"REgeneration MOdel for accelerating the smart URBAN transformation"

HORIZON2020-WORK PROGRAMME 2004-2015 – 10. Secure, clean and efficient energy

SCC 1–2014: Smart Cities and Communities solutions integrating energy, transport, ICT sectors through lighthouse (large scale demonstration - first of the kind) projects

Document title

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12/01/2016	2.3	CAR, SER	Added conclusions and clustering maps
13/01/2016	2.4	CAR, SER	Added conclusions and final version

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Abbreviations and Acronyms

Acronym	Description
REMOURBAN	REgeneration MOdel for accelerating the smart URBAN transformation
SCC	Smart Cities and Communities
KPI	Key performance indicator
EIP-SCC	The European Innovation Partnership on Smart Cities and Communities
LA	Local Authority
SEAP	Sustainable Energy Action Plan
CL	City level
NL	National level
CoM	Covenant of Mayors

Executive Summary

The aim of this report is to characterize European cities as a basis for the replication framework of the urban regeneration model developed within WP1.

This therefore represents the first step for the definition of the methodology and framework for the replication of the REMORUBAN regeneration model, from the 3 main lighthouses (Nottingham, Valladolid and Tepebasi) to the follower cities (Seraing and Miskolc), and from there, to any other city in Europe, as a holistic strategy for city transformation and planning, integrating all the existing strategies for energy, mobility, ICTs and citizen engagement.

This deliverable contributes to create a classification of the European cities based on different layers (management, financing, energy, mobility and infrastructures) and identify a replication zone where to evaluate the potential for replicating the REMOURBAN regeneration model. As a result, 41 European cities from 18 countries have been characterized and a set of groups of cities with similar profile have been established by each layer and on basis of whole criteria. Apart of the characterization of cities, it is provided the methodology applied for this purpose which covers the list of indicators, available databases enabling to classify the cities into different groups and the statistical procedure for establishing the clusters of cities.

The final goal is to define a classification of the European cities based on their main features in the application domains of the regeneration model as basis to evaluate the replication potential in the follower cities (and by extension, of the cities from the different groups), and develop the replicability plan using the regeneration model.

Therefore, this first replicability deliverable covers the starting point of the nexus between the demonstration activities in the project (direct implementation in the lighthouse cities) and the future exploitation and dissemination of the project results, being part of the strategy defined as REMOURBAN dissemination cascade, which comprises specific activities for each of these steps, leading to different levels of engagement.

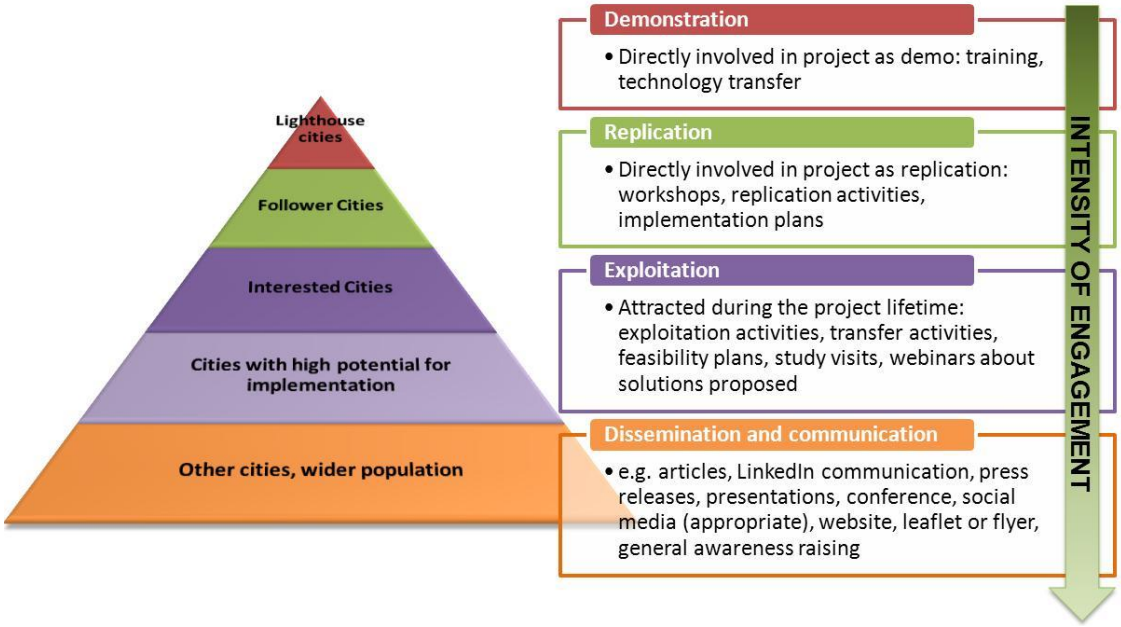

Figure 1: REMOURBAN scale-up approach for demonstration, replication, exploitation and dissemination

1 Introduction

1.1 Purpose and target group

The main purpose of the deliverable is the characterization of a selected group of European cities based on available quantitative statistics and qualitative indicators in order to build a relevant typology of cities and generate homogeneous groups of cities on which to evaluate the replicability potential of REMOURBAN model. Next step will consist of identifying the main features of each of this cluster as basis for the further replication activities.

Concerning target groups, this report intends to set the basis for the cities characterized for evaluating the potential of the REMOURBAN regeneration model but also to contribute to other European municipalities who can develop sustainable practices through the methodology applied for cities characterization (list of indicators, databases and statistical tools employed).

In order to a better reading of the report, it is detailed the structure followed:

- **Chapter 1** introduces the purpose of the report and the relation with other deliverables.
- **Chapter 2** depicts the urban regeneration model expected to be replicable in European cities.
- **Chapter 3** describes the methodology approach applied for the characterization of European cities and the barriers found which lead to select new cities, indicators and statistical methods for the study.
- **Chapter 4** shows the main indicators for the characterization of European cities and compiles the existing data sources for collecting information from cities.
- **Chapters from 5 to 9** deal with the characterisation of cities by different features (management, financing, energy, mobility and infrastructures) and a brief description of the indicators and data source used.
- **Chapter 10** This section deals with the definition of cities types when a global analysis is conducted taking into account all the indicators and layers
- **Chapter 11** depicts the future directions and links the characterisation results with the replicability plan development in the upcoming tasks under this work package.
- **Chapter 12** provides the conclusions and recommendations after the analysis of the cities' clustering.
- Finally, in the **annexes**, supporting information for the future directions, the complete list of discarded indicators due to the lack of information, and the results of the hierarchical clustering method are included.

1.2 Contribution of partners

The following Table 1 depicts the main contributions from participant partners in the development of this deliverable. Almost all partners of the project have been involved in this task, mainly in the data collection part.

Table 1: Contribution of partners

Participant short name	Contributions
CAR	Responsible of the collection of data related to the Mobility indicators with DEM Responsible of the definition of the Urban Regeneration Model and description of the methodology for cities characterisation

	Responsible of the development of the non-hierarchical characterisation approach
NCC	Responsible of the collection of data related to the Management / People and social characteristics indicators with MIS
TEP	Responsible of the collection of data related to the Management / Sustainable and Smart City strategies indicators
VAL	Responsible of the collection of data related to the Management / Governance indicators
IBE	Responsible of the identification of indicators for City Characterisation
ACC	Responsible of the collection of data related to the Energy indicators with NEP
NTU	Future directions (Chapter 14) and global support on the methodology (aligned with task 5.4 – Development of a replicability plan using the regeneration model for each follower city)
NEP	Responsible of the collection of data related to Energy indicators with ACC
DEM	Responsible of the collection of data related to Mobility indicators with CAR
ANA	Responsible of the data analysis of the collected data for characterisation
SER	Deliverable leader Responsible for setting up the data collection distribution of efforts and collection of data and responsible of the collection of data related to ICT indicators
MIS	Responsible of the collection of data related to Management / People and social characteristics indicators with NCC
VER	Responsible of the collection of data related to Finance indicators

1.3 Relation to other activities in the project

The following Table 2 depicts the main relationship of this deliverable to other activities (or deliverables) developed within the REMOURBAN Project and that should be considered along with this document for further understanding of its contents.

Table 2: Relation to other activities in the project

Deliverable number	Description
D1.19 D1.20	These deliverables provide the overall description of the Urban Regeneration Model and it is linked to chapter 3 - Methodology of this document.
D2.1	Evaluation framework of sustainability and smartness in cities. The work on progress being carried out for this deliverable (due in M19) have been used as a basis for the identification of the most appropriate indicators for the Section 5 of this deliverable.
D3.1	This deliverable relates to the audits (especially concerning the 3 main lighthouses

D3.2 D3.3	but also the follower cities) and it is linked to section 5 of this document - List of indicators identified of this document.
D5.2	The model for replication potential will be based on the cities characterization.
D7.2	The characterization report is a basis for the market study.
D7.3	Establishment of a dissemination cascade – This report will help establishing this dissemination cascade to the concerned cities.

2 Urban Regeneration Model and replication potential

The main goal in REMOURBAN is to provide a Sustainable Urban Regeneration Model that defines a holistic process for urban transformation with a jointly approach in the fields of Sustainable Buildings and Districts, Sustainable Urban Mobility, and Integrated Infrastructures and Process. This model provides solutions in both technical and non-technical fields addressing the temporal goals, the main Smart City enablers within the transformation process –towards a more sustainable and smarter environment– and innovations in the priority actions of energy, mobility and ICTs.

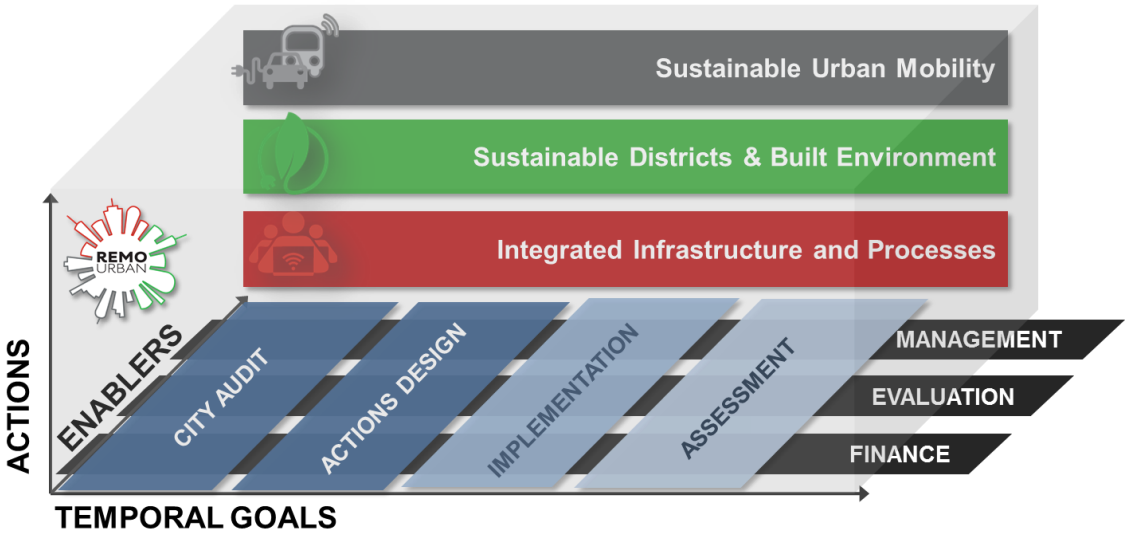

Figure 2: Sustainable Urban Regeneration Model

This toolkit of solutions, integrated through the model, is able to be adapted and implemented in a wide range of European Cities, focusing on their specific goals and targets, and the boundary conditions that characterise their ecosystem.

Figure 3: Implementation and replication approach in lighthouse and follower cities

Therefore, REMOURBAN aims at not only implementing this model in the lighthouse cities in the project (Valladolid, Nottingham and Tepebasi) – where the main benefits and suitability of the model will be tested and demonstrate its replication potential and ability to be adapted to these different conditions. A first replication stage will be tested in the follower cities of Seraing (Belgium) and Miskolc (Hungary); but also a wider replicability plan to European Cities will be defined and validated.

