Planning urban distribution center location with variable restocking demand scenarios: general methodology and testing in a medium-size town

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Linked areas of smart city (European Commission, 2012)
Planning for Smart mobility

- Transport planning
- ICT planning
- Energy planning
In this paper (for freight distribution in urban area)

Assumption:
Output of ICT and Energy planning are external input in this paper
In this paper (for freight distribution in urban area)
Novelties (support feasibility analysis with ex ante evaluations)

Trade-off between public authority and management (needs/objectives) in a smart city

- Policy (sections *.1)
- Freight Planning (sections *.2)
Introduction

**Novelties** (support feasibility analysis with ex ante evaluations)

Trade-off between public authority and management (needs/objectives) in a smart city

- Policy
- Freight Planning

(sections *.1)
(sections *.2)

1. State of the art
   - Policy
   - Freight Planning

2. Method
   - Policy
   - Freight Planning

3. Test case
   - Policy
   - Freight Planning

4. Conclusion
1. State of the art

1.1 Policy

<table>
<thead>
<tr>
<th>Sustainable objectives and indicators</th>
<th>Economic</th>
<th>Social</th>
<th>Environmental</th>
</tr>
</thead>
</table>

City logistics measures
(Holguín-Veras, 2007; Russo and Comi, 2011; Silas et al., 2012; Nuzzolo et al., 2016)

UDC planning/management models (Tario et al., 2011)

- Regulatory context
- Transportation solutions
- Actors in planning and financing
- Responsibility for the delivery
- Spatial coverage and location
1. State of the art

1.2 Freight Mobility Planning

**Location problem**

- Physical infrastructures
  - Daganzo, 1988; Tario et al., 2011; Janjevic et al., 2016, ..

- UDC
  - Barahona and Jensen, 1998; Taniguchi et al., 1999; Syam, 2002; Syam, 2002; Browne et al., 2007; Yang et al., 2007; Sun et al., 2008, van Rooijen, 2010; Ubeda et al., 2011; Browne et al, 2011; Morganti and Żak and Węgliński, 2014; Gonzalez-Feliu, 2015;

**Vehicle Routing Problem**

- Routing
  - Laporte, 2009; Lin et al., 2016; ..

- Location and routing
  - Nagy and Salhi, 2007; Hiermann et al., 2016; Keskin and Çatay, 2016; Lin et al., 2016; ..
## 2. Method

<table>
<thead>
<tr>
<th>Planning, financing and management</th>
<th>Spatial coverage for Distribution Centre (DC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban (U) area (few solutions)</td>
<td>Metropolitan (M) area (many solutions)</td>
</tr>
<tr>
<td>Public-Private-Partnership (PPP)</td>
<td>PPP-UDCs</td>
</tr>
<tr>
<td>Private Company (PC)</td>
<td>PC-UDCs</td>
</tr>
<tr>
<td></td>
<td>PC-MDCs</td>
</tr>
</tbody>
</table>
2. Method

- Objectives and constraints
  - Electrical vehicles and grids
  - Energy planning
  - Freight planning
  - Measures (UDC location, ...)
  - Hardware, software and data
  - ICT planning
2. Method

- Objectives and constraints
  - Electrical vehicles and grids
    - Energy planning
  - Location (Outer)
    - Delivering (Inner)
    - Freight planning
  - Measures (UDC location)
  - Hardware, software, and data
    - ICT planning
2. Method

2.1 Policy

Objectives (O), constraints (G)

Selected UDC location (I_b) and routes X_i

VRP

Energy planning

Electrical vehicles and grids

Freight planning

Hardware, software and data

ICT planning

Energy planning
2. Method

2.1 Policy

- Feasible UDC locations: \( I = \{I_1, I_i, \ldots\} \)
- Retailers demand scenarios: \( R \)
- Ri-definition of Objectives, Constraints, Locations

**Freight planning (Outer level)**

**VRP (Inner level)**

- Objectives (O), constraints (G)

- Selected UDC location \( (I_b) \) and routes \( X_i \)

