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CATCH

Carbon-Aware Travel Choice in the City, Region and World of Tomorrow

D3.2 Report on data analysis and GHG emissions estimates related to travel choice

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Executive Summary

This report describes the objectives and activities defined and carried out by task 3.2 “Data Collection/Collation/Specification” within Work Package 3 in CATCH.

The Carbon Aware Travel Choice (CATCH) project was developed in response to the FP7 call for proposals that would help cities to reduce the amount of CO_2 produced by travel choices. Alternative fuel technologies, sustainable transport policies, and new technologies applied to support mobility (and virtual mobility) are being developed and fine tuned throughout Europe. These technologies offer opportunities to move towards a more sustainable future. However, despite a range of initiatives, most of which are supported through projects funded by the European Commission, there is still a need for a trusted and easily accessible resource which enables travellers, policy makers and operators, and other stakeholders, to determine appropriate actions to address the growing environmental challenge of reducing the carbon dioxide emissions from urban transport by encouraging carbon-friendly travel choices.

In response to that, the CATCH project aims to develop a knowledge engine to inject carbon reduction into the public’s and policy maker’s decision making[1]. This will be an online knowledge platform that aims to:

- support city stakeholders to develop sustainable transport policies;
- motivate travellers to adopt sustainable transport choices.

The CATCH project has developed a knowledge platform that includes two tools that allow for visualisation of data at the city level (the co-benefit tool, also called “My City”, and the Scenario tool, developed in WP4). The input to both tools is the GHG and Performance Database. The database structure was initially developed in T3.1 and described in D3.1. This document describes how data was identified and assessed, and how the database has been populated with relevant data as well as the estimation of city-specific per-capita road transport CO_2 emissions.

Road transport CO_2 emissions were estimated by using the European Pollutant Release and Transfer Register (E-PRTR), GIS data and the application of a ‘top-down’ methodology. The publishing in 2011 of a spatially disaggregated inventory of a range of diffuse atmospheric emissions based on the E-PRTR marked a significant advance in understanding variations in emissions from various sources Europe. Through this release, the CATCH platform was able to estimate city-level road transport CO_2 emissions for over one hundred cities.

Over 40 different indicators had sufficient coverage for the 149 cities for which per-capita road transport CO_2 emissions estimates were created. That data feeds the My City tool of WP4. The My City tool allows for cities to be compared and ranks them according to their per-capita road transport CO_2 emissions (and other indicators, or ‘co-benefits’). Further, it uses the 43 indicators to show how the cities are performing in six different policy areas.

The data that feeds into the Scenario tool is not as expansive. However, over seventy cities were identified that had 10 common indicators with at least three distinct results. Currently, the only transport indicator is car ownership and it is not possible to include CO_2 emissions estimates as only one year exists in the E-PRTR data.

Future directions of this work include expanding and building upon the indicators that are available for both tools. In particular, now that a baseline has been established using the E-

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[1] WP2 D2.1: Design Guidance – INTERIM report (not publically available).

PRTR, accurate historic data and future versions of the E-PRTR data would allow for trending.

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Glossary

Green House Gas emissions (GHG): *gases in an atmosphere that absorb and emit radiation within the thermal infrared range.*

Transport Performance Indicators (TPI): *standardized information suitable for analysis in order to appraise the feasibility of a transport policy or infrastructural project.*

Sustainable Performance Indicators (SPI): *standardized information suitable for analysis in order to appraise the environmental sustainability of a policy.*

Co-benefits: *the benefits from policy options implemented for various reasons at the same time (IPCC TAR, 2001), when decision makers implement a policy with a single aim and then discover that the policy resulted in additional co-benefits (IES HANDBOOK, 2004).*

Emission factor: *the average emission rate of a given pollutant from a given source relative to the intensity of a specific activity*

Acronyms

DfT: UK Department for Transport

EMTA: European Metropolitan Transport Authorities

E-PRTR: European Pollutant Release and Transfer Register

LUZ: Large Urban Zone

UK-NAEI: UK National Atmospheric Emissions Inventory

UTBI: Urban Transport Benchmarking Initiative

D3.2 Report on data analysis and GHG emissions estimates related to travel choice

1 Introduction

The Carbon Aware Travel Choice (CATCH) project was developed in response to the FP7 call for proposals that would help cities to reduce the amount of CO_2 produced by travel choices. Alternative fuel technologies, sustainable transport policies, and new technologies applied to support mobility (and virtual mobility) are being developed and fine tuned throughout Europe. These technologies offer opportunities to move towards a more sustainable future. However, despite a range of initiatives, most of which are supported through projects funded by the European Commission, there is still a need for a trusted and easily accessible resource which enables travellers, policy makers and operators, and other stakeholders, to determine appropriate actions to address the growing environmental challenge of reducing the carbon dioxide emissions from urban transport by encouraging carbon-friendly travel choices.

In response to that, the CATCH project developed a knowledge engine (Figure 1) to inject carbon reduction into the public's and policy maker's decision making, as defined by WP2[2]. This will be an online knowledge platform that aims to:

- support city stakeholders to develop sustainable transport policies;
- motivate travellers to adopt sustainable transport choices.

The CATCH project has developed a knowledge platform that includes two tools that allow for visualisation of data at the city level (the co-benefit tool, also called "My City[3]", and the Scenario tool, developed in WP4). The input to both tools is the GHG and Performance Database. The database structure was initially developed in T3.1 and described in D3.1 (Pernice and Brignola, 2011). This document describes the methodology through which data and indicators have been identified (i.e sources explored and specifications defined), cleaned and gathered and how it has been populated with relevant data. Furthermore D.3.2 describes the algorithms generated to cover data gaps and to estimate city-level transport CO_2 emissions.

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[2] This document, D2.1: Design Guidance – INTERIM, was for internal review only and is not publically available. However, the final report for WP2 will be available in 2012.

[3] Please see D4.2 Building, Visualisation, and Integration of the Cobenefit Tool.

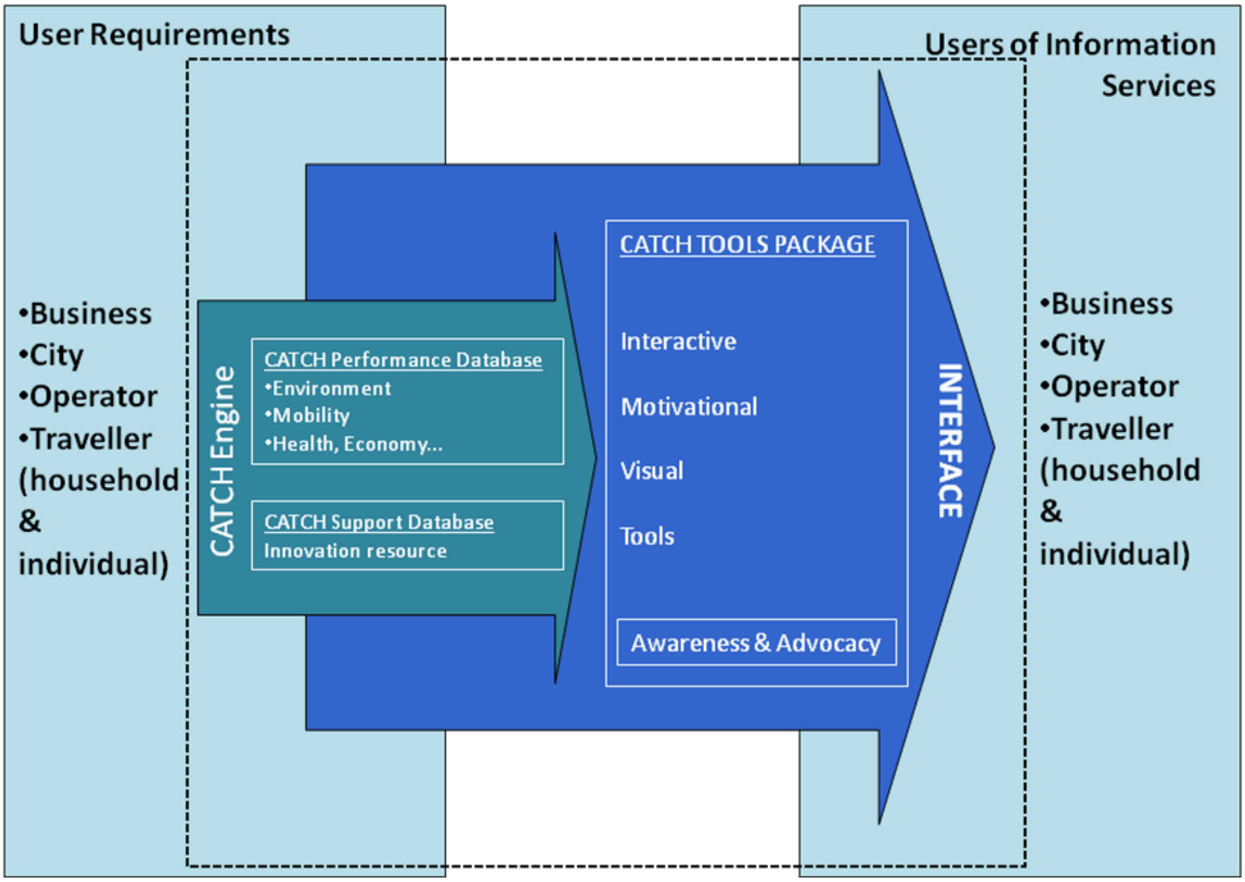

Figure 1 CATCH project concept.

1.1 The Purpose of the task

To achieve the aims set out above, the CATCH platform had to develop and incorporate a GHG and Performance Database which includes Transport Performance Indicators (TPIs), Sustainable Performance Indicators (SPIs), Greenhouse Gas (GHG) emissions related to TPIs and SPIs affecting eco-friendly mobility choices and plans.

Climate change is caused by a range of gases collectively known as greenhouse gases (GHGs). Although other gases are emitted from transport such as nitrogen dioxide or methane, CO_2 is the most common[4] and is the focus of this project. All GHGs can be represented by CO_2 equivalents (CO_2e), but currently only CO_2 is officially reported by the EU (T&E 2009), so this will remain the focus of the work reported here.

Relevant to this document, WP3 has the following two main aims in the project:

- To design a common database of GHG emissions and transport performance indicators to support the tools being developed in WP4.
- To estimate GHG emissions related to travel at the city level.

WP3 was composed to two primary tasks, T3.1 and T3.2. T3.1 was devoted to developing the CATCH GHG and performance database which is able to store data needed for the following purposes:

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[4] http://www.epa.gov/climatechange/fq/emissions.html

- to support a range of visual options defined in WP2 that were further refined in WP4;
- to estimate the level of CO_2 associated to different transport scenarios.

Transport scenarios are defined here as the travel outcomes in a city. Each city acts as its own experiment in transport with different inputs and outputs. Through estimating the per capita CO_2 levels of different cities, it is possible to see who are the leaders, and thus where an individual, policy maker, researcher, and any other individual would learn which cities should be emulated. On the other side of that, it would also highlight which cities should improve.

The primary purpose of T3.2 was to populate the database developed in T3.1 to support the visual tools being developed in WP4. Based on recommendations from WP1 and WP2, the database should include city-level CO_2 emission estimates along with transport and other indicators.

1.2 Methodology

Task 3.2 (T3.2) has evolved in step with the project. Findings from WP1 (Avineri and Waygood, 2010; Waygood and Avineri, 2010) suggested that to motivate both individuals and policy decision makers, it would be necessary to provide information beyond just that of transport CO_2 emissions. The initial description of T3.2 is as follows (from original Description of Work):

> This task will be aimed to collect the data and to estimate the GHG emissions related to the different travel choice. This will be done upon secondary prime and surrogate sources. Database must be transparent and provide indications of the robustness of the measures used. Sophisticated statistics tools will be used to data estimation, such as LIMDEP. The quality of the estimates will be tested in terms of reliability, consistency, accuracy and uncertainty. The results of this task will be used to model scenarios in WP4. Furthermore, they will support WP5 and WP6.

As results from the Grounding (WP1) emerged, it became clear that numerous resources already existed that could estimate the CO_2 emissions of different travel choices (D1.1, Avineri and Waygood, 2010). The thought was to then estimate the city-level transport CO2 emissions for four core cities involved in the project as well as expanding to include other indicators. Therefore, in a revised Description of Work, T3.2 evolved to:

> This task will be aimed to collect the data and to estimate the GHG emissions/other performance indicators related to the different travel scenarios. This will be done based upon secondary prime and surrogate sources. Database must be transparent and provide indications of the robustness of the measures used. The results of this task will be used to model user centred scenarios in WP4, to be used in the Tools. The database will be hosted by Q-Sphere and incorporated by them into the development of WP5.

The initial stage (Figure 2) identified available data to estimate city-level transport CO_2, other indicators, and potential comparison cities. However, at this point, a crucial source of data was released that was not foreseen when the project was envisioned and proposed. This data, later described in section 2.1.3, allowed for transport CO_2 to be estimated for far more cities, thus allowing for greater comparison and inclusion of European cities.

That evolution in data availability, required a response by T3.2 to then identify a source of indicators for such a large number of cities and one was identified (see section 2.1.2).

While this database was growing, interactions with WP4 (Scenario Development), which was responsible for the visualisation of the data, helped define what the final data sets would be that would presented through the CATCH platform (a detailed account can be found in Chapter 4).

Finally, with the database populated and data sets developed for the use of WP4 tools, analysis could be carried out on the data that might suggest relations between transport CO_2 and other city indicators.

Ultimately the data must be updated and results verified. Although considerable efforts were made in this task to verify the data, it has not been possible to verify the results for all cities. A community of interested individuals is envisioned to keep the data as accurate and up-to-date as possible.

