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The routing problem of an innovative urban freight distribution scheme

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Abstract

The paper refers to an innovative urban freight distribution scheme, aimed at reducing the externalities connected with the freight delivery process. Both packages destined to commercial activities and to private consumers (e-commerce) are taken into account. Packages are firstly delivered to urban distribution centers (UDCs) on the border of urban areas; 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. The FURBOT vehicle has a capacity of 2 boxes. The paper focuses on the problem of choosing the couple of boxes to be loaded on each vehicle and on the related choice of the route to be assigned to each vehicle: from the UDC to the first stop where the first box should be unloaded, to the second stop where the second box should be unloaded, and then back to the UDC. A methodology for the specific routing problem is proposed and its application to the case study of Genoa city centre is presented.

Keywords: urban freight distribution; efficient and sustainable freight transport; vehicle routing; optimization.

Résumé

Le document se réfère à un innovant système urbain de distribution des marchandises, visant à réduire les externalités liées au processus de livraison des marchandises. Les colis destinés aux activités commerciales et aux consommateurs privés (e-commerce) sont pris en compte. Les colis sont d'abord livrés aux centres de distribution urbaine (CDU), au limite des zones urbaines, chaque colis est caractérisé par un adresse et ses dimensions. Les boxes FURBOT sont consolidées dans CDU par ces colis. Chaque box est adressée à une place de déchargement temporaire et il est transporté là par un véhicule FURBOT. Le véhicule FURBOT a une capacité de deux boîtes. Le document met l'accent sur le problème du choix du couple de boîtes à charger sur chaque véhicule et sur le choix de la route liés à attribuer à chaque véhicule: de l'UDC à la première étape où la première case doit être déchargé, à la deuxième arrêt où la deuxième case doit être déchargé, et puis de nouveau à l'UDC. Une méthodologie pour le problème de routage spécifique est proposé et son application à la centre-ville de Gênes est présentée.

Mots-clé: livraison urbaine des marchandises; performant et viable transport des merchandises; vehicle routing; optimisation.

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1. Introduction

The retail sector demonstrates how fragmentation of demand for urban freight transport (e.g. numerous independent retail outlets located in a city centre) combined with the fragmentation of supply of urban freight transport (e.g. numerous wholesalers and other suppliers using their own vehicles to make just-in-time deliveries) results in a greater number of urban freight transport movements with only part-loads than would be possible if both demand and supply were more concentrated. The larger retail chains have greater volumes of traffic and are more likely, by working with their logistics providers, to be able to optimise their deliveries in terms of overall efficiency. While diversity in the retail sector provided by small and medium sized independent retail outlets offers greater choice for consumers and can be seen as providing wider benefits to society, economies of scale in the provision of freight transport services in all sectors tend to lead to greater logistics efficiency, lower costs and more sustainable distribution.

Inefficiency in distribution in urban areas can be exhibited in the following ways:
- low load factors and empty running;
- a high number of deliveries made to individual premises within a given time period;
- long dwell times at loading and unloading points.

Inefficiency in distribution leads to additional costs for transport operators, which would normally be passed on to receivers/shippers (in the case of third party operators) or absorbed as costs for own account operators. These costs are ultimately borne by the wider economy. However, shippers, receivers and their transport operators do not always have a significant incentive to increase the efficiency of the deliveries to reduce costs. This is because the transport cost is often only a small proportion of the value of the goods that are being transported and the overall costs of the shippers/receivers (MDS, 2012).

These problems related to urban freight distribution are going to increase in the future because urbanization will bring more consumers in urban areas and more freight will be addressed to consumers since e-commerce is quickly increasing. Just some data: in Europe the total e-commerce revenue in 2012 was 305 billion of euro and the 43% of the European population buys habitually on line products and services (source: Eurostat). In 2012 in Italy e-commerce moved 76000 packages each day and, comparing with 2011, the growth rate was remarkable (15%). This growth trend is expected to continue (source: Osservatori.net).