This replicability plan is based on the characterisation of the European Cities, and grouping of them into specific target areas according to a set of indicators in the main fields of work of this model. Thus, it is necessary first to understand how the model works in order to define its replication potential. The whole model will be defined within D1.19 and D1.20: Urban Regeneration Model. However, the following sections depict the main sets of the three axes.

2.1 Urban transformation temporal goals: defining the phases

The Urban Regeneration model covers the four main phases of the city transformation process, which are linked to the specific actions and the Smart City enablers. These main phases are:

- **City audit** is the first phase of this model, aiming at implementing a set of integrated existing methods and tools that can support the evaluation of the current conditions of the cities in which the Sustainable Urban Regeneration Model will be implemented. This diagnosis has a twofold approach, defining first a macro-level characterisation of the city that somehow is linked to the overall framework for the evaluation of its smartness and sustainability and secondly, a key area targeted diagnosis to define the current conditions as the basis for the design of the measures to be implemented.
- **Actions design**. The objective of this second phase is the definition of the specific interventions or actions that will be undertaken in the city. After the analysis of the information collected in the first phase, it will be proposed a solution according with the expectations about energy savings and costs. This is a decision-making process.
- **Implementation**. The actions designed in the second phase will be implemented and commissioned, covering all fields involved in this urban transformation. In this phase, the deployment of the monitoring program will be key to allow gather the necessary information for assessing the impact of the intervention in the following phase.
- Assessment. This last phase is in charge of assessing the impact of the interventions following evaluation protocols and using the information gathered during the implementation phase. For this evaluation, the most appropriate KPIs will be selected in order to assess the sustainability and the smartness and some specific parameters as the energy consumption, CO_2 emissions reduction, reduction of the journey delays, even the social acceptance of the final users and citizens.

2.2 Urban transformation actions: addressing energy, mobility and infrastructures challenges

To ensure city transformation is holistic, it is necessary designing multi-sectorial actions that allows achieve more ambitious goals. Most opportunities for city transformation are in energy, mobility and ICT sectors. In fact, it is in the common zone in which these three sectors could act jointly where is possible to find relevant impact.

2.2.1 Urban districts and built environment

Energy sector, considering the energy supply, distribution and use (mainly in buildings) is a sector with a big impact in city sustainability. A set of actions focused on increasing the overall energy efficiency of a residential district will be developed encompassing the retrofitting of a

residential area towards a low energy district, the installation and connection of the heating and cooling systems to a centralized one with a high ratio of generation with renewable energy and the use of advances building energy management systems to automatically monitor and control the main facilities, devices and services at district level.

2.2.2 Urban transport

Taking into account the mobility sector has a very important impact on quality of life, some sustainability mobility actions will be carried out in order to create a new culture of urban transport. In this field, the use of cleaner vehicles will be promoted and clean power for transport will be improved using electric or hybrid vehicles and charging infrastructure. The logistics supply chain inside cities (last mile delivery) will be enhanced and alliances that use open data will be supported to ease the deployment of demand-responsive and integrated mobility services which help minimize energy consumption.

2.2.3 Integrated infrastructures and processes

Within the ICT sector and taking advantage of this sector is fully integrated in cities, an ICT platform for integrating information and deploying added value services for the grid management and traffic systems will be deployed.

ICT sector will enable the deployment of integration strategies of the urban infrastructures with a variety of targets, for instance empowering people to interact with infrastructures, enabling people to become a sensor within overall city infrastructure systems through mobile devices as ubiquitous means, enabling business cases based on the integration of a city's network infrastructures.

In the project, each city will use its own Local ICT platform with the main goal of monitoring all the devices exiting in the city for the project and a Global ICT platform will be used to consolidate the data from these local ICT platforms. Due to the key goal of the REMOURBAN project being its replicability to other cities, a platform with a common model is needed which defines and manages a set of parameters and indicators for assessing the success of the project. This platform is the city integrated infrastructure and this city integrated infrastructure will be created and deployed in the Global ICT platform.

2.3 Urban transformation enablers: managing, evaluating and financing the Smart City

2.3.1 Management framework for the Urban Regeneration

2.3.1.1 Governance and civic involvement

It is necessary to optimise the current regulatory framework developing new forms of smart city policies and regulation or optimizing of the existing documents.

Moreover, a strategy will be developed for innovative public procurement procedures.

2.3.1.2 People

Aspects such as human and social capital, equity, diversity, accessibility, safety, health or quality of housing and the built environment will be taken into account. These will be considered when defining city transformation strategies and designing specific actions, as well as when assessing the achievement of goals at the end of the process.

2.3.1.3 City strategies

Development of new strategies for favouring the transition to Smart Cities, integrating existing urban plans and redefine them in a common and unique sustainable urban plan (mobility, energy, ICT,..), that would implement a holistic strategy with the objective to transform the city and to make it smarter.

2.3.2 Evaluating the Urban Regeneration

An evaluation framework is defined in order to assess the sustainability and smartness of demonstration cities involved in the project. This framework allows estimating the effect of the urban regeneration model and the intervention plans for the demonstration cities.

Monitoring and evaluation procedures allow quantifying the actual impact of the renovations in order to reduce investment risks, improve the benefits perception and favour the replicability.

2.3.3 Financing the Urban Regeneration

2.3.3.1 Economy

Understanding the current status of the city economic ecosystem is essential to define find out suitable economic models for the city transformation, in which a combination of innovative schemes of Public Private Partnerships can be drivers for the implementation of the model.

2.3.3.2 Access to financial instruments

Smart Cities require large amounts of investment to be realised and capital invested in this sector will likely grow every year for decades.

Several financial instruments are necessary in order to support these investments. Some financial schemes are already available to stimulate investments in smart cities and, more generally, energy efficiency projects.

In this field, innovative financial schemes and business plans for each of the pillars of the project will be developed in order to get that most of the possible interventions can be feasible.

3 Methodological approach

3.1 Objectives and approach

The characterisation approach should be able to define groups of cities in order to establish how the Sustainable Urban Regeneration Model should be adapted and consider a wide diversity of boundary conditions when implementing it to address a sustainable urban transformation in the framework of a Smart City Strategy.

The methodology developed intends to categorize cities in five layers according to the REMOURBAN domains for a final generation of groups of cities which show same profile according to an aggregated scheme of indicators.

The methodology comprises 5 steps which are briefly explained below:

- Selection of indicators for each REMOURBAN domain (management, finance, energy, mobility and ICTs) at city level. The choice will be based on their representativeness and availability in the existing sources.
- Exploration of database where find information for each indicator.
- Selection of cities which count with information for all the indicators in the databases.
- Collection of data for each city to complete indicators and generate groups of cities with similar features.
- Characterization of groups of cities in basis on range of values for each analysed field.

Therefore, the scope of the replicability will be delimited to those cities with detailed information in databases (boundary condition).

The approach for characterization of European cities is summarized in Figure 4.

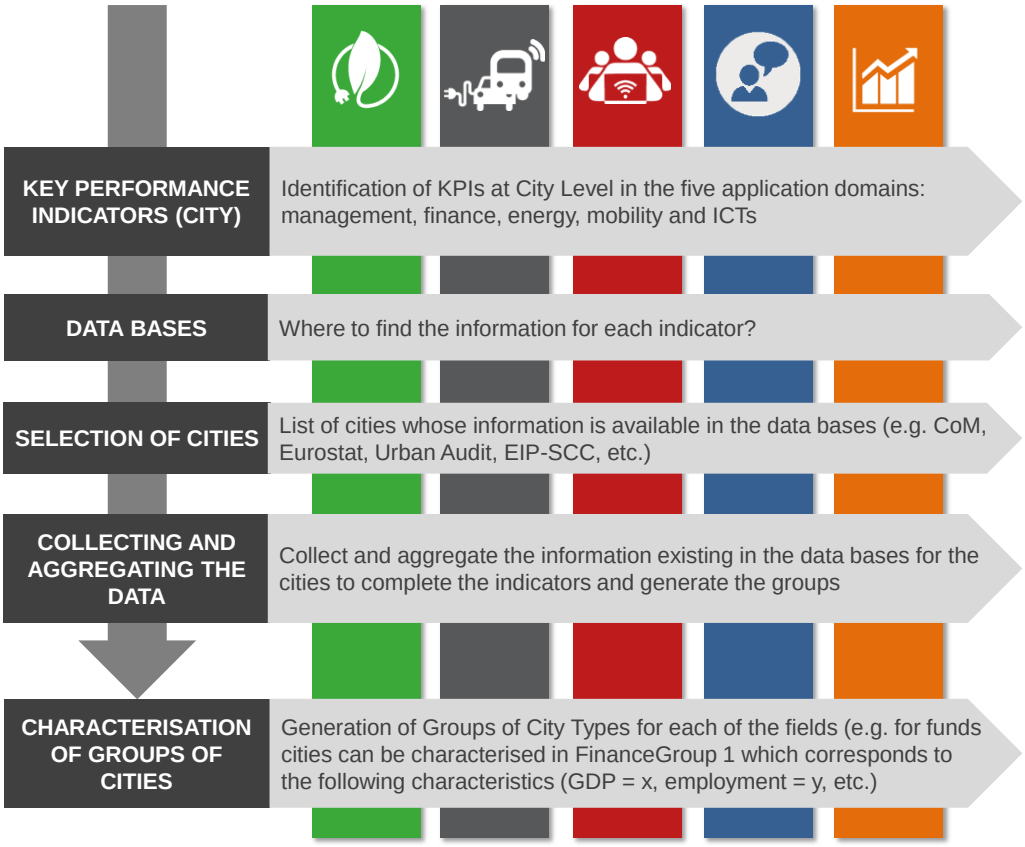

Figure 4: Overall scheme of the methodology

With the application of the methodology, it is contemplated to narrow the study to 41 European cities of a certain size and establish groups of cities with homogenous characteristics in each domain. Within each of these groups of cities, the representative value will be calculated for each indicator in order to have the most representative values for a city within that cluster.

In a second interaction, the relationship among the different layers is analysed, leading to a cross-field characterisation at a higher level than the detailed classification by layer. The combination of both analyses allows different levels of detail in the clustering, which will deal to the identification of how the urban regeneration model can be adapted to the specific city characteristics of each group, ensuring therefore its replicability.

3.2 Definition of cities to cover the characterisation

In order to narrow the scope, **medium-size cities** are considered (from 50.000 to 500.000 inhabitants), since they are the main target cities in REMOURBAN, besides a small sampling of larger cities (but no major European capital) are included. The study will be also delimited to those medium size cities with counts with smart detailed information in databases and are involved in Smart Cities and Community projects (SCC) since it is expected to be easier to find data available on these cities.

- The typology of cities will be applied to all the European municipalities (LAU2 statistic level)
- The characterization will be implemented on a representative sample of cities.

Regarding the temporal scope, the following considerations have been established:

- To establish the typology, data will be considered for the most recent year for which it is available for all the cities.
- For the characterization, the methodology will allow for more temporal flexibility (for some indicators, it will be possible to take into account the most recent data).

A first set of 50 cities was selected according to the previous methodology, from all over Europe. Among the 50 cities listed below, a big part of them are already involved in EIP-SCC projects[1]. However, lack of data for chosen indicators leads to a new set of **41 cities** from **18 countries** in Europe where information was mostly available in existing databases.