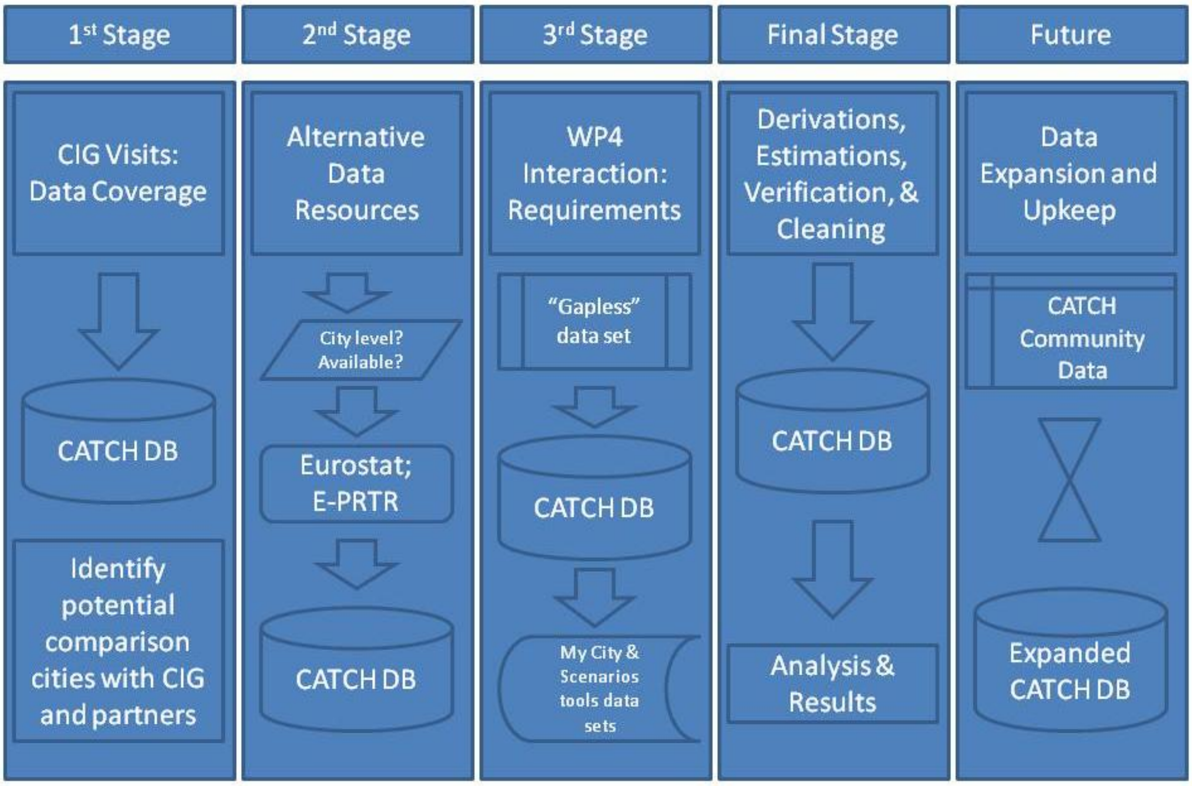

Figure 2 Process chart for T3.2.

1.3 Structure of Database

The database structure was developed in T3.1 (Pernice and Brignola, 2011). There were originally nine tables as shown in Table 1. Through the development of the project, a further table was introduced, DATA_SOURCE, that would record all the data sources used (Table 2). This was added as a new column to the INDICATOR_VALUE table.

Table 1 List of Tables in the CATCH DB originating from T3.1.

Table Name	**Comment**
CITY	Name of city (currently smallest geographical focus)
COBENEFIT_AREA	Class of indicators
COBENEFIT_AREA_INDICATOR	Association table between co-benefit area and indicator
GEOGRAPHIC_AREA	Set of cities grouped at geographical level
INDICATOR	Standardized information suitable for analysis in order to appraise the feasibility of a transport policy or infrastructural project

Table Name	Comment
INDICATOR_VALUE	Value of an indicator for a specific city and for a specific reference year
MEASUREMENT_UNIT	Measurement unit adopted for a specific indicator
NATION	Nation where city is located
PERFORMANCE_CLASS	Performance class of a city

Table 2 Description of new Table, DATA_SOURCE.

Name	Datatype	Null Option	Comment
ID	INTEGER	IDENTITY	Unique identifier of the city
Short description	Text	No	Short description of the data source
Long description	Text	No	Long description of data source.
CREATED	DATETIME	NOT NULL	Date & time of the creation of the record
MODIFIED	DATETIME	NOT NULL	Date & time of the last edit operation on the record

Further additions exist that relate to column additions to various Tables. These are listed in Table 3.

Table 3 List of additions to existing Tables.

TABLE	Addition
CITY	COMPLETE_DATA to indicate whether the city had sufficient data coverage to be included in the Co-Benefits tool “My City”
CITY	SCENARIO_TOOL_DATA to indicate whether the city had sufficient data coverage to be included in the Co-Benefits tool “Scenarios”
Logarithmic_d	A binary variable to indicate whether the data should be shown in a logarithmic scale as its default presentation form.
Low_is_good_d	A binary variable to indicate whether the data should be interpreted as “lower is better”. In ambiguous cases, the relation (if any) to CO_2 is used to make this judgement.
COMPLETE_IND_DATA	This binary variable indicates whether there is sufficient data for the indicator to be shown in the list of available indicators in the “My City” tool.
SCEN_TL_DATA	This binary variable indicates whether there is sufficient data for the indicator to be shown in the list of available indicators in the

	“Scenarios” tool.
LOG_VALUE	This variable includes the logarithmic (base 10) value of the VALUE variable.
DATA_SOURCE_ID	The identification code of the source of the data.

1.4 Summary

As outlined above, the primary purpose of T3.2 was two-fold: to identify and gather transport performance indicators and sustainable performance indicators to support the tools being developed in WP4, and to estimate GHG emissions related to travel at the city level. As the task progressed in parallel with WP4’s development of the tools that would use the data, the database structure was expanded to meet needs.

The next chapter describes the process of data population.

2 General Data

A primary goal of CATCH was to provide transport CO_2 information for cities to increase awareness. Through research carried out in WP1 (Avineri & Waygood 2010; Waygood & Avineri 2010), it was highlighted that CO_2 awareness, although important for behaviour change, might be insufficient. It is argued that information on CO_2 emissions might not necessarily lead to behaviour change, and that information from other policy areas that supported change might help reduce transport CO_2 emissions. Therefore, along with city-level transport CO_2 emissions, additional indicators should be included.

An Internet-based search of available databases uncovered considerable amounts of national data (e.g. International Monetary Fund, World Health Organization, European Environment Agency, International Road Federation, International Transport Forum, International Energy Agency, Organisation for Economic Co-operation and Development), but little city-level data.

City-level data that was identified includes: Urban Transport Benchmarking Initiative (UTBI), UK Department for Transport (DfT), European Metropolitan Transport Authorities (EMTA), Millenium DB, Mobilities in Cities DB, and Eurostat's Urban Audit. The final source listed, Urban Audit, formed the majority of the data that is present in the CATCH DB as it met a set criteria considered as mandatory to the performance of the CATCH tools: city-level, year or year span known, trusted source, and available for use. This source, which provides a substantial database, has been complemented by a number of other sources listed below (Table 4).

Table 4 Data sources currently (18.11.11) in the CATCH DB along with the respective number of indicator values. See Appendix C for links to the data sources.

Short description	Total indicator values in DB entered from that source
Urban Audit, Eurostat	58314
Derived from other source	4130
E-PRTR (European Pollutant Release and Transfer Register)	596
City direct	298
UNFCCC (United Nations Framework Convention on Climate Change)	104
Instituto Brasileiro de Geografia e Estatística (IBGE)	25
London Travel Survey	5
Pro-Aim	5
FETRANSPOR	4
Sistema de Indicadores de Percepção Social	4
Aramzem de Dados	3
Confederação Nacional de Municípios (CNM)	3

Central Statistics Office Ireland	2
UOL educação - 2008	2
Estado de Sao Paulo	2
Secretaria Municipal de Meio Ambiente	1

2.1.1 Role of cities in data identification and gathering

This section discusses the role of the cities in data identification and gathering that was primarily carried out by UNIPA.

Earlier work

WP3 recognizes a key role to the CATCH Interest Group set up to define the development and direction of the CATCH knowledge platform and including:

- representatives from local governments, NGO sector, business sector, and research arena in the fields of carbon and environmental management and transport;
- Core Interest Group (CIG) cities, chosen through a competitive Call for interest, distinct in terms of their geography, in terms of their levels of awareness with respect to carbon reduction strategies in transport and in their level of advancement in terms of climate strategies. CATCH CIG cities are: Lisbon (Portugal), London Borough of Hounslow (UK), Odense (Denmark) and Baia Mare (Romania).

More in particular, task 3.2 has foreseen several interactions with CIG and city experts involved in the project for the following purposes:

- to identify data requirements by analysing present strategies followed by cities to bring about carbon reduction in the urban transport sector, during IG meetings and city visits;
- to assess data availability of cities and refine the inventory of data needed in the project, through feedback on progresses made;
- to gather data from cities through a data collection process, through electronic procedures.

Furthermore, in order to develop a meaningful range of cities which enables comparison based on the results achieved by using different transport policies, a wider set of cities has been identified with the support of other project partners not necessarily involved in WP3: in particular POLIS and UITP shared their list of city contacts to extend the arena of cities for data gathering.

Specifically, a list of cities was selected, spread out across Europe and representing different sizes and different urban and mobility characteristics with the aim of enabling comparison among cities. The list included: Berlin, Bologna, Brussels, Cork (County Council), Dresden, Dublin, Edinburgh, Eindhoven, Göteborg, Merseytravel (Liverpool), Örebro, Rome, Stuttgart, The Hague, Utrecht Manchester, Milan, Copenhagen, Vienna, Valencia, Barcelona, Prague, Warsaw.

Also SICE and the Brazilian partner COPPE/ UFRJ, have offered the possibility to respectively include in the project Madrid and the two main Brazilian cities of Sao Paulo and Rio de Janeiro.

Current Work

Data was received from Odense and Baia Mare in the requested format from work conducted in T3.1. Data was also received from the London Borough of Hounslow, though the indicators did not necessarily match. Data was later received from both Brazil (Sao Paulo and Rio de Janeiro) and China (Jinan). All data for Lisbon was gathered through Eurostat as personnel changes there made direct data provision difficult. The managers of WP3 appreciate the efforts of all partners to find and provide data.

As will be discussed in this report, the possibility for estimating transport CO2 for a large number of European cities was made feasible through the release of the E-PRTR data in 2011. With its release, the project expanded its potential for estimating city-level transport CO2 from just the four core cities up to over 100.

Further, WP4's tools demand a relatively "gapless" dataset, meaning that it was necessary to identify indicators that were available for a large set of cities. This resulted in the Urban Audit data being identified as the primary source for data in this project.

This large set of cities allowed for comparisons beyond anything previously conceived in earlier versions of WP3. Not only was there now data to estimate city-level transport CO2 for a large number of cities, but it was also possible to compare with much more similar cities as defined by indicators such as population, population density, or economic measures amongst others.

2.1.2 General Indicators: Eurostat's Urban Audit

Eurostat provides the European Union with statistics at the European level that enables comparisons between countries and regions. The Urban Audit program[5] (Feldmann 2008) collects objective measures of the urban quality of life in European cities and has been available through Eurostat since 2008.

The data itself has a potential range of 1989-2010 depending on availability. Data is collected on the core city as well as the large urban zone (a functional boundary as opposed to a political one). There are currently over 400 cities included in the database for the core city level and over 380 for the Large Urban Zones (LUZ). For the core cities there are over 320 indicators and for the LUZ there are over 190 indicators, though neither are complete for all cities. . The indicators are available from a wide range of areas including: demography (e.g. population), social aspects (e.g. housing), economic aspects (e.g. economic activity), civic involvement, training (e.g. education), environment (e.g. air quality), travel and transport (e.g journey-to-work mode shares), information society (e.g. infrastructure), culture and recreation (e.g. share of land given to recreation)[6]. As can be seen, a wide range of data is potentially available, but not all of it is relevant to CATCH. Unfortunately, for the purpose of CATCH, less than 50% of the cities have environmental data and CO_2 information is not included.

Data from the Urban Audit has formed the foundation of CATCH's database as it is from a respected source, Eurostat, and has already gone through a quality control process. A total of 66 distinct indicators from Eurostat were included in the CATCH database, with another 7 derived (Appendix F). Where gaps existed in key points, attempts have been made to gather data from national, civic, and independent sources.

The standard practice to fill gaps was to do an Internet based search for the indicator (with variations of the indicator name), relevant city name, and either "statistics" or "data". For example, searching for London's journey-to-work split, "London journey-to-work statistics"

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[5] http://epp.eurostat.ec.europa.eu/portal/page/portal/region_cities/city_urban

[6] http://epp.eurostat.ec.europa.eu/portal/page/portal/region_cities/city_urban/urban_audit_data_collections

would be entered in a Google search returning the UK's Department for Transport's National Statistics "Travel to Work" pdf. Within that document, some relevant data may be gathered (e.g. the average journey to work for Londoners is 39 minutes). In this example, the original source, the National Travel Survey would be sought as a next step.

2.1.3 City-Level CO_2 Estimates

Although CO_2 emission information is available at the national level from the United Nations Framework Convention on Climate Change (UNFCCC), there are no obvious sources of city-level information.

One method of accomplishing this task would be to use Geographic Information System (GIS). Unfortunately, spatially disaggregated emissions inventories for CO_2 at a national level are not commonly produced within Europe. Therefore, the publishing in 2011 of a spatially disaggregated inventory of a range of diffuse atmospheric emissions based on the E-PRTR (European Pollutant Release and Transfer Register) marked a significant advance in understanding variations in emissions from various sources Europe. The E-PRTR Diffuse Air Emission Datasets are produced by the European Commission (EC) and EEA (European Environment Agency) under the conditions of Article 8 of the E-PRTR Regulation (No., 166/2006). The road transport emissions include those from passenger cars, light duty vehicles, heavy duty vehicles, and mopeds and motorcycles (Theloke et al. 2011), p.69. That data comes from two sources:

- National emissions of CO_2 available from the EEA-website for 2008;
- National emissions reported to "Convention on Long-Range Transboundary Air Pollution.

