

OLAP technologies applied to the integration of geographic, thematic and socioeconomic data in the context of ESPON

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► To cite this version:

Roger Milego, Maria-José Ramos, Francisco Domingues, César Martinez. OLAP technologies applied to the integration of geographic, thematic and socioeconomic data in the context of ESPON. [Research Report] ESPON. 2014. hal-03609708

HAL Id: hal-03609708 https://hal.science/hal-03609708

Submitted on 15 Mar 2022

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TECHNICAL REPORT





OLAP technologies applied to the integration of geographic, thematic and socioeconomic data in the context of ESPON

CONTENT

This technical report details the methodology that has been developed within ESPON M4D in order to combine and integrate in a single database data from heterogeneous sources, so that they can be queried to obtain valuable results.

Data are integrated through a Reference Grid structure, at 1 km² resolution or 100 m² in the case of the urban data.

This method has resulted in the production of different ESPON OLAP Cubes, at European, Urban and Neighbourhood levels.

An ESPON OLAP webtool has been produced to facilitate querying the OLAP Cubes and get maps and charts in a swift way.



50 pages

ESPON M4D -MULTI DIMENSIONAL DATABASE DESIGN & DEVELOPMENT



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1 Setting the scene

This technical report has been prepared by the UAB in the framework of the ESPON M4D project. It is an update of a former technical report entitled "Disaggregation of socioeconomic data into a regular grid: Results of the methodology testing phase" and it gathers all the technical and methodological aspects of the work carried out by the UAB in order to develop a method and tools to integrate and analyse heterogeneous datasets to benefit the ESPON Programme, in particular, and territorial and spatial assessment, in general.

The challenge of integrating data which are thematically, spatially and/or temporary heterogeneous was already faced in the former ESPON Programme. The harmonization of datasets in a fixed spatial division (NUTS3) solution, which was chosen by many ESPON 2006 projects, presented some doubts and not always convincing results. Another strategy for data integration was needed.

The Modifiable Areas Unit Problem (MAUP) study (Grasland et al, 2006) already highlighted the integration of heterogeneous databases as one of the most promising application of gridding methods for ESPON. Two potential fields of applications were pointed out: time harmonisation of changing territorial units and thematic harmonisation and combination of heterogeneous spatial sources. Furthermore, the so-called "Eurostat oriented" strategy was suggested to be replaced by another strategy that could be named "EEA oriented", where all the data would be transformed into a grid and integrated on this basis (Grasland et al, 2006).

The terms of reference for the ESPON 2013 DB project already emphasized the need towards a different way of data integration, where socioeconomic information were put into smaller units comparable to those used for environmental or natural data. The analysis of different experiences of data integration worldwide (Deichmann et al, 2001; Gallego, 2001; Nordhaus, 2006) led to the conclusion that the best way to downscale socioeconomic data and make them comparable with other kind of data, is using a regular grid structure, in which each cell takes a figure of the indicator or variable. Moreover, recent territorial cohesion policies derived from the Territorial Agenda 2020 have highlighted the importance for a place-based approach and territorialisation of policies (Zaucha, 2013), which can benefit from spatial data integration like the one applied under the ESPON M4D project by the UAB.

Another important key fact with regard to the methodology described in this technical report was the release of the GEOSTAT 2006 population grid¹. It was an initiative from the European Forum for Geostatistics and Eurostat, through the GEOSTAT project, published in April 2012. It is a one square kilometre gridded dataset containing population figures for the year 2006. It integrates data from national grid initiatives and, wherever this has not been possible, the European disaggregated dataset produced by the Austrian Institute for Technology (AIT) by means of detailed datasets, such as a Soil Sealing layer at 30x30m resolution.

To conclude the presentation section, an introduction to OLAP should be made. Online Analytical Processing is a computer-based technique to answer multi-dimensional analytical queries swiftly. OLAP tools enable users to analyse multidimensional data interactively from multiple perspectives. It experienced a strong growth in the late 90s, but it had been mainly applied to business data in the search for business intelligence. The application of such technique to social and geographical information

¹ <u>http://www.efgs.info/data/GEOSTAT_Grid_POP_2006_1K</u>

as shown in this technical report is rather innovative and provides added value to the integration of data by means of a grid. Moreover, integrating such technique in a web tool, to facilitate querying the database to any kind of user is also an asset of the methodology that has been implemented during the ESPON M4D by the UAB, which has lead to the delivery of different OLAP Cubes and an online webtool to query them. All the technical details with regard to the methodology implemented and results obtained is included in these pages.

2 Background and introductory concepts

The methodology and results achieved under the ESPON M4D project by the UAB started within the former ESPON 2013 Database project, in which the basis for the methodology was set up. Under M4D the methodology has evolved, several OLAP Cubes have been build up at different scales and an online webtool has been developed in order to facilitate the querying of the Cubes in an interactive, more user-friendly manner.

Under the ESPON 2013 DB project the UAB assumed the challenge of "combining socio-economic data measured for administrative zoning (NUTS level) and environmental data defined on a regular grid (like Corine Land cover)". The ESPON 2006 program had developed some indicators in which the environmental data was transposed to NUTS division by means of GIS tools, in order to make them comparable to socioeconomic data. The results from this integration strategy, not always convincing, make clear the necessity of implementing a new integration process based on grid methods as it was said in the tender of the ESPON 2013 Database project and by the Modifiable Areal Unit Problem study:

Modifiable Areal Unit Problem (ESPON 3.4.3)

The MAUP study, in its chapter 4 "*Exploration of gridding methods"*, highlighted the integration of heterogeneous databases as one of the most promising application of gridding methods for ESPON.

Two potential fields of applications were distinguished for gridding methods:

• Time harmonisation of changing territorial units.

"The use of grid help to build an harmonised territorial framework where all changing territorial divisions are harmonised and can further be used for the analysis of time variation" MAUP study (ESPON 3.4.3)

• Thematic harmonisation and combination of heterogeneous spatial sources.

The ESPON 2006 integration strategy, called "Eurostat oriented" by MAUP study, based on transferring all the information that it is not delivered on the basis of administrative units (NUTS 2 or NUTS 3) toward administrative units, was questioned, and the use of a new strategy was proposed.

"Information of good quality (as CLC) is therefore transformed into information of bad quality when projected in spatial units which are not adapted" MAUP study (ESPON 3.4.3).

""Eurostat oriented" strategy could be replaced by another strategy that could be called the "EEA oriented" where all data would be transformed into grid and integrated on this basis" MAUP study (ESPON 3.4.3).

Existing experiences

At the very beginning, a literature review was made in order to support the best decision on the methodology to be implemented. The following examples show different approaches in which a regular grid structure was used as a common data integrator:

• "A Downscaled Population Density Map of the EU from Commune Data and Land Cover Information" by Javier Gallego, JRC-ISPRA.

A combination of commune population data with Corine Land Cover to produce an EUwide grid with 1 ha resolution of downscaled population density².

• **G-Econ Research project** of the University of Yale to develop a geophysically based data set on economic activity.

Estimation of gross output at a 1-degree longitude by 1-degree latitude resolution at a global scale for virtually all terrestrial grid cells based on spatial rescaling settled on proportional allocation³.

• **FARO-EU** (Foresight Analysis of Rural areas Of Europe)

The project is aimed to analyse Rural Development in Europe by analysing patterns and trends of a selection of territorial indicators specific for rural areas within a Spatial Regional Reference Framework⁴.

• "Transforming Population Data for Interdisciplinary Usages: From census to grid" by Deborah Balk & Greg Yetman from Columbia University.

Creation of the Gridded Population of the World (GPW) data base implementing **a proportional allocation** of population from administrative units to grid cells⁵.

