Evaluation of GHG emissions for Road and Rail/Public Transport Projects

Elisabet Vila Jorda, Neri di Volo - JASPERS

Brussels, 29th & 30th September 2015
F.8.2. Explain how climate change related risks, adaptation and mitigation considerations and disaster resilience have been taken into consideration.

**Aim:** What types of assessments have been carried out and how climate change has been considered in the whole project development?

- **calculation of GHG emissions**
- **adapting infrastructure to a changing climate through all project preparation**

**Guidance Questions:** How were the volume of GHG externality and the external cost of carbon assessed? What is the shadow cost of GHG and how has it been integrated in the economic analysis?...

Link to E.2 section.
Regulatory framework

- CBA must take into account costs and benefits of the project in the context of GHG emissions and climate change.
- Calculation of GHG emissions based on recognised and transparent methodology.


- Proposed approach to integrate CC externalities into economic analysis is based on EIB Carbon Footprint

“European Investment Bank Induced GHG Footprint - Methodologies for the Assessment of Project GHG Emissions and Emission Variations ”, EIB, April 2014

http://www.eib.org/attachments/strategies/eib_project_carbon_footprint_methodologies_en.pdf
Evaluation of GHG emissions (I)

Steps:

1. Quantification of emissions saved/emitted to atmosphere
2. Calculation of CO2e
3. Evaluation of externality using unit cost of CO2e

Cost of GHG emissions =

\[ V_{GHG} \times C_{GHG} \]

- **Incremental volume of GHG emissions produced by the project (tC02e)**
- **Unit shadow price of CO2e**

<table>
<thead>
<tr>
<th>Value 2010 (Euro/t-CO2e)</th>
<th>Annual adders 2011 to 2030 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>40</td>
</tr>
<tr>
<td>Central</td>
<td>25</td>
</tr>
<tr>
<td>Low</td>
<td>10</td>
</tr>
</tbody>
</table>

Source: EIB (2013)
Evaluation of GHG emissions (II)

Metrics: Which emissions to measure and report in AF?

- **Absolute emissions**: total emissions produced by the project in a typical operating year (tCO2e)

- **Relative emissions**: incremental emissions (increase/saved) between investment and non-investment options considered in the CBA in a typical operating year (tCO2e)
Project boundaries

- **Scope 1 - Direct GHG emissions**: emissions physically occurring from sources that are operated by the project within the project boundary - e.g. emissions produced by the combustion of fossil fuels (normally not applicable in transport infrastructure projects as there are not usually direct emissions associated with the infrastructure).

- **Scope 2 - Indirect GHG emissions**: account for GHG emissions from the generation of electricity that is consumed by the project. The indirect emissions are produced outside the project boundary (i.e. at power plant level) but since a project has control over consumption and can improve it with energy efficiency measures, emissions should be allocated to the project.

- **Scope 3 - Other indirect GHG emissions**: consequence of the activities of the project but that occur from sources not operated by the project.
What are the GHG emissions generated by transport projects?

Transport projects GHG assessment will mainly refer to the consequences of the project activities (Scope 2 and Scope 3 Indirect GHG emissions), i.e. vehicles travelling on the physical transport infrastructure. The GHG relative emissions are calculated based on the displacement of passengers from one type of transport to another (modal shift effects), shifts in travel patterns (one road to another or from one time of day to another) and the induced increase in passengers / traffic. If the Project also includes the replacement of rolling stock, the savings in emissions from this intervention should also be taken into account. This can be both direct - e.g. scope 1 when replacing buses, or indirect – e.g. scope 2 when replacing trams.
Calculation principle

For each option, multiply the transport volume data by the emission factors

- Road modes: transport volume are total veh-km considered on a certain time frame (e.g. year)
  - *Emission factors are dependent on fuel consumption and therefore on the vehicle category, speed, road condition and road geometry.*

