if $u_{q,bb}^{**}=1$ and u_{qj}^{*} is maximum $\forall j \neq bb$ and $\forall j$ capable to contain the item *q*.

5. THE CASE STUDY

The overall methodology has been applied to a trial and illustrative case of study. A squared urban area having dimensions of 1 km x 1 km has been taken into account. The overall area is flat.

The road network is formed by parallel and perpendicular roads 50 meters distant each other. It is represented by a network of links and nodes. Links represent 10 meter long road sections. Nodes represent the midpoint of each road section. All the nodes have the same probability to be extracted as addresses for packages.

The daily freight transport demand consists of 100 packages. Their addresses have been randomly extracted from the nodes list and corresponds to the small dots in the figure 8 and 9. The typologies of the generated packages are: 40 of type A, 40 of type C and 20 of type B. Given this freight transport demand, we hypothesized two scenarios.

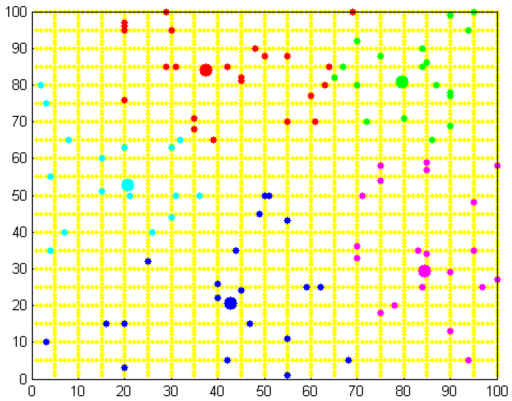

Figure 8: The Cluster of Packages in the Case of 5 LBL Boxes

In a first scenario we assumed 5 LBL boxes and the clusters of packages provided by the algorithm are shown in figure 8: all packages belonging to the same cluster are displayed in the same color; the big dot corresponds to the location of the centre of the cluster its color refers to. The maximum distance travelled by receivers results of 416 m, the average distance travelled by receivers results of 166 m and the LBL box load factors are: 0.96; 0.82; 0.98; 1.0; 0.86 (the average value is 0.92). In a second scenario we assumed 6 LBL boxes and the clusters of packages provided by the algorithm are shown in figure 9. The maximum distance travelled by receivers results of 414 m, the average distance travelled by receivers results of 148 m and the LBL box load factors are: 0.92; 0.70; 0.63; 0.85; 0.76; 0.75 (the average value is 0.77).

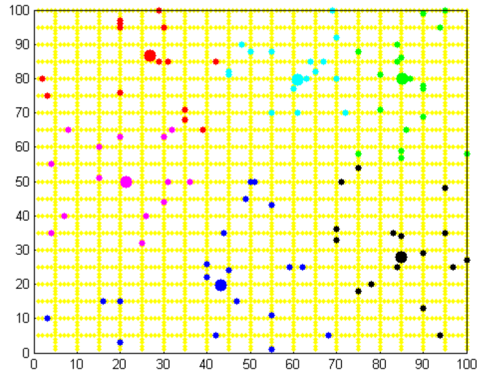

Figure 9: The Cluster of Packages in the Case of 6 LBL Boxes

6. CONCLUSIONS

From the simulation outputs it results that 5 LBL boxes are enough to satisfy the freight transport demand with good performance in terms of maximum and average distances travelled by receivers (the increase in the performance due to an additional LBL box is negligible).

The algorithm assumes a continuum space therefore the locations of the cluster centers could be any point in the area. A off line check should be performed on the locations of the cluster centers because each urban area has a list of possible places that can be used as unloading bays. These places should be accessible from the FURBOT vehicle and the receivers and the impact of the FURBOT box temporarily places there on pedestrian flows and vehicular flows should be minimum.

In the presented case of study the freight transport demand refers only to e-commerce. It could be interesting to analyze the performance of the proposed urban freight transport system in the case we consider also deliveries to commercial activities and therefore a huge increase in the freight transport demand.

In the presented case of study the area is completely trial. It could be interesting to apply the overall procedure to a real urban area.