The objectives established in the tender of the ESPON 2013 DB, the MAUP study results and recommendations, the bibliography research on existing methodologies and our experience at the UAB, as European Topic Centre on Land Use and Spatial Information, supporting the EEA in monitoring the land use/land cover change in Europe and analyzing the environmental consequences; lead us to the conclusion that the best way to downscale socioeconomic data and make them comparable with other kind of data, is **using a regular grid structure**, in which each cell takes a figure of the indicator or variable.

²

http://epp.eurostat.ec.europa.eu/portal/page/portal/research_methodology/documents/S14P3_JAVIER_GALLEGO_DO WNSCALED_POPULATION_DENSITY.pdf

³ "New Metrics for Environmental Economics: Gridded Economic Dats" by William D. Nordhaus. http://www.oecd.org/dataoecd/44/7/37117455.pdf

⁴ <u>www.faro-eu.org</u>

⁵ <u>http://sedac.ciesin.columbia.edu/gpw-v2/GPWdocumentation.pdf</u>

The 1 km² European Reference Grid

The 1st Workshop on European Reference Grids⁶ was organized by the Joint Research Centre of the European Commission following a request of the EEA and the request of the INSPIRE Implementing Strategies Working Group that recommended the adaptation of a Europe-wide reference grid to facilitate the management and analyses of spatial information. The interest of the creation of a common coordinate reference system and a common equal-area grid to represent EU and Pan-Europe was also expressed by the National Statistical Institutes.

In this way, the European Reference Grid (ERG) was born, usign a standard European projection system (ETRS89-LAEA 52N 10E) and having a spatial resolution of 1 km².

ERG has become an European standard dataset, broadly used by all the European institutions and research centres.

Therefore, taking into account this recommendations and our experience under some EEA projects such as LEAC (Land and Ecosystem Accounting), we proposed to disaggregate socioeconomic data into the **1 km² European Reference Grid⁷**, as it is the way in which valuable data for the ESPON projects, such as the Corine Land Cover datasets, are stored as well.

GEOSTAT Population Grid

In April 2012, an initiative from the European Forum for Geostatistics and Eurostat, through the GEOSTAT project, led to the publication of a gridded population dataset, with a 2006 time stamp. It is a one square kilometre (1 km^2) gridded dataset containing population figures for the year 2006. It integrates data from national grid initiatives and, wherever this has not been possible, the European disaggregated dataset produced by the Austrian Institute for Technology (AIT⁸). This results into an integrated single population grid dataset.

⁶ <u>http://eusoils.jrc.ec.europa.eu/projects/alpsis/Docs/ref_grid_sh_proc_draft.pdf</u>

⁷ http://dataservice.eea.europa.eu/dataservice/metadetails.asp?id=760

⁸ Austrian Institute for Technology



Figure 1. GEOSTAT Population Grid 1 km² (2006)

The added-value of this dataset compared to the former JRC 2001 population grid is the improvement in the population disaggregation phase, made for some countries at national level (AT, FI, FR, SE, DK, PL, EE, ES, SI, NL, NO, UK, PT) and, for the rest, at European level by AIT, by means of detailed datasets, such as the Soil Sealing layer. The GEOSTAT 2006 Population grid can be used by any user within the user's own organisation, but there are some restrictions regarding its use for commercial purposes and its dissemination to third parties.

The GEOSTAT 2006 population grid has become the main ancillary data for the disaggregation process of socioeconomic data, as it will be further detailed in the methodological chapter.

The next section describes the methodology that has been defined and carried out throughout the project, which has resulted in the creation of different ESPON OLAP Cubes, a user manual on how to use them and a webtool aimed at facilitating the querying of OLAP Cubes and obtaining prompt and nice charts and maps out of them.

3 Methodology description

The methodological process in order to build up the ESPON OLAP Cubes can be described in two main phases:

- Data integration within the ERG
- OLAP Cube creation

In figure 4, a general schema of data preparation for integration within an OLAP database is shown.



Figure 2. General schema of data processing for OLAP integration

In order to combine socioeconomic data with other types of datasets within an OLAP database, the 1 km² European Reference Grid (ERG), adopted by several European stakeholders at the First Workshop on European Reference Grids (JRC-IES-LMU-ESDI, 2003), is used as the **common integrator layer**. This means, in the end, that each single grid cell must store a single figure for each variable, either numeric or alphanumeric.

As it can be seen in figure 1, in the end the ERG will store all types of information, so that they can be compared on a cell-by-cell basis.



Figure 3. The 1 km2 European Reference Grid will hold both environmental and socioeconomic information

Actually, depending on the nature of the dataset or variable, we distinguish:

- **Geographic dimensions**: they define the geographical unit each cell belongs to (NUTS region, LUZ, UMZ, biogeographical unit, etc.)
- **Thematic dimensions**: they define a physical characteristic of a grid cell, such as land cover type.
- **Measures**: they are numeric variables which can be aggregated by any combination of the data dimensions available in the system. They are surface units (e.g. hectares) but also socioeconomic figures (population, unemployment, GDP...).

Depending on the type of dataset different procedural steps are applied in order to integrate them within the ERG. These methods are defined in the next section.

3.1 Integration methods

As for **geographic dimensions**, an overlay (intersection) between the dimension and the 1 km² ERG is undertaken, in order to give each grid cell a single feature code (e.g. a NUTS3 code, a LUZ code, etc.). Aiming at avoiding coastal discrepancies, some dimensions, such as NUTS regions, are previously submitted to spatial extension processes generating proximity layers.



Figure 4. Example of the intersection process

In the case of different geographic units overlaying one cell, a maximum area criterion is applied:

Maximum area criteria: the cell takes the value of the unit which covers most of the cell area. It should be a good option for uncountable variables.



Taking into account that some **thematic layers** have a higher resolution than 1 km^2 (e.g. Corine Land Cover is available at 100 m² resolution), the combination of such information is carried out at **100 m²**. In this way, it is possible to store, for instance, the different land cover classes and their surfaces for each grid cell. The grid cell index (unique identifier for each grid cell) might appear duplicated in the resulting output table, as many times as different land cover classes exist within the square kilometre. Geographic dimensions will have their code repeated as well:

Index	NUTS99	NUTS03	NUTS06	NUTS10	FUA	LUZ04	LUZ12	MUA	UMZ00	CLC90	CLC00	CLC06	HA
26421951	1178	1202	1004	1141	745	267	535	1013	117593	111	111	111	58
26421951	1178	1202	1004	1141	745	267	535	1013	117593	112	112	112	42
												\square	
	UNIC	UE COM	IBINATIO	ON OF UN	IITS								
	26421	1951-117	78-1202-	1004-114	1-745-	267-535	5-1013-1	17593- 1	11-111	-111			
	26421951-1178-1202-1004-1141-745-267-535-1013-117593-112-112-112												

Figure 5. Example of unique combination of units within a grid cell

When it comes to **socioeconomic data**, typically stored by NUTS3, the main challenge is how to disaggregate such figures and get a single value for each cell. In order to do so, population has been used as an **ancillary variable**. With the release of the GEOSTAT 2006 population grid, high quality 2006 population figures are available at 1 km² resolution. That valuable information is used to redistribute population figures at NUTS3 level for the time series 1990-2011 (compiled by ESPON M4D) proportionally to the distribution of population in 2006. When doing so, figures by each grid cell are a proxy of the actual value, but they compensate each other when grid cells are aggregated back to show the result of a query, which always should be done by a bigger reporting unit (NUTS3, LUZ, UMZ...). The rest of socioeconomic variables, such as GDP/capita or unemployment are redistributed in the same way, weighting the figures by population in each grid cell. In this way, those figures can be aggregated back in a query, despite the different NUTS breakdowns or geometries involved (urban delimitations, administrative levels, etc.).