3.2.1 Initial list of selected cities

The initial list of cities (50) selected before the search for data sources at city level is shown below:

Table 3: Initial list of selected cities

No.	City	Country	Population	City code	EU project (if applicable)
01	Graz	Austria	269.997	AT-01	Pitagoras/ GrowSmarter
02	Innsbruck	Austria	121.329	AT-02	Sinfonia
03	Seraing	Belgium	61.237	BE-01	REMOURBAN

[1] Source : EIP-SCC – the Market Place of the European Innovation Partnership on Smart Cities and Communities – EU projects page (https://eu-smartcities.eu/eu-projects)

04	Ghent	Belgium	247.486	BE-02	STEP-UP
05	Liege	Belgium	196.000	BE-03	BRICKER
06	Kortrijk	Belgium	175.000	BE-04	ECO-LIFE
07	Ruse	Bulgaria	167.585	BG-01	Pleec
08	Paphos	Cyprus	47.300	CY-01	Sinfonia
09	Copenhagen	Denmark	551.580	DK-01	Pleec & TRANSFORM
10	Tartu	Estonia	103.284	EE-01	Pleec
11	Jyväskylä	Finland	135.958	FI-01	Pleec
12	Tampere	Finland	215.315	FI-02	EU-GUGLE
13	Turku	Finland	184.300	FI-03	Pleec
14	La Rochelle	France	75.882	FR-01	Sinfonia
15	Lyon	France	474.946	FR-02	TRANSFORM
17	Aachen	Germany	258.664	DE-01	EU-GUGLE
18	Koln	Germany	1,034,175	DE-02	GrowSmarter
19	Leipzig	Germany	550.000	DE-03	Triangulum
20	Rosenheim	Germany	59.935	DE-04	Sinfonia
21	Trikala	Greece	51.862	GR-01	InSMART
22	Miskolc	Hungary	162.905	HU-01	REMOURBAN
23	Cork	Ireland	120.000	IR-01	GrowSmarter
24	Bolzano	Italy	104.029	IT-01	Sinfonia
25	Cesena	Italy	97.056	IT-02	InSMART
26	Firenze	Italy	370.702	IT-03	Steep
27	Genova	Italy	608.154	IT-04	TRANSFORM & R2CITIES
28	Eindhoven	Netherlands	210.333	NL-01	Triangulum
29	Delft	Netherlands	96.172	NL-02	Pleec
30	Stavanger	Norway	130.745	NW-01	Triangulum
31	Trondheim	Norway	179.000	NW-01	Zenn & Comm*ON*Energy

32	Évora	Portugal	57.791	PT-01	InSMART
33	Porto	Portugal	32.659	PT-02	GrowSmarter
34	Suceava	Romania	25.000	RO-01	GrowSmarter
35	Ljubljana	Slovenia	272.554	SI-01	Pleec
36	San Sebastian-Donostia	Spain	183.308	ES-01	Steep/Zenn
37	Santiago de Compostela	Spain	95.092	ES-02	Pleec
38	Sestao	Spain	28.651	ES-03	EU-GUGLE
39	Sabadell	Spain	207.540	ES-04	Triangulum
40	Valladolid	Spain	307.000	ES-05	REMOURBAN
41	Eskilstuna	Sweden	97.692	SE-01	Pleec
42	Vasteras	Sweden	110.877	SE-02	Pleec
43	Boras	Sweden	66.273	SE-03	Sinfonia
44	Stockholm	Sweden	917.297	SE-04	GrowSmarter
45	Gothenburg	Sweden	520.374	SE-05	Celsius/EU-GUGLE/ STEP-UP
46	Tepebasi	Turkey	315.000	TK-01	REMOURBAN
47	Nottingham	U.K.	306.000	UK-01	REMOURBAN
48	Stoke-on-Trent	U.K.	239.700	UK-02	Pleec
49	Manchester	U.K.	515.000	UK-03	Triangulum
50	Bristol	U.K.	428.200	UK-04	Steep

3.2.2 Final list of selected cities

Below, the final list of cities (41) used for the data collection phase after reviewing:

Table 4: Final list of selected cities

No.	City	Country	Population	City code	EU project (if applicable)
01	Graz	Austria	269.997	AT-01	Pitagoras/ GrowSmarter
02	Innsbruck	Austria	121.329	AT-02	Sinfonia
03	Ghent	Belgium	247.486	BE-01	STEP-UP

04	Liege	Belgium	196.000	BE-02	BRICKER
05	Brugge	Belgium	118.145	BE-03	EU-GRASP
06	Ruse	Bulgaria	167.585	BG-01	Pleec
07	Tartu	Estonia	103.284	EE-01	Pleec
08	Jyväskylä	Finland	135.958	FI-01	Pleec
09	Tampere	Finland	215.315	FI-02	EU-GUGLE
10	Turku	Finland	184.300	FI-03	Pleec
11	La Rochelle	France	75.882	FR-01	Sinfonia
12	Poitiers	France	135.635	FR-02	----
13	Aachen	Germany	258.664	DE-01	EU-GUGLE
14	Koeln/Köln	Germany	1,034,175	DE-02	GrowSmarter
15	Leipzig	Germany	550.000	DE-03	Triangulum
16	Rosenheim	Germany	59.935	DE-04	Sinfonia
17	Thessaloniki	Greece	376.047	GR-01	----
18	Miskolc	Hungary	162.905	HU-01	REMOURBAN
19	Cork	Ireland	120.000	IR-01	GrowSmarter
20	Bolzano	Italy	104.029	IT-01	Sinfonia
21	Firenze	Italy	370.702	IT-02	Steep
22	Genova	Italy	608.154	IT-03	TRANSFORM
23	Eindhoven	Netherlands	210.333	NL-01	Triangulum
24	Utrecht	Netherlands	321916	NL-02	-----
25	Stavanger	Norway	130.745	NW-01	Triangulum
26	Trondheim	Norway	179.000	NW-02	Zenn & Comm*ONE*nergy
28	Porto	Portugal	32.659	PT-01	GrowSmarter
27	Braga	Portugal	182110	PT-02	-----
29	Ljubljana	Slovenia	272.554	SI-01	Pleec
30	San Sebastian-Donostia	Spain	183.308	ES-01	Steep/Zenn
31	Málaga	Spain	568479	ES-02	Green eMotion

32	Sevilla	Spain	702355	ES-03	CROSS
33	Valladolid	Spain	307.000	ES-04	REMOURBAN
34	Santa Cruz de Tenerife	Spain	207.000	ES-05	(REM Survey)
35	Stockholm	Sweden	917.297	SE-01	GrowSmarter
37	Gothenburg	Sweden	520.374	SE-02	Celsius/EU-GUGLE/ STEP-UP
36	Malmö	Sweden	302835	SE-03	ZenN
38	Nottingham	U.K.	306.000	UK-01	REMOURBAN
39	Manchester	U.K.	515.000	UK-02	Triangulum
40	Bristol	U.K.	428.200	UK-03	Steep + REM Survey
41	Oxford	U.K.	158.000	UK-04	(REM Survey)

The following map shows the European cities that submitted the SEAP to the Covenant of Mayors. For 78 cities (between 50,000 and 350,000 inhabitants), there is information about the SEAP, including the last stage of its implementation (monitoring).

Figure 5: Map of SEAP signatories. Source: Covenant of Mayors

Below is a picture of all the cities involved in the characterisation data collection process (In Blue: All cities used in the data collection process. In Red: Ignored cities – Not (enough) data available in the chosen data sources-).

Figure 6: Map of all cities included in the data collection process for the characterization

3.3 Indicators selection for city characterization

A set of indicators has been defined for the characterisation of the cities. A first set of 50 indicators was identified taking into account the following activities:

- City audits (activities within WP3);
- Identification of indicators for the evaluation of the smartness and sustainability of the cities (activities within WP2);
- The CITYkeys project.

Due to the lack of data available for the calculation of some of the indicators, they were replaced with others with available data for the sample of cities chosen. In addition, some of them were reorganised among layers in order to be able to proceed with the statistical analysis.

The final list of indicators which have been used for the European cities characterization consists of 41 indicators. The number of indicators identified per domain in the first and final lists can be seen in table below.

Table 5: Number of indicators per application layer

Layer	Number of initial indicators	Number of final indicators
Management	22	19
Financing	4	5
Energy	6	5
Mobility	7	8
Infrastructures	4	4
Total	50	41

The complete list of initial indicators can be found in Chapter 4.1. The definitive indicators used on the characterisation analysis are collected in Chapters 5-9 for each application domain.

3.4 Data availability

The analysis of the existing data sources is described in Chapter 4.2.1, considering mainly the following data bases or methods:

- Existing data sources: Eurostat, Covenant of Mayors, CIVITAS, Databases developed by EU Projects (CONCERTO, CITYkeys, CELSIUS, etc.)
- Use of other data sources: a questionnaire has been launched and distributed along European cities (See chapter 4.2.2 below).

An exhaustive analysis was performed in order to evaluate the availability of data requested to characterise the selected cities. The data sources identified for initial indicators can be found in Chapter 4.3.

3.5 Data collection and processing

The statistical method applied for data processing consisted of cluster analysis which involves sorting items into grouping based on the similarity.

Two separate analyses were conducted in SPSS and Rapid Miner under different statistical methods in order to compare results obtained (Hierarchical and Non-hierarchical methods, respectively).

3.5.1 Hierarchical method

The agglomerative method was selected for the cluster analysis under the different possibilities to be applied. As a result, subjects start in their own separate cluster and then the individual elements are merged in cluster progressively in basis of a defined similarity measure. This clustering in pairs is done repeatedly until all subjects belong to one cluster and the optimum number of cluster is chosen out of all cluster solutions at the end of the process.

For our analysis, the average is the linkage criterion which specifies the similarity (distances) between individual objects.

The result of this cluster analysis is a binary tree or dendrogram that connects data points in a hierarchical tree. The height of each *U* represents the distance between the two data points being connected.

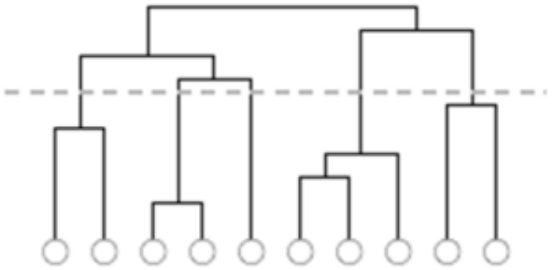

Figure 7: Sample of dendrogram (Source: Wikipedia)

3.5.2 Non-hierarchical method

Known as well as k-means clustering method, it aims to partition *n* observations into *k* clusters in which each observation belongs to the cluster with the nearest mean (centroid), serving as a prototype of the cluster. The process consists of steps described below which are represented in the diagram of Figure 8.

1. Partition the items into k initial clusters.
2. Proceed through the list of items; assigning an item to the cluster whose centroid (mean) is nearest. Recalculate the centroid for the cluster receiving in the new item and for the cluster losing the item.
3. Repeat step 2 until no more assignments take place.

Finally, it is relevant to point that data are subject to a normalization procedure in order to make comparison among them.

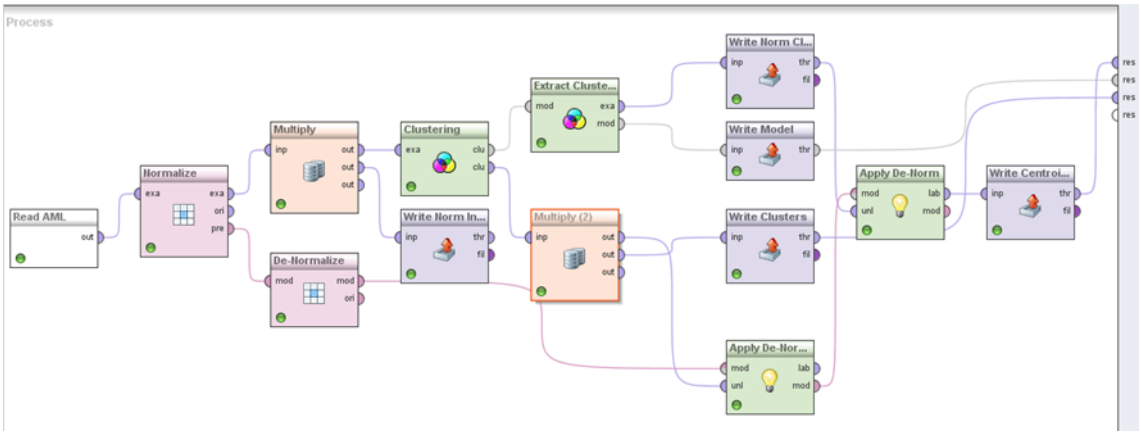

Figure 8: Scheme of data processing conducted in Rapid Miner

After both analyses were performed, it was decided to characterize the cities according to the non-hierarchical method (see chapters 6-10) since this is a more robust method and therefore the city typologies are more reliable. Concerning the number of desired city typologies, hierarchical method helped to this decision since all the possibilities were observed in dendrogram plotted in advance. In Annex C. Hierarchical Method, as a complementary analysis, can be observed the results obtained with this statistical procedure.