**Energy planning**
- Electrical vehicles and grids
- ICT planning

**Hardware, software and data**
2. Method

### 2.1 Policy

**Objectives (O), constraints (G)**

- **Carriers services design (VRP)**
- **Freight transp. services (routes) \( X_i \) for each \( l_i \)**
- **Sustainability indicators \( \varphi \) for each \( l_i \)**

**Feasible UDC locations**

\( I = \{ l_1, l_i, \ldots \} \)

**Retailers demand scenarios (R)**

**Ri-definition of Objectives, Constraints, Locations**

**Freight planning (Outer level)**

**VRP (Inner level)**

**Carriers services design (VRP)**

**Freight transp. services (routes) \( X_i \) for each \( l_i \)**

**Sustainability evaluation for each \( l_i \)**

**Selected UDC location \( (l_b) \) and routes \( X_i \)**

**Best solution**

**At least for one \( l_i \), goals reached and constraints respected**

**Yes**

**No**

**Energy planning**

**Electrical vehicles and grids**

**ICT planning**

**Hardware, software and data**
## 2. Method

### 2.2 Freight Mobility Planning

**Some specifications**

<table>
<thead>
<tr>
<th>Sustainable objectives (O)</th>
<th>Criterion (example)</th>
<th>Indicators (example)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Economic</strong></td>
<td>Maximum efficiency</td>
<td>Travel times</td>
</tr>
<tr>
<td><strong>Environmental</strong></td>
<td>Minimum pollution</td>
<td>Amount of greenhouse emissions</td>
</tr>
<tr>
<td><strong>Social</strong></td>
<td>Minimum social effects</td>
<td>Number of road accidents</td>
</tr>
</tbody>
</table>
## 2. Method

### 2.2 Freight Mobility Planning

**Some specifications**

<table>
<thead>
<tr>
<th>Constraints (G)</th>
<th>Outer level (UDC location) constraints ($G_0$) (Examples)</th>
<th>Inner level (Freight delivery) constraints ($G_l$) (Examples)</th>
<th>Analytic expression</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Economic and monetary</strong></td>
<td>monetary budget (€) available energy (kw/h)</td>
<td>management contracts (€)</td>
<td>$\varphi_F(l_i \mid T, R) \leq B_F$</td>
</tr>
<tr>
<td><strong>Environmental</strong></td>
<td>greenhouse emissions (g)</td>
<td>vehicle unitary emissions (g/km)</td>
<td>$\varphi_A(l_i \mid T, R) \leq B_A$</td>
</tr>
<tr>
<td><strong>Social</strong></td>
<td>social risk</td>
<td>Drivers risk (individual)</td>
<td>$\varphi_S(l_i \mid T, R) \leq B_S$</td>
</tr>
</tbody>
</table>
## 2. Method

### 2.2 Freight Mobility Planning

**Some specifications**

<table>
<thead>
<tr>
<th>Constraints (G)</th>
<th>Outer level (UDC location) constraints ($G_o$) (Examples)</th>
<th>Inner level (Freight delivery) constraints ($G_i$) (Examples)</th>
<th>Analytic expression</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technical</strong></td>
<td>territorial characteristics (km²)</td>
<td>driving range of electric vehicles (km)</td>
<td>$\varphi_T(l_i \mid T, R) \leq B_T$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>recharge battery time (h)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>maximum number of vehicle (n.)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>maximum vehicle capacity (ton)</td>
<td></td>
</tr>
</tbody>
</table>
## 2. Method

### 2.2 Freight Mobility Planning

**Some specifications**

<table>
<thead>
<tr>
<th>Constraints (G)</th>
<th>Outer level (UDC location) constraints (G&lt;sub&gt;o&lt;/sub&gt;) (Examples)</th>
<th>Inner level (Freight delivery) constraints (G&lt;sub&gt;i&lt;/sub&gt;) (Examples)</th>
<th>Analytic expression</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normative</td>
<td>temporal restrictions (time windows) (hh.mm)</td>
<td>Freight classes restrictions (e.g. dangerous goods)</td>
<td>$\varphi_N(l_i \mid T, R) \leq B_N$</td>
</tr>
<tr>
<td></td>
<td>spatial restrictions (restricted zone) (km&lt;sup&gt;2&lt;/sup&gt;)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2. Method