In this case, a proportional and weighted calculation is applied for each cell:

Proportional and weighted calculation: the cell takes a proportionally calculated value by area, but this value is weighted for each cell, according to an external

variable (e.g. population). This method is applied to improve the territorial distribution of a socioeconomic indicator. For instance, a GDP indicator is redistributed by 1 km² grid and weighted by the population figures of each cell (coming from the GEOSTAT database).



Cell value = $W_c \Sigma$ ($V_i * Share_i$)

Where: V_i = Value of unit i Share_i = Share of unit i within the cell W_c = weight assigned to cell c In the example: W_c * (V_1 * 0.85 + V_2 * 0.15)

In the example above, the weighting figure corresponds to the share of population living in that grid cell. In this way, a single figure for each socioeconomic variable is calculated by each unique grid cell.

Once the data dimensions and measures have been overlaid with the ERG and each grid cell has a single figure for each variable (or more, in the case of Corine Land Cover), then it is possible to join all the information in a unique OLAP database. In order to build it up, a star schema has been selected. It is composed by one **fact table** and one **dictionary table** for each geographical or thematic dimension.



Figure 6. Example of the selected star schema

The **fact table** stores, in the end, all the data dimensions (geographic and thematic) and all the variable measures. They are all referred to a unique identifier for each grid cell. Whenever different land cover classes occur in a single grid cell, the cell code and geographic codes appear as many times as different CLC classes exist. As for measures (numeric values) they are distributed proportionally to the area share of each grid cell piece:

1.1 OUTPUT TABLE																		
Grid Index	Nuts3		CLC C	lass	Area	a (ha)	1.2 OUTPUT TABLE					[1.3 OUTPUT TABLE					
49815413	371		211		4		Grid	Index	Po	p90		Pop 11	Ì	Grid Inde	x	Active99		Gdp99
49815413	371		311		96		49815413			5,12		5,07	ĺ	49815413	3	2,32		0,57
		Grid Inde 498	ex 15413	Nuts3 371		CLC Class 211	OLAP Area (ha) 4	P FACT TA Pop90 0,21	BLE	Pop11 0,20	alues	Actv99	g or	Gdp99	ha) f	_) ìeld (4 %, 9	5 %)	
		498	15413	371		311	96	4,91		4,87		2,23		0,55	-			

Figure 7. Schema of OLAP fact table built-up

The **dictionary tables** store the description of a specific dimension (e.g. NUTS names). They are put into relation with the fact table by means of the dimension codes.

Once the fact and dictionary tables are built, then the OLAP database (also named OLAP cube, as a shortcut for multidimensional) is ready to be created.

3.2 OLAP Cubes creation

Once the fact and dictionary tables are ready, they can be integrated within a single **OLAP (Online Analytical Processing) database or cube**.

The OLAP technology⁹ use a multidimensional data model, allowing complex analytical and ad-hoc queries with a rapid execution time. This solution facilitates the integrated analysis of several types of geographic and statistical data to users with or without GIS knowledge.

OLAP (Online Analytical Processing) is a computer-based technique to answer multidimensional analytical queries swiftly. OLAP tools enable users to analyse multidimensional data interactively from multiple perspectives. It experienced a strong growth in the late 90s, but it had been mainly applied to business data in the search for business intelligence. The application of such techniques to social and geographical information is rather innovative and provides added value to the integration of data by means of a grid.

The OLAP database (also called **Cube**, as for being multidimensional) is created by means of Microsoft SQL Analysis Services 2000. The resulting product is a .CUB file that can be queried using Microsoft Excel or an online connection to a remote server. A User Manual (annex $\frac{x}{x}$) has also been produced to allow users to connect to and query the OLAP database.

⁹Some OLAP information resources:

¹⁻ http://en.wikipedia.org/wiki/Online analytical processing

²⁻ http://www.cs.sfu.ca/CC/459/han/papers/chaudhuri97.pdf

³⁻ http://es.wikipedia.org/wiki/Cubo_OLAP

In this way, users are able to ask some questions taking into account the different socioeconomic, thematic and geographic variables integrated within the database. For example, having the GDP and CLC changes in the ESPON OLAP cube, we could analyse which land cover flows occur by different GDP ranges, and, in the end, get the results on a NUTS3, NUTS2 or country (NUTS0) basis.

As mentioned, those OLAP Cubes can be queried by means of Microsoft Excel through a dynamic table, allowing the user to choose what dimensions appear as rows or columns and which measures will be shown as values after the query. In this way, the user can swiftly get results like the example in figure $\frac{4}{3}$.

	A	В	С	D	E	F	G
1	NUTS3 (2010) 🔻	Population 1990 thou Po	pulation 1998 thou P	Population 2001 thou	Population 2005 thou	Population 2010 thou G	DP 2006 Million Euro
19	⊞ IS	253,79	272,38	283,36	293,58	317,63	,00
20	⊞IT	56.618,42	56.832,68	56.890,15	58.381,92	60.254,84	1.440.002,47
21	BITC	14.933,24	14.851,57	14.884,49	15.399,88	15.975,45	468.376,67
22	■ITC1	4.310,28	4.224,99	4.205,74	4.316,11	4.431,88	118.838,66
23	ITC11	2.257,67	2.187,64	2.169,09	2.236,30	2.296,93	63.428,96
24	ITC12	185,14	179,31	177,73	177,57	180,10	4.858,60
25	ITC13	191,90	188,24	187,60	188,19	186,72	4.935,15
26	ITC14	154,36	152,23	151,52	153,69	155,17	3.436,16
27	ITC15	328,95	333,36	337,02	348,93	363,84	9.867,97
28	ITC16	543,93	551,01	554,92	569,49	589,07	16.369,90
29	ITC17	206,96	207,27	207,94	213,06	220,82	4.933,67
30	ITC18	441,37	425,92	419,93	428,87	439,23	11.008,25
31	⊟ITC2	115,23	118,87	120,04	123,68	128,70	3.690,50
32	ITC20	115,23	118,87	120,04	123,68	128,70	3.690,50
33	⊟ITC3	1.699,93	1.613,74	1.584,52	1.597,82	1.621,60	36.948,34
34	ITC31	214,15	208,44	205,76	215,37	221,66	4.367,01
35	ITC32	286,88	277,50	274,30	282,71	288,43	6.329,12
36	ITC33	965,85	903,15	883,25	875,81	883,26	21.102,23
37	ITC34	233,05	224,65	221,21	223,93	228,25	5.149,98
38	⊞ITC4	8.807,80	8.893,97	8.974,19	9.362,26	9.793,27	308.899,17
39		13.887,83	14.017,39	13.938,78	14.085,78	14.167,64	227.661,38
40	⊞ITG	6.607,85	6.657,64	6.614,65	6.663,13	6.715,40	107.719,64
41		10.346,29	10.451,05	10.588,16	11.026,92	11.547,94	325.847,11
42	⊞ITI	10.843,22	10.855,03	10.864,06	11.206,21	11.848,42	310.397,67
43	۳u	39,20	42,80	33,77	46,42	48,21	41,62
44	⊞LT	3.693,05	3.561,58	3.486,33	3.424,67	3.328,42	23.876,93
45	⊞LU	377,81	420,22	437,02	459,05	499,51	33.163,85
46	. LV	2.668,35	2.420,98	2.364,44	2.306,63	2.248,59	15.902,80
47	®MK	176,87	183,13	183,42	181,31	179,85	,00
48	⊞MT	352,43	376,51	391,42	402,67	416,96	4.602,48
49		14.860,29	15.622,33	15.954,64	16.273,11	16.542,57	536.973,42
50	BNL1	1.590,79	1.637,84	1.668,47	1.698,32	1.710,81	54.343,44
51	B NL11	548,31	552,56	560,98	569,58	571,26	24.901,60
52	NL111	145,73	146,76	148,24	148,08	146,24	2.770,09
-							

Figure 8. Sample result of an OLAP Cube query within MS Excel

Section 4 shows the results derived from the implementation of the OLAP technology, including the different OLAP Cubes created under ESPON M4D, plus an advanced web tool to query those OLAP Cubes through a simple web browser.