The E-PRTR data consists of 32 maps at 5 km x 5 km resolutions, projected using the World Geodetic System (WGS84). The maps cover emissions of six atmospheric pollutants (nitrogen oxides (NOx), sulphur oxides (SOx), carbon monoxide (CO), ammonia (NH3), carbon dioxide (CO_2) and particulate matter (PM10)), and divide the emissions across seven sectors (Agricultural, Domestic Aviation, Domestic Shipping, Industrial Releases, International Shipping, Non-Industrial Combustion, and Road Transport). The maps are intended to cover all EU27 states and the European Free Trade Association countries (Switzerland, Lichtenstein, Norway and Iceland), 31 countries in all. Whilst the data for conventional air pollutants is based on official submissions to United Nations Economic Commission for Europe under the Convention on Long-Range Transboundary Air Pollution, the CO_2 emissions are based on national submissions to the United Nations Framework Convention on Climate Change (UNFCCC). The inventory is produced using a 'top–down' methodology (see Lindley et al. 1996) based on the spatial disaggregation of nationally reported emissions totals. The following provides a short description of the methodology behind the datasets (for a detailed description of the methodology see Theloke et al., 2011).

The first stage is for the national sector-specific emissions to be allocated to the regional level within countries (e.g. NUTS3). For Road Transport, this is done on the basis of traffic count information. The second stage is to distribute these into a 5 km x 5 km grid using geospatial referenced datasets (such as road networks for road transport emissions). For industrial sources, a process has had to be derived for distinguishing between those sources reported as point source emissions under the E-PRTR and those that need to be treated as diffuse sources. This process is not relevant for road transport sector emissions which are all counted as diffuse emissions.

Disaggregating Road Transport

UNFCCC submissions report Road Transport emissions under the IPCC Common Reporting Format (CRF) source category 1A3b. This category is not disaggregated according to either vehicle type (e.g. passenger cars, light duty vehicles, mopeds, etc.) or road class (e.g.

highway, urban, rural), and CO_2 emissions are therefore disaggregated for both of these according to the proportions indicated by the TREMOVE model (Figure 3)..

The resulting road and vehicle classes are then 'harmonised' with the road network from the TRANS-TOOLS model[7]. This only covers highways and major rural roads. It is assumed that only 50% of rural road emissions can be allocated to the roads covered by TRANS-TOOLS, the remaining 50% are simply allocated as 'rural road emissions'. Whilst highways are all counted as line sources, rural and urban roads are split between line and area sources (70:30 and 50:50 line: area for the remaining rural and all urban roads respectively).

These are then distributed on the 5 km resolution grid using mapped road segments for line sources, or geographical statistical information and land cover/land use data as a proxy for area sources.

Therefore according to the 2-steps process described earlier:

(i) National emissions are regionalised according to traffic volume data for each road section covered by TRANS-TOOLS, and population density for those roads not covered by TRANS-TOOLS.

(ii) The regional emissions are then gridded according to:

- Traffic volume and road network from TRANS-TOOLS for highways and partly for rural roads;
- Road network divided by road type from GISCO (ROAD) (GISCO, 2011) for the roads not covered in TRANS-TOOLS (secondary and local roads);
- Gridded population density as weighting factor for line sources in relation to rural and urban roads not covered by TRANS-TOOLS. Additionally as distribution parameter for rural and urban area sources.
- Degree of urbanization (densely, intermediate and thinly populated areas) as defined by the Labour Force Survey[8] (GISCO, 2011)

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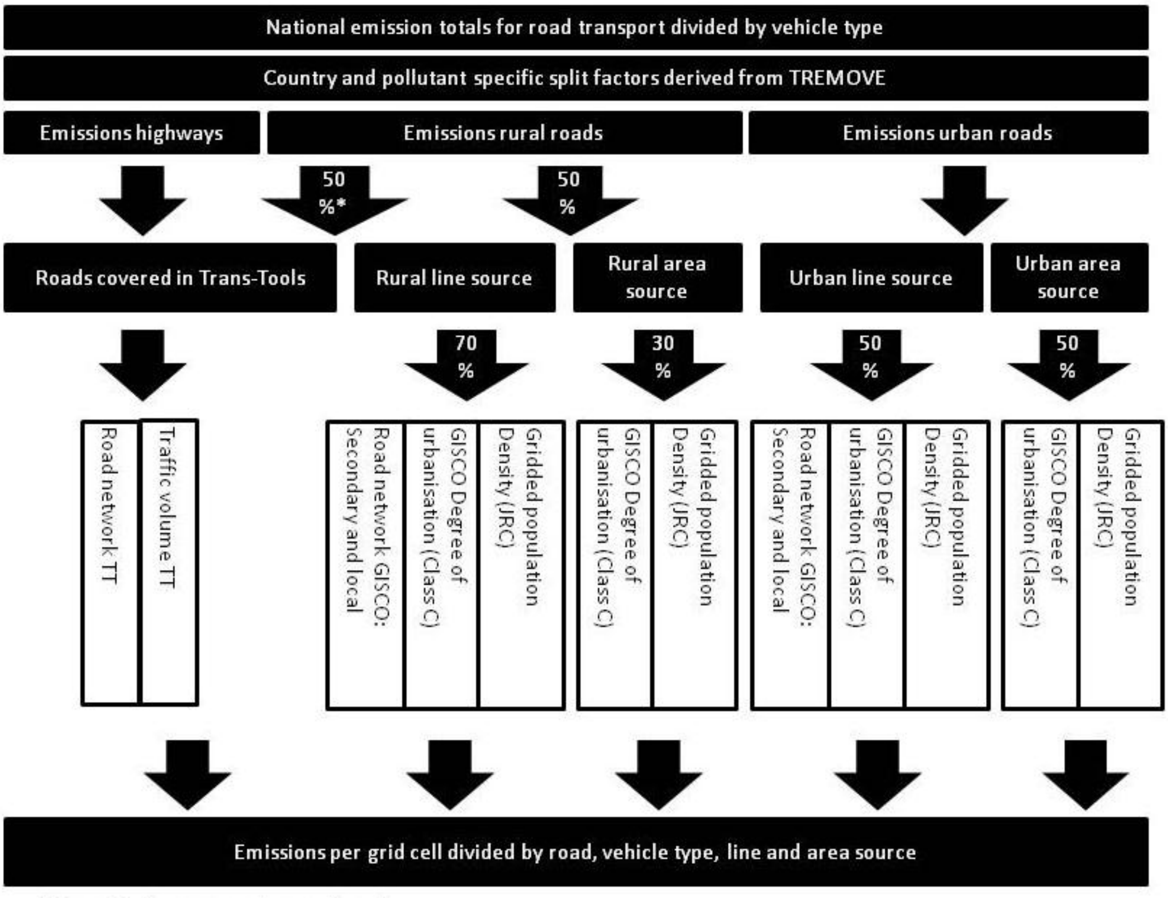
[7] http://energy.jrc.ec.europa.eu/transtools/; "TRANS-TOOLS ("TOOLS for TRansport Forecasting ANd Scenario testing") is a European transport network model that has been developed in collaborative projects funded by the European Commission Joint Research Centre's Institute for Prospective Technological Studies (IPTS) and DG TREN."

[8] http://circa.europa.eu/irc/dsis/employment/info/data/eu_lfs/; or http://circa.europa.eu/irc/dsis/employment/info/data/eu_lfs/lfs_main/lfs/lfs_concepts_and_definitions.htm



**Trans-Tools covers major rural roads*

Figure 3 Overview of the applied methodology for the spatial distribution of the road transport (adopted from Theloke et al 2011).

2.1.4 Entering Data

Data was entered into the database built in T3.1 through several steps that included a number of excel files that allowed for some automatic processes. The basic process was:

- Gather relevant data
- Assign CITY_ID to the data
    - using the VLOOKUP function in Excel in combination with:
        - a list of city names as they appear in an expanded roman alphabet
        - a list of city names by their English names
- Assign an INDICATOR_ID (create if necessary)
- When a sufficient number (subjectively chosen with respect to data availability) of cities exists,
    - Check if the information should be presented in a logarithmic form:
        - Using the MIN and MAX functions in Excel, check if the difference is 100 fold. If so, assign 1 to *logarithmic_d* for the indicator in the Indicator table.
        - Using the QUARTILE function in Excel, determine and assign the quartiles (Performance_class) to the values.
- Assign a DATA_SOURCE_ID (create one if necessary in the Data_source table).

- Assign appropriate CREATED time stamps.
- Enter notes where relevant.

Finished excel files were uploaded through the *Import* command of the Xamp SQL program and also through Microsoft's Access (which linked to the database).

The current database contains over 60,000 entries, though only a portion of those are available through the tools due to specifications there. As is mentioned later in 4.1, the My City tool for example requires that a city have data for at least 2/3rds of all indicators displayed. In many cases, data is available for a number of indicators over a number of years, but not a sufficient number of total indicators. Future work could look at how to best utilise such data.

3 City-level CO_2 estimates

To carry out comparisons of the E-PRTR data and allocate values to pre-determined boundaries, the X-ToolsPro (www.xtoolspro.com/) Shape to Centroid command was used to convert the polygon grid data format of the E-PRTR data to create points. These were then allocated to the administrative boundary in which they fell. That method was chosen as an alternative to a more conventional Intersect command in order to avoid having to divide emissions for a grid cell across two administrative units where cells fell across boundaries. When allocated at a country level, this resulted in 97.1% coverage (4753 grid cells being unattributed to countries, along with some cell values also being attributed to Turkey and Croatia, which were not part of the 31 countries dataset). Therefore a revised methodology was adopted that allocated emissions from each centroid to the nearest of the 31 countries covered by the dataset. This resulted in 100% allocation of emissions to countries.

3.1 Verifying Boundary Methodology

Country totals were then compared from the 5 km^2 data and with the country data taken from the EEA-website reporting the original UNFCCC figures for 2008[9]. For 30 out of the 31 countries, the summed country totals from the E-PRTR data were between 88.73% (Bulgaria) and 100.03% (Malta) of the emissions reported for the UNFCCC (see Figure 4).. The one exception was Liechtenstein where summed totals were only 31.64% of the UNFCCC reported figures. This may be partially due to the very small size of the country (160 km^2) and that only 3 grid cells (75 km^2) were attributed to it, suggesting that many of its emissions might have been allocated to neighbouring countries. In comparison, Malta may be the most accurate as it shares none of its grid cells with other countries. In general, this comparison indicated that the disaggregation of the emissions to mapped data still preserved their relationship to countries, and in total over 98% of emissions were preserved in this process.

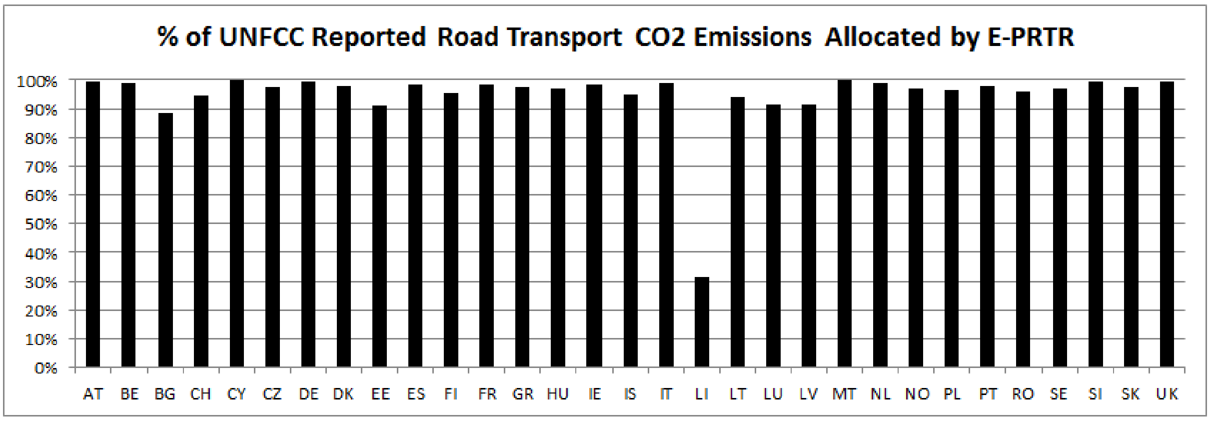


Figure 4 Comparison of mapped country totals with original Road Transport Emissions reported to UNFCCC. (from Waygood et al., 2012).

3.2 Comparison with UK data

As described above, spatially disaggregated emissions inventories at a national level are few and far between in Europe. Three countries were identified for which these are known: the United Kingdom, the Netherlands and Sweden. The data for these was only available for the

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[9] http://www.eea.europa.eu/data-and-maps/data/national-emissions-reported-to-the-unfccc-and-to-the-eu-greenhouse-gas-monitoring-mechanism-4

UK at the time of writing this report. If work in this area continues, datasets from the latter two countries would allow for validation in mainland Europe.

Comparison of emissions inventories is not commonly done between scales. Winiwarter et al. (2003) have discussed methods for comparing urban scale emission inventories that are based on the same grids but compiled using different methodologies. This work has some relevance to the task undertaken here and has been used to inform our analyses, but we argue that the differences in scales, and the purposes of the inter-comparison (i.e. verification of the E-PRTR data at a city scale) means that there are some differences. Lindley et al. (2000) describe a comparison of emission inventories produced at different resolutions. This again has informed our analysis, but does not provide a transferable methodology.

3.2.1 UK Emissions Inventory

The UK National Atmospheric Emissions Inventory (UK-NAEI) is produced annually, disaggregated across a 1 km x 1 km resolution grid that is based on the Ordnance Survey Great Britain (OSGB) grid system. The inventory is produced for CO_2 as well as 24 other air pollutants and GHGs. The mapping methodology for the inventory is set out in detail in Bush et al. (2010). A summary of the process for road transport is provided below. It is important to note that the UK-NAEI is used to calculate the emissions reported to the UNFCC, and which in turn are disaggregated by the E-PRTR inventory.