3.6 City typologies definition

Five types of groups of cities were generated according to an aggregated scheme of the indicators divided according to five main groups or layers.

Each of these layers defines a set of city types per category, according to the indicators depicted; related to:

- **Management:** including physical characteristics, people, governance and city strategies
- **Economic/Finance:** including the definition of the city economy
- **Energy:** covering the evaluation of the built environment
- **Mobility:** addressing the urban transportation indicators
- **Infrastructures:** which includes the analysis of existing infrastructures and the integration potential through ICT actions

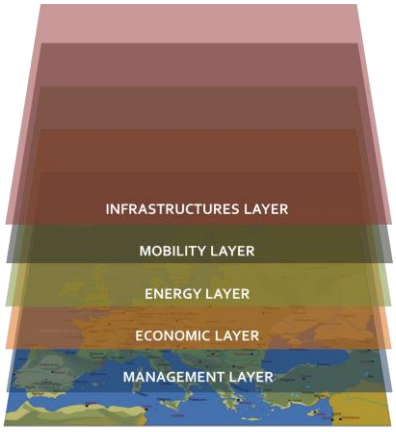

Figure 9: Characterisation layers

4 First set of indicators and data sources

4.1 Identification of indicators to define the city typologies by layers

As described in section 3.3 above, an initial set of indicators was selected for the characterisation and identification of groups of cities in the context of replication of REMOURBAN.

Tables below show the first list of indicators chosen which suffered changes due to the difficulty for collecting data for all the cities and indicators. Those indicators which were not available at city level are shown in Annex B. List of Indicators Discarded

Table 6: First set of indicators for management layer (people and social characteristics)

MANAGEMENT: PEOPLE AND SOCIAL CHARACTERISTICS			
INDICATOR	**FORMULA**	**UNIT**	**DESCRIPTION**
Population density	Total city population / Land area city	inh/km^2	Population per unit area in the city
Population dependency ratio	(Population<14 + Population>64) / Population of adults) x 100	%	Population of children and senior citizen in relation to the adults population
Annual population change	Total population (year x) / Total population (year x-1) x 100	%	Change in the number of inhabitants in the last year
Foreigners as a proportion of population	Number of foreigners living city / total city population	%	Population of foreigners in relation to the city population
Affordability of housing	Population living on affordable housing / total city population	%	Percentage of population living in affordable housing
Residential Land occupation	Residential area (km^2) / Land area city (km^2) x 100	%	Urbanised area of the municipality: residential areas in the extension covered by the city
Percentage of students completing secondary education	100 x Number of students in a school who complete the final grade of secondary education / total number of students in the school	%	Percentage of students enrolled in the first grade of secondary education who reached the final grade of secondary education
Students in higher education	-	Number of students	Students in higher education correspond with Level 5-6 of Standard Classification of Education (ISCED)
Youth unemployment	100 x Total number of unemployed youth /	%	The unemployment rate is defined as the number of unemployed youth

MANAGEMENT: PEOPLE AND SOCIAL CHARACTERISTICS			
INDICATOR	**FORMULA**	**UNIT**	**DESCRIPTION**
Rate	youth labour force		(typically 15-24 years) divided by the youth labour force
Satisfaction with city quality of life	-	%	Percentage of population satisfied with their city's quality of life
Green areas	Green areas (km^2) / Land area city (km^2) x 100	%	Green areas in the extension covered by the city
Average life expectancy	-	Age	Average number of years to be lived by a group of people born in the same year, if health and living conditions at the same through their lives
Waste generated per capita	Total amount of solid waste generated (household and commercial) / total city population	ton/inh	Municipal waste refer to waste collected by or on behalf of municipalities which include waste originating from households, commercial and institutions

Table 7: First set of indicators for management layer (Governance)

MANAGEMENT: GOVERNANCE			
INDICATOR	**FORMULA**	**UNIT**	**DESCRIPTION**
Voter turnout in last municipal election	Number of persons that voted in the last municipal election / Total city population eligible to vote x 100	%	Voter participation level
Number of local associations per capita	Number of associations / Total city population	Number of associations / inh	Total number of citizen associations in the city
R&D expenditure per capita	City's R&D expenditure / Total city population	Euro / inh	The running cost that a city employed for research and development issues
ICT citizen oriented platforms	-	YES/NO	Is there any public ICT global platform available for citizen offering general information about the city?
Percentage of the city's solid waste that is recycled	100 x Total amount of city's solid waste that is recycled in tonnes / total amount of solid waste produced in the city in tonnes	%	Recycled materials shall denote those materials diverted from the waste stream, recovered and processed into new products following local government permits and regulations

Table 8: First set of indicators for management layer (Sustainable and Smart city strategies)

MANAGEMENT: SUSTAINABLE AND SMART CITY STRATEGIES			
INDICATOR	**FORMULA**	**UNIT**	**DESCRIPTION**
Existence of local sustainability plans	-	YES/NO	Is there any specific sustainability plan in the city?
Existence of Smart Cities strategies	-	YES/NO	Is there any specific Smart Cities strategy in the city?
Existence of an Agenda 21	-	YES/NO	Has the city elaborated an Agenda 21?
Signature of Covenant of Mayors	-	YES/NO	Has the city signed the Covenant of Mayors?
Existence of public incentives to promote energy efficient districts	-	YES/NO Numbers of plans	Are there any specific public incentives for promoting of energy efficient districts in the city?
Existence of public incentives to promote sustainable mobility	-	YES/NO Numbers of plans	Are there any specific public incentives for promoting of sustainable mobility in the city?
Percentage of the ICT sector on GDP	-	%	Gross value added (at basic prices) minus other taxes less other subsidies on production on ICT sector (based on NACE Rev. 2)

Table 9: First set of indicators for financing layer

FINANCING			
INDICATOR	**FORMULA**	**UNIT**	**DESCRIPTION**
GDP per inhabitant	-	€/inh	It is a monetary measure of the value of all final goods and services produced in a period of time
Average disposable income	-	€/inh	The amount of money that households have available for spending and saving after income taxes have been accounted for. Disposable personal income is often monitored as one of the many key economic indicators used to gauge the overall state of the economy.

City unemployment rate	Number of citizens unemployed / Total labour force x 100	%	Unemployed citizens in relation to employed and unemployed who are legally eligible to work

Table 10: First set of indicators for energy layer

ENERGY			
INDICATOR	**FORMULA**	**UNIT**	**DESCRIPTION**
Annual final energy consumption of buildings	-	MWh/m^2	Final energy consumption of buildings for all usages (heat and water heating, cooling, lighting, cooking ventilation and other ancillary services, electrical appliances) per m^2 of buildings
Residential energy consumption per capita	Total residential energy consumption / Total city population	MWh/inh	Final energy consumption of residential users for all usages (heat and water heating, cooling, lighting, cooking, ventilation and other ancillary services, electrical appliances) per inhabitant in a period of a year
Total residential electrical energy use per capita	Total residential electricity energy use / Total city population	kWh/inh	Residential electricity consumption in a period of a year
Energy consumption of public buildings per year	Total use of electricity by public buildings / Total floor space of these buildings	kWh/m^2	Electricity consumption by public buildings
The percentage of total energy derived from renewable sources	Total consumption of electricity generated from renewable sources / Total energy consumption	%	Energy derived from energy renewable sources related to the total energy
GHG emissions per capita from buildings	Annual Tonnes of CO_2 eq / Total City Population	Annual tonnes CO_2 eq /inh	GHG emissions from buildings (residential and public) according to the Global Protocol for Community Scale GHG Emissions (GPC)

Table 11: First set of indicators for mobility layer

MOBILITY			
INDICATOR	**FORMULA**	**UNIT**	**DESCRIPTION**
Private car ratio	Total number of private cars / Total city population	Number of cars / inh	Total number of private cars (excluding automobiles, trucks and vans used for the delivery of goods and services by commercial

			enterprises), related to the total number of inhabitants
People killed in road accidents (per 10000 population)	-	%	People killed in road accidents
Access to public transport	100 X Number of trips in public transport / Total trips (private + public transport)	%	Number of trips in public transport in relation to all trips
Kilometres of high capacity public transport system per 100 000 population	Length of high capacity public transport / 100.000	km/100.000 Inh	Length of high capacity public transport network (heavy rail metro, subway and commuter rail systems)
Kilometres of light passenger public transport system per 100 000 population	Length of light capacity public transport / 100.000	km/100.000 Inh	Length of light capacity public transport network (light rail streetcars, tramways, bus, trolleybus and other)
Kilometres of bicycle paths and lanes per 100 000 population	Length of bicycle paths and lanes / 100.000	km/100.000 Inh	Length of bicycle paths (independent roads or parts of a road designated for cycles and signed-posted as such) and lanes (part of carriageways designated for cycles and distinguished from the rest by longitudinal road markings)
Percentage of EV per sector (private, public and service (taxi and first mile))	Total number of all type EV (per sector)/ Total number vehicles	%	Number of electric vehicles related to total number of vehicles
GHG emissions per capita from transportation	Annual Tonnes of CO_2 eq / Total City Population	Annual tonnes CO_2 eq / Inh	According to the Global Protocol for Community Scale GHG Emissions (GPC)

Table 12: First set of indicators for infrastructure layer

INFRASTRUCTURES			
INDICATOR	**FORMULA**	**UNIT**	**DESCRIPTION**
Smartphone penetration	Number of smartphones / Total mobile phones	%	Number of smartphones in relation to total mobile phones
Percentage of households having access to high speed internet of above	100 X Households with access to high speed internet / Total households	%	Coverage/availability of high speed internet in households

INFRASTRUCTURES			
INDICATOR	**FORMULA**	**UNIT**	**DESCRIPTION**
30 Mbps			
Percentage of the population covered by at least a 3G mobile network	100 X Population with at least 3G coverage/ Total city population	%	Percentage of the population covered by at least a 3G mobile network
Availability of Internet access in households	Number of households with Internet access for any household member via a fixed or mobile network at any given time / Total households	%	Percentage of households with Internet access for any household member via a fixed or mobile network at any given time in relation to total households
Number of infrastructure components with installed sensors.	-	Num.	The components covers the traffic, public transit demand, parking, waste, water and public lighting
Number of services integrated in a singular operations centre leveraging real-time data	-	Num.	The services include ambulance, emergency/disaster response, fire, police, weather, transit and air quality,

4.2 Identification of databases

4.2.1 Benchmarking existing data sources

In preparation to the data collection process, a benchmark of existing data sources was carried out to identify which were the most relevant one in relation with the characterization KPIs identified.

Below is a description of the main data sources benchmarked and finally used, for the different domains (layers), and whether they cover quantitative or qualitative data.

4.2.1.1 Urban Audit and State of European Cities Report[2]

The Urban Audit, coordinated by the European Commission through the DG for Regional Policy and Eurostat started in 1999 to collect and analyse data about Europe-wide cities. In the Second State of European Cities Report, 322 cities in the European Union, as well as others from non-EU countries, the results of a characterisation approach for cities is depicted, including only those indicators of the Urban Audit that can be compared.

[2] http://ec.europa.eu/eurostat/en/web/products-statistics-in-focus/-/KS-SF-08-082

It mainly covers quantitative information of a wide number of issues as demography, social conditions, economic aspects, education, civic involvement, environment, transport and culture for different special levels of cities: core cities, larger urban zones (LUZ), sub-city districts and national averages. In the case of REMOURBAN, considering the application domain of the Urban Regeneration Model, only core cities have been considered.

4.2.1.2 Eurostat[3]

In the frame of the current task, Eurostat was used as one of the main data sources for quantitative data thanks to the Urban Audit (see 4.2.1.1. above). But in many cases, data appeared not to be available anyway on some of the selected cities of our list, or to answer to the chosen indicators.

4.2.1.3 Covenant of Mayors[4]

After the adoption, in 2008, of the EU Climate and Energy Package, the European Commission launched the Covenant of Mayors (CoM) to endorse and support the efforts deployed by local authorities in the implementation of sustainable energy policies.