3.2.1 Specificities of the Urban OLAP Cube

This section details some of the aspects that concerned the creation of the Urban ESPON OLAP Cube. In this case, it was decided to build up an OLAP Cube for the urban areas at a higher resolution than the regular ESPON OLAP Cube for Europe. This fact means that the integration grid has a 100m*100m (1 hectare) cell size instead of the "classical" 1 km².

Input data

The data to be processed and included in the ESPON Urban OLAP Cube was mainly EU based datasets that characterizes cities by its morphology, uses, cover and structure, among others. Those include:

- Urban Morphological Zones (UMZ) 2000
- Morphological Urban Areas (MUAs)
- Functional Urban Areas (FUAs)
- Large Urban Zones (LUZ) 2004
- Large Urban Zones (LUZ) 2012
- Urban Atlas¹⁰ 2006 and update 2012

Additionally, it was decided to include administrative boundaries as LAU2 (Local Administrative Units 2 - GISCO) and population data using GEOSTAT 2006 Population grid.

The input data have different extents and resolution, some covers the Atlantic Portuguese and Spanish islands and others not, most layers have 100 meters resolutions, except for Urban Atlas raster (10 meters resolution) and GEOSTAT Population (1km²). For that reason different quality checks, firstly, and data harmonization, afterwards, have been carried out in order to be able to combine the different datasets correctly.

Quality check and harmonization

Data have been treated in a way that no pixels are skipped: The first step consists on harmonizing data by grouping it by resolution. All 100 meters resolution layers were snapped into the main layer Urban Atlas and then 'No Data' zones were converted to zero, so that when applying the "combine" tool no pixels are left behind. Data cover different extents and zones and when 'no data' is present in a shared/overlapping area no combine is done, so a value must be present.

Population raster at 1km² resolution was integrated in the "combine" as it is so no harmonization is needed as the pixel borders were correctly aligned with all other input rasters.

The struggling point comes when trying to harmonize Urban Atlas due to its resolution (10 m) which increased the processing time of each step and sometimes the results were not fully correct as the software used (ArcGIS 10.1) got some outputs corrupted. Although the big effort and huge time spent treating 10m resolution data, Urban Atlas was integrated in two steps. First, UA 2006 was included in the "combine" and,

¹⁰ <u>http://land.copernicus.eu/local/urban-atlas</u>

afterwards, another "combine" was done with the UA 2012 updates. The urban zones outside urban atlas were included afterwards, as it was impossible to deal with Urban Atlas 'No Data' areas and convert them into zero.

In order to pre-process the data to be included in the final "combine", the third one, it was needed to create a mask with presence/absence of urban atlas classes 2006 or 2012. The first step was reclassifying both UA 2006 and UA 2012 'Nodata' to 1 and UA classes to 'Nodata'. Afterwards, mosaicking both masks into a single one to have a final presence/absence raster was needed. The time spent was huge due to the extent to be covered.

Combination of input data

As mentioned before, the "combine" process had to be done in three steps, first by combining all urban layers and LAU2 at 100m with UA 2006 and Population grid; the second "combine" the same, but using the UA 2012 update instead; and, finally, the third and last one using all urban layers, LAU2, Population raster and the 10m mask with the zones outside UA 2006 and 2012. The "combines" were done always at 10m resolution. The 1km EEA reference grid was included as well because each population pixel should have and ID in order to be distributed within the correct area of urban fabric within its zone.

To merge all "combines" in a final table the tool "append" (access/sql server) was executed twice, using the first "combine" table as the main one, and adding the second and third ones to the end.

Population was distributed among the continuous and discontinuous urban fabric Urban Atlas classes present within that 1 km² grid cell. This process assumes that population is located in urban fabric zones. In areas outside Urban Atlas the population was distributed according to the amount of area covered.

To reduce the amount of rows and enhance the performance avoiding replicated values, the output table was summarized by all columns using a "group by" in MS Access, except for the population column that had to be added.

The final table was inserted into MS SQL Server 2003 database and then the Cube was built in MS SQL Analysis Services Projects database with the following characteristics:

Dimensions:	Measures:	Calculated Members:
LAU2	Population UMZ 2000	Area in Hectares
UMZ 2000	Area	
MUA	Population 2006	
FUA		
LUZ 2004		
LUZ 2012		
Urban Atlas 2006-12		

For each dimension a definition table was constructed with the respective code and a description to be displayed further on.

A final quality check was done comparing the real areas with the areas calculated. It is very important to check that all the definition tables have their corresponding values in the main fact table. Otherwise, they would not be correctly added.

Difficulties

During the processing steps several difficulties were found, mainly related to the size of the input datasets. Both 2006 and 2012 Urban Atlas rasters at 10 meters resolution are extremely big datasets that take a lot of time for each of the steps, when it is needed to harmonize them and create a sub-product. When making a data mosaic, needed to have both UA together, or even to create the mask including the zones outside UA, or reclassifying UA and exporting to other raster; each of these processes always took too much time. Additionally, due to an ArcGIS bug, pyramids are always created when using "mosaic" or "mosaic to new raster", and it was very difficult to find a workaround within ArcGIS 10.1.

During quality check of outputs, when rasters were at 10 m resolution, ArcGIS spent between 3-5 minutes each, only to complete the display of the raster.

The next table shows approximate processing times, to get an idea of how costly the processing was:

Display of rasters 10 m	3-5 minutes each time			
Reclassify of 10 m rasters at EU	1h 30 to 2h			
extent				
Mosaic to new raster (masks)	2h to 3h			
Mosaic or reclassify with pyramids	More than 2 days			
Combine with 8/9 layers	5h			

3.2.2 Specificities of the Neighbourhood OLAP Cube

In this chapter the source data used and the different steps of the methodology applied to prepare the Neighbourhood OLAP Cube are detailed.

Data sources

Globcover

Data source: ESA (http://due.esrin.esa.int/globcover/)

- Globcover2009_V2.3

- Globcover 200412 200606 V2.2

GDP

Reference year: 2010 Data source: PREVIEW <u>http://preview.grid.unep.ch/index.php?preview=data&events=socec&evcat=1</u> <u>&lang=eng</u>

Population

Reference year: 2000

Data source: GRUMPv1 (http://sedac.ciesin.columbia.edu/data/set/grump-v1population-count)

Recommended Citation(s)*:

Center for International Earth Science Information Network - CIESIN -Columbia University, International Food Policy Research Institute - IFPRI, The World Bank, and Centro Internacional de Agricultura Tropical - CIAT. 2011. Global Rural-Urban Mapping Project, Version 1 (GRUMPv1): Population Count Grid. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). http://dx.doi.org/10.7927/H4VT1Q1H. Accessed DAY MONTH YEAR.

Employment

Reference year: 2007 Data source: (ILO : International Labor Organisation, LABORSTA. <u>http://laborsta.ilo.org/</u> and UNSD : UN Statistical Division. <u>http://unstats.un.org/unsd/environment/qindicators.htm</u>).

Step 1. Generation of the reference Grids (RefGrids)

The Geospatial Modelling Environment Tool (<u>http://www.spatialecology.com/gme/</u>) has been used to generate the RefGrids in ETRS89.

The command '**genvecgrid**' allows you to generate a regular grid in vector format (<u>http://www.spatialecology.com/gme/genvecgrid.htm</u>)

The attribute table contains information on coordinates for each cell.