Road transport emissions for the UK-NAEI are calculated using a ‘bottom up’ methodology (see Lindley et al., 1996). Whilst conventional air pollutants in the inventory are calculated on the basis of speed related emission factors, the spatial distribution of CO_2 is based on fuel consumption as a proxy. This in turn is based on speed related fuel consumption factors multiplied by vehicle flows.

Census point traffic flow data is available for all major roads (motorways and A roads) covering Annual Average Daily Flow for light and heavy duty vehicles. Where traffic flow data were available for minor roads, this has been used in the same manner. For all other minor roads, regional average flows by vehicle type have been attributed for each type of road. In the 2007 methodology, this was improved so that the regional averages were at a County level. The age of the fleet is not varied regionally. 90% of Light Goods Vehicles are assumed to be diesel. From 2007, different fuel splits were assumed for passenger cars for urban, rural and motorways.

Each major road link is attributed an ‘area type’ using Department for Transport (DfT) definitions of urban areas. The vehicle kilometre (VKM) estimates by vehicle type are then multiplied by the fuel consumption (or emission factors) for each road link, based on the DfT average speed based on the Urban Area Type. A similar calculation is undertaken for minor roads, but differentiating fuel consumption and average speeds used for different types of minor road.

Additional emissions due to vehicles running under ‘cold start’ conditions are also calculated. These are classified as “home to work”, “home to other locations” and “work based” trips. They are based on census travel to work information, mapped data on ownership of cars, and mapped information on the distribution of employment across the UK.

The two methodologies (the UK-NAEI and the E-PRTR) offer two very different methods (bottom-up vs top-down) of attributing road transport based emissions of CO_2 on a spatial basis.

3.2.2 Comparison Methodology

The UK 1km x 1km resolution emissions inventory for CO_2 (as carbon) was obtained from the UK NAEI data warehouse (originally in the format of ASCII file for generating a raster coverage in ArcGIS) was converted into a polygon grid, that was then transformed from the UK’s Ordance Survey of Great Britain (OSGB) national grid projection to the World Geodetic

System (WGS84) projection used for the E-PRTR 5km x 5km data. Then, using X-Tools, centroids were created for each of the 1 km x 1km polygons. Using the Intersect command, these were then each attributed to one of the 5 km x 5km E-PRTR grid cells. Finally, using the Dissolve command, statistics were created for the number of 1km x 1km UK-NAEI cells within each 5km x 5km E-PRTR cell along with the sum, mean, min and max of their related emissions. In order to match the units between the UK-NAEI and E-PRTR reported figures, the UK figures were then multiplied by a factor of 3.664173 (to convert from CO_2 as carbon to its full mass), and multiplied by 10^{-3} to convert from tonnes to kilotonnes (kt). X-Tools were used again for the 5 km x 5km grid cells. This then allowed the two datasets to be compared at a number of spatial scales: UK, GB, 5km x 5km cells, Urban Audit (UA) Core City, Large Urban Zone (LUZ; Figure 5), UK district/unitary, and UK county. Comparisons have been presented for both the United Kingdom and Great Britain, as there are differences in the quality of the data used in Northern Ireland that may affect the accuracy of the disaggregation (Table 5). The results are presented next.

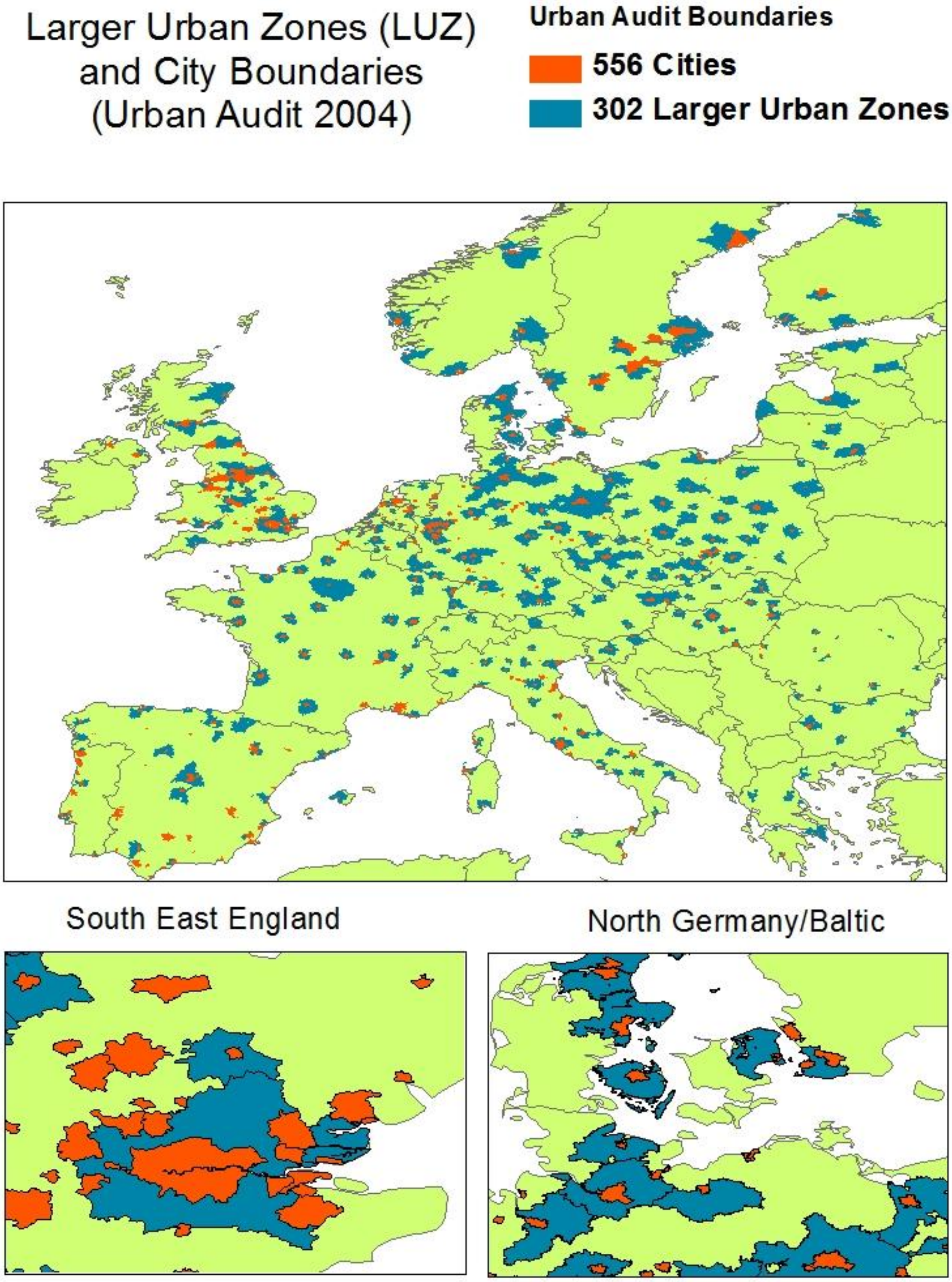


Figure 5 The Large Urban Zones (LUZ) and Core City (within the LUZs) boundaries.

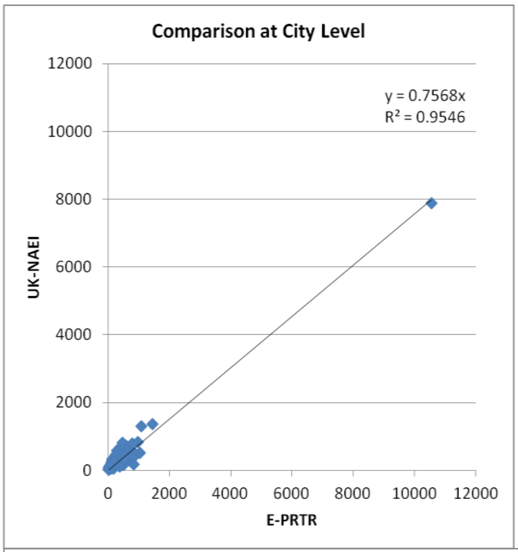
3.2.3 Results of comparison at national level

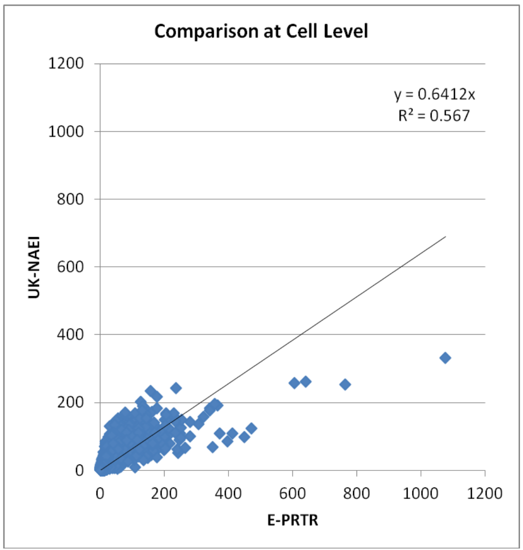
The number of cells and total road transport CO_2 emissions for the 5 km x 5km resolution E-PRTR data for the UK and GB, and for the UK-NAEI data at raw 1 km x 1km resolution and when aggregated to 5 km x 5km resolution on the E-PRTR grid are shown in Table 5. The comparison indicates that there is a 301 kt (0.26%) difference between the total emissions inventories at the UK level. For Great Britain this difference is slightly higher at 425.5 kt (0.38%). There has been no attrition in the methodology so total emissions have been conserved in the UK inventory within the aggregation process. However, there are 64 E-PRTR grid cells that have no UK-NAEI cells attributed to them where the E-PRTR predicts emissions and the UK-NAEI doesn't. These cells were predominantly along the coast, on islands, and extreme rural areas such as the Highlands of Scotland. They varied in emissions between 0.1 and 13.1 kt compared to an overall mean value of 12 kt and a maximum of 331. This was therefore not considered to be a very significant problem.

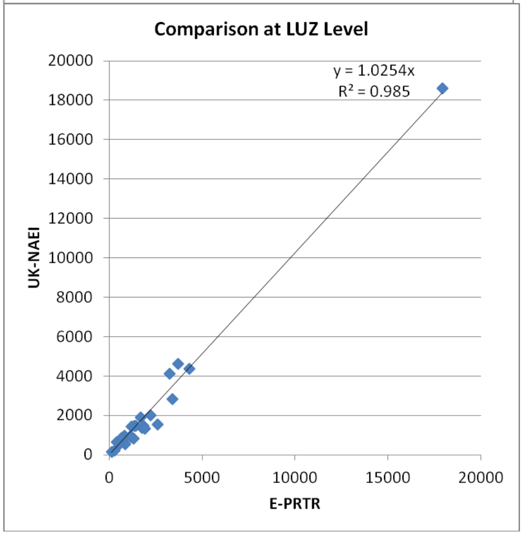
Table 5 Number of cells and total CO_2 road transport emissions for E-PRTR data and UK-NAEI data at 1 km x 1km and 5 km x 5km resolutions (from Waygood et al., 2012).

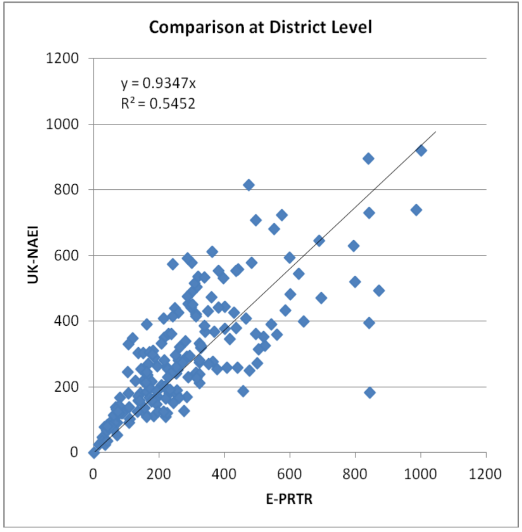
	Emissions Inventory and Resolution	**UK**	**GB**
Number of Cells	E-PRTR 5km x 5km	9698	9088
	UK-NAEI @ 1km x 1km	176,234	163,446
	UK-NAEI @ 5km x 5km	9634	9033
CO_2 (Road Transport) Emissions Kt	E-PRTR 1km x 1km	116,971.3	112,734.4
	UK-NAEI @ 1km x 1km	116,670.3	112,308.9
	UK-NAEI @ 5km x 5km	116,670.3	112,308.9

Comparisons have been undertaken at the level of individual 5 km x 5km cells and Urban Audit City and LUZ levels (Figure 9), as well as for a range of UK local authority areas (district, London borough, metropolitan borough, unitary, and county) (Figure 6,Table 6). Slope and R^2 have been calculated using a zero intercept.