In order to translate their political commitment into concrete measures and projects, Covenant signatories notably undertake to prepare a Baseline Emission Inventory and submit, within the year following their signature, a Sustainable Energy Action Plan outlining the key actions they plan to undertake.

Since the CoM includes many qualitative data about the signatories, it seemed logical to use it as a valuable data source for the present characterization of European cities.

4.2.1.4 CIVITAS[5]

CIVITAS initiative was launched in 2002 to redefine transport measures and policies in order to create cleaner, better transport in cities in Europe. This platform was also used to qualify the data of the mobility layer

4.2.1.5 Databases developed by EU Projects – EIP-SCC[6]

The EIP-SCC platform and especially its online Market Place[7] is the ideal source of information about all the projects related to SCC in Europe. The EU Projects page provides a list of all the ongoing projects with all cities involved in them).

Previous EU SCC projects such as CONCERTO[8] are also very valuable sources of information and were studied in detail to help us in defining our methodology and actions.

Apart from the EIP-SCC, a close partnership with some specific EU projects aimed at similar targets as ours, such as with the CITYkeys[9] project, CITyFiED[10], CELSIUS[11], and more.

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[3] http://ec.europa.eu/eurostat/web/main/home

[4] http://www.covenantofmayors.eu/

[5] For more on CIVITAS, please refer to http://civitas-initiative.org/

[6] The European Innovation Partnership on Smart Cities and Communities - http://ec.europa.eu/eip/smartcities/

[7] https://eu-smartcities.eu/

[8] http://www.concerto-project.org/

[9] http://www.citykeys-project.eu/citykeys/home

4.2.2 Utilisation of other data sources

In parallel with the previous tasks, a survey has been launched to evaluate the level of smartness of European cities and identify the cities willing get smarter (and join a possible future REMOURBAN cluster of follower cities to help in the replicability of the REMOURBAN model).

The survey was built using EUSurvey tools[12]. This online survey was launched on 6th October, 2015 and will remain open still to leave time to as many EU cities to participate.

By the end of month of December 2015, **20 cities from 6 countries** (Belgium, France, Italy, Spain, Sweden and UK), took part already to the survey, and many are still expected to participate as the survey link has been sent over by many partner projects dissemination and communication channels, different media and groups, social networks (LinkedIN, Facebook, Twitter…) and of course, is available from the home page of the REMOURBAN website. All the partners' cities and companies also forwarded the information to their contacts in their region also.

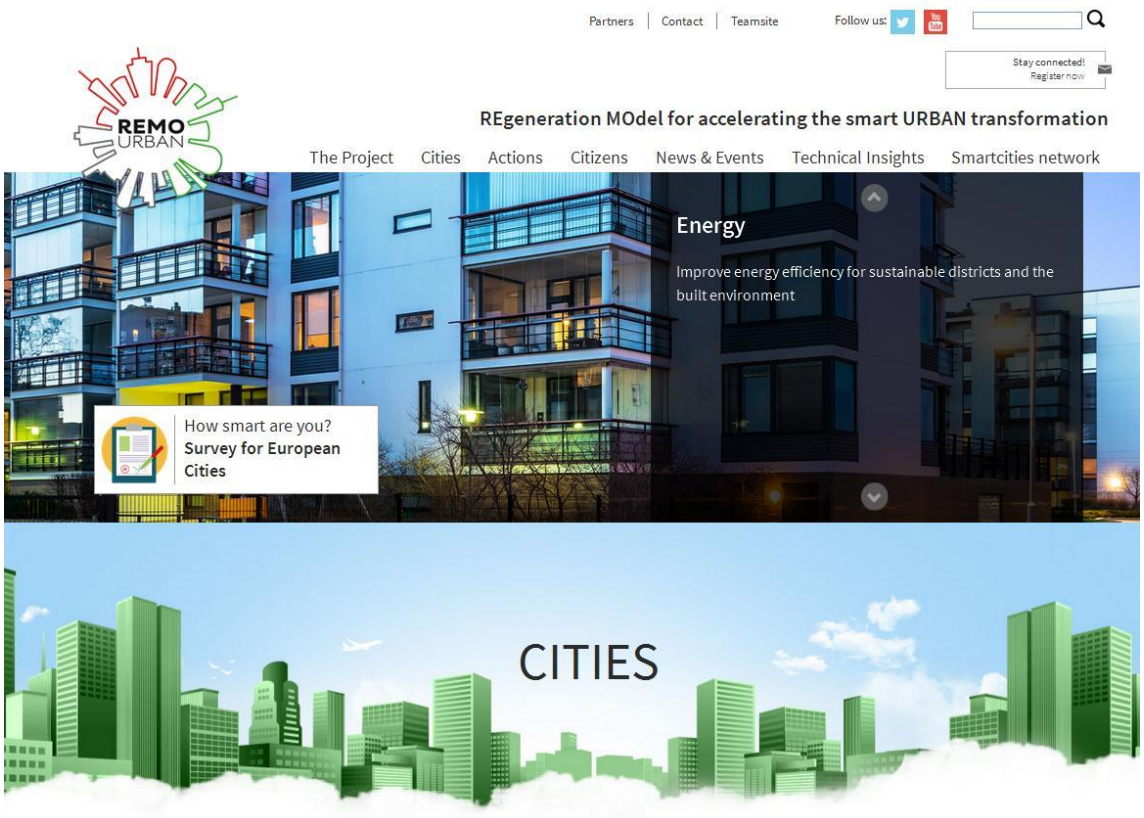


Figure 10: Screen shot of the REMOURBAN web site with the link to the survey for European cities

The results of the first 20 cities who participated by end of October 2015 is shown below:

- 65% (13 out of 20) answered "Yes" to the question: "Is your city willing to get "smarter" in the future, and join the cluster of the follower cities of the REMOURBAN project?"
- 25 % (5 out of 20) answered "We don't know", and

[10] http://www.cityfied.eu/

[11] http://celsiuscity.eu/

[12] For more information on EUSurvey, please check https://ec.europa.eu/eusurvey/. The survey is accessible at the following page : https://ec.europa.eu/eusurvey/runner/REMOURBAN_H2020_survey

- 10 % (2 out of 20) answered “No”.
- This means that a **total of 90% is potentially interested** in following the results of the REMOURBAN project and may be replicate some actions at their level.

The reason why 5 cities answered “We don’t know” is mainly related to availability of resources and staff time.

4.3 Identification of data sources for each indicator

Table 13 compiles the databases where the information for each indicator at city, regional or national level can be found.

Table 13: Identification of data bases for each indicator

LAYER	INDICATOR	KPI_ID	DATA BASE
MANAGEMENT	Population density	MG_P1	Eurostat CPOPCB[13] and State EU Cities Report[14]
	Population dependency ratio	MG_P2	Eurostat CPOPCB [15] and State EU Cities Report[16]
	Annual population change	MG_P3	Eurostat CPOPCB [17]
	Foreigners as a proportion of population	MG_P4	Eurostat CPOPCB [18]
	Affordability of housing	MG_P5	Eurostat ILC and CLIVCON[19]
	Residential Land occupation	MG_P6	Eurostat CLIVCON[20]
	Proportion of working age population with higher education	MG_P7	Eurostat CEDUC[21]
	Students in higher/tertiary education	MG_P8	Eurostat CEDUC[22]

[13] (EUROSTAT) and http://ec.europa.eu/eurostat/web/products-datasets/-/urb_cpopcb (Population by citizenship and country of birth - cities and greater cities)

[14] (Rheinisch-Westfälisches Institut für Wirtschaftsforschung, November 2010)

[15] http://ec.europa.eu/eurostat/web/population-demography-migration-projections/population-data/database and http://ec.europa.eu/eurostat/web/products-datasets/-/urb_cpop1

[16] (Rheinisch-Westfälisches Institut für Wirtschaftsforschung, November 2010)

[17] See notes 4 and 5 above.

[18] http://ec.europa.eu/eurostat/web/products-datasets/-/urb_cpop1 (Foreign-born)

[19] http://ec.europa.eu/eurostat/web/products-datasets/-/ilc_mded04 and http://ec.europa.eu/eurostat/web/products-datasets/-/urb_clivcon (Suggested Urban audit indicator: Population living in private households. See formula above chapter 5.1.1)

[20] Check if national websites/Agendas 21 are at English but also try to find if there are any reports which include this data through internet. Otherwise, consider the number of private households (http://ec.europa.eu/eurostat/web/products-datasets/-/urb_clivcon divided by the area of the city, to measure the compactness of the city.

[21] http://ec.europa.eu/eurostat/web/products-datasets/-/urb_leduc (Urban audit indicator : Proportion of working age population qualified at level 5 or 6 ISCED)

[22] http://ec.europa.eu/eurostat/web/products-datasets/-/urb_ceduc (Urban audit indicator : Student in higher school education (ISCED level 5-6), total) and http://ec.europa.eu/eurostat/web/products-datasets/-/educ_momo_dst

LAYER	INDICATOR	KPI_ID	DATA BASE
	Youth unemployment rate	MG_P9	Eurostat CLMA[23]
	Satisfaction with city quality of life	MG_P10	Eurostat URB_PERCEP[24]
	Average life expectancy	MG_P11	Eurostat URB_PERCEP[25]
	Green area	MG_P12	Eurostat URB_PERCEP[26]
	Number of public libraries	MG_P13	Eurostat CTOUR[27]
	Voter turnout in last municipal election	MG_G1	Local authorities website
	ICT citizen oriented platforms	MG_G2	Local authorities website
	Waste generated per capita	MG_G3	Eurostat[28]
	Existence of local sustainability plans	MG_S1	CoM[29]
	Existence of Smart Cities strategies	MG_S2	EIP-SCC[30]
	Existence of an Agenda 21	MG_S3	CoM[31]
	Signature of Covenant of Mayors	MG_S4	CoM[32]
	Existence of public incentives to promote energy efficient districts	MG_S5	CoM[33]

[23] http://ec.europa.eu/eurostat/web/products-datasets/-/urb_clma and http://ec.europa.eu/eurostat/web/products-datasets/-/tipslm80

[24] http://ec.europa.eu/eurostat/web/cities/data/database - urb_percep (Perception survey results) – Indicator: "Are you satisfied to live in the city: strongly agree" - %.

[25] http://ec.europa.eu/eurostat/web/cities/data/database - urb_percep (Perception survey results) – Indicator: "Health care services offered by hospitals in the city : very satisfied" - %

[26] http://ec.europa.eu/eurostat/web/cities/data/database - urb_percep (Perception survey results) – Indicator: " Green spaces such as public parks and gardens : very satisfied" - % and http://knoema.es/CITIES/metropolitan-areas?tsId=1015420

[27] http://ec.europa.eu/eurostat/web/products-datasets/-/urb_ctour (Urban audit indicator: Number of public libraries).

[28] http://ec.europa.eu/eurostat/web/products-datasets/-/ten00110 (at Country level only) No data available found at city level. Should we decide not to use this indicator?

[29] http://www.covenantofmayors.eu/actions/sustainable-energy-action-plans_en.html and See also Excel sheet from CoM provided by SER (SEAP sheet)

[30] EIP-SCC platform (https://eu-smartcities.eu/eu-projects). Consider ok if the city appears in website EIP-SCC, in EU Projects for instance

[31] http://www.covenantofmayors.eu/. See also Excel sheet from CoM provided by SER (SIGN sheet)

[32] Ibid.

[33] Search in each city signatory page on the Covenant of Mayors website E.g. : See the benchmarks page of Seraing : http://www.covenantofmayors.eu/about/signatories_en.html?city_id=6363&benchmarks. The Financing sources are mentioning the public funding so the answer is YES to this indicator.

LAYER	INDICATOR	KPI_ID	DATA BASE
	Existence of public incentives to promote sustainable mobility	MG_S6	CoM[34]
FINANCE	GDP per inhabitant	FI1	Eurostat[35]
	Average disposable income	FI2	Eurostat[36]
	City unemployment rate	FI3	Eurostat[37]
	Proportion of working age population with higher education	FI4	Eurostat CEDUC[38]
ENERGY	Annual final energy consumption of buildings	EN1	Eurostat[39] and CoM
	Residential energy consumption per capita	EN2	Eurostat[40] and CoM
	Total residential electrical energy use per capita	EN3	Eurostat[41] and CoM
	Energy consumption of public buildings per year	EN4	Eurostat[42] and CoM
	The percentage of total energy derived from renewable sources	EN5	Eurostat[43] and CoM
	GHG emissions per capita from buildings	EN6	Eurostat[44] and CoM

[34] Ibid.