2.2 Freight Mobility Planning

Location Problem (outer level)

\[ l_b = \arg \min_{l_i \in l} \varphi_E(l_i \mid T, R) \]

subject to the constraints \((G_o)\)
2. Method

2.2 Freight Mobility Planning

**Vehicle Routing Problem (inner level)**

\[ \varphi_{\text{sc}_E}(l_i, h| T, R) = \arg \min_{\Gamma|l_i,h} g_{\Gamma|l_i} \]

subject to the constraints \((G_i)\)

and

\[ \varphi_E(l_i | T, R) = \sum_h f_h \cdot \varphi_{\text{sc}_E}(l_i, \text{sc}_h | T, R) \]
3. Test case

**Study area**
- Central area of Reggio Calabria

**Goal**
- Increase sustainable mobility

**Data**
- 3 location - 23 retailers (15 daily)
### 3. Test case

#### 3.1 Policy

| Environmental scenario | • delivered using FEVs  
|                        | • minimize the amount of pollution  
|                        | • investing large quantity of financial resources |
| Economic scenario      | • delivered using TFVs with high EURO standard  
|                        | • threshold of pollution emission ($\delta_1$)  
|                        | • minimising financial resources |
| Viable scenario        | • delivered using a mix of FEVs and TFVs  
|                        | • threshold of pollution emission ($\delta_2 < \delta_1$)  
|                        | • trade-off between emissions and financial res. |
### 3. Test case

#### 3.1 Policy

<table>
<thead>
<tr>
<th>Policy scenario</th>
<th>Outer level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Environmental</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Objective Criterion</th>
<th>Min pollution</th>
<th>Min resources</th>
<th>Min pollution and resources</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Quantity of CO₂</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Environmental Constraints</th>
<th>CO₂ ≦ 0</th>
<th>CO₂ ≤ δ₁</th>
<th>CO₂ ≤ δ₂</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Policy scenario</th>
<th>Inner level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Environmental</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Objective Criterion</th>
<th>Max efficiency</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Travel times</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Environmental Constraints</th>
<th>FEV</th>
<th>TFV</th>
<th>FEV and TFV</th>
</tr>
</thead>
</table>
3.2 Freight Mobility Planning

*Inner level*

<table>
<thead>
<tr>
<th>Travel Time (sec)</th>
<th>UDC location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$l_1$</td>
</tr>
<tr>
<td>Value, $\varphi_E$</td>
<td>17406</td>
</tr>
<tr>
<td>(SQM)$^{0.5}$</td>
<td>133</td>
</tr>
</tbody>
</table>
### 3. Test case

#### 3.2 Freight Mobility Planning

**Outer level**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>UDC</th>
<th>UDC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$l_1$</td>
<td>$l_2$</td>
</tr>
<tr>
<td>Environmental</td>
<td>Cost EV (€/day)</td>
<td>CO$_2$ (kg/day)</td>
</tr>
<tr>
<td>Value</td>
<td>138</td>
<td>124</td>
</tr>
<tr>
<td>(SQM)$^{0.5}$</td>
<td>40.1</td>
<td>47.1</td>
</tr>
<tr>
<td>Economic</td>
<td>Cost EV (€/day)</td>
<td>CO$_2$ (kg/day)</td>
</tr>
<tr>
<td>Value</td>
<td>107</td>
<td>96</td>
</tr>
<tr>
<td>(SQM)$^{0.5}$</td>
<td>0.8</td>
<td>0.9</td>
</tr>
<tr>
<td>Viable</td>
<td>Cost EV (€/day)</td>
<td>CO$_2$ (kg/day)</td>
</tr>
<tr>
<td>Value</td>
<td>Between the Environmental and Economic scenarios</td>
<td></td>
</tr>
<tr>
<td>(SQM)$^{0.5}$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4. Conclusion

Results
Methodology that integrates public and private point of views

Further
Advanced tools and procedure for planning support

Optimum method for location and management costs

Extension in the case of large area with high number of possible location