In order to improve the efficiency of urban freight transport, the FURBOT freight transport system has been proposed (Cepolina and Farina, 2013b). This system is aimed at reducing the capillarity of last mile freight distribution, concentrating packages in fixed points and asking the receivers to collect them, like the Pack station operated by DHL in Germany. This system has been specifically designed for those places where, because of narrow roads, freight delivery through vans and medium-sized trucks is difficult or impossible. This system makes use of small vans, called FURBOT (i.e. Freight Urban RoBoTic vehicles), which have been specifically designed to limit the space occupancy as much as possible. The freight arrives at the Urban Distribution Centre (UDC), on the border of the urban area, in pallets (usually addressed only to retailers) or in packages (addressed to both retailers and end consumers). Freight could be addressed to retailers and end consumers. At the UDC, freight is split in load units. These have a standard dimension: 800 mm x 1200 mm x 1800mm (H) and two types of them have been designed: LBL box and FBL box. A LBL box is divided in parcels and each parcel can accommodate packages addressed to a given receiver. A FBL box instead contains an euro ISO pallet addressed to a given commercial activity place. Further details on the proposed boxes characteristics are provided in Cepolina and Farina (2013a). FBL boxes will be addressed as close as possible to commercial activities places, where enough space is available. Packages are clustered in LBL boxes in order to minimize the distance the receivers have to walk for collecting their packages. The unloading bay for each LBL box is baricentric of the addresses of the packages contained in it.

At the UDC, FURBOT vehicles are consolidated: each vehicle has the capacity of 2 boxes. According with the unloading bays assigned to the boxes, couples of boxes to be loaded on the vehicles are selected. Round trips with the origin and destination in the UDC and including the two stops where the two boxes should be unloaded, are assigned to each vehicle. According to the time at disposal for completing the freight distribution, each vehicle could perform more than one delivery trip. Then consolidated FURBOT vehicles deliver the boxes at their proper location. After the freight delivery is completed, consumers and retailers have to collect their freight in the boxes. The paper focuses on the vehicle consolidation problem.

The vehicle has been designed in order to limit the space occupancy as much as possible: it is 2 metres long, 1.8 metres wide, and 2 metres high. The weight of the vehicle is 1100 kg and its maximum payload is 850 kg. A design of the vehicle is provided in figure 1. The greatest majority of the vehicle dimensions consists on the load area (Dinale et al., 2013). The area for the driver is reduced to the minimum. The vehicle is provided with a fork lift system which allows an automatic unloading of the boxes in a short dwell time (Muscolo et al., 2014). This facility is highly important because it allows, on one hand to reduce the duration of delivery trips, on the other hand to limit the space occupancy because the unloading operation of the boxes is almost instantaneous.

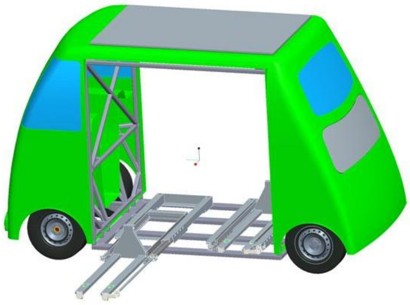

Figure 1. A representation of the FURBOT vehicle, with the load area and its fork lift system.

The vehicle is mounting a Lithium-polymer battery; the battery provides the power for the traction of the vehicle, the fork lift and the service (i.e. lighting, doors, sensors, control, braking, human machine interface). The battery is capable of providing 12.04 kWh and it has been dimensioned in order to provide enough power for about 5 hours of operation without being recharged. Thanks to the battery characteristics, opportunity charging is possible without memory effect. The battery has been developed by Mazel Ingenerios, a Spanish company which is partner of the FURBOT project. A system of sensors (laser scanners) is mounted on the vehicle to detect obstacles: this allows assisted driving of the FURBOT vehicle.

A simulation model of the proposed transport system has been developed. The simulator receives in input: the freight transport demand (which is stochastic, and changes day by day), the road network, the available time windows to perform deliveries, the number of available LBL boxes, and the boxes unloading bays. The number of available LBL boxes is assessed from the freight transport demand and is the minimum necessary to accommodate all the packages.

The simulator includes:

- An optimization procedure for the LBL box consolidation. This algorithm optimizes the boxes position and the consolidation of packages in the boxes according to receivers addresses. A fuzzy clustering logic has been adopted. Details of this algorithm are provided in Cepolina and Farina (2013a).
- An optimization procedure for determining the optimal delivery routes of FURBOT vehicles. This paper is focussed on this procedure.