[35] http://ec.europa.eu/eurostat/en/web/products-press-releases/-/2-21062010-AP and http://ec.europa.eu/eurostat/web/products-datasets/-/nama_10r_3gdp

[36] http://ec.europa.eu/eurostat/en/web/products-statistical-working-papers/-/KS-RA-07-007

[37] http://ec.europa.eu/eurostat/web/products-datasets/-/lfst_r_urgau

[38] http://ec.europa.eu/eurostat/web/products-datasets/-/urb_leduc (Urban audit indicator : Proportion of working age population qualified at level 5 or 6 ISCED)

[39] http://ec.europa.eu/eurostat/web/products-datasets/-/t2020_rk210 and CoM Final energy consumption per capita (http://www.covenantofmayors.eu/search_en.html?q=+Final+energy+consumption+per+capita+&x=27&y=9) Search in every signatories Action Plan.

[40] http://ec.europa.eu/eurostat/en/web/products-press-releases/-/8-21092006-AP1 and/or http://www.covenantofmayors.eu/. Search in every signatories Action Plan.

[41] http://ec.europa.eu/eurostat/en/data/database (nrg_105a) and/or http://www.covenantofmayors.eu/. Search in every signatories Action Plan.

[42] http://ec.europa.eu/eurostat/en/data/database (tsdpc320) and/or http://www.covenantofmayors.eu/. Search in every signatories Action Plan.

[43] http://ec.europa.eu/eurostat/en/web/products-statistical-books/-/KS-37-01-647 and/or http://www.covenantofmayors.eu/. Search in every signatories Action Plan.

[44] http://ec.europa.eu/eurostat/en/web/products-statistical-books/-/CH10_2008 and http://www.energy-cities.eu/spip.php?page=index_en and/or http://www.covenantofmayors.eu/. Search in every signatories Action Plan.

LAYER	INDICATOR	KPI_ID	DATA BASE
MOBILITY	Private car ratio	MO1	Eurostat CTRAN[45]
	People killed in road accidents (per 10000 population)	MO2	Eurostat CTRAN [46]
	Access to public transport	MO3	Eurostat CTRAN [47]
	% of journey to work by bicycle	MO4	Eurostat CTRAN [48]
	Percentage of EV per sector (private, public and service(taxi and first mile))	MO5	McKinsey Report[49]
	GHG emissions per capita from transportation	MO6	Eurostat[50]
	Mobility plan	MO7	Local city website or EIP-SCC[51]
ICT	Availability of IT infrastructure within the city	IN1	European Smart Cities[52]
	Availability of Internet access in public space	IN2	Eurostat URB_PERCEP[53]
	ICT patent	IN3	Eurostat PAT_EP_RICT[54]
	Availability of Internet access in households	IN4	Eurostat URB_PERCEP[55]

[45] http://ec.europa.eu/eurostat/web/products-datasets/-/urb_ctran (Data 14 sheet)

[46] http://ec.europa.eu/eurostat/web/products-datasets/-/urb_ctran (Data 15 sheet) and http://ec.europa.eu/eurostat/web/products-datasets/-/tps00165

[47] http://ec.europa.eu/eurostat/web/products-datasets/-/urb_ctran (Data 2 and 12 sheets) and http://ec.europa.eu/eurostat/web/products-datasets/-/ilc_hcmp06

[48] Idib.

[49] http://www.mckinsey.com/~/media/McKinsey%20Offices/Netherlands/Latest%20thinking/PDFs/Electric-Vehicle-Report-EN_AS%20FINAL.ashx Exhibit 1.1

[50] http://ec.europa.eu/eurostat/web/products-datasets/-/t2020_rd300 (Country level only) and http://ec.europa.eu/eurostat/web/products-datasets/-/med_en1

[51] https://eu-smartcities.eu/sustainable-urban-mobility

[52] European Smart cities ranking by Vienna University of Technology- http://www.smart-cities.eu/ (

[53] http://ec.europa.eu/eurostat/web/cities/data/database - urb_percep (Perception survey results) – Indicator : "Public Internet access such as Internet Cafés or libraries in the city : very satisfied" - %

[54] http://ec.europa.eu/eurostat/web/products-datasets/-/pat_ep_rict: ICT patent applications to the EPO by priority year by NUTS 3 regions [pat_ep_rict] per million inhab. Data at regional level when not available at city level.

[55] http://ec.europa.eu/eurostat/web/products-datasets/-/isoc_ci_in_h and http://ec.europa.eu/eurostat/web/products-datasets/-/pat_ep_rict or http://ec.europa.eu/eurostat/web/cities/data/database - urb_percep (Perception survey results) – Indicator : "Internet access at home in the city : very satisfied" - %

5 Characterization of European cities by Management Features

This section deals with the characterization of the sample of European cities by management features. Typologies of cities will be defined in basis to physical/ people characteristics and Governance and Sustainable and Smart Strategies. The set of indicators and databases used are also introduced.

5.1 Final list of indicators and data sources

The following tables define the final set of indicators, and the data sources where the information can be found, selected after the analysis of the data availability for the selected cities.

Table 14: Final set of indicators for Physical Characterization

INDICATOR	KPI ID	FORMULA	UNIT	DESCRIPTION	DATABASE
Population density	MG_PC1	Total city population / Land area city	Inh./km^2	Population per unit area in the city	Eurostat CPOPCB[56] and State EU Cities Report[57]
Population	MG_PC2	-	Inhabitants	Total number of persons inhabiting a city	Eurostat CPOPCB[58]
Area	MG_PC3	-	km^2	Land area city	Wikipedia/Google/local webs
Elevation	MG_PC4	-	m	Altitude of a city above sea level	Wikipedia/Google/local webs

Table 15: Final set of indicators for People

INDICATOR	KPI_ID	FORMULA	UNIT	DESCRIPTION	DATABASE
Population dependency ratio	MG_P1	(Population< 14 + Population>64) / Population of adults) x 100	%	Population of children and senior citizen in relation to the adults population	Eurostat CPOPCB [59] and State EU Cities Report[60]

[56] (EUROSTAT) and http://ec.europa.eu/eurostat/web/products-datasets/-/urb_cpopcb (Population by citizenship and country of birth - cities and greater cities)

[57] (Rheinisch-Westfälisches Institut für Wirtschaftsforschung, November 2010)

[58] http://ec.europa.eu/eurostat/web/products-datasets/-/urb_cpopcb

[59] http://ec.europa.eu/eurostat/web/population-demography-migration-projections/population-data/database and http://ec.europa.eu/eurostat/web/products-datasets/-/urb_cpop1

[60] (Rheinisch-Westfälisches Institut für Wirtschaftsforschung, November 2010)

INDICATOR	KPI_ID	FORMULA	UNIT	DESCRIPTION	DATABASE
Annual population change	MG_P2	Total population / Total population x 100	%	Change in the number of inhabitants in the last year	Eurostat CPOPCB [61]
Foreigners as a proportion of population	MG_P3	Number of foreigners living city / total city population	%	Population of foreigners in relation to the city population	Eurostat CPOPCB [62]
Students in higher education	MG_P4		Number of students	Number of students in higher education (ISCED Level 5-6)	Eurostat CEDUC[63]
Youth unemployment rate	MG_P5	100 x Total number of unemployed youth / youth labour force	%	The unemployment rate is defined as the number of unemployed youth (typically 15-24 years) divided by the youth labour force	Eurostat CLMA[64]
Number of public libraries	MG_P6	Number of public libraries per 10,000 inhabitants	Number of libraries	Number of public libraries as indicator of the level of education of the population.	Eurostat CTOUR[65]
Median population age	MG_P7	-	Years	Median age is the age that divides a population into two numerically equal groups	Eurostat CPOPSTR[66]

[61] See notes 4 and 5 above.

[62] http://ec.europa.eu/eurostat/web/products-datasets/-/urb_cpop1 (Foreign-born)

[63] http://ec.europa.eu/eurostat/web/products-datasets/-/urb_ceduc (Urban audit indicator : Student in higher school education (ISCED level 5-6), total) and http://ec.europa.eu/eurostat/web/products-datasets/-/educ_momo_dst

[64] http://ec.europa.eu/eurostat/web/products-datasets/-/urb_clma and http://ec.europa.eu/eurostat/web/products-datasets/-/tipslm80

[65] http://ec.europa.eu/eurostat/web/products-datasets/-/urb_ctour (Urban audit indicator: Number of public libraries).

[66] http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do

INDICATOR	KPI_ID	FORMULA	UNIT	DESCRIPTION	DATABASE
Voter turnout in last municipal election	MG_P8	Number of persons that voted in the last municipal election / Total city population eligible to vote x 100	%	Voter participation level	Local authorities website
Percentage of the city's solid waste that it is recycled	MG_P9	100 x Total amount of city's solid waste that is recycled in tonnes	%	Recycled materials shall denote those materials diverted from the waste stream, recovered and processed into new products following local government permits and regulations	Local authorities website

Table 16: Final set of indicators for Governance & Smart city strategies

INDICATOR	KPI_ID	FORMULA	UNIT	DESCRIPTION	DATABASE
Existence of local sustainability plans	MG_G1	-	YES/NO	Is there any specific sustainability plan in the city?	CoM[67]
Existence of Smart Cities strategies	MG_G2	-	YES/NO	Is there any specific Smart Cities strategy in the city?	EIP-SCC[68]
Existence of an Agenda 21	MG_G3	-	YES/NO	Has the city elaborated an Agenda 21?	CoM[69]
Signature of Covenant of Mayors	MG_G4	-	YES/NO	Has the city signed the Covenant of	CoM[70]

[67] http://www.covenantofmayors.eu/actions/sustainable-energy-action-plans_en.html and See also Excel sheet from CoM provided by SER (SEAP sheet)

[68] EIP-SCC platform (https://eu-smartcities.eu/eu-projects). Consider ok if the city appears in website EIP-SCC, in EU Projects for instance

[69] http://www.covenantofmayors.eu/. See also Excel sheet from CoM provided by SER (SIGN sheet)

[70] Ibid.

				Mayors?	
Mobility Plan	MG_G5	-	YES/NO	Does the city have a smart mobility plan?	Local city website or EIP-SCC[71]
ICT citizen oriented platforms	MG_G6	-	YES/NO	Is there any public ICT global platform available for citizen offering general information about the city?	Local authorities website

[71] https://eu-smartcities.eu/sustainable-urban-mobility

5.2 Data collection and aggregation for the cities

Table 17: Aggregated data for the management layer for Physical characteristics

Code	City	MG_PC1	MG_PC2	MG_PC3	MG_PC4
		Population density	Population	Area	Elevation
AT-01	Graz	1,960	265,778	127.58	353
AT-02	Innsbruck	1,125	122,458	104.91	574
BE-01	Ghent	1,421	249,754	156.18	8
BE-02	Liege	2,839	382,009	69.39	68
BE-03	Brugge	840	118,145	138.4	7
BG-01	Ruse	860.6	147,817	187124	45
EE-01	Tartu	2,504.7	99,518	38.86	57.2
FI-01	Jyväskylä	112.7	134,658	1446.34	85
FI-02	Tampere	391	220,446	690.6	84.5
FI-03	Turku	716	182,072	306.4	59
FR-01	La Rochelle	2,703.06	147,556	28.43	12
FR-02	Poitiers	2,119.52	135,635	42.11	105

DE-01	Aachen	1,500	241,683	160.83	156
DE-02	Koeln	2,457	1,034,175	405.15	37
DE-03	Leipzig	1831	531,562	297.4	113
DE-04	Rosenheim	175	60,464	37.22	440
GR-01	Thessaloniki	7,338.8	376,047	111703	20
HU-01	Miskolc	710.14	162,905	236.66	131
IR-01	Cork	3194	118,713	37.3	10
IT-01	Bolzano	1,970.48	105,713	52.34	262
IT-02	Firenze	3,708.19	377,207	102	50
IT-03	Genova	2,503.06	596,958	243.66	20
NL-01	Eindhoven	2,407	218,433	88.84	18
NL-02	Utrecht	3,442	321,916	99.32	4
NW-01	Stavanger	1,674.9	129,191	71.2	1
NW-02	Trondheim	488.88	179,692	341	1
PT-01	Porto	5,324	227,535	41.66	104
PT-02	Braga	990.79	182,110	183.51	193
SI-01	Ljubljana	974.3	280,607	275	295