Та	[able												
0	🗄 📲 📲 🌄 🖾 🐠 🗶												
ge	genvecgrid												
	FID	Shape	ld	CELLID	MinX	MaxX	MinY	MaxY	CenterX	CenterY			
Þ	0	Polygon	0	1	3993000	3994000	2760000	2759000	3993500	2759500			
	1	Polygon	0	2	3994000	3995000	2760000	2759000	3994500	2759500			
	2	Polygon	0	3	3995000	3996000	2760000	2759000	3995500	2759500			
	3	Polygon	0	4	3996000	3997000	2760000	2759000	3996500	2759500			
	4	Polygon	0	5	3997000	3998000	2760000	2759000	3997500	2759500			
	5	Polygon	0	6	3998000	3999000	2760000	2759000	3998500	2759500			
	C	Delverer	0	7	2000000	4000000	070000	0750000	2000500	0750500	1		

Figure 9. Attribute table of a vector grid generated with the command 'genvecgrid' of GME tool

Step 2. Field "CELLCODE"

Note that GME tool generates an error in the attribute table. The field name "MinY" and "MaxY" should be inverted.

An identify field "CELLCODE" in string format was added to each cell of the RefGrids. The name contains the cell resolution (1km) and Xmin and Ymin coordinates divided by thousand.

Example : CELLCODE= 1kmE4009N2565

"1kmE" & ([MinX]/1000) & "N" &([MinY]/1000)

"1kmE" & ([MinX]/1000) & "S" &(-[MinY]/1000)

The AOI is too large to be process at once; therefore the RefGrids have been generated separately for 10 different zones.

			1		
RefGrid	Xmin	Xmax	Ymin	Ymax	
(zone)	(left)	(right)	(bottom)	(top)	
Europe1_GME	1547000	3848000	3241000	5541000	
Europe2_GME	3847000	6148000	3241000	5541000	
Europe3_GME	1066000	3847000	926000	3241000	
Europe4_GME	3847000	6147000	941000	3241000	
Europe5_GME	6147000	8447000	941000	3241000	
AfricaE_GME	4255000	7129000	-615000	2092000	
AfricaW_GME	1390000	4265000	-615000	2092000	
Russia_GME	4936000	8210000	2472000	6830000	
Greenland_GME	1549000	4937000	5159000	7157000	
Feroe GME	3400000	3489000	4355000	4473000	

Step 3. Buffer of 5 km

In order to alleviate the processing, RefGrids have been clipped to an area of interest (AOI) defined by a buffer of 5 km around a country layer "GRID_GADM_levels23lam.shp".

Note that information falling outside this border has not be considered.



Xmin ; Ymin

Step 4. Disaggregating socioeconomic data

The methodology applied consists in:

- 1) converting wgs84 raster data (GlobCover, GDP, POP) into feature
- 2) project the vector file into etrs89
- 3) union it with the RefGrid in etrs89



Figure 10. Union of GlobCover (vector) projected into ETRS89 with the RefGrid (1km)



Figure 11. Simplified method schema, example with GlobCover (GlobCover Raster: GCR and GlobCover Vector: GCV)

Step 5. Attribute tables

Tables processing was done in PostgreSQL software.

Globcover

Percent area of each GlobCover class was calculated for each cell, as well as the majority class ("the_class").

GDP

Sum of GDP values by cell of reference.

POP

Sum of population values by cell of reference.

Employment

Percentage of workers by cell of reference.

4 Results

4.1 ESPON OLAP Cubes

Different OLAP Cubes can be created according to the user needs, including chosen data dimensions and measures, if they have been prepared for OLAP integration as explained in the previous section.

In the context of the ESPON M4D, three types of OLAP Cubes have been created.

- **ESPON OLAP Cube** : it covers the entire ESPON area, holding different geographic dimensions plus Corine Land Cover and main socioeconomic variables. This Cube has been updated several times during the project. The working resolution is 1 km².
- **ESPON Urban OLAP Cube** : it covers urban areas (i.e. LUZ coverage) and it holds all the different urban delineations, plus population and Urban Atlas as land cover information. The working resolution is 100 m².
- **ESPON Neighbourhood OLAP Cube** : it covers the Neighbouring areas of the ESPON space (those of the ESPON ITAN project). It includes SNUTS geometries, Globcover information, population, GDP and unemployment. The working resolution is 1 km².

These are the contents of each of the OLAP Cubes developed under ESPON M4D :

ESPON OLAP Cube (version 6.0)

The last update of the ESPON OLAP Cube was delivered in June 2013 and focused on urban geographical dimensions and the newest population statistics. Its content is:

Measures:

- Area in hectares
- GDP 2000 Million Euros
- GDP 2003 Million Euros
- GDP 2006 Million Euros
- GDP 2009 Million Euros
- Population 2000 thousand inhabitants
- Population 2003 thousand inhabitants
- Population 2006 thousand inhabitants
- Population 2009 thousand inhabitants

Thematic dimensions:

- CLC00 Hierarchical
- CLC06 Hierarchical
- CLC90 Hierarchical
- Land Cover Flows 1990-2000

- Land Cover Flows 2000-2006
- Land Cover Flows 2000-2006

Geographic dimensions:

- Nuts 1999 code
- Nuts 1999 name
- Nuts 2003 code
- Nuts 2003 name
- Nuts 2006 code
- Nuts 2006 name
- Nuts 2010 code
- Nuts 2010 name
- Functional Urban Areas (FUA)
- Morphological Urban Areas (MUA)
- Urban Morphological Zones (UMZ)
- Large Urban Zones (LUZ)

ESPON Urban OLAP Cube (version 2.0)

The last update of the Urban OLAP Cube was delivered in June 2014. It includes the following content:

Measures:

- Area in hectares
- Population 2006

Thematic dimensions:

- Urban Atlas 2006
- Urban Atlas 2012

Geographic dimensions:

- LAU2 2008
- LUZ 2004
- LUZ 2012
- FUA
- MUA
- UMZ 2000

ESPON Neighbourhood OLAP Cube (version 1.0)

This OLAP Cube was delivered in June 2014, with the input from UNEP/GRID (University of Geneva), who has processed Globcover and the socioeconomic variables for the entire neighbourhood space. Its contents are:

Measures:

- Population 2000
- GDP 2010
- Employment 2007

Thematic dimensions:

- GLobcover 2004
- Globcover 2009

Geographic dimensions:

- SNUTS 2012

Next table summarises the contents of the three updated OLAP Cubes, as main result for data integration through the grid, under ESPON M4D:

	Resolution	Geographic dimensions	Thematic dimensions	Measures
ESPON OLAP Cube (v6)	1 km²	NUTS 1999, NUTS 2003, NUTS 2006, NUTS 2010, LUZ, FUA, MUA, UMZ	CLC00 Hierarchical, CLC06 Hierarchical, CLC90 Hierarchical, Land Cover Flows 1990-2000, Land Cover Flows 2000-2006, Land Cover Flows 2000-2006	Area in hectares, GDP 2000, GDP 2003, GDP 2006, GDP 2009, Population 2000, Population 2003, Population 2006, Population 2009
ESPON Urban OLAP Cube (v2)	100 m²	LAU2 2008, LUZ 2004, LUZ 2012, FUA, MUA, UMZ 2000	Urban Atlas 2006	Area in hectares, Population 2006
ESPON Neighbourhood OLAP Cube (v1)	1 km²	SNUTS 2012	GLobcover 2004, Globcover 2009	Population 2000, GDP 2010, Employment 2007

4.1 ESPON OLAP Cubes user-oriented scenarios

The objective of this section is showing some examples of particular applications or questions that can be solved by means of one of the ESPON OLAP Cubes that have been prepared under ESPON M4D.

User case #1 : Can we build up a time series between 2000 and 2009 on population and GDP reported by NUTS level 1 (2010) ?

Database to be used : ESPON OLAP Cube

Advantages : Using the Cube we overcome the problem of different NUTS breakdowns when dealing with long time series.