These two optimization algorithms work in sequence.

The simulation outputs are:

- the number of required LBL boxes, and for each LBL box the cluster of packages that will be consolidated in each box and the boxes localization,
- Vehicle consolidation and routing and the number of FURBOT vehicles required

The paper is organized as follows. Section 2 describes in details the proposed methodology of the vehicles routing. Section 3 describes the application of the methodology to the field case study of Genoa, Italy, and the discussion of the results obtained. Conclusions follow.

2. The proposed methodology

The target of the vehicle consolidation and routing is to minimize the operative costs of the boxes delivery. A route is a round trip with one or two intermediate stops: one in the case the vehicle moves only one box or if the vehicle moves two boxes and the two boxes have the same unloading bay. The cost of a route *p* is the sum of the costs of the links belonging to *p*:

$$C_p = \sum_i c_i \delta_{ip} ; \qquad \delta_{ip} = \begin{cases} 1 \text{ if } & i \in p \\ 0 \text{ otherwise} \end{cases} \tag{1}$$

The link cost is a function of the battery power consumption and of the travel time:

$$Ci = f\,(power\ comsumption,\ ti) \tag{2}$$

The power consumption is a function of the link length, of the average speed on the link and of the average slope of the link. The travel time is a function of the average speed on the links and of the links lengths.

The problem of determining the optimum vehicle consolidation and routing can be reconducted to the Capacitated Vehicle Routing Problem (CVRP), with some modifications.

2.1. The existing capacitated vehicle routing problem

The Capacitated Vehicle Routing is one of the best known problems of Operative Research: a fixed fleet of delivery vehicles of a given capacity must service known customer demands for a single commodity from a common depot at minimum transit cost. The problem can be formalized as follows.

Given a *complete* graph $G = (V, A)$, where V is the set of nodes and A is the set of links, the nodes $i = 1,\dots, n$ correspond to customers, while the node “0” corresponds to the depot. Each link $(i, j) \in A$ has associated a non negative cost c_{ij}, which is the cost for running from the node i to the node j. In general, loops are not allowed and this is formalized by imposing $c_{ii} = +\infty \ \forall\ i \in V$. The number of routes is fixed a priori. K is the set of all routes. q_i is the demand associated to each customer visited by a circuit and C_k the capacity of the vehicle performing the route k.

Variable: $x_{ij}^k = \begin{cases} 1 \text{ if } (i, j) \in A \text{ belongs to the route } k, k \in K \\ 0 \text{ otherwise} \end{cases}$

Cost function:

$$\min \sum_{k\in K} \sum_{(i,j)\in A} c_{ij} x_{ij}^k \tag{3}$$

Constraints:

$$\sum_{k\in K} \sum_{j\in V} x_{ij}^k = 1 \qquad \forall i \in V \tag{4}$$

$$\sum_{i\in V} q_i \sum_{j\in V} x_{ij}^k \le C_k \qquad \forall k \in K \tag{5}$$

$$\sum_{j\in V} x_{0j}^k = 1 \qquad \forall k \in K \tag{6}$$

$$\sum_{i\in V} x_{ih}^k - \sum_{j\in V} x_{hj}^k = 0 \qquad \forall h \in C, \forall k \in K \tag{7}$$

$$\sum_{i\in V} x_{i,0}^k = 1 \qquad \forall k \in K \tag{8}$$

$$x_{ij} \in \{0,1\} \qquad \forall i, j \in V \tag{9}$$

The constraint (4) imposes that each customer is assigned exactly to one delivery route; the constraint (5) regards capacity constraints. Constraints (6), (7) and (8) impose to each vehicle to start from the depot (node 0), enter a generic node $h \in V$, leave this node and finally return to the depot.

