Objectives and motivation
This paper present preliminary results of the iNEXT (Innovation for green Energy and eXchange in Transportation) project (Smart Cities Italian national project). Within iNEXT CNR TAE Institute is involved in infrastructure, logistic and vehicles development with the aim to reduce the impact of transportation on the cities and touristic areas. iNEXT aims to support innovation in the field related to road transport and energy demand of buildings. Particularly, the first field promotes the use of ecological vehicles in passenger transport and freight distribution considering the energy production from renewable sources (RES). At the same time the project will address the development of production plants from RES with advanced electrochemical storage systems and hydrogen production/stORAGE able to interface the electric/hybrid vehicles under control of an ICT platform.

The freight distribution considers the use of an Urban Distribution Centre (UDC) and the optimization of the vehicle routes. The goal is twofold: the UDC allows reducing the number of freight vehicles in the downtown, the route optimization allows to minimize the energy consumption by the vehicles.

The paper discusses the elements of models and algorithms to solve the Vehicle Routing Problem (VRP) for city logistics. A real case application is reported.

General description
The freight distribution in an urban area is defined as the process for optimizing the logistics and transport activities considering the traffic conditions, congestion issues and combustible (or energy) consumption, with the aim to reduce the number of vehicles optimizing its operations (Taniyuchi et al., 1999). Two optimization levels are considered in this work: first, the use of an UDC to consolidate the freight and reduce the number of heavy vehicles in the city; second the route optimization of a fleet of light electric vehicles to minimize the energy consumption.

An Urban Distribution Centre (UDC) is a component of a multi-level distribution scheme implemented in several cities to reduce the impacts of freight distribution in urban areas (Cattaruzza et al., 2015). A Multi-level distribution considers that the freight is collected and stored in the UDC and hence delivered to users (i.e. retailers). This problem can be formulated as a VRP in which is introduced the use of electric vehicles and the energy minimization defining an Electric Vehicles - Vehicle Routing Problem (EV-VRP). 

The assumptions are that the energy consumption depend on the vehicle travelled distance (is not considered the vehicle load). The EV considered in this work is a new concept delivery van, designed to optimize the energy use and characterized by innovative features as a new type of rolling chassis, a different upper body solutions, high payload and a lifting platform.

The urban freight distribution is affected, in several cases, by temporal constraints (i.e. the delivery operations can be made only in time windows established in advance). To take this into account, it is proposed a EV-VRP with Time Windows (EV-VRPTW) as follows. Being $G (N, L)$ a graph schematizing the road supply, with $N$ the set of users and $L$ the set of links. Moreover, being $Z \subseteq N$ a subset of $N$ containing the users and the UDC. The problem is formulated as a minimum problem respect to a variable vector $X$.

Objective function

Minimize $f(X) = \sum_{i=1}^{m} \sum_{j=1}^{N} d_{ij} \cdot x_{ij}$

$d_{ij}$ is the distance to move from $i$ to $j$;
$x_{ij}$ is a binary variable (1 if the vehicle $v$ move from $i$ to $j$, 0 otherwise)

Constraints

\[ \sum_{i=1}^{m} \sum_{j=1}^{N} x_{ij} = 1 \quad \forall i \in Z, i \neq d, j \neq d \]  
\[ \sum_{i=1}^{m} \sum_{j=1}^{N} x_{ij} = m \]  
\[ \sum_{v=1}^{V} \sum_{j=1}^{N} x_{iv} = m \]  
\[ \sum_{i=1}^{m} \sum_{j=1}^{N} x_{ij} \leq d_{v} \quad \forall v \in V \]  
\[ x_{iv} \in \{ 0, 1 \} \quad \forall i, j, v \in V \]  
\[ e_{ti} \leq e_{rt} \quad \forall i, j \in Z \]  
\[ e_{ti} + e_{rt} \leq e_{rt} \quad \forall i, j \in Z \]

where:
$v$ is the quantity delivered at node $j$;
$V = \{ 1, 2, \ldots m \}$ is the vehicle set;
\( b_i \) is the vehicle capacity;
\( e_t \) is the arrival instant at node \( j \);
\([l_t, r_t] \) is the time window at node \( j \);
\( o_t \) the operation time at node \( j \).
The constraint (2) indicate that a node can be reached only once; the constraints (3) and (4) impose that the vehicles start from the depot and return to it; the constraint (5) is related to vehicle capacity; the constraints (6) indicate that the problem variable is binary; constraints (7) and (8) are the time window constraints.

### Results and conclusions

A real case application is made in Capo d'Orlando city (about 40,000 inhabitants) located in Sicily (Italy). The UDC is placed in the suburb of the city (about 5 kilometres from the downtown), reachable by a main road. A set of 84 retailers is considered, the freight is referred to traditional groupage market, not are considered perishable goods. The electric vehicles have a capacity of 2 euro pallets and an autonomy of about 100 km, the energy consumption in the urban context under analysis is assumed proportional to the distance travelled. Table 1 resume some results obtained optimizing the vehicle routes, the UDC is labelled with 150, the other labels indicate the retailers. Figure 1 shows an example of designed routes. A second level of optimization consists on assign the route at the vehicles, with the constraint that a driver turn may not exceed seven hours. With this assumption, two vehicles are sufficient to guarantee the service.

#### Table 1: Some results

<table>
<thead>
<tr>
<th>Routes</th>
<th>Time (h)</th>
<th>Load (kg)</th>
<th>Distance (m)</th>
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<tbody>
<tr>
<td>441-293-292-437-297-299-301-340-150</td>
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<td></td>
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<tr>
<td>150-235-240-440-422-176-180-421-279-150</td>
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<tr>
<td>150-423-218-221-223-226-227-229-426-324-150</td>
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<tr>
<td>150-338-334-347-362-150</td>
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<td>150-354-150</td>
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<td>1.422,80</td>
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<td><strong>10:45</strong></td>
<td><strong>1.727,20</strong></td>
<td><strong>96.732,70</strong></td>
</tr>
</tbody>
</table>

#### References

#### Keywords: city logistics; urban distribution centre; electric vehicles; vehicle routing problem.