In this first case, we are going to use the OLAP Webtool. We make the following query :



We have selected to get table and charts:

				MeasuresLevel	
NUTS 2010 LEVEL 1 ▲	Population 2000 (1000 inh.)	Population 2003 (1000 inh.)	Population 2006 (1000 inh.)	Population 2009 (1000 inh.)	GDP
AT1 OSTOSTERREICH	3304.0	3358.0	3452.0	3519.0	-
AT2 SUDOSTERREICH	1702.0	1710.0	1725.0	1729.0	
AT3 WESTOSTERREICH	2831.0	2875.0	2916.0	2948.0	
BE1 REGION DE BRUXELLES-CAPITALE / BRUSSELS HOOFD*	956.0	987.0	1015.0	1064.0	
BE2 VLAAMS GEWEST	5708.0	5774.0	5857.0	5982.0	
BE3 REGION WALLONNE	3203.0	3228.0	3278.0	3333.0	
BG3 SEVERNA I IZTOCHNA BULGARIA	4304.0	4091.0	3975.0	3880.0	
BG4 YUGOZAPADNA I YUZHNA CENTRALNA BULGARIA	3777.0	3659.0	3634.0	3614.0	
CH0 SCHWEIZ/SUISSE/SVIZZERA	6936.0	7087.0	7239.0	7473.0	
CY0 KYPROS / KIBRIS	0.0	0.0	0.0	0.0	
CZ0 CESKA REPUBLIKA	10029.0	9959.0	10001.0	10200.0	
DE1 BADEN-WURTTEMBERG	10243.0	10396.0	10490.0	10512.0	
DE2 BAYERN	11798.0	12013.0	12116.0	12155.0	
DE3 BERLIN	3399.0	3399.0	3404.0	3442.0	
DE4 BRANDENBURG	2465.0	2458.0	2430.0	2391.0	
DE5 BREMEN	653.0	651.0	653.0	653.0	-
4					F

Ohoose chart type
Values: relative
Values:



All the time series are complete:

MeasuresLevel											
Population 2003 (1000 inh.)	Population 2006 (1000 inh.)	Population 2009 (1000 inh.)	GDP 2000 (in PPS)	GDP 2003 (in PPS)	GDP 2006 (in PPS)	GDP 2009 (in PPS)					
3358.0	3452.0	3519.0	88189.0	97368.0	108381.0	113380.0					
1710.0	1725.0	1729.0	35703.0	39081.0	44428.0	46344.0					
2875.0	2916.0	2948.0	71248.0	78813.0	90002.0	95476.0					
987.0	1015.0	1064.0	45674.0	51308.0	55195.0	57784.0					
5774.0	5857.0	5982.0	137984.0	153652.0	169816.0	177327.0					
3228.0	3278.0	3333.0	56408.0	62330.0	68530.0	72916.0					
4091.0	3975.0	3880.0	20938.0	24392.0	28775.0	30698.0					
3659.0	3634.0	3614.0	22395.0	29729.0	40751.0	49463.0					
7087.0	7239.0	7473.0	190498.0	206573.0	236734.0	278183.0					
0.0	0.0	0.0	0.0	0.0	0.0	0.0					
9959.0	10001.0	10200.0	133896.0	155536.0	188552.0	206024.0					
10396.0	10490.0	10512.0	267060.0	290974.0	330631.0	335366.0					
12013.0	12116.0	12155.0	319247.0	353627.0	403619.0	399188.0					
3399.0	3404.0	3442.0	70278.0	72305.0	80641.0	91984.0					
2458.0	2430.0	2391.0	39767.0	43185.0	49193.0	49772.0					
651.0	653.0	653.0	19657.0	21831.0	24982.0	24964.0					

User case #2 : Which is the Land Cover (Urban Atlas) of the UMZ in France ?

Database to be used : ESPON Urban OLAP Cube

Advantages : OLAP Cubes facilitate interoperability between the different urban delineations.

By means of Excel, we make the following query :

=	Lista d	e campos de tal	ola dinámica	- v X					
	Seleccionar campos para agregar al informe:								
	□ Σ ESPON Urban Cube 14052014 ▲								
		Area							
		Peopulation 20	one						
		Population U	MZ 2000						
		Functional Urba	n Areas						
	±	Functional Ur	ban Areas	_					
	8	Large Urban Zor	nes 2004						
	±	Large Urban	Zones 2004	_					
	8	Large Urban Zor	nes 2012						
	±	Large Urban	Zones 2012						
	8	LAU2							
	6	LAU2		Y					
		Country		Υ·					
	Arrast Y F	rar campos entre iltro de informe	las áreas siguie	entes: s de c					
	LAUZ	2 🔻	Urban Atlas	-					
	E	tiquetas de fila	Σ Valores						
	UMZ	2000 🔻	Area in Hect	a 🔻					

Result of the query :

	Α	В	С	D	E	F	
1	LAU2	FR 🖵					
2							
3	Area in Hectares	Etiquetas d 🔻					
4	Etiquetas de fila 🔹	Agricultural + 9	Airports	Construction	Continuous Urban F	Discontinuous Dense Urban F	Disconti
5	Agen						
6	Aix En Provence	227,29	60	26,57	108,44	628,07	
7	Albi						
8	Ales						
9	Amiens	277,62	81,14	23,09	321,03	637,54	
10	Angers						
11	Angouleme						
12	Annecy						
13	Armentieres	88,95		8,37	100,67	269,52	
14	Arras						
15	Avignon						
16	Basel French Part						
17	Bayonne // Anglet // Biarritz						
18	Beauvais						
19	Belfort						
20	Besancon	409,53		37,02	364,14	920,13	
21	Bethune // Noeux Les Mines	3,54				0,55	
22	Beziers						
23	Blois						
24	Bordeaux	1611,67	676,46	52,96	2189,8	7542,85	
25	Boulogne Sur Mer						
26	Bourg En Bresse						
27	Bourges						
28	Brest						
29	Brive La Gaillarde						
30	Bruay La Buissiere // Auchel						
31	Caen	820,24	220,66	51,36	1206,62	1327,81	
32	Calais						
33	Chalon Sur Saone						

We get the area of Urban Atlas land cover classes in hectares for each French UMZ (blank lines mean that UA is not covering such UMZs).

User case #3 : Which was the population in 2006 for each Functional Urban Area in the UK?

Database to be used : ESPON Urban OLAP Cube

Advantages : OLAP Cubes facilitates populating databases with external datasets (in this case, population is added to FUAs)

By means of Excel, we make the following query :

Lista de	campos de tab	ola dinár	nica	- - - ×			
Seleccio	onar campos para	a agrega	ral (1 •			
ΞΣ	ESPON Urban Cube 14052014						
		2006					
	Population UN	4Z 2000					
•	Functional Url	oan Are Urban A	as Areas	E			
	Large Urban Zor	nes 2004 Zones 20)04				
•	Large Urban Zor	nes 2012 Zones 20)12				
8	LAU2 LAU2 Country			7 -			
Arrastr Fil	ar campos entre tro de informe T	las área:	s siguier iquetas	ntes: de c			
Et	iquetas de fila	Σ Va	lores				
Funct	ional Ur 🔻	Popul	ation 20	006 🔻			
📃 Apl	azar actualizació	n d	Actu	alizar			

Result of the query:

	A	В
1	LAU2	UK 🖵
2		
3	Etiquetas de fila 🔻	Population 2006
4	Aberdeen	305564
5	Alloa - Stirling	74931
6	Ashford	100341
7	Aylesbury	112099
8	Ayr	55120
9	Ballymena	68799
10	Banbury	95262
11	Bangor	49418
12	Barrow-in-Furness	31741
13	Bedford	176077
14	Belfast	483341
15	Birmingham metropolitan area	1958639
16	Blackburn/Burnley	426383
17	Blackpool	292972
18	Boston	64826
19	Bournemouth/Poole	504427
20	Braintree	62892
21	Bridlington	10895
22	Brighton/Worthing/Littlehampton	540465
23	Bristol metropolitan area	642070
24	Burton on Trent	130519
25	Bury St.Edmonds	85294
26	Cambridge	208732
27	Canterbury	149637
28	Cardiff and South Wales valleys metropolitan area	762836
29	Carlisle	126306
30	Cheltenham	159607
31	Chichester	73488
32	Clacton	82100
33	Colchester	206978
34	Coleraine	72273
35	Colwyn Bay	15830
36	Crewe/Nantwich	121976

We get the population figures (2006) for each FUA in the UK.