2.2. The proposed problem formulation

In the proposed transport system, surveys on the field have shown that the freight demand may be very high and in several scenarios boxes cannot be accommodated everywhere but only in a given set of specific positions. In this case, several boxes are placed in the same bay, close to each other. In the formulations of the vehicle routing problem existing in literature, each customer can be can be served by only one vehicle and therefore each node can be crossed only once by the vehicles routes. If we consider the customer i of the previously described routing problem as an unloading bay, it may occur very often that the i's demand is greater than the vehicle capacity, because in an unloading bay more than 2 boxes can be accommodated. Therefore, we have decided to consider the customer i as a box position: if some boxes should be unloaded in the same bay, we will have several nodes with the same geographical coordinates.

Each FURBOT vehicle can carry one or two boxes, therefore each FURBOT route will be composed of 1 or 2 stops. The two stops are coincident if the two boxes are destined to the same unloading bay.

Therefore, the proposed routing algorithm simplifies the algorithms existing in literature in the following ways:

1. $q_i = 1 \quad \forall i \in V$;
2. if nodes i and j have the same geographical coordinates, $c_{ij} = 0$;
3. the vehicle capacity is equal to 2 (boxes) therefore $C_k = 2 \quad \forall k \in K$;
4. the vehicle load can be only 0, 1 or 2.

2.3. The solution algorithm

A genetic algorithm has been proposed for solving the routing problem. The fitness function is:

$$-\min \sum_{k\in K} \sum_{(i,j)\in A} c_{ij} x_{ij}^{k} \tag{10}$$

Genetic Algorithms (GAs) are adaptive heuristic search algorithms premised on the evolutionary ideas of natural selection and genetic. The basic concept of GAs is designed to simulate processes in natural system necessary for evolution, specifically those that follow the principles first laid down by Charles Darwin of survival of the fittest. As such they represent an intelligent exploitation of a random search within a defined search space to solve a problem.

GAs were introduced as a computational analogy of adaptive systems. They are modelled loosely on the principles of the evolution via natural selection, employing a population of individuals that undergo selection in the presence of variation-inducing operators such as mutation and recombination (crossover). A fitness function is used to evaluate individuals, and reproductive success varies with fitness.

A solution algorithm for this problem has been proposed by Ren (2012). We have slightly modified this algorithm to better adapt it to our problem.

The proposed algorithm works as follows. An initial population of n chromosomes is generated: $X^0 = \{x_1^0, \ldots, x_i^0, \ldots, x_n^0\}$. n has been assumed equal to 5 given the dimension of the problem. *Each* chromosome is composed of *all routes* that are performed in a given day. Each route is composed of 3 elements, i.e. the identifiers of the depot and of the two boxes loaded in the vehicle (the route is composed of 2 elements if only one box is loaded). At each generic iteration t of the algorithm, the following operations are applied:

1. A given population of X^t is known.
2. *Selection of the two "parents" chromosomes*: from the population X^t of chromosomes available at iteration t, the two chromosomes having the highest fitness are selected.
3. The following operations are applied n times: n is the number of "children" chromosomes created at the t^{th} iteration of the algorithm:

2.1. Among the two “parents” chromosomes, the chromosome is extracted, which will be used to generate the beginning of the child’s genome. We will call this chromosome “first chromosome” in the following. The other chromosome will be called “second chromosome”.

2.2. *Extraction of the routes in which crossover should be performed*: in order to preserve some parts of good genome, crossover will be performed in such a way to keep some routes of the chromosome unaltered. Therefore, according to Ren (2012), a string of 0 and 1 is extracted. Each element of the string corresponds to a route, therefore if K routes are performed, the string contains K elements. If the generic element k of the string, $k = 1,\ldots, K$, is equal to 0, then the crossover will be applied to the corresponding route. If the element of the string is equal to 1, no crossover will be applied to the corresponding route. For each route, the position of the crossover is extracted randomly.

2.3. *Crossover*: Each route is composed of 3 elements (2 elements if only one box is loaded). The position of the crossover, i.e. between the depot and the 1st stop, between the 1st stop and the 2nd stop, between the 2nd stop and the depot, is extracted randomly

2.4. *Integration of the missing elements, elimination of repeated elements:* It usually happen that for some boxes, the same box may appear several times in the chromosome “son” (each box should appear once) and some other boxes do not appear. Therefore, the repetitions of the same box are deleted (only the first time a given box appears in a chromosome is taken) and the missing boxes are integrated in the chromosome.