Comparison at City Level
y = 0.7568x
R² = 0.9546
UK-NAEI
0
2000
4000
6000
8000
10000
12000
E-PRTR
0
2000
4000
6000
8000
10000
12000


Comparison at Cell Level
y = 0.6412x
R² = 0.567
UK-NAEI
0
200
400
600
800
1000
1200
E-PRTR
0
200
400
600
800
1000
1200


Comparison at LUZ Level
y = 1.0254x
R² = 0.985
UK-NAEI
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
E-PRTR
0
5000
10000
15000
20000


Comparison at District Level
y = 0.9347x
R² = 0.5452
UK-NAEI
0
200
400
600
800
1000
1200
E-PRTR
0
200
400
600
800
1000
1200

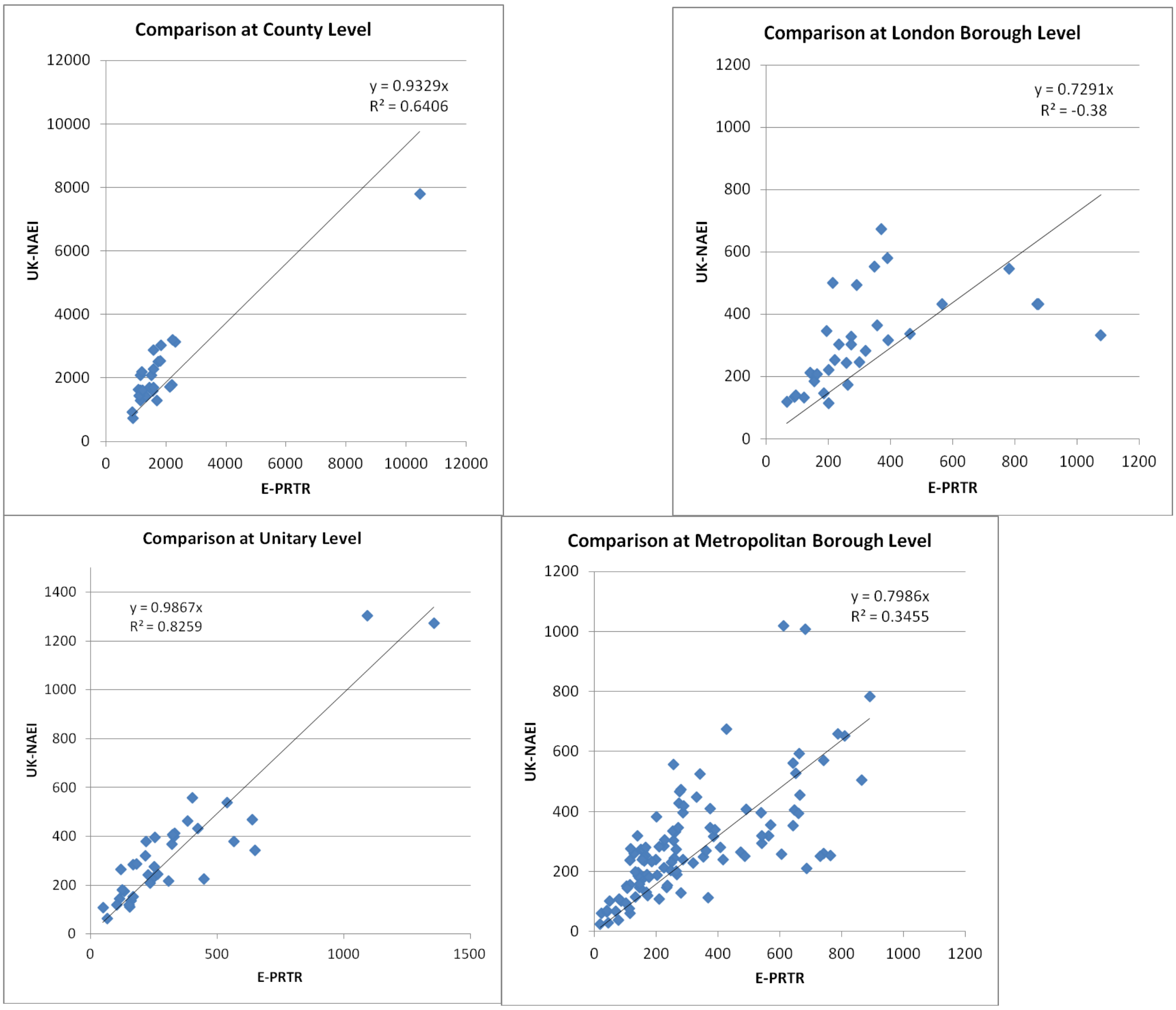


Figure 6 Scatter plots showing comparison of E-PRTR and UK-NAEI data at 9 spatial levels.

Table 6 Comparison of E-PRTR results for the UK with the UK's NAEI GIS data (from Waygood et al., 2012).

	Cell	City	LUZ	Dist & Uni	County	London Borough	Unitary	Metropolitan
n	9698	106	26	374	28	33	35	108
Max E-PRTR	1075	10548	17914	1357	10453	1075	1357	890
Max UK-NAEI	331	7885	18600	1303	7801	674	1303	1020
Slope	0.64	0.76	1.03	0.88	0.93	0.73	0.98	0.80
R^2	0.66	0.96	0.99	0.84	0.90	0.75	0.93	0.82

The correlations indicate that there is a strong relationship between the E-PRTR and the UK-NAEI datasets. As would be expected, correlations are weakest at the level of individual cells

(R^2=0.66 and slope of 0.64). The strongest correlation (R^2=0.99 and slope of 1.03) was found for the comparison at the LUZ level. This gives weight to the use of the LUZ based on a 'functional urban region' (EC, 2004) as the most appropriate area on which to benchmark road transport emissions.

Although the findings suggest a high correlation between the UK cities in the E-PRTR and the UK-NAEI datasets, it is not completely clear whether this holds for other European cities. Further research that includes other European countries would help to establish whether cross-country comparisons are truly valid. Future work could compare against data for the Netherlands and Sweden. For the time being, we will assume that this result allows us to use the information with a reasonable level of trust.

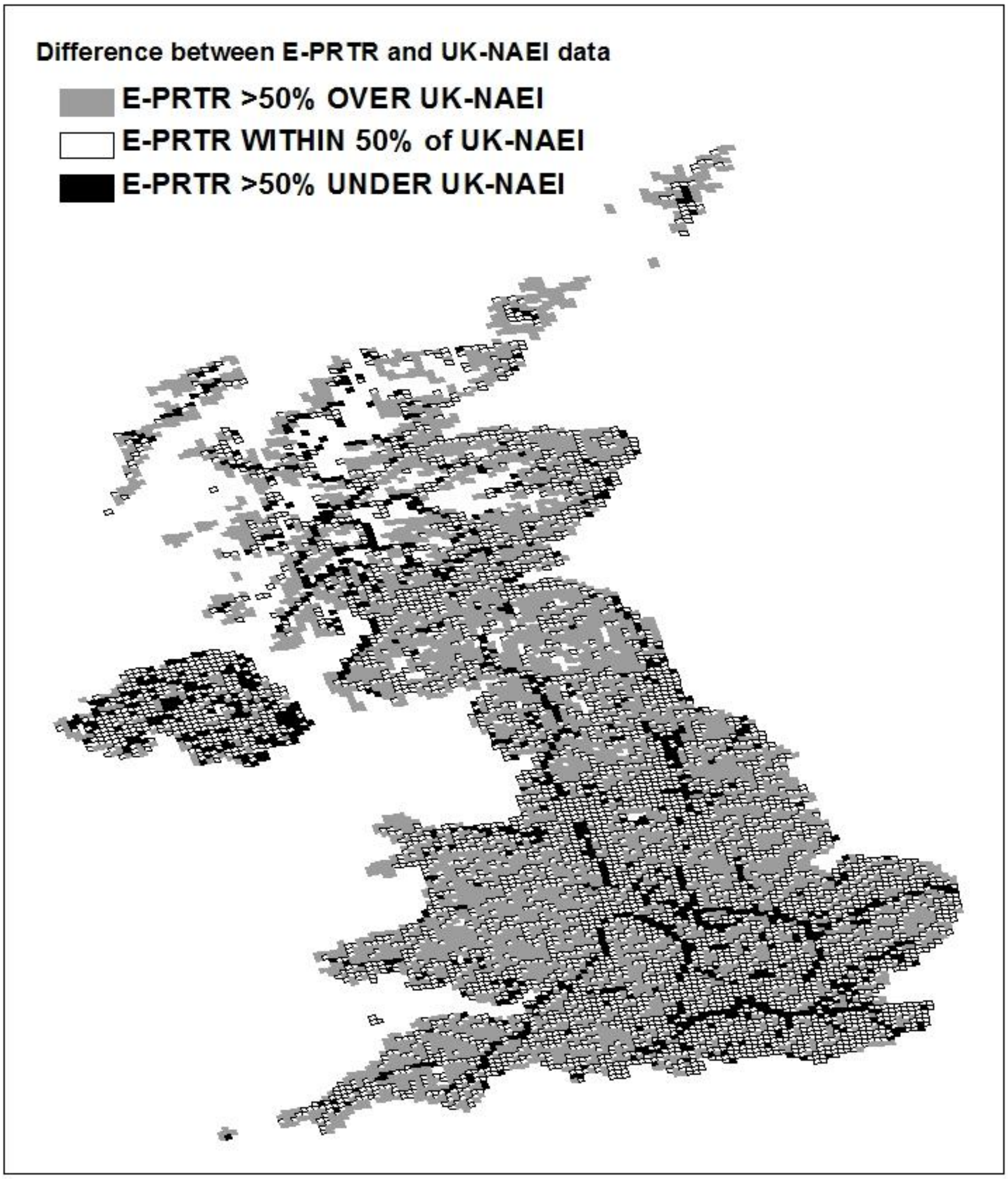


Figure 7 Map showing spatial patterns of difference between E-PRTR and UK-NAEI

The percentage difference between E-PRTR and UK-NAEI data at a 5 km x 5km grid cell level is shown in Figure 7. Difference is calculated as (UKNAEI-EPRTR)/UKNAEI. Areas of the map in grey indicate where the E-PRTR emissions are greater than 50% (of the UK-NAEI emissions) above the UK-NAEI emissions. Black cells E-PRTR emissions are greater than 50% (of the UK-NAEI emissions) under the UK-NAEI emissions. The clear pattern that emerges is that the UK-NAEI predicts higher concentrations along major roads in the mainland Britain, whilst the E-PRTR inventory is predicting higher concentrations in rural areas (for example Wales and Northumberland).

3.3 CATCH DB Coverage

Through the E-PRTR it was possible to provide information on road transport CO_2 for nearly 150 cities (Figure 8; **Error! Reference source not found.**), representing different travel scenarios.

For identifying the relevant domain for cities, the city administration and the Larger Urban Zone (LUZ) boundaries from the 2006 Urban Audit were used (Figure 8). The LUZ approximates the “functional urban region”. The city administration, or “core city”, boundaries resulted in unexpectedly high per capita values. This is a result of CO_2 emissions being assigned to where the traffic travels (not where it originates). To reduce this effect, the LUZ results are currently the recommended value to be used.

These have then been used to allocate CO_2 emission from road transport to a sample of 149 cities (Appendix D) on the basis of both the City and LUZ boundaries (see Figure 9).

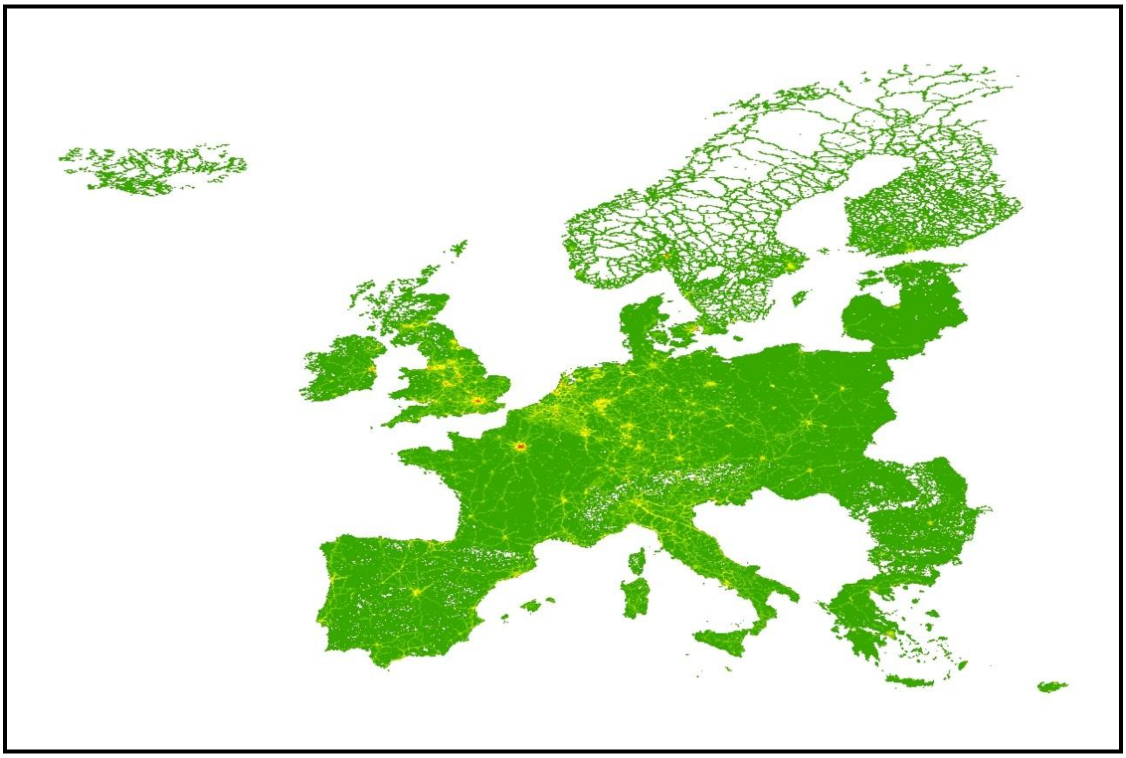


Figure 8 Map showing E-PRTR 5km x 5km grid for CO_2 emissions from road transport

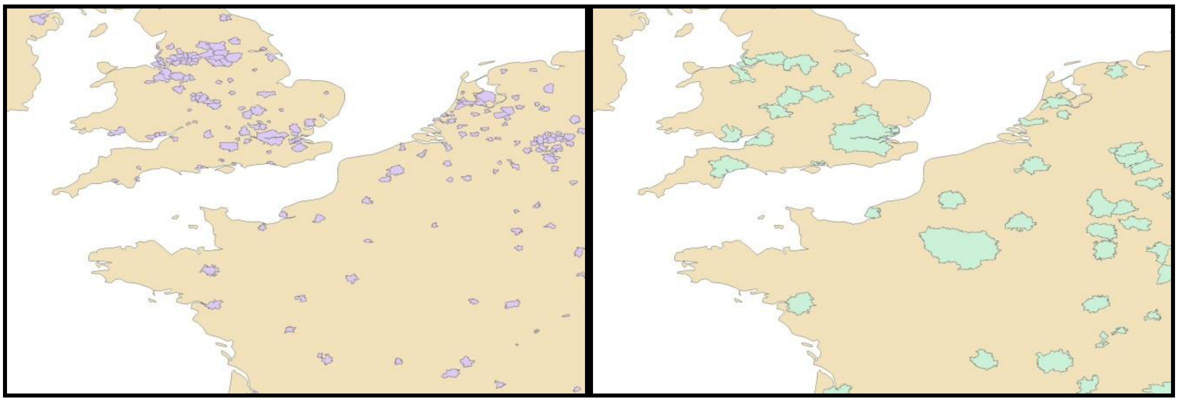


Figure 9 Illustration of 2006 Urban Audit boundaries (UA City on left UA LUZ on right)