ES-01	San Sebastian-Donostia	3,056.76	186,126	60.89	6
ES-02	Málaga	1,423.51	566,913	398.25	11
ES-03	Sevilla	4,967.98	696,676	140.8	7
ES-04	Valladolid	1,550.35	306,830	197.91	698
ES-05	Santa Cruz de Tenerife	1,363.44	205,279	150.56	4
SE-01	Stockholm	7,300	864,324	188	0
SE-02	Gothenburg	2,700	520,374	447.76	12
SE-03	Malmö	1,769	302,835	335.14	12
UK-01	Nottingham	4,097	309,800	74.61	61
UK-02	Manchester	4,313	512,600	115.6	38
UK-03	Bristol	3,892	435,000	110	95
UK-04	Oxford	3,371	153,700	45.59	128

Table 18: Aggregated data for the management layer for People Characteristics

Code	City	MG_P1	MG_P2	MG_P3	MG_P4	MG_P5	MG_P6	MG_P7	MG_P8	MG_P9
		Population dependency ratio	Annual population change	Foreigners as a proportion of population	Students in higher education	Youth unemployment rate	Number of public libraries per 10,000 inhabitants	Median Population age	Voter turnout in last municipal election	Percentage of the city's solid waste that is recycled
AT-01	Graz	30.6	3114	14.29	55,304	7.9	0.15	39.50	70.00	57.7
AT-02	Innsbruck	30.56	885	15.35	35,975	6.0	1.80	40.50	65.5	57.7
BE-01	Ghent	33.13	549	7.70	79,040	16.0	0.60	45.27	91.00	55.00
BE-02	Liege	34.24	2031	13.38	38,422	32.3	1.20	43.10	73.00	55.00
BE-03	Brugge	35.92	528	3.67	7,244	13.2	1.10	43.10	89.37	55.00
BG-01	Ruse	30.37	-533	0.62	9,226	24.9	1.15	42.57	48.25	55.00
EE-01	Tartu	31.20	-40	5.29	22,472	15.0	1.91	34.00	53.00	17.4
FI-01	Jyväskylä	31.54	1420	2.01	19,981	20.1	4.98	36.00	55.00	32.5
FI-02	Tampere	30.82	2253	3	33,745	20.1	0.77	37.00	56.00	32.5
FI-03	Turku	31.97	1595	3.92	30,833	22.9	0.33	39.00	56.00	32.5

FR-01	La Rochelle	36.30	1316	2.43	12,628	25.9	0.27	44.00	54.00	37.6
FR-02	Poitiers	29.59	-989	3.53	25,414	25.9	1.25	33.00	54.00	37.6
DE-01	Aachen	29.79	1597	12.01	44,004	9.6	1.08	41.40	75.00	44.3
DE-02	Koeln	30.69	9802	15.20	81,652	9.6	0.17	41.00	70.00	44.3
DE-03	Leipzig	34.23	10724	3.29	35,559	12.5	0.30	42.70	66.00	44.3
DE-04	Rosenheim	33.56	529	9.37	4,668	3.7	0.83	43.10	71.00	44.3
GR-01	Thessaloniki	22.99	-1495	7.17	9,440	53.4	0.45	38.86	58.00	19.3
HU-01	Miskolc	32.19	-2068	0.42	12,851	25.6	1.23	40.00	61.84	26.4
IR-01	Cork	29.59	1175,8	15.71	8,285	22.3	1.10	35.00	58.00	36.6
IT-01	Bolzano	37.57	1822	11.65	2,060	12.4	1.80	44.50	41.00	39.4
IT-02	Firenze	38.67	11168	12.64	56,523	35.7	0.42	44.50	67.21	39.4
IT-03	Genova	39.58	14638	7.90	34,656	45.0	1.32	47.00	75.19	39.4
NL-01	Eindhoven	31.66	1208	0	13,306	11.5	0.14	38.28	45.00	49.8
NL-02	Utrecht	27.44	5641	0	32,188	11.5	0.28	32.72	54.00	49.8

NW-01	Stavanger	31.18	1685	11.95	7,425	6.5	0.15	35.00	58.00	39.2
NW-02	Trondheim	24.51	3344	7.22	15,852	7.7	0.45	35.00	61.00	39.2
PT-01	Porto	37.05	-5526	1.68	58,704	35.7	0.13	46.00	55.82	25.8
PT-02	Braga	29.38	-66	2.26	18,807	35.7	0.22	37.00	62.61	25.8
SI-01	Ljubljana	30.25	467	5.64	13,788	15.7	0.18	41.90	35.92	42.7
ES-01	San Sebastian-Donostia	34.50	-374	6.71	18,304	45.0	0.11	45.00	66.65	30.00
ES-02	Málaga	31.94	-1566	13.78	38,232	61.5	0.11	39.00	57.80	30.00
ES-03	Sevilla	32.72	-3493	4.47	75,642	61.5	0.14	40.00	61.25	30.00
ES-04	Valladolid	34.48	-2884	5.90	29,574	50.4	0.29	45.00	69.64	30.00
ES-05	Santa Cruz de Tenerife	31.01	-1314	6.35	26,013	57.4	0.73	40.00	60.53	30.00
SE-01	Stockholm	26.08	17251	11.10	52,686	21.5	0.51	36.00	82.13	49.00
SE-02	Gothenburg	26.15	6623	7.41	39,273	22.7	0.65	36.00	79.20	49.00
SE-03	Malmö	27.35	3872	11.53	18,301	23.1	1.22	35.00	75.19	49.00
UK-01	Nottingham	29.05	3500	6.77	56,465	16.0	0.58	30.00	31.00	43.5

UK-02	Manchester	28.07	5800	7.22	71,700	18.4	0.57	29.00	44.00	43.5
UK-03	Bristol	30.87	4700	6.81	18,740	12.6	0.64	33.00	27.92	43.5
UK-04	Oxford	27.39	2300	19.9	34,790	13.1	0.26	29.00	64.39	43.5

Table 19: Aggregated data for the management layer for Governance and sustainable and smart strategies

Code	City	MG_G1	MG_G2	MG_G3	MG_G4	MG_G5	MG_G6
		Local sustainability plans	Smart Cities strategies	Agenda 21	Covenant of Mayors	Mobility plan	ICT citizen oriented platforms
AT-01	Graz	0	1	1	0	1	1
AT-02	Innsbruck	0	1	1	0	0	1
BE-01	Ghent	1	1	1	1	1	1
BE-02	Liege	0	1	1	0	0	1
BE-03	Brugge	0	1	1	1	1	1
BG-01	Ruse	0	1	1	0	1	1
EE-01	Tartu	0	1	1	1	1	1
FI-01	Jyväskylä	0	1	1	0	0	1
FI-02	Tampere	1	1	1	1	1	1
FI-03	Turku	1	1	1	1	1	1
FR-01	La Rochelle	1	1	1	1	1	1

FR-02	Poitiers	0	1	1	0	1	1
DE-01	Aachen	1	1	1	1	1	1
DE-02	Koeln	1	1	1	1	1	1
DE-03	Leipzig	0	1	1	0	1	1
DE-04	Rosenheim	0	1	1	0	1	1
GR-01	Thessaloniki	1	1	1	1	1	1
HU-01	Miskolc	0	1	1	1	1	1
IR-01	Cork	1	1	1	1	1	1
IT-01	Bolzano	1	1	1	1	1	1
IT-02	Firenze	1	1	1	1	1	1
IT-03	Genova	1	1	1	1	1	1
NL-01	Eindhoven	1	1	1	1	1	1
NL-02	Utrecht	1	1	1	1	1	1
NW-01	Stavanger	1	1	1	1	1	1

NW-02	Trondheim	1	1	1	1	1	1
PT-01	Porto	1	1	1	1	1	1
PT-02	Braga	1	1	1	1	1	1
SI-01	Ljubljana	1	1	1	1	1	1
ES-01	San Sebastian-Donostia	1	1	1	1	1	1
ES-02	Málaga	1	1	1	1	1	1
ES-03	Sevilla	1	1	1	1	1	1
ES-04	Valladolid	1	1	1	1	1	1
ES-05	Santa Cruz de Tenerife	1	1	1	1	0	1
SE-01	Stockholm	1	1	1	1	1	1
SE-02	Gothenburg	1	1	1	1	1	1
SE-03	Malmö	1	1	1	1	1	1
UK-01	Nottingham	1	1	1	1	1	1
UK-02	Manchester	1	1	1	1	1	1

UK-03	Bristol	1	1	1	1	1	1
UK-04	Oxford	0	1	1	1	1	1

5.3 Definition of city types for the management layer

5.3.1 Physical characteristics

In this section, physical characteristics of each city have been taken into account in order to classify them based on these variables and analyse the influence of these characteristics in the other fields.

The cluster analysis of the 41 cities considering their area, population, density and elevation can be seen in the following table:

Table 20: Clusters for Management-Physical characteristics – List of cities

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Koln	Thessaloniki	Ghent	Tampere	Graz
Genova	Firenze	Liege	Leipzig	Innsbruck
	Porto	Brugge	Trondheim	Rosenheim
	Sevilla	Ruse	Málaga	Ljubljana
	Stockholm	Tartu	Gothemburg	Valladolid
	Nottingham	Jyväskylä		
	Manchester	Turku		
	Bristol	La Rochelle		
		Poitiers		
		Aachen		
		Miskolc		
		Cork		
		Bolzano		
		Eindhoven		
		Utrecht		
		Stavanger		
		Braga		
		San Sebastian		
		Santa Cruz de Tenerife		
		Malmö		

		Oxford		

From these results, and using the z-normalisation for the centroids values of each cluster (that represents a city type for each of them), the values included in the following table are obtained.

Table 21: Denormalised centroids for each cluster for the Physical characteristics clustering

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
MG_PC1	2,479.2	4,784.5	1,972.4	1,040.4	1,609.8
MG_PC2	810,177.5	524,543.4	169,986.9	396,098.6	204,281.8
MG_PC3	324.4	110.5	108.8	401.6	126.3
MG_PC4	28.5	46.9	65.3	44.3	473.4

The following figure represents the characterisation of these clusters according to their z-normalised centroids values.

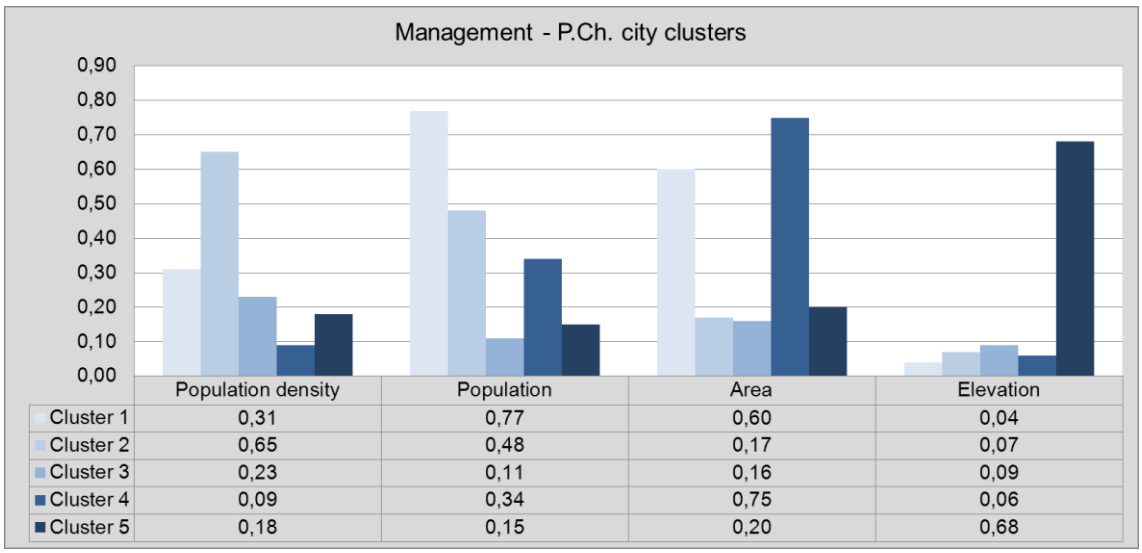


Figure 11: Characterization of the clusters according to their z-normalised centroids values

Hence, and according to these results, the characterisation of the city types for this layer is included in the following sections.