2.5. *Mutation*: Two positions in the chromosome are extracted. These positions must not correspond to the depot. The boxes corresponding to the two extracted positions are exchanged.

4. When the n children chromosomes are generated, the fitness of the children chromosomes is evaluated. The initial population of the $(t+1)^{th}$ iteration, i.e. X^{t+1}, is generated by deleting the n chromosomes having the least fitness.

A screenshot of this procedure is shown in figure 2.

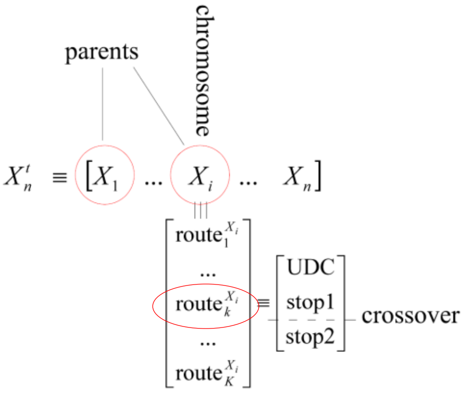

Fig. 2. Definition of the population of chromosomes

The algorithm is stopped when for 50 consecutive iterations the same two parents chromosomes are selected. Among these, the chromosome having the highest fitness will be the best solution.

The proposed algorithm determines: the routes which minimize the overall cost of the system, and the number of routes necessary to satisfy the demand, i.e. to deliver all the boxes. The algorithm provides also the trip times and the energy demand for the trip. Given the delivery time window, it is possible to calculate the number of required FURBOT vehicles.

2.4. Assumptions and limitations of the proposed approach

Two main assumptions have been made in the proposed approach. The first assumption refers to the overall simulation described in section 1: the optimization of the operative cost of the system is performed after the optimization of the users cost. More in detail, in our approach, at first the LBL boxes positions are determined according to the receivers addresses, in order to minimize the cost supported by them for collecting their freight. After, the FURBOT vehicle routing is optimized, according to the boxes positions determined at the previous step. This highly simplifies the problem but is quite a strong assumption, because the boxes positions determined according to the receivers addresses are not the optimum ones from the routing point of view.

The other assumption refers specifically to the routing problem the paper focuses on: the battery discharge and recharge process of the FURBOT vehicle is not taken into account explicitly. It is assumed that the battery duration is sufficient for the vehicle to perform the most consuming delivery trip. This assumption is consistent because the vehicle battery has been dimensioned with this aim. Indeed, in developing the battery prototype, several working cycles for the FURBOT vehicle were simulated, in several different scenarios.

3. The assessment of the FURBOT freight distribution schema performance in the Genoa urban area

3.1. The scenario under study and the input data

The historical city centre of Genoa is the oldest part of the city and it is organized in several small roads of middle-aged origin, called “carrugi”. These roads are much narrow (they are often less than 2 metres wide) and steep, and are completely restricted to private traffic, except for only the residents. The extension of the area is 1.2 km^2, however, the population density is one of the highest in Europe: in the area live about 20000 inhabitants. Moreover, 2106 commercial activities are registered there. In this area, usually freight deliveries are performed through vans, but several retails are however not accessible by them. Therefore often vans are parked in some dedicated places and deliveries are completed through trolleys. An average of 4500 deliveries are performed every day. Each delivery consists on an average of 4.5 packages.

The *urban distribution centre* (UDC) has been hypothesized besides the port, close to the highway gate, far about 1.5 km from the historical city centre, in an area where the density of road infrastructures is high.

FURBOT vehicles do not need any dedicated space for box unloading operations, since the operation is completely automatic and requires a very short time. FBL boxes are delivered close to the receiver’s address. Instead, *unloading bays* are needed to place the LBL boxes. On the whole, 33 places of Genoa historical city centre are available as potential unloading bays, they are homogeneously distributed in the territory and are capable to accommodate on the whole 2800 boxes.

The input data of the methodology are the road network and the number of LBL and FBL boxes.

Genoa road network consists on: the roads where FURBOT vehicles are allowed to travel, the localization of the UDC, the localization of LBL unloading bays, and the commercial activities addresses where FBL boxes must be delivered. The road network is represented through a set of links and nodes. Each 50 meters long road section has been represented through a node. Nodes represent: the UDC, FBL and LBL boxes positions, and road intersections. Each portion of road comprised between two nodes is represented through a link. A cost is associated to each link, which is function of the slope, link length and average speed.