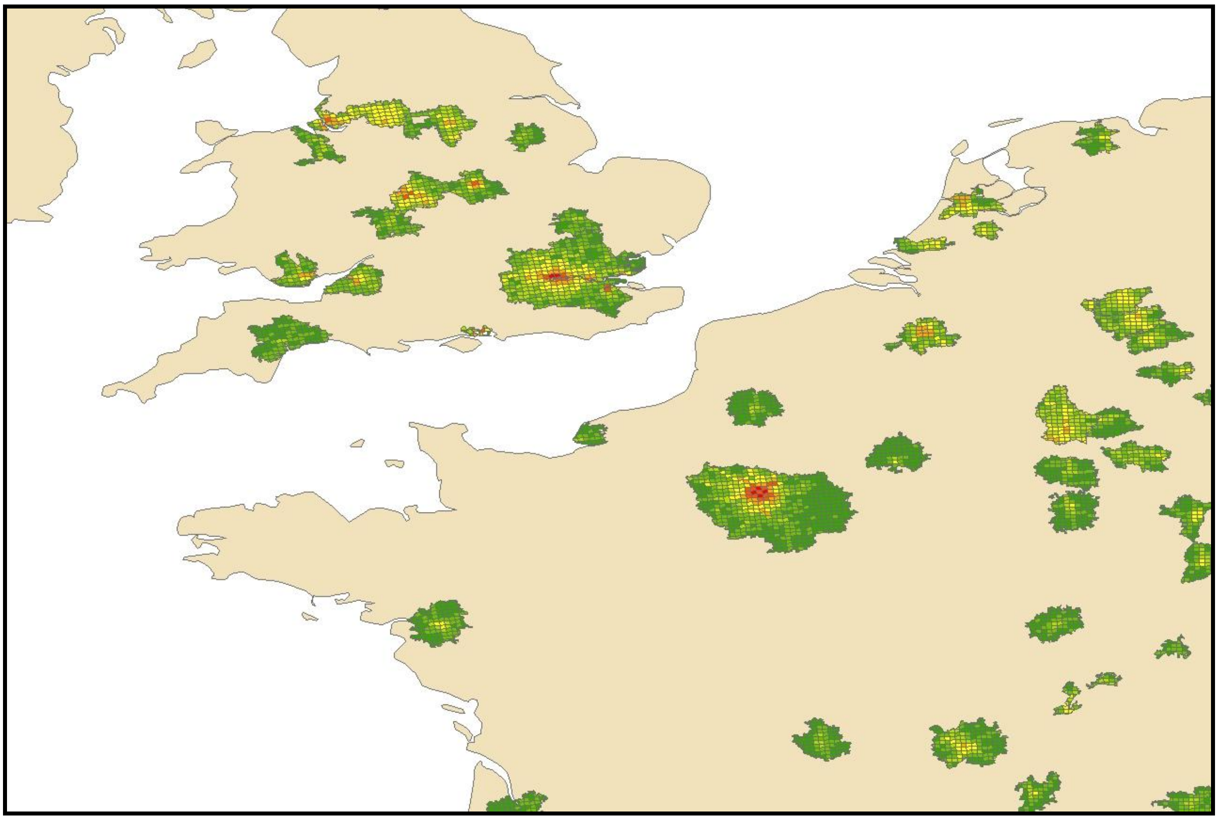


Figure 10 Sample of CO_2 cells associated with cities at LUZ level.

3.4 Example of Results

The following table (Table 7), shows results of the estimation. It is interesting to note that Italy has cities in all categories. It would be valuable to understand why this is, but such work must be left to future activities.

Table 7 Twenty examples representing the four quartiles of results of per capita road transport CO_2 estimates.

City, Nation	CO_2 tonnes/capita	Performance Quartile
(top five below)		
Bari, Italy	0.40	4
Rome, Italy	0.46	4
Badajoz, Spain	0.50	4
Sofia, Bulgaria	0.58	4
Turin, Italy	0.58	4
… (top five of 3rd quartile)		
Grenoble, France	1.33	3
Murcia, Spain	1.34	3
Málaga, Spain	1.38	3
Perugia, Italy	1.39	3
Cagliari, Italy	1.40	3
… (bottom five of 2nd quartile)		
Mönchengladbach, Germany	2.19	2
Birmingham, United Kingdom	2.24	2
Cambridge, United Kingdom	2.26	2
Trento, Italy	2.26	2
Sheffield, United Kingdom	2.30	2
… (bottom five below)		
Lincoln, United Kingdom	4.07	1
Weimar, Germany	4.76	1
Trieste, Italy	5.21	1
Vitoria/Gasteiz, Spain	5.42	1
Campobasso, Italy	7.37	1

3.5 Results from Other Sources

Verifying these results is difficult, and one approach was to compare with available data from the UK, as described above. Work published by Newman and Kenworthy (1999) estimated CO_2 from transport for various cities around the world. However, those results are now outdated, though they could be used as a reference point.

The World Bank published estimates of various cities' CO2 per capita[10], but a number of results seem quite unusual. For example, Rotterdam (The Netherlands) has a per capita

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[10] http://www.unep.org/urban_environment/PDFs/Representative-GHGBaselines.pdf

CO2 of 29.8 tonnes, compared with Oslo (Norway) at 3.5 tonnes. Rotterdam's amount is higher than the average for the USA and Oslo's is lower than the average for Thailand.

The Covenant of Mayors[11] has documents hundreds of Sustainable Energy Action Plans that include transport CO2 reduction targets (percentage and tons). Unfortunately, the totals shown are in graphs and the actual amount is not clear. However, doing some simple back calculations using the 2020 expected reduction (tons) divided by the percentage, it is possible to estimate that amount. Unfortunately, the amounts do not also correspond to what would be expected from the graphs. For example, Firenze has an expected reduction of 23% which is listed as 114811 tons. This results in an initial amount of nearly 500,000 tons, but the graph shows something in the range of 800,000 tons.

Of the cities listed in Table 7, only a few can be found in the Covenant of Mayors list, and fewer still have data. Of the cities in the Table 7, only Turin and Vitoria/Gasteiz have data (Table 8). If the calculation described above is used with the city's reported (to the Covenant of Mayors) population is used for the baseline year, the transport CO_2 amounts are 0.93 tonnes/capita and 0.59 tonnes/capita respectively. This is contrast to the 0.58 t/cap and 5.42 t/cap that were estimated using the E-PRTR data. As can be seen in Table 8, only three cities differ by less than 10% at the Urban Audit (UA) level and some cities have very different reported amounts to those estimated by the E-PRTR data.

Table 8 Covenant of Mayor (CofM) estimates[12] of transport CO_2 per capita compared[13] with E-PRTR estimates at the UA and LUZ levels.

	E-PRTR estimate (UA)	E-PRTR estimate (LUZ)	CofM estimate	% Difference UA	% Difference LUZ
Barcelona, Spain	0.63	0.80	0.62	0.8%	29.2%
Turin, Italy	0.35	0.58	0.93	-62.1%	-37.0%
Vitoria/Gasteiz, Spain	2.05	5.42	0.59	247.8%	819.4%
Málaga, Spain	1.36	1.38	0.65	109.7%	113.4%
helsinki, Finland		1.54	0.90	-100.0%	70.5%
Porto, Portugal	2.09	1.56	1.98	5.9%	-21.1%
Gothenburg, Sweden	1.46	1.59	1.31	11.6%	21.5%
Nitra, Slovakia	1.03	1.67	1.08	-4.6%	53.9%
Frankfurt, Germany	2.26	1.68	1.96	15.0%	-14.5%
Paris, France	3.99	1.99	5.75	-30.7%	-65.4%
Copenhagen, Denmark	5.35	3.34	0.68	691.0%	393.3%

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[11] http://www.eumayors.eu/actions/sustainable-energy-action-plans_en.html

[12] These were calculated by first using the estimated reduction of transport CO_2 emissions by 2020 divided by percentage estimate to estimate the baseline transport CO_2 amount and then dividing that result by reported population.

[13] (E-PRTR_amount – CofM_amount)/CofM_amount

3.6 Summary of Verification Results

This work suggests that, at least for the UK, the E-PRTR is a close approximation of the transport-related CO_2 emissions estimated by bottom-up methods, and accurate enough at the LUZ level. Although it cannot be definitively said that this holds for the remaining estimates of Europe, as there are discrepancies with the Covenant of Mayors data, it does suggest that the methodology used by E-PRTR is relatively robust, though the data inputs may vary across countries. Considering the discrepancies with other sources, we must conclude that further work at the city level is extremely important if value feedback is to help guide cities as they attempt to reduce CO_2 emissions.

4 Interactions with Work Package 4

4.1 Co-benefit Data

To facilitate the tools being developed in WP4, “gapless” data sets were sought for each. The requirements for each tool differ and the process of identify the data that would make up the data sets are described below.

Work conducted in WP1, (Avineri and Waygood, 2010; Waygood and Avineri, 2010) suggested that linking transport with other policy areas and individual concerns could increase behaviour change. The Transtheoretical Model, based on Stages of Change (Prochaska et al. 2008) for example suggests that for different motivators, or triggers, are required to stimulate a person into considering behaviour change. Interviews with transport practitioners (Waygood and Avineri, 2010) also suggested that policy decision makers appreciated additional benefits, or “co-benefits”, that would address more than one concern. Thus, the CATCH project aimed to include a wide range of indicators at the city level.

4.1.1 My City

The basic requirement of the My City tool was to have a data set with one data point for each indicator and city included in it. That data should be the most recent data available. Ideally, all data would be from the same year for each indicator, but this was, unfortunately, generally not possible.

Identifying the cities and the data

A call to the database for a table of the number of occurrences of each indicator by each city was made. An Excel file was then created where any instance of the indicator was equated to 1 so that a table of binary results (1 = data available, 0 = no data available) resulted. The data was sorted so that the indicator with the highest availability was listed first. A minimum of fifty cities was used as a cut off point. This was chosen so that a range of countries would be represented within the My City tool.

Using the indicators that were identified as being substantially represented within the database, the list of cities were then organised by the number of those indicators available. A two-thirds (2/3rds) coverage was used here as a cut-off point. This was again used so that as wide a range of cities in Europe was available with a reasonable amount of gaps.

This list was then limited by the cities where the CO_2 estimate was available. This resulted in cities that were involved with the project, such as the non-European CATCH partners of Brazil (Federal University of Rio de Janeiro) and China (Municipality of Handan) not being included along with the Romanian City Baia Mare (one of the four core cities in the CATCH Interest Group) not being included. For Baia Mare, only a GIS map of the city boundaries and the LUZ boundary is required to enable the information to be estimated. For Brazil and China, estimates might come from a range of methods, so notes would be required if they were included.

Following that final data sub-set, an Internet-based search was carried out to fill gaps.

Table 9 Example of call results that were used to identify the My City data set.

City	Indicator 1	Indicator 2	Indicator 3	…	Indicator n	Sum
City 1	3	0	1		2	E
City 2	2	1	0		3	F
City 3	3	0	0		3	G

…	…					…
City m	3	2	1		1	H
Sum	A	B	C	…	D	Z

The final number of cities was 149 (as per the number of cities where CO_2 was estimated) and the number of indicators was 43. Over 200 indicators exist in the CATCH database, but most do not have the coverage necessary. The total number of related indicators for each co-benefit category are shown in Table 10. In many cases, an indicator may be used in more than one category, thus the summation in Table 10 is greater than 43. Not all categories are represented in the My City tool's co-benefit section.

Table 10 Total number of indicators for each co-benefit category in the My City tool.

Co-Benefit Category	Total related indicators
Planning	18
Budget	12
Community	12
Time and Accessibility	21
Health	14
Safety	7
Economy	7
CO_2	3

4.1.2 Scenarios Tool

Unlike the My City tool, the Scenarios tool required a data set where for each indicator more than one year of data was available. A similar process to the one described in relation to the My City (see section4.1.1) was applied, but using at least two occurrences as the requirement was conducted. In some cases, the same data was entered for multiple years because of unclear dating. The initial method of entry for such pieces of data was to enter the same data value for each year within the range with a note specifying that the data was from somewhere within that range of years. The reasoning behind that method was if individuals wanted to seek data that corresponded to a particular year. Unfortunately, this meant that in many instances, there were not two distinct pieces of data, but merely that the same data was entered more than once in the database. Once this problem was identified, the new method was to enter the data only for the earliest year with a note specifying that the data could be from anywhere within the relevant range of years. The earliest year was used as a conservative measure with respect to data reporting.

As a result of that, a further step was introduced in the search of the database that allowed for the value to be visible. Those results were then recoded into an Excel sheet so that if the value for a specific indicator and city did not change from one year to the next it was only counted once. This would result in cases where the value did not actually change from one year to the next not being counted correctly, but for most indicators this was felt to be a valid screening process.

Table 11 Example of data requested to create the Scenarios tool data set.