User case #4 : Which is the population and the area of artificial surfaces in 2009 by each SNUTS?

Database to be used : Neighbourhood OLAP Cube

Advantages : OLAP Cubes facilitate interoperability between land cover (in this case Globcover) and socioeconomic data.

By means of Excel, we make the following query :

GC2004 - No data - burnt areas or douds etc GC2004 - Open 15-40 percent - broadleaved deciduous forest woodland more 5n GC2004 - Open 15-40 percent - needleleaved deciduous or evergreen forest more 5m GC2004 - Post-flooding or irrigated croplands - or aquatic GC2004 - Sparse more 15 percent vegetation GC2009 - Attificial surfaces and associated areas - Urban areas more 50 percent GC2009 - Attificial surfaces and associated areas - Urban areas more 50 percent GC2009 - Olosed more 40 percent - broadleaved deciduous forest more 5m GC2009 - Closed more 40 percent - broadleaved forest or shrubland permanently flooded GC2009 - Closed more 40 percent - broadleaved forest regularly flooded - Fresh or bradsish GC2009 - Closed more 40 percent - broadleaved forest regularly flooded - Fresh or bradsish GC2009 - Closed more 40 percent - broadleaved forest regularly flooded - Fresh or bradsish GC2009 - Closed to open more 15 percent - broadleaved devergreen or semi-deciduous forest m Seleccionar campos para agregar al informe: Versours - sporse more 12 percent / vegetation GC2009 - Water bodies V Population in inhabitants NUTS Name NUTS Name NUTS Name SNUTS ID SNUTS ID SNUTS ID SNUTS Code V Floode informe Fitto de informe Etiquetas de fila X Valores NUTS Code V Population in inhabitants	GC2004 - No data - burnt areas or douds etc GC2004 - Open 15-40 percent - broadleaved deciduous forest woodland more Sm GC2004 - Permanent snow and ice GC2004 - Rainfed croplands GC2004 - Sparse more 15 percent vegetation GC2009 - Artificial surfaces and associated areas - Urban areas more 50 percent GC2009 - Dare areas GC2009 - Closed more 40 percent - broadleaved deciduous forest more Sm GC2009 - Closed more 40 percent - broadleaved deciduous forest more Sm GC2009 - Closed more 40 percent - broadleaved deciduous forest more Sm GC2009 - Closed more 40 percent - broadleaved forest regularly flooded - Fresh or bradsh. GC2009 - Closed to open more 15 percent - broadleaved forest regularly flooded - Fresh or bradsh. GC2009 - Closed to open more 15 percent - broadleaved evergreen or semi-deciduous forest m. decconor campos para agregar al Informe: UC GC2009 - Water bodies Ø Population in inhabitants J MUTS Herarchy MUTS Name Siturts Code J Siturts Code J Siturts Code J Siturts Name Siturts Name Etiquetas de columna Etiquetas de fila Sital columna								
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Result of the query:

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2	AL001	201742	363,7661062
3	AL002	196914	42,86723
4	AL003	255957	206,217485
5	AL004	365508	1502,189265
6	AL005	361422	1801,847787
7	AL006	124428	1502,975624
8	AL007	271148	1431,787134
9	AL008	116578	675,1033823
10	AL009	142346	258,8282174
11	ALOOA	254495	2248,225246
12	AL00B	559570	441,7417422
13	ALOOC	191830	933,2587528
14	AM00	3079160	36046,57109
15	AZ00	8070218	226151,1403
16	BA011	57468	12921,41746
17	BA021	19656	4369,987095
18	BA022	320999	122155,2033
19	BA023	323571	27978,19929
20	BA024	89791	20645,95621
21	BA025	348815	48126,67331
22	BA026	242796	76004,07153
23	BA027	359839	28252,86521
24	BA028	303836	63132,97513
25	BA029	243427	81069,17963
26	BA02A	42753	19806,0567
27	BA031	603981	211485,7917
28	BA032	135176	50262,04329
29	BA033	89290	20043,15616
30	BA034	8/416	58331,65727
31	BA035	218801	30284,51158
32	BAU36	144359	55390,96151
33	BA037	2020/1	57056,22933
34	BY10	1/83992	1740,868284
35	BYII	1450936	2/0/6,83659
36	BT20	1524207	35/9,5226/5
3/	DT21	11/9405	5499,882493
38	DTZZ BV22	14/9095	2408,710093
39	DT25	13/9950	5061,200389
40	D7101	1196596	4705,548692
41	DZ101	1120524	1857,545841
42	02102	1040091	3851,02425

We quickly get the population figures and hectares of artificial surfaces.

5 ESPON OLAP Webtool

Although querying OLAP Cubes with MS Excel is not complicated, once you get the result of the query producing charts or maps out of it is not straight-forward and specific knowledge is needed. Therefore, the ESPON OLAP Webtool was created with the aim of facilitating the querying of OLAP Cubes for the different users and producing maps and charts in an easy way.

Currently, the tool can be used through this link : <u>http://158.109.174.100/webbi/</u>

The webtool has had different improvements since it was launched. Although it currently allows the user to query only the ESPON OLAP Cube (ESPON space one), it is prepared for the possibility to choose amongst different potential OLAP Cubes :

OLAP CUBE VIEWER					
The OLAP cube viewe been prepared for a s cube.	r is an interactive tool to explore data that has pecific thematic area in a database called OLAP				
Select cube:	~				
	Go				

Figure 12. Window to select the OLAP Cube within the ESPON OLAP Cube Viewer

The web tool is used to query an OLAP Cube through a simple web interface, by choosing the data dimensions and measures the user wants to see:



Figure 13. Screenshot of the OLAP web tool homepage

The user only has to select a spatial dimension, a thematic one and a measure (socioeconomic variable) to produce a query. He can also choose which outputs will be obtained after the query is launched (map, table and/or charts).

The selection of a spatial dimension can be refined by selecting just some elements :



Figure 14. Subselection of spatial dimensions in the webtool

Results are shown at the same time in a table, chart and/or map, depending on user's selection:



Figure 15. Map, table and charts displayed after a query

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This map does not necessarily reflect the opinion of the ESPON Monitoring Committee. Part-	BG4 YUGOZAPADNA I YUZHNA CENTRALNA BULGARIA	36698.0	9895.0	2671.0	2.0	197.0
financed by the European Regional Development Fund.	CH0 SCHWEIZ/SUISSE/SVIZZERA	162845.0	76504.0	32890.0	221.0	5723.0
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	CZ0 CESKA REPUBLIKA	116783.0	72403.0	15468.0	23.0	1347.0
	DE1 BADEN-WURTTEMBERG	184854.0	118641.0	29790.0	164.0	1917.0
	DE2 BAYERN	238137.0	129086.0	29152.0	343.0	2470.0
	DE3 BERLIN	85759.0	2360.0	2874.0	14.0	977.0 🔻

Figure 16. Screenshots of the OLAP web tool results after a query



Figure 17. Example of output from the webtool without map

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	MK FYR of Macedonia	MT Malta	NL Netherlands	NO Norway	PL Poland	PT Portugal	R0 Romania
	RS Serbia	SE Sweden	SI Slovenia	SK Slovakia	SM San Marino	TR Turkey	UK United Kingdom
				VA Vatican City			

Figure 18. Example of output from the webtool without table

The results obtained via web tool can be exported as PDF files.