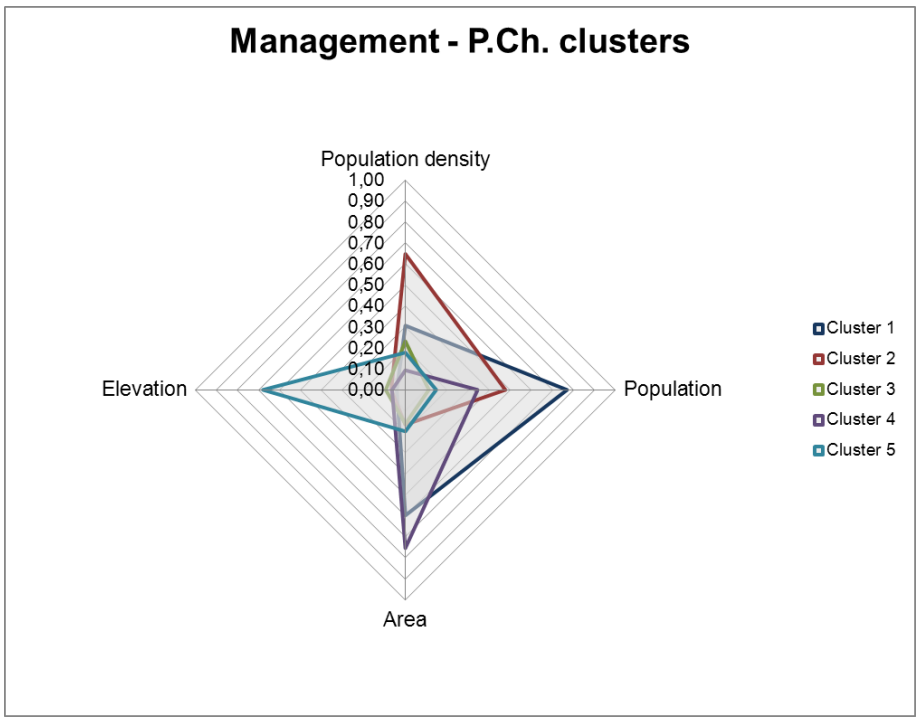


Figure 12: Radar representation of the Management-Physical Characteristics clusters

5.3.1.1 Management - Physical characteristics city type 1

Koln and Genova are included in this first type of cities whose main characteristic is their size. These cities have a high value of population but there are cities whose population also is very high that have been included in other groups because these have other characteristics more relevant. This is the case of Thessaloniki whose population is higher than Genova but its characteristic more highlighted is its high population density.

Figure 13: Management-Physical Characteristics city type 1

5.3.1.2 Management - Physical characteristics city type

In this case, the main characteristic is the population density. The eight cities included in this cluster have a high population density. These cities have a high population but they have not a very big area as can be seen in the following figure.

The cities included in this group are: Thessaloniki, Firenze, Porto, Sevilla, Stockholm, Nottingham, Manchester and Bristol. Most of the English cities considered in the study are in this group.

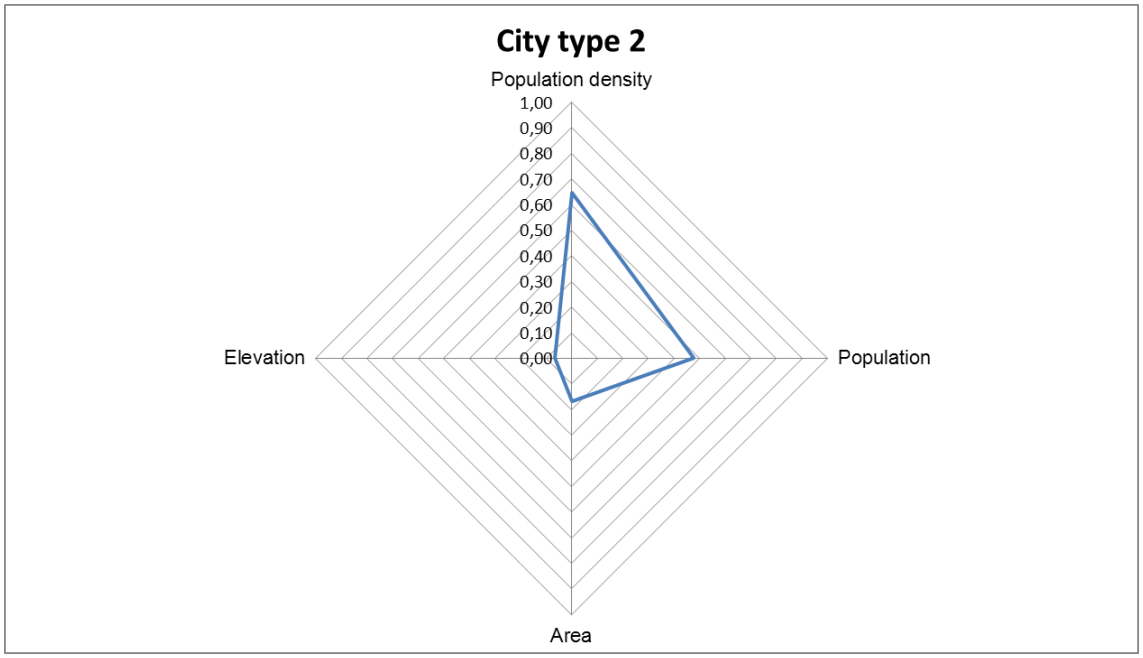


Figure 14: Management-Physical Characteristics city type 2

5.3.1.3 Management - Physical characteristics city type 3

This city type is where the most cities of the study are included. There are 21 cities in this group: Ghent, Liege, Brugge, Ruse, Tartu, Jyväskylä, Turku, La Rochelle, Poitiers, Aachen, Miskolc, Cork, Bolzano, Eindhoven, Utrecht, Stavanger, Braga, San Sebastian, Santa Cruz de Tenerife, Malmö and Oxford. These are cities with medium-low values for these indicators.

Each of the other groups is characterized by one of the four indicators: population for the first, population density for the second, area for the fourth and elevation for the last group. In the case of this third group, the cities included in it don't have high values for any of the indicators considered.

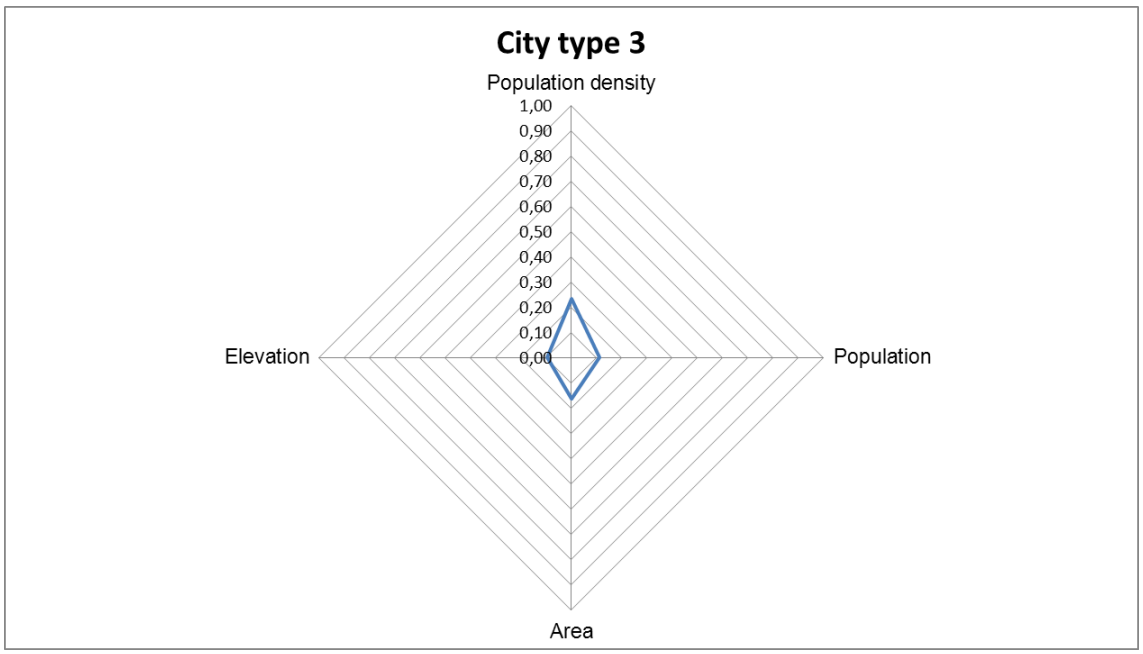


Figure 15: Management-Physical Characteristics city type 3

5.3.1.4 Management - Physical characteristics city type 4

In the fourth cluster of cities, the main characteristic is their area. Tampere, Leipzig, Trondheim, Málaga and Gothenburg have been included in this group. Due to these great areas, these cities have the lowest population density.

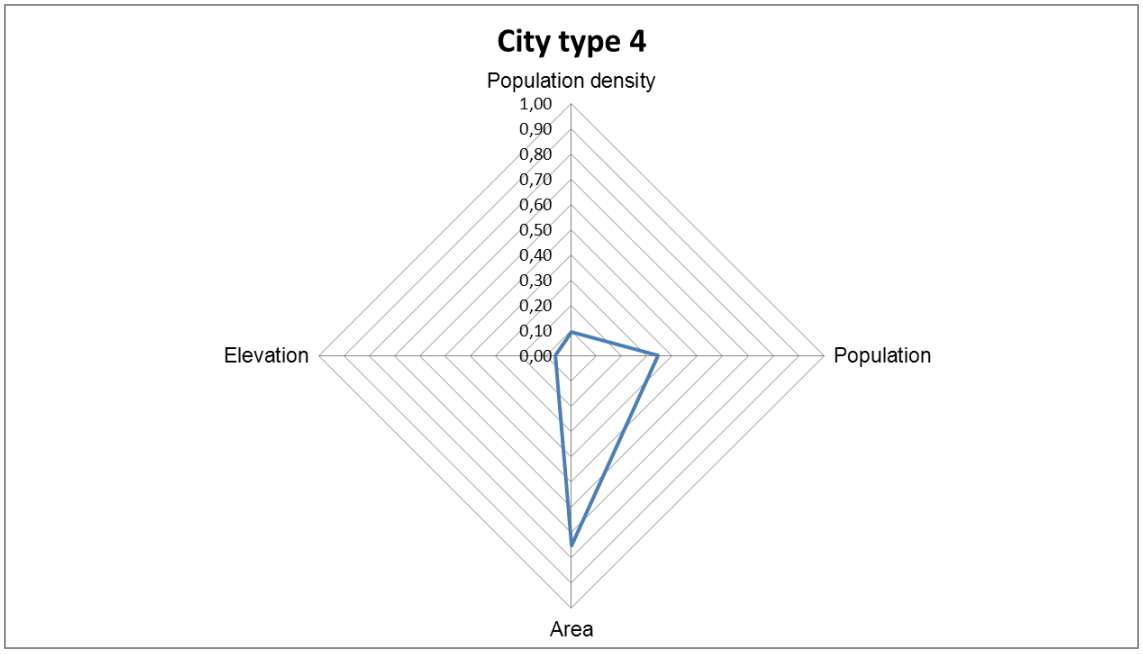


Figure 16: Management-Physical Characteristics city type 4

5.3.1.5 Management - Physical characteristics city type 5

The last group is characterized by the elevation of their cities. Graz, Innsbruck, Rosenheim, Ljubljana and Valladolid have been included in this group. The elevation of the cities influences in their climate conditions or in the pollution of the city.