- Public Transport: transport volume is the yearly service production (veh-km or train-km), and for consumption/emissions
  - *Rail modes and trolleybuses/electric buses:*
    - the power consumption rate per electrical vehicle or train (in KWh/veh-km or KWh/train-km);
    - the CO$_2$e emission factor (tCO$_2$/KWh).
  - *Buses:*
    - Same calculation as for road modes.
Example 1: Polish national CBA guide for Roads - Blue Book

Calculation of GHG emissions economic impact

\[ K_{ZK} = 365 \cdot \sum_{j=1}^{2} k_{zk,j} \left( V_{pdrt,j}, T, S \right) \cdot W_j^{km} \]

Emission factor

- \( (Tn \ CO_2e/vehkm) \)

**Speed (km/h)** | Unit climate change factors - \( tCO2/veh-km \) - flat terrain (pavement after rehabilitation/construction)
---|---
LV | HGV
---|---
0-10 | 0,000267 | 0,000999
11-20 | 0,000242 | 0,000900
21-30 | 0,000222 | 0,000825
31-40 | 0,000206 | 0,000772
41-50 | 0,000195 | 0,000741
51-60 | 0,000188 | 0,000732
61-70 | 0,000186 | 0,000746
71-80 | 0,000188 | 0,000783
81-90 | 0,000195 | 0,000842
91-100 | 0,000206 | 0,000923
101-110 | 0,000222 | 0,001027
111-120 | 0,000242 | 0,001154
121-130 | 0,000267 | 0,001402
131-140 | 0,000296 | 0,001673

**CO2e unit cost**

- \( (€/Tn \ CO_2e \ or \ PLN/Tn \ CO_2e) \)

\[ \text{25 €/Tn in 2010} \]
\[ \text{annual adders 1 €/Tn} \]
\[ \text{(price level 2006)} \]

To be actualized and expressed at the prices of the year of which analysis is carried out.

Unit cost 2015:

143.61 PLN/tCO2e (price level 2014)

**Transport work**

- \( (veh-km) \)

**Example 1:** Polish national CBA guide for Roads - Blue Book

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- \( (veh-km) \)

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**Emission factor**

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\[ \text{(price level 2006)} \]

To be actualized and expressed at the prices of the year of which analysis is carried out.

Unit cost 2015:

143.61 PLN/tCO2e (price level 2014)

**Transport work**

- \( (veh-km) \)
Example 2: Calculation of GHG emissions – Road project

Construction of new motorway section of about 16 km

- New TEN-T section
- Existing road has reached its capacity limit
- Mostly transit traffic
- Existing road running through small and medium towns intersecting with roads of lower category and causing congestion related effects and lowering traffic safety conditions.
Example 2: Calculation of GHG emissions – Road project

Calculation approach

- Climate change impact is estimated as part of the project economic impacts in the CBA
- Incremental approach
- “Project option” and “Without-the-project option” are the same ones and include the same network of analysis as for rest of CBA
Example: Calculation of GHG emissions – Road project

Input data: Traffic forecasts

- Source: Traffic model results
- No induced traffic considered
**Example: Calculation of GHG emissions – Road project**