City	Year	Indicator 1	Indicator 2	Indicator 3	…	Indicator n	Sum
City 1	Year 1	(Value)	(Value)	(Value)	…	(Value)	E
City 1	Year 2	(Value)	(Value)	(Value)	…	(Value)	F
City 1	Year 3	(Value)	(Value)	(Value)	…	(Value)	G
…	Year 4	…	…	…	…	…	…
City 1	2011	(Value)	(Value)	(Value)	…	(Value)	H
City 2	Year 1	(Value)	(Value)	(Value)	…	(Value)	I
…	…	…	…	…	…	…	
Sum		A	B	C	…	D	Z

Taking only cities that had at least three independent results (e.g. the results were not the same from year to year), and preferring a large sample of cities (and thus nations) over indicators, a data set was established with 71 cities (Appendix E) by 10 indicators. Each indicator had 3 or more distinct results per city at least 75% of the time. The ten indicators were:

- Population city;
- Population density city;
- Population region;
- Population density region;
- Passenger cars per thousand inhabitants;
- Mortality rate u64;
- Economic activity rate;
- Days ozone concentration exceeds 120 µg/m³;
- LUZ total land area;
- Number of day PM10 concentration exceeds 50 µg/m^3.

Those indicators represent planning, economy, and health co-benefit areas. Unfortunately, the only obvious transport indicator that met the criteria was car ownership.

4.2 Filling in the gaps

Gaps in the data affect the performance of the tools using the data. As far as possible, gaps that were identified in the Urban Audit data were filled with data from other trustworthy sources. However, in some cases it was not possible to find such data. This resulted in two general responses:

- Could the data be estimated using other sources?
    - Yes -> estimate;
    - No -> leave as empty.

An example of data that could be reasonably estimated would be a gap for one year between two years. Another might be a gap for a year before or after at least three years of reliable data (allowing projections). An example of data that could not be estimated would be journey to work rates of walking if no other journey to work information was available.

When such estimates were made, they were acknowledged in the Notes variable of the *indicator_value* entry.

4.3 Others: Assumptions and calculations for derived indicators

In a number of cases, it was necessary to derive values for indicators. This section explains how these were calculated.

4.3.1 Per capita or similar

The most common case was creating a “per capita” or similar value so that cities could be compared on a more level field. For example, taking the yearly totals of crash fatalities from London and comparing them with a small city would not be a fair assessment of the relative safety of either. By creating a per capita value, the general impact on society could be better compared.

To calculate per capita values, the totals for the boundary area (city, LUZ, etc.) were divided by the population of the same boundary area. If the date of the two data pieces did not correspond, the date for the first was given as the “reference year”, while in “notes” the year of the population data was recorded.

In the case of indicators such as injuries per 10000, the above per capita value was simply multiplied by 10000 (or whatever the relevant unit was).

4.3.2 Target 2020

Results of research in WP1 suggested that a reference point (Waygood and Avineri 2010) would be useful to individuals trying to judge whether the CO_2 emissions value was high or low. As well, an indicator that could act as an injunctive norm (something that suggests what society approves of) (Avineri and Waygood 2010) might increase a person’s tendency to behave that way. Thus, such a reference indicator was sought.

The European Union has a goal of reducing CO_2 from 1990 levels by 20% by 2020 (European Commission 2010). The Covenant of Mayors[14] contains nearly 1000 signatories, however a search for concrete 2020 transport reduction targets for the 149 cities estimated through the E-PRTR data found only a few relevant cities (see Table 8). Where data was available, the preference was to use the transport CO_2 reduction percentage, followed by the overall reduction percentage if the transport specific one was not available. In all other cases, an estimate would have to be made based on available data.

The calculation of the road transport CO_2 2020 target was a more complex task[15] than the per capita estimates. Here, relevant available data was first identified and then algorithms based on that information were calculated. Nationally relevant data included population, car ownership, and reported data for transport CO_2 to the UNFCCC was used. City-level data

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[14] http://www.eumayors.eu/actions/sustainable-energy-action-plans_en.html

[15] NOTE: The authors want to emphasise that this exercise was to produce a functional amount based on available statistics that would facilitate this addition to the My City tool. They do not contend that this is the best way to estimate such a number, nor that these numbers are official. Moreover, the authors argue that city targets might not be simply derived from national and European targets; one city (who has performed well in producing lower GHG emissions) may need to reduce by less than 20% whereas others who have not performed well may need to reduce by more than that. However, in the lack of policy targets and guidelines at the city level, the use of 20% when no other information was available was applied to make this exercise possible. One might argue that considering that cities are where decisions are made about infrastructure that relates to daily travel for the majority of citizens in Europe, that efforts should be made to create a more accurate estimation of the 2020 targets.

such as population, car ownership and the modal share of cars in the journey to work were also available in some cases for the appropriate years (1990, 2008). For CO_2, the estimates made through E-PRTR were used as for the current city-level data. For nine cities (Frankfurt, Munich, Hamburg, Stockholm, Brussels, Vienna, Copenhagen, Amsterdam, Paris), estimates of transport CO_2 in 1990 were available (Newman and Kenworthy 1999). That last bit of data helped to develop the algorithms to estimate 1990 levels for each city. The target 2020 CO_2 values were thus:

Target_2020 = CO_2_estimate_1990*0.8

The available data across cities varied, so a number of algorithms had to be used. All equations were calculated using the nine cities from the earlier study. The 1990 per capita transport CO_2 was estimated in the order of preference listed below based on r^2 values. In all cases the ratio between the 1990 and 2008 values were used, so that each variable (e.g. car ownership) is the result of the 1990 value divided by the 2008 value. Using the 1st priority equation as an example, the equation used was:

$$\frac{\alpha_{90}}{\alpha_{08}} = \beta_0 + \beta_1 \frac{\gamma_{90}}{\gamma_{08}} + \beta_2 \frac{\theta_{90}}{\theta_{08}} \qquad (1)$$

Where,

α = Per capita road transport CO_2;

β = coefficients;

γ = The percentage of all journey-to-work trips by car;

θ = Car ownership levels per 1000 people.

The subscripts *90* and *08* refer to the years 1990 and 2008 respectively.

1st (equation 1): 2008 CO_2 estimate *(-5.063 + 4.964*% journey to work by car + 2.072*car ownership); (r^2 = 1.000)

2nd: 2008 CO_2 estimate *(-1.639 + 5.423*% journey to work by car – 1.904*LUZ population); (r^2 = 1.000)

3rd: 2008 CO_2 estimate *(-3.033 + 5.008*% journey to work by car); (r^2 = 0.996)

4th : 2008 CO_2 estimate *(5.731 – 2.943*National transport CO_2 – 12.457*National population + 10.746*National car ownership); (r^2 = 0.757)

5th: 2008 CO_2 estimate *(2.048 + 0.988*National CO_2 – 2.089*National population); (r^2 = 0.689)

6th: 2008 CO_2 estimate *(0.197 + 1.782*National CO_2 – 0.839*National car ownership); (r^2 = 0.647)

The results are “functional” results and should not be taken as the actual 2020 targets, as it would require more advanced calculations and data than was possible in this project. As is the case with the Covenant of Mayors, if better data is made available, then the results could be updated.

5 Contributions

The work conducted in this work package has contributed to knowledge in the area of climate change by estimating the city-level transport CO_2 emissions for nearly 150 cities across Europe. It has confirmed that the methodology used in the European Commission work, E-PRTR, was valid for at least the UK. Although discrepancies exist between these results and those of sources such as the Covenant of Mayors, in the least it provides a starting point to evaluate cities, stimulating research into further validation and explanations about why one city is performing well, while another is not.

The data in the CATCH DB is primarily owned by Eurostat, so cannot “sold”. However, the value of the work here was to organise data that may influence or be influenced by transport into one DB which could then be exploited by innovative visual tools developed in WP4 in collaboration with WP1 and WP2. Whereas previous work, e.g. TEMS, might present one specific piece of transport data across Europe, the CATCH DB presents numerous transport indicators along with other policy indicators for consideration by individuals, transport professionals, and policy decision makers amongst others.

Further, the structure of the database and additional calculations made have made some ground breaking research ideas a reality. Users of the tools built in WP4 have responded in focus groups and surveys (see D1.3 Project Evaluation Report (due in 2012)) that the techniques and presentation of the information are stimulating and create motivation to change travel behaviour.

6 Future Directions

6.1 Future data

Better data supports better tools. Although Eurostat's Urban Audit is a valuable resource, incorrect entries have been found during the course of this project such as the city of Florence (Firenze) reporting a monthly public transport pass as being 1 euro. When the public transport authority's website in Florence was consulted, the actual amount was 35 euros [16] . Therefore a systematic analysis of the data for outliers, and then a confirmation/correction of that data would help improve the validity of the database and its tools.

It is envisaged that this role would be best covered by an "educated" community. This is seen as a group of informed users who share interests in urban transport and concerns about CO_2 emission levels. The cities themselves and interested individuals would validate and update the database as required[17].

As links between transport and other areas of policy concern continue to grow, available data at the city level should be entered into the database first in the My City tool and then, when more than one result of data is available, into the scenario tool once they have reached the critical points of representation.

If, in a future development of the tools, it is possible to change data sets, more limited ones could be included. For example, a ranking of cities based on an indicator may be published, but may only refer to a limited number of cities in the CATCH database. It would likely be desirable to compare the CO_2 levels of those cities without having to manually search them out.

Data on the Urban Audit website is updated from time-to-time. Efforts should be made to maintain the CATCH database so that the information contained there is as up-to-date as possible. If a CATCH community exists, then this would be an obvious function for them.

The estimation of city-level road transport CO_2 emissions that was conducted for 149 cities could be further expanded with more investment as is shown by the over 300 LUZ boundaries in Figure 5.

As well, the research suggests that the method used by E-PRTR is reasonably accurate at the LUZ level and if this process was carried out for earlier years, or future years, projections and trending would be possible. However, discrepancies exist between the results that we have estimated and those reported to other sources of data such as the Covenant of Mayors.

Ideally, the CATCH database would function as a repository for reliable data fed by the cities themselves as they progressed towards a low carbon transport future. Discussion of how this might work will be left for WP7 Exploitation.

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[16] Such information was forwarded on to Eurostat.

[17] This is a similar approach to TEMS (http://www.epomm.eu/tems/about_tems.phtml), a EPOMM-PLUS project funded in part by Intelligent Energy Europe.

7 Summary

This report documented how data was identified and assessed, and how the database has been populated with relevant data as well as the estimation of nearly 150 city-specific per-capita road transport CO_2 emissions that feed the tools developed in WP4, “My City” and “Scenarios”.

Road transport CO_2 emissions were estimated by using the European Pollutant Release and Transfer Register (E-PRTR) GIS data. The publishing in 2011 of a spatially disaggregated inventory of a range of diffuse atmospheric emissions based on the E-PRTR marked a significant advance in understanding variations in emissions from various sources in Europe. Through this release, the CATCH platform was able to estimate city-level road transport CO_2 emissions for just a few, but over one hundred cities.

Over 40 different indicators had sufficient coverage for the 149 cities for which per-capita road transport CO_2 emissions were created. This data feeds the My City tool of WP4. The My City tool allows for cities to be compared and ranks them according to their per-capita road transport CO_2 emissions.

Future directions of this work include expanding and building upon the indicators that are available for both tools. In particular, now that a baseline has been established using the E-PRTR, accurate historic data and future versions of the E-PRTR data would allow for trending.

8 References

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9 Appendix A: Permissions

9.1 Urban Transport Benchmarking Initiative

Email dated Fri 10/06/2011 15:07

Dear Owen,

I apologise for the delay in responding to your email.

The data collected as part of the Urban Transport Benchmarking Initiative is all available on the 'Benchmarking tool' which forms part of the project website:

http://www.transportbenchmarks.eu/tool/benchmarking-tool.php

As this data is publicly available, it would be fine to use it in your project as long as it is referenced to the Urban Transport Benchmarking Initiative.

Please note that today is my last day in the office before I go on maternity leave so if you have any further queries about the Urban Transport Benchmarking Initiative, please contact my colleague Kieran Holmes (kieran.holmes@ttr-ltd.com) who was involved during the last year of the project.

Kind regards,

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9.2 European Metropolitan Transit Authorities

Email dated Fri 11/03/2011 09:48

Dear Owen Waygood,

I just had an exchange with my colleagues of Madrid in charge of the Barometer publication.

Their suggestion is that you make contact and ask for the specific data you need and they would extract them for you from their data base.

PLease send your query to Laura Delgado Hernandez at <laura.delgado@ctm-comadrid.com> and copy me so I can follow the progress.

With best regards

Sabine AVRIL
Secretary General

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Email dated: Wed 09/03/2011 12:32

Dear Owen Waygood,

I thank you for the interest you take into EMTA activities.

CATCH is indeed an interesting project congratulations!

I believe you already have been through the full reports on Barometer 2006 and 2004 from our website http://www.emta.com/article.php3?id_article=267

and that you are looking for the excel sheets of data collected? the next issue is expected end of April on data 2009- we skipped a year.

There is no problem to hand over to the CATCH project those sheets as long as the sources and data are duly referenced in the CATCH working documents and final publications, as you mentioned it already yourself.

I will turn to our colleagues of the Transport Authority of Madrid CRTM who are in charge of the EMTA Barometer, they are the ones keeping the excel sheets.

Should you have any question on the data itself, please contact Laura Delgado Hernandez (she is copy of this mail) at CRTM Madrid .

I'll keep you informed of the release of the next Barometer issue.

With best regards

Le Mar 8, 2011 à 1:41 PM, Owen Waygood a écrit :

To the owners of the EMTA data,

This is Owen Waygood, I am a researcher working on a EC project called Carbon Aware Travel Choice (CATCH;http://www.carbonaware.eu/). One of the tools we are building will compare cities on CO_2 outputs and their transport network structures including public transport.

From EMTA's bi-annual reports, I can see that there is good city-level data on public transport. I am writing to ask if there is a data-sheet that contains what is being reported? If there is, would it be possible for us to have a copy so that we can include that data in the project? The source of the data would be referenced in the publically available tool.

Thank you for considering our request.

Sincerely,

Owen Waygood on behalf of CATCH

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10 Appendix B: Indicators in the My City data set

Table 12 Indictators, their descriptions, and the Co-Benefit Areas[18] that they apply to.