The input data of the routing algorithm are the output of the clustering algorithm. The clustering assesses the number of LBL boxes, the boxes localization and the clustering of packages in the boxes. All these quantities are determined according to the freight transport demand. The freight transport demand consists on: the number of packages delivered per day, the packages dimensions and the receivers addresses. Both the demand directed to commercial activities and the demand directed to consumption zones (i.e. e-commerce) have been considered. The resulting average number of boxes to be delivered is equal to 1195 LBL boxes and 200 FBL boxes. The maximum distance walked by customers is equal to 362 m; the average walking distance is equal to 24.72m. The 1195 LBL boxes are accommodated in 33 unloading bays and their average load factor is 93%.

3.2. Results

The optimum number of delivery trips is 698. The total kilometers travelled each day are 4925.3 km. The maximum trip length is equal to 12 km and the average trip length is 7.0 km. The distribution of trip lengths is shown in figure 3. The average trip duration is equal to 40 minutes. The trip duration comprises also the time required for loading and unloading the vehicle: it is fixed and equal to 2-3 minutes for each box.

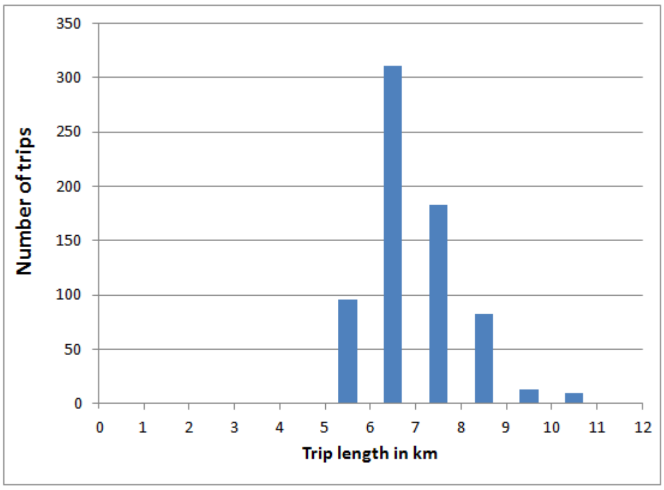

Fig. 3. The distribution of trip lengths

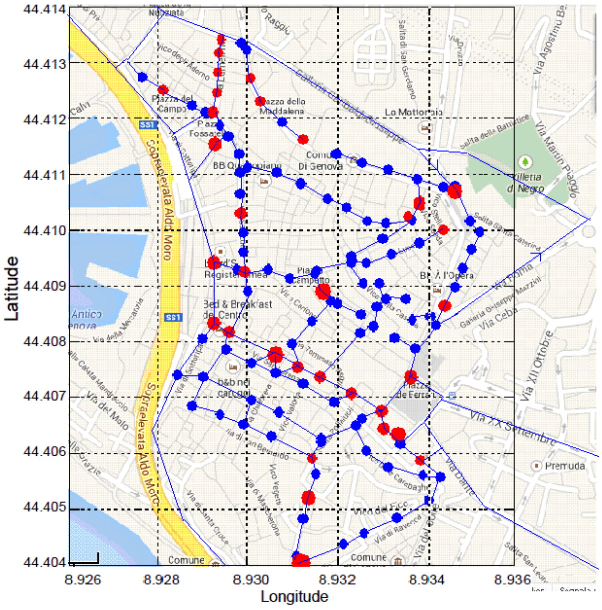

Figure 4. Possible localization of LBL and FBL boxes in the historical city centre of Genoa. LBL boxes are represented in red, the localization of FBL boxes is represented in blue. In the x axis the longitude of points is reported, while in the y axis the latitude is shown. Both latitude and longitude are expressed in decimal degrees. When several LBL boxes are placed in the same unloading bay, only one red dot is shown. The width of the red dot is proportional to the number of boxes placed in the same bay.