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REFERENCES

Browne, M., Allen, J., 1997. Strategies to reduce the use of energy by road freight transport in cities. *Proceedings of 25th PTRC Annual Meeting*. September 1-5, London (U.K.).

Cepolina, E.M.., Farina, A., Lupi, M., 2012. Overview on facilities, policies and strategies for better freight delivery in urban areas. *Proceedings of 15th International Conference on Transport Science, ICTS 2012*. May 28, Portoroz (Slovenia).

CityLog project website: www.city-log.eu [accessed June 2013].

Dablanc, L., 2007. Goods transport in large European cities: Difficult to organize, difficult to modernize. *Transportation Research Part A: Policy and Practice, 41*(3), 280-285.

Di Bugno, M., Guerra, S., Liberato, A., Ambrosino, G., 2008. *CEDM - Centre for Eco-Friendly City Freight Distribution. Un approccio integrato alla city logistics*. Lucca: CEDM Consortium edition.

Eurostat [accessed April 2013]: http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/E-commerce_statistics

Furbot project website [accessed April 2013]: http://www.dimec.unige.it/PMAR/furbot/p_dimec.shtml

Hoppner, F., Klawonn, F., 2008. Clustering with Size Constraints. In: L.C. Jain, M. Sato-Ilic, M. Virvou, G.A. Tsihrintzis, V.E. Balas, eds. *Computational Intelligence Paradigms*. Springer. Retrieved from: http://public.fh-wolfenbuettel.de/~klawonn/Papers/hoeppnerklawonn08.pdf

Klawonn, F., Hoeppner, F., 2006. Equi-sized, homogeneous partitioning. In: B. Gabrys, R.J. Howlett, L.C. Jain, eds. *Knowledge-Based Intelligent Information and Engineering Systems, Part II*. Berlin: Springer, 70–77.

Observer on e-commerce website [accessed April 2013] http://www.osservatori.net/ecommerce_b2c

Park, M., Regan, A., 2004. *Issues in Emerging Home Delivery Operations*. UC Berkeley: University of California Transportation Center. Retrieved from: http://www.escholarship.org/uc/item/3754142p

Tseng Y-Y., Yue, W.L., Taylor, M.A.P., 2005. The role of transportation in the logistics chain. In: K. Satoh, ed. *Proceedings of the eastern Asia society for transportation studies*, vol. 5, pp. 1657–1672

Zhu, S., Wang, D., and Li, T., 2010. Data Clustering with Size Constraints. *Knowledge-Based Systems*, 23(8), 883-889.

Shipping companies websites [accessed April 2013]:
http://www.brt.it/en/index.do
http://www.dhl.com/en.html
http://www.gls-group.eu/276-I-PORTAL-WEB/content/GLS/BE01/EN/1.htm
http://www.tnt.com/portal/location/en.html
http://www.fedex.com/
http://www.poste.it/

AUTHORS BIOGRAPHY

Elvezia M. Cepolina, PhD, assistant professor at the University of Pisa. She is professor of Transport Planning at the University of Pisa and of Transport Design at the University of Genoa. She has been research fellow at the University College London, UK.
Elvezia is the person in charge of scientific and technical/technological aspects in the following European projects for the University of Pisa: FURBOT, Freight Urban RoBOTic vehicle (FP7-SST-2011-RTD-1); PICAV, Personal Intelligent City Accessible Vehicle System (FP7-SST-2008-RTD-1). Elvezia has been Overseas Scientist in the project SPIRAL Scientific Pedestrian Interaction Research in an Accessibility Laboratory, International Joint Project - 2004/R3-EU Europe (ESEP), founded by Royal Society, UK.
Elvezia is author of many papers on international journals and international conference proceedings.
Elvezia is a member of the SIDT (Italian Society of Transport Professors).

Alessandro Farina received the M.Sc. degree in Civil Engineering from the University of Bologna, Italy, in 2009, and the Ph.D. degree from the University of Pisa, in 2012. He is currently a research associated at the University of Pisa. His research interests include car sharing systems, transport logistic and maritime transport.