**Input data: Average running speeds**

<table>
<thead>
<tr>
<th>Section</th>
<th>Length (km)</th>
<th>Without project</th>
<th></th>
<th></th>
<th>With project</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Year 1</td>
<td>Year 20</td>
<td>Year 1</td>
<td>Year 20</td>
<td>Year 1</td>
<td>Year 20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LV</td>
<td>HGV</td>
<td>LV</td>
<td>HGV</td>
<td>LV</td>
<td>HGV</td>
</tr>
<tr>
<td>E2</td>
<td>1.7</td>
<td>51.4</td>
<td>46.5</td>
<td>41.0</td>
<td>40.2</td>
<td>64.7</td>
<td>53.8</td>
</tr>
<tr>
<td>E3</td>
<td>3.6</td>
<td>35.2</td>
<td>35.2</td>
<td>31.9</td>
<td>31.9</td>
<td>38.8</td>
<td>38.6</td>
</tr>
<tr>
<td>E4</td>
<td>3.1</td>
<td>42.7</td>
<td>42.1</td>
<td>32.3</td>
<td>31.8</td>
<td>57.2</td>
<td>53.0</td>
</tr>
<tr>
<td>E5</td>
<td>3.7</td>
<td>40.6</td>
<td>39.3</td>
<td>34.5</td>
<td>33.9</td>
<td>54.8</td>
<td>51.0</td>
</tr>
<tr>
<td>E6</td>
<td>5.6</td>
<td>69.0</td>
<td>57.6</td>
<td>55.1</td>
<td>47.5</td>
<td>79.1</td>
<td>63.6</td>
</tr>
<tr>
<td>N1</td>
<td>5.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>104.8</td>
<td>75.2</td>
</tr>
<tr>
<td>N2</td>
<td>10.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>113.0</td>
<td>74.5</td>
</tr>
<tr>
<td>N3</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>79.7</td>
<td>70.0</td>
</tr>
</tbody>
</table>

*Source: Traffic model results*
Example: Calculation of GHG emissions – Road project

Calculation of yearly emission volumes for each option

<table>
<thead>
<tr>
<th>Emissions Volume $(Tn \ CO_{2e})$ in a given year</th>
<th>Traffic volume $(AADT, \ veh/day)$</th>
<th>Length of road $(km)$</th>
<th>Emission factor $(Tn \ CO_{2e}/vehkm)$ (dependent on fuel consumption)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$365$</td>
<td>$X$</td>
<td>$X$</td>
<td>$X$</td>
</tr>
</tbody>
</table>

Emission factors - Assumptions considered:

Fuel Consumption $(l/100km)$ – flat terrain and good road condition

<table>
<thead>
<tr>
<th>$v$ $(km/h)$</th>
<th>LV</th>
<th>HGV</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>10.85</td>
<td>38.46</td>
</tr>
<tr>
<td>20</td>
<td>9.85</td>
<td>34.68</td>
</tr>
<tr>
<td>30</td>
<td>9.03</td>
<td>31.77</td>
</tr>
<tr>
<td>40</td>
<td>8.39</td>
<td>29.72</td>
</tr>
<tr>
<td>50</td>
<td>7.93</td>
<td>28.54</td>
</tr>
<tr>
<td>60</td>
<td>7.66</td>
<td>28.23</td>
</tr>
<tr>
<td>70</td>
<td>7.57</td>
<td>28.78</td>
</tr>
<tr>
<td>80</td>
<td>7.66</td>
<td>30.19</td>
</tr>
<tr>
<td>90</td>
<td>7.94</td>
<td>32.48</td>
</tr>
<tr>
<td>100</td>
<td>8.40</td>
<td>35.62</td>
</tr>
<tr>
<td>110</td>
<td>9.04</td>
<td>-</td>
</tr>
<tr>
<td>120</td>
<td>9.86</td>
<td>-</td>
</tr>
<tr>
<td>130</td>
<td>10.87</td>
<td>-</td>
</tr>
</tbody>
</table>

Share of vehicles type

<table>
<thead>
<tr>
<th>Share of vehicles type</th>
<th>LV</th>
<th>HGV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel</td>
<td>50%</td>
<td>100%</td>
</tr>
<tr>
<td>Gasoline</td>
<td>50%</td>
<td>-</td>
</tr>
</tbody>
</table>

CO2 Emissions Diesel (g / litre) | 2,338
CO2 Emissions Gas (g / litre)   | 2,611

From VOC (based on national fleet data)

Depending on
- Vehicle
- Road geometry
- Road condition
**Example: Calculation of GHG emissions – Road project**

Calculation of yearly emission volumes for each option

<table>
<thead>
<tr>
<th>Emissions Volume (Tn CO$_{2e}$) in a given year</th>
<th>Traffic volume (AADT, veh/day)</th>
<th>Length of road (km)</th>
<th>Emission factor (Tn CO$_{2e}$/vehkm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>365</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

To be applied for each of the sections considered in the given option and each year of the analysis period

<table>
<thead>
<tr>
<th>C02 emission WITHOUT project</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>..</th>
<th>...</th>
<th>25</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>C02 emission WITH project</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C02 emission Difference</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Example: Calculation of GHG emissions – Road project

Calculation of absolute and relative project emissions

<table>
<thead>
<tr>
<th>Section</th>
<th>Length (km)</th>
<th>CO2 emissions (tC02e) - Average Operating Year</th>
<th>Without project</th>
<th>With project</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>LV (t)</td>
<td>HGV (t)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>LV (t)</td>
<td>HGV (t)</td>
</tr>
<tr>
<td>E2</td>
<td>1.7</td>
<td>2,384.54</td>
<td>2,851.99</td>
<td>561.81</td>
</tr>
<tr>
<td>E3</td>
<td>3.6</td>
<td>6,158.03</td>
<td>7,914.86</td>
<td>2,042.18</td>
</tr>
<tr>
<td>E4</td>
<td>3.1</td>
<td>4,089.48</td>
<td>5,269.47</td>
<td>1,243.47</td>
</tr>
<tr>
<td>E5</td>
<td>3.7</td>
<td>4,881.00</td>
<td>6,289.37</td>
<td>1,202.49</td>
</tr>
<tr>
<td>E6</td>
<td>5.6</td>
<td>5,648.26</td>
<td>7,313.67</td>
<td>853.27</td>
</tr>
<tr>
<td>N1</td>
<td>5.7</td>
<td>-</td>
<td>5,362.02</td>
<td>6,618.22</td>
</tr>
<tr>
<td>N2</td>
<td>10.7</td>
<td>-</td>
<td>9,277.36</td>
<td>10,283.78</td>
</tr>
<tr>
<td>N3</td>
<td>2</td>
<td>-</td>
<td>548.59</td>
<td>877.66</td>
</tr>
</tbody>
</table>

**Total CO2 emissions (tC02e)**:

Absolute emissions = (21,091.18 t + 26,622.27 t) = 32.97 ktCO2e

Relative emissions = (21,091.18 t + 26,622.27 t) – (23,161.31 t + 29,639.36 t) = - 5.09 ktCO2e (Savings)
Calculation of GHG emissions for Road Project – conclusions and considerations

- Calculation presented is based on certain assumptions (VOC – speed flows, fuel consumption model, no induced traffic) that will depend on the project/country

- Calculation presented is assuming some simplifications that can be enhanced (e.g. vehicles efficiency over time)

- Traffic models can already include a module for CO2 calculations (or other specific models such as HDM); then, it is necessary to present and justify assumptions considered

- Example results in CO2 savings but road infrastructure projects can also result in CO2 increase
Example: Calculation of GHG emissions – Public Transport project (urban case)

Calculation approach (1)

- Climate change impact is estimated as part of the project economic impacts in the CBA - “Project option” and “Without-the-project option” are the same ones and include the same network of analysis as for rest of CBA

- Absolute emissions = emissions from operation of the project

| Emissions Volume (Tn CO₂e) in a given year | Service production (Veh-km or Train-km) | Energy consumption (Trams/Trolleybuses: KWh/veh-km or KWh/train-km) | Buses: litres/veh-km | Emission factor (Trams/Trolleybuses: Tn CO₂e/KWh Buses: Tn CO2/litre) |
Example: Calculation of GHG emissions
Public Transport project (urban case)

Calculation approach (1)

- Climate change impact is estimated as part of the project economic impacts in the CBA - “Project option” and “Without-the-project option” are the same one and include the same network of analysis as for rest of CBA.

- Absolute emissions = emissions from operation of the project

### Emissions (g/veh-km) - URBAN CYCLE

<table>
<thead>
<tr>
<th>Bus</th>
<th>Service</th>
<th>Energy consumption</th>
<th>Urban Buses</th>
</tr>
</thead>
<tbody>
<tr>
<td>NoX</td>
<td>17.928</td>
<td>12.550</td>
<td>8.964</td>
</tr>
<tr>
<td>VOC</td>
<td>2.005</td>
<td>1.504</td>
<td>1.403</td>
</tr>
<tr>
<td>SO2</td>
<td>0.204</td>
<td>0.204</td>
<td>0.204</td>
</tr>
<tr>
<td>PM</td>
<td>0.879</td>
<td>0.602</td>
<td>0.404</td>
</tr>
<tr>
<td>CO2</td>
<td>1132.855</td>
<td>1132.876</td>
<td>1132.829</td>
</tr>
</tbody>
</table>

### EU 27 Countries + Croatia

<table>
<thead>
<tr>
<th>Country</th>
<th>CO2 emission factor (kgCO2/KWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>0.214</td>
</tr>
<tr>
<td>Belgium</td>
<td>0.260</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>0.448</td>
</tr>
<tr>
<td>Croatia</td>
<td>0.318</td>
</tr>
<tr>
<td>Cyprus</td>
<td>0.758</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>0.527</td>
</tr>
<tr>
<td>Denmark</td>
<td>0.341</td>
</tr>
<tr>
<td>Estonia</td>
<td>0.640</td>
</tr>
<tr>
<td>Finland</td>
<td>0.242</td>
</tr>
<tr>
<td>France</td>
<td>0.085</td>
</tr>
<tr>
<td>Germany</td>
<td>0.404</td>
</tr>
<tr>
<td>Greece</td>
<td>0.725</td>
</tr>
<tr>
<td>Hungary</td>
<td>0.344</td>
</tr>
<tr>
<td>Ireland</td>
<td>0.535</td>
</tr>
<tr>
<td>Italy</td>
<td>0.404</td>
</tr>
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<td>Latvia</td>
<td>0.167</td>
</tr>
<tr>
<td>Lithuania</td>
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</tr>
<tr>
<td>Luxembourg</td>
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<td>Malta</td>
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<td>Netherlands</td>
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<td>Poland</td>
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</tr>
<tr>
<td>Portugal</td>
<td>0.416</td>
</tr>
<tr>
<td>Romania</td>
<td>0.429</td>
</tr>
<tr>
<td>Slovakia</td>
<td>0.223</td>
</tr>
<tr>
<td>Slovenia</td>
<td>0.350</td>
</tr>
<tr>
<td>Spain</td>
<td>0.568</td>
</tr>
<tr>
<td>Sweden</td>
<td>0.048</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>0.505</td>
</tr>
<tr>
<td>Other EU 27 Countries + Croatia</td>
<td>0.318</td>
</tr>
</tbody>
</table>
Example: Calculation of GHG emissions – Public Transport project (urban case)

Calculation approach (2)

- Relative emissions (compared to baseline) = a + b + c

a. difference in emissions from operation of the project:
   - project is a new line or an extension of a line or an increase in service frequency & production
   - project keeps the same total production but with a renewal of rolling stock or improvement in traffic management (bus lanes, new traffic lights, ...) with increase in average Vc -> reduction of consumption/emission factor per vehic-km

b. difference in emissions from reduction/increase in other PT services related to the Project (+/-)

c. emissions avoided due to modal shift from private vehicles to PT (-) =

\[
\text{(avoided Emissions Volume (Tn CO}_2\text{e)) in a given year} = \text{(avoided Traffic volume (vehicles/year) pass/year shifting from private to PT/avg. occupancy rate} \times \text{Avg. pass. trip length (km)} \times \text{Emission factor (Tn CO}_2\text{e/vehic-km)}
\]
Construction of a new urban tramway line connecting the city centre to a main district in the outskirts

**Input data (1):**

- new line length = 9.6 km (with 13 stops)

- service operational scheme (frequencies, etc.)

- redesign of the rest of PT network around the project

**Project production**

1.1m vehkm/year

**Buses production**

* before 17 m vehkm/year
* after 15.9 vehkm/year
Example: Calculation of GHG emissions – Public Transport project (urban case)

Construction of a new urban tramway line connecting the city centre to a main district in the outskirts

Input data (2):
- project demand (reference year):
  - 7m pass/year
- average passengers’ trip length: 4.8 km
- average private vehicle occupancy rate: 1.3 pass/vehicle
- average consumption: buses avg. ~ 50 l/100km
  trams 1.2 KWh/veh-km
  cars (national data on avg. fleet comp)
- emission factor: electricity production 0.659 kgCO2/KWh
  diesel traction 2.6 kgCO2/l
  private cars avg. 0.277 kgCO2/km
Example: Calculation of GHG emissions – Public Transport project (urban case)

Construction of a new urban tramway line connecting the city centre to a main district in the outskirts

Output data/results:

- **Project Absolute Emissions** = 
  \[1.1 \text{m vehic-km} \times 1.2 \text{ KWh/vehic-km} \times 0.659 \text{ kgCO2/KWh} / 1000\]
  \[= 870 \text{ tonn CO2/year}\]

- **Project Relative Emissions** =
  a. difference in emissions from operation of the project (new line)
  \[= +870 \text{ tonn CO2/year} +\]
  b. difference in emissions from reduction/increase in other PT services related to the Project (reduction in bus services)
  \[= (15.9 - 17.0) \text{ m vehic-km} \times 1,138 \text{ kgCO2/vehic-km}\]
  \[= -1252 \text{ tonn CO2/year} +\]
  c. emissions avoided due to modal shift from private vehicles to PT
  \[= 0.16 \times 7 \text{m pass/year/1.3 x 4.8 km x 0.277 kgCO2/vehic-km/1000}\]
  \[= -1146 \text{ tonn CO2/year}\]

\[= -1528 \text{ tonn CO2/year}\]

the Project saves CO2 (!)
Example: Calculation of GHG emissions – Transport Plan (urban case)

Calculation approach

- Climate change impact of a Plan in terms of GHG emissions can be calculated with analogy with that of a Project.

- It needs a multimodal traffic model for the estimate of flows and conditions of circulation on the entire network considered in the reference area for the Plan.

- **Absolute Emissions** = those in the selected Plan Scenario, associated with private vehicles flows and operation of public transport in the reference Plan Area, for a selected future time horizon (usually calculated over y standard year).

Calculation of GHG emissions for Transport Projects and Plans - a few considerations

- The methodologies presented are simplified ones, that give (mainly) an order of magnitude – fitting (also) the needs of CBA

- Fundamental factors in an accurate estimate of CO2 emissions are traffic data, current and predicted, and for PT projects in particular modal shift assumptions/predictions

- The preparation of an appropriate Traffic Model is therefore a fundamental step in this process

- Most of current Traffic Models already include a module for the calculation of CO2 emissions, both at the level of projects corridor and of area (plan)

- In certain cases, e.g. for the calculation of CO2 emissions for road projects (including “softer” measures such as interventions on the traffic management) or for area plans, it is recommendable to use microsimulation models that allow a more detailed and accurate modelling of traffic behavior and traffic/circulation characteristics, such as “stop&go” situations etc. – which strongly affect the level of emissions.
For info or further questions on the CBA forum meetings and the activities of the JASPERS Networking Platform, please contact:

Massimo Marra
JASPERS Networking and Competence Center
Senior Officer
ph: +352 4379 85007
m.marra@eib.org

www.jaspersnetwork.org
jaspersnetwork@eib.org