The delivery time window is assumed: from 6 a.m. to 7:30 a.m, and from 9 a.m. to 12 a.m. It has been chosen not to perform deliveries in the morning peak period therefore: on one hand delivery trips do not increase their duration because of road congestion, on the other hand impedance to passenger cars because of FURBOT vehicles is avoided. Moreover, during the peak hour FURBOT vehicles can be put in charge. Given the delivery time window, each vehicle is able to perform about 6.5 trips. Therefore at least 108 FURBOT vehicles are required to perform the deliveries.

The road network and the boxes positions are represented in figure 4. The blue dots correspond to the FBL boxes receivers, while the red dots are the localizations of LBL boxes. The dimensions of the red dot are proportional to the number of LBL boxes placed in each given position.

The number of trips performed by FURBOT vehicles is about half the number of trips currently performed by vans each day (data collected on the field in the projects MERCI and Genova Eco (Contursi, 2004; Merella, 2005)).

4. Conclusions

A new freight delivery system for urban areas has been proposed. This system has been specifically designed for those places where, because of narrow roads, freight delivery through vans and medium-sized trucks is difficult or impossible. This system makes use of small vans, called FURBOT (i.e. Freight Urban RoBoTic vehicles), which have been specifically designed to limit the space occupancy as much as possible. The vehicle is 2m long and 1.7 m wide. The loading space is 1.2 m long and 1.6 metres wide, as it has been dimensioned to accommodate two Euro pallets.

The proposed system makes use of boxes, whose footprint is that of an Euro pallet, i.e. 120 cm long and 80 cm wide. These boxes store the packages directed to receivers, who could be both commercial activities and individual consumers. Boxes are consolidated at the urban distribution centre (UDC) and are delivered through FURBOT vehicles to some specific temporary unloading bays, where boxes will be accessed by customers. The positions of potential FURBOT unloading bays, i.e. the areas where boxes can be placed, are fixed. FURBOT unloading bays are placed in areas easily accessible by FURBOT vehicles and where enough space is available to accommodate the boxes.

In the article a procedure for optimizing the FURBOT vehicles routing is presented. The faced problem can be reconducted to the Capacitated Vehicle Routing problem (CVRP). Some modifications to the originals problem have been proposed because the original CVRP problem requires that each customer must be served by maximum 1 delivery route. Instead in the proposed transport system, several boxes may have the same unloading bays, but the vehicle can carry maximum two boxes, therefore more than one delivery route stop at the same location. The proposed idea is to associate a customer, not to each commercial activity and to each unloading bay, but to each box, independently from the box position. In this way the solution algorithm for CVRP can be applied also to resolve out problem. The general problem is simplified by the fact that, in this configuration, each customer has a demand equal to 1 and the load of the FURBOT vehicle is equal to 0, 1 or 2.

According to Ren (2012), a genetic algorithm has been developed to resolve the FURBOT vehicle routing.

The proposed optimization model shows some limitations. Firstly, the optimizations of the users cost, which depends on the total distance walked by them to collect their packages, and of the operator cost, which depends on the overall distance travelled by vehicles, and by the number of required vehicles, have been performed in sequence. This highly simplifies the problem but is quite a strong assumption, because the boxes positions determined according to the receivers addresses are not the optimum ones from the routing point of view.

Secondly, the battery recharge procedure has been neglected. The battery of the vehicle has an autonomy of an average of 5 hours, which is enough to perform the most consuming delivery trip, but not enough for a vehicle to be always available to perform deliveries. Therefore the required fleet dimension should be affected by the time required for the recharging processes. This problem is faced by performing deliveries before and after the morning peak period, therefore on one hand FURBOT vehicles do not create impedance to passenger cars and public transport, on the other hand FURBOT vehicles have enough time to recharge the battery.

The overall transport system has been applied to the scenario of Genoa historical city centre. The application results show that the system has a good performance. In fact, the number of trips performed by FURBOT vehicles is 698, while the number of trips currently performed by vans each day is equal to 1303. Moreover, the load factor of LBL boxes is equal to 93%: this is a good result because the load factor of vans currently delivering the freight in Genoa is equal to 65% (Contursi, 2004). Furthermore, as FURBOT vehicles are electrically powered, the degree of pollution related to freight distribution is zero.

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