Indicator name	Indicator description	Co-Benefit Area(s)
Population city	Number of inhabitants in a given city	1
Passenger cars per thousand inhabitants	Number of passenger cars divided by population: expressed in number of cars per thousand inhabitants	7, 2
Annual passenger transport fatalities per million inhabitants	Number of people that are killed by road accidents divided by population: expressed in fatalities per million inhabitants	6
Annual CO_2 emissions due to passenger transport per inhabitant	Annual polluting emissions due to passenger transport divided by population: expressed in tonnes per capita	8
Number of day PM10 concentration exceeds	Number of days of particulate matter PM10 concentration exceeds 50 microg/m3 in the urban area	5
Serious injuries per 1 million	Number of people that are seriously injuried by road accidents divided by population: expressed in number of injuries per million inhabitants	6
Proportion of journeys to work by car or motor cycle	Proportion of journeys to work by car or motor cycle	2, 3
Proportion of journeys to work by cycling or walking	Proportion of journeys to work by cycling or walking	5, 4
Area of city	The area (km^2) of the city.	1
Number of annual road fatalities	Total number of annual fatalities from crashes on roads.	6
Mortality rate u64	Mortality rate for persons aged 64 or less from heart diseases and respiratory illnesses living in Urban Audit cities - number of deaths per 1000 inhabitants	5
Population density city	The population density in people/km2	1, 4
living area per person m2	The average amount of living space per person in m^2	1, 3
days ozone concentration exceeds 120 µg/m³	Number of days ozone concentration exceeds 120 µg/m³ in Urban Audit cities - days per year	5

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[18] Please see Table B-2 for what the co-benefit areas are.

Economic activity rate	Economic activity rate in Urban Audit cities - %	7
LUZ Population region	The population of the region/metropolitan area	1
LUZ Population density region	The population density of the region/metropolitan area.	1
JTW duration	Duration (min) of the journey to work	4, 1
JTW by car	Proportion of journey to work by car	2, 3
JTW walk	Proportion of journeys to work by foot.	5, 4
JTW bicycle	Proportion of journey to work by bicycle.	5, 4
length of PT	Length (km) of the public transport network	1
total road injuries	Total number of road injuries recorded.	6, 5
Days over 200 mg/m3 of NO2	Number of days nitrogen dioxide NO2 concentrations exceed 200 microgram/m3	5
Accessibility by road	Accessibility by road (EU27=100)	1, 4
Accessibility by rail	Accessibility by rail (EU27=100)	1, 4
JTW motorcycle	Proportion of journey to work by motorcycle	2
Target CO_2	This is the CO_2 per capita value that the city aims to reach.	8
Apt costs m2	Average price for an apartment per m2	2, 3
Jobs	Total employment / jobs (work place based)	7, 4
People commuting into the city	People commuting into the city	1, 4
Jobs per capita	Based on the number of jobs divided by the population	7, 3
Proportion of area in green space	Proportion of the area in green space	1
LUZ total land area	Total land area of the Large Urban Zone in (km2).	1
LUZ road transport CO_2 per capita	The road transport CO_2 per capita for the Large Urban Zone	8
LUZ Economic activity rate	Large Urban Zone; Economic activity rate in Urban Audit cities - %	7
LUZ registered cars	Large Urban Zone; Registered cars in Urban Audit cities - number of cars per 1000 inhabitants	2
LUZ injuries from crashes per 10000 citizens	Large Urban Zone; Number of persons seriously injured in road accidents per 10000 population	6
LUZ JtW by car	Large Urban Zone; Percentage of journeys to work by car	4, 6, 2
LUZ JtW PT	Percentage of journeys to work by public transport (rail, metro, bus, tram)	2, 4
LUZ JtW by bicycle	Large Urban Zone; Percentage of journeys to work by bicycle	5, 2, 4

LUZ Fatalities per 10000	Large Urban Zone; Number of deaths in road accidents per 10000 population	6
Estimate of 1990 Transport CO_2 per capita	Functional estimate of 1990 transport CO_2 per capita.	8

Table 13 Co-Benefit Areas

Number	Name
1	Planning
2	Budget
3	Community
4	Time and Accessibility
5	Health
6	Safety
7	Economy
8	CO_2

11 Appendix C: Data sources

Table 14 Data sources for the CATCH database.

Short description	Total indicator values in DB entered from that source
Urban Audit, Eurostat http://epp.eurostat.ec.europa.eu/portal/page/portal/region_cities/city_urban/data_cities/database_sub1? _piref1715_3143760_1715_3143753_3143753.p=h&_piref1715_3143760_1715_3143753_3143753.nextActionId=2	58314
Derived from other source	4130
E-PRTR (European Pollutant Release and Transfer Register) http://www.bipro.de/__prtr/	596
City direct	298
UNFCCC (United Nations Framework Convention on Climate Change) http://unfccc.int/ghg_data/items/3800.php	104
Instituto Brasileiro de Geografia e Estatística (IBGE) http://www.ibge.gov.br/english/	25
London Travel Survey http://www.tfl.gov.uk/assets/downloads/corporate/London-Travel-Report-2007-final.pdf	5
Pro-Aim	5
FETRANSPOR http://www.fetranspor.com.br/	4
Sistema de Indicadores de Percepção Social http://www.ipea.gov.br/portal/index.php?option=com_content&view=article&id=6186&Itemid=33	4
Aramzem de Dados	3

http://www.armazemdedados.rio.rj.gov.br/	
Confederação Nacional de Municípios (CNM) http://www.cnm.org.br/	3
Central Statistics Office Ireland http://www.cso.ie/	2
UOL educação – 2008 http://educacao.uol.com.br/atualidades/pnad-2008.jhtm	2
Estado de Sao Paulo http://www.estadao.com.br/	2
Secretaria Municipal de Meio Ambiente www0.rio.rj.gov.br/smac/	1

12 Appendix D: Cities where road transport CO_2 was estimated

Table 15 List of 149 cities estimated in CATCH GHG DB.

Name	Country		Name	Country		Name	Country
Aalborg	Denmark		London	United Kingdom		Portsmouth	United Kingdom
Arhus	Denmark		Grenoble	France		Potenza	Italy
Amiens	France		Groningen	The Netherlands		Praha	Czech Republic
Amsterdam	Netherlands		Halle an der Saale	Germany		Presov	Slovakia
Ancona	Italy		Hamburg	Germany		Regensburg	Germany
Athina	Greece		Hannover	Germany		Reggio di Calabria	Italy
Augsburg	Germany		Helsinki	Finland		Reims	France
Badajoz	Spain		Jonkoping	Sweden		Riga	Latvia
Banska Bystrica	Slovakia		Karlsruhe	Germany		Roma	Italy
Barcelona	Spain		Kiel	Germany		Rotterdam	The Netherlands
Bari	Italy		Koblenz	Germany		Saarbrucken	Germany
Berlin	Germany		Kosice	Slovakia		Santiago de Compostela	Spain
Bern	Switzerland		Lausanne	Switzerland		Sassari	Italy
Besancon	France		Le Havre	France		Schwerin	Germany
Bielefeld	Germany		Leicester	United Kingdom		Setubal	Portugal
Birmingham	United Kingdom		Leipzig	Germany		Sevilla	Spain
Bologna	Italy		Lincoln	United Kingdom		Sheffield	United Kingdom
Bonn	Germany		Lisboa	Portugal		Sofia	Bulgaria
Bordeaux	France		Liverpool	United Kingdom		Stockholm	Sweden
Braga	Portugal		Ljubljana	Slovenia		Strasbourg	France
Bratislava	Slovakia		Luxembourg	Luxembourg		Stuttgart	Germany
Bremen	Germany		Lyon	France		Tallinn	Estonia
Bristol	United Kingdom		Madrid	Spain		Tampere	Finland
Brno	Czech Republic		Magdeburg	Germany		Taranto	Italy
Bruxelles / Brussel	Belgium		Mainz	Germany		Tartu	Estonia
Bucuresti	Romania		Malaga	Spain		Toulouse	France

Budapest	Hungary		Malmo	Sweden		Trento	Italy
Cagliari	Italy		Manchester	United Kingdom		Trier	Germany
Cambridge	United Kingdom		Metz	France		Trieste	Italy
Campobasso	Italy		Milano	Italy		Torino	Italy
Cardiff	United Kingdom		Monchengladbach	Germany		Turku	Finland
Caserta	Italy		Munchen	Germany		Umea	Sweden
Catania	Italy		Murcia	Spain		Usti nad Labem	Czech Republic
Catanzaro	Italy		Nancy	France		Utrecht	The Netherlands
Clermont-Ferrand	France		Nantes	France		Valencia	Spain
Coimbra	Portugal		Napoli	Italy		Valladolid	Spain
Koln	Germany		Newcastle upon Tyne	United Kingdom		Valletta	Malta
Kobenhavn	Denmark		Nitra	Slovakia		Venezia	Italy
Cremona	Italy		Nurnberg	Germany		Verona	Italy
Darmstadt	Germany		Odense	Denmark		Wien	Austria
Dresden	Germany		Oslo	Norway		Vilnius	Lithuania
Dusseldorf	Germany		Ostrava	Czech Republic		Vitoria/Gasteiz	Spain
Erfurt	Germany		Oviedo	Spain		Warszawa	Poland
Exeter	United Kingdom		Palermo	Italy		Weimar	Germany
Frankfurt am Main	Germany		Pamplona/Iruna	Spain		Wiesbaden	Germany
Freiburg im Breisgau	Germany		Paris	France		Worcester	United Kingdom
Geneve	Switzerland		Perugia	Italy		Wrexham	United Kingdom
Glasgow	United Kingdom		Pescara	Italy		Zaragoza	Spain
Goteborg	Sweden		Plzen	Czech Republic		Zilina	Slovakia
Gottingen	Germany		Porto	Portugal			

13 Appendix E: Scenarios Tool Cities

Table 16 Cities that are included in the Scenarios Tool data set.

City, Nation	City, Nation	City, Nation
Bristol, United Kingdom	Bonn, Germany	Turin, Italy
Cardiff, United Kingdom	Bremen, Germany	Gdansk, Poland
Manchester, United Kingdom	Darmstadt, Germany	Warsaw, Poland
Birmingham, United Kingdom	Frankfurt (Oder), Germany	Bydgoszcz, Poland
Leicester, United Kingdom	Freiburg im Breisgau, Germany	Krakow, Poland
Liverpool, United Kingdom	Göttingen, Germany	Lodz, Poland
Lisbon, Portugal	Halle an der Saale, Germany	Suwalki, Poland
Brussels, Belgium	Hamburg, Germany	Szczecin, Poland
Gent, Belgium	Hanover, Germany	Torun, Poland
Antwerp, Belgium	Karlsruhe, Germany	Madrid, Spain
Charleroi, Belgium	Kiel, Germany	Seville, Spain
Liège, Belgium	Mainz, Germany	Palma de Mallorca, Spain
Prague, Czech Republic	Mönchengladbach, Germany	Pamplona/Iruña, Spain
Brno, Czech Republic	Munich, Germany	Toledo, Spain
Ostrava, Czech Republic	Saarbrucken, Germany	Stockholm, Sweden
Plzen, Czech Republic	Wiesbaden, Germany	Vienna, Austria
Usti nad Labem, Czech Republic	Frankfurt, Germany	Graz, Austria
Cologne, Germany	Nuremburg, Germany	Linz, Austria
Dresden, Germany	Dortmund, Germany	Vilnius, Lithuania
Stuttgart, Germany	Budapest, Hungary	Tallinn, Estonia
Augsburg, Germany	Rome, Italy	Ljubljana, Slovenia
Berlin, Germany	Florence, Italy	Maribor, Slovenia
Bielefeld, Germany	Pescara, Italy	Banska Bystrica, Slovakia
Bratislava, Slovakia	Kosice, Slovakia	

14 Appendix F: Indicators from Urban Audit and Derived

Table 17 Indicators directly from Urban Audit.

Indicator short description	Indicator short description	Indicator short description
Population_city	Population_density_region	Proportion of area in green space
Green space per capita	Cost of monthly combined PT pass	Proportion of space in transport
Passenger cars per thousand inhabitants	GRP	Recreational space per capita
Annual passenger transport fatalities per million inhabitants	JTW duration	LUZ total land area
Number of day PM10 concentration exceeds	JTW by car	LUZ Apt price wrt median HH income
Proportion of journeys to work by car or motor cycle	JTW walk	LUZ Car thefts per 1000 inhabitants
Proportion of journeys to work by public transport (rail, metro, bus, tram)	JTW bike	LUZ Economic activity rate
Proportion of journeys to work by cycling or walking	length of PT	LUZ Green space (m2) per capita
length of cycle network	total road injuries	LUZ Green space proportion
length of segregated bus lanes	Residents exposed to daytime traffic noise	LUZ recreation space proportion
Area of city	Days over 200 mg/m3 of NO2	LUZ Residential proportion
registered cars	Residents exposed to daytime rail noise	LUZ registered cars
Number of annual road fatalities	Accessiblity by road	LUZ injuries from crashes per 10000 citizens
Number of annual road injuries	Accessiblity by rail	LUZ recreation space per capita m2
registered motorcycles	length of jtw	LUZ Motorcycles per 1000
mortality_rate_u64	PPS per capita	LUZ JtW by car
population_density_city	JTW motorcycle	LUZ JtW PT
living area per person m2	Apt costs m2	LUZ JtW by bike
days ozone concentration exceeds 120 µg/m³	Housing cost (m2)	LUZ Fatalities per 10000
Economic activity rate	Jobs	LUZ PT network coverage
Population_region	People commuting into the city	LUZ PT length per capita

Table 18 Derived indicators.

Indicator short description	Indicator short description	Indicator short description
Annual CO2 emissions due to passenger transport per inhabitant	Jobs per capita	Estimate of 1990 transport CO2 per capita
Serious injuries per 1 million	LUZ road transport CO2	
Target CO2	LUZ road transport CO2 per capita	