Technology of the OLAP webtool

The cube viewer has been built using a number of free software technologies, making possible to re-use the application for different thematic areas. This approach also encourages improvements and customizations from any interested party. In this way, the tool has filled an important gap in the software field, as no comparable open source tool is currently available in the market.

The main technologies used on the project are:

- PostgreSQL + PostGIS, as spatially-enabled relational database management system.
- GeoMondrian and Spatial-OLAP server.
- OpenLayers javascript library in order to provide map visualization and navigation.
- ExtJS and GeoExt in order to build the user interface.
- GeoTools and JTS for geographic data processing and delivering.
- Olap4j, which provides a uniform programming access (API) to different OLAP servers
- JFreeChart, used to generate charts.

Note that all those applications and libraries are open source technologies.

6 Conclusion and further developments

The methodology and results presented in this technical report respond to a need for data integration within the ESPON context, useful for analysing territorial development and cohesion in Europe. They might also be helpful in the framework of territorialisation and place-based approaches of different sectorial policies, as they allow integrating and analysing spatial data together with socioeconomic figures. Although it has not been tested for policy-making purposes, the OLAP approach presented might be useful for spatial planning and spatial monitoring at different scales.

Furthermore, this methodology overcomes several classical problems, like working with different NUTS breakdowns or the combination of thematic with administrative and socioeconomic data. It should be stated that the purpose of this method it is not getting detailed disaggregated datasets, but using disaggregation as an intermediate process to combine data, and being able to query them to get sound results in a fast way that might help to analyse trends or facts regarding territorial and social development. Nevertheless, the better disaggregated datasets are built up in Europe, or the better disaggregation techniques can be applied, the better will be the OLAP database produced.

Some key conclusions are summarised in the next bullet points:

- Disaggregating socioeconomic data by a regular grid is the best solution in order to downscale such information reported by administrative areas.
- The 1 km European Reference Grid is a good option to undertake the disaggregation because:
 - It has an European coverage
 - It follows Inspire specifications
 - It is used for several institutions as the reference grid
 - Its resolution is optimal in order not to lose data precision
- For uncountable data (non-numeric values), the best aggregation method is the "maximum area criterion".
- The "proportional and weighted" aggregation method is the one that gives better results, plus some added value to the downscaling. Using disaggregated population as ancillary variable is a good approach to disaggregate socioeconomic figures.
- The different methods are independent from the source data format and can be applied to vector and raster format.
- The OLAP methodology helps to overcome the problem of managing different NUTS breakdowns, as everything is referred to the grid, which never changes over time.
- This methodology allows the integration of socio-economic, thematic and geographic data in a unique database, which facilitates the querying and analysis of such data together.

- The benefits of having the ESPON OLAP Cube built up has been proven, although the pre-processing and data selection steps take quite a long time and resources. Furthermore, once the Cube is ready, it is not possible for the users to add data dynamically.
- The ESPON OLAP Webtool facilitates the usage of OLAP Cubes for non-expert users.

There are several improvements and future implementations which are possible in order to make this methodological approach and derived products and tools improve and grow up in the future. We list below some of them:

- a) Methodological improvements: Some aspects that have to be deeply analysed are:
 - Treatment of administrative units with no data values.
 - Differences between geographical extents, for example between NUTS divisions and Corine Land Cover (e.g. different coastlines).
 - Improvement of the disaggregation performance in terms of time and manageability of the final layer.
 - General improvements on performance, especially for large layers when working at high resolution.
 - Calculation of standard errors introduced by the disaggregation methods.
- b) Follow-up of the EFGS: It might be very useful to keep following up the outcomes of the European Forum for Geostatistics¹¹ in order to contrast the proposed method and upcoming gridded datasets. For instance, a new population grid 2012 is expected to be available.
- c) Usage of new datasets: the recent availability of high quality datasets, such as the population historical time-series database at LAU2 level, produced by DG Regio will definitely be a step forward on data integration at local level, where the OLAP methods defined in this technical report may pay an important role.
- d) Integration within the ESPON Database: In the future, a major integration of the different ESPON tools is expected. It should be well analysed the most suitable solution to integrate grid data in the ESPON toolbox and to make the ESPON OLAP Cube available to users through a common ESPON portal or interface. The possible integration of the ESPON OLAP Webtool within the ESPON toolbox should also be discussed and further developed in the future.

¹¹ <u>http://www.efgs.info/</u>

Annex 1 – ESPON OLAP Cube User Manual

This Annex is aimed at explaining how to query the ESPON OLAP Cube file by means of the default PivotTable application included in MS Excel 2003 and 2010.

An OLAP Cube can be queried **online** and **offline**. So far, the online connection has not been implemented. In order to use the cube, a single file **.CUB**, which works offline, has been provided.

The .CUB file can be connected to and queried from Microsoft Excel with a few steps detailed in the following pages:

MICROSOFT EXCEL 2003

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- Select "Pivot Table..." in the Data Menu

• Select "External data source"¹² and Pivot Table as report type

PivotTable and PivotCha	rt Wizard - Step 1 of 3	? 🗙
	Where is the data that you want to analyze? Microsoft Office Excel list or database External data source Multiple consolidation ranges Another PivotTable report or PivotChart report What kind of report do you want to create? PivotTable PivotChart report (with PivotTable report)	
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• Click on "Get Data..."



• Go to "OLAP Cubes" Tab. Choose <New Data Source>. Click OK

Choose Data Source					
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2					

¹² In this case, "external data source" means that the data we are going to build the pivot table from is not coming from an Excel sheet, but from an "external" data source. In our case, this external data source is the .CUB file, i.e. the ESPON OLAP Cube.

• Write down a name for your connection. Choose "MS OLE DB Provider for OLAP Services 8.0 (note: this component should be installed in order to connect to an OLAP Cube). Click Connect... button.

Cre	ate New Data Source 🛛 🔀
1.	What name do you want to give your data source? ESPON_CUBE
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3.	Connect
	Select the Cube that contains the data you want:
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	Save my user ID and password in the data source definition
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• Choose Cube file, and browse and choose the .cub file in your computer. Click Finish.

🗇 Multidimensional Connec	ction 🔀
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	Select the Cube that contains the data you want:
4.	ESPONCUBE03_06V2
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• Choose the connection just created. Click OK

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• Click "Next >"

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• Choose either a new or existing worksheet. Click Finish.

PivotTable and PivotChart Wizard - Step 3 of 3	?×
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• The Cube is ready!

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Select how you want to view the data. The default is as Pivot Table Report



The Cube is ready to be used!



How to query the Cube

• Drag & Drop dimensions (e.g. Nuts 3 Code 06) in the Row Area

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• Drag & Drop measures (e.g. GDP M€ 06) in the Data Area

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9	AT113	466,7078947	886,6163315	414,2395753	1,204954306		- Level 2	
10	AT121	1443,833608	2682,674183	1453,895441	0,179907983		- Level 3	
11	AT122	2022,892244	2030,112194	1398,791619			🗉 🔄 CLC06 Hierarchial LEAC	
12	AT123	1653,11915	1807,431627	/6/,433/5//	2,000240020		Dominant Land Cover 00	
13	AT124	1274,770293	2178,709857	1205,322014	2,892318638		Dominant Land Cover 06	
14	ATT25	554,5629655	1229,536177	112,5733632	0.042190424		Elevation Breakdown	
10	AT120	2472,993142	2090,310209	1000 200000	0,043109434			
17	AT127	5014,0003/7 60604,06710	4000,071427	7203,352052			Large orban zones	
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In case of using Microsoft Excel 2010 64 bits, you should use the specific Cube created for MS Excel 2010, and simply drag & drop the .cub file to an Excel spreadsheet.

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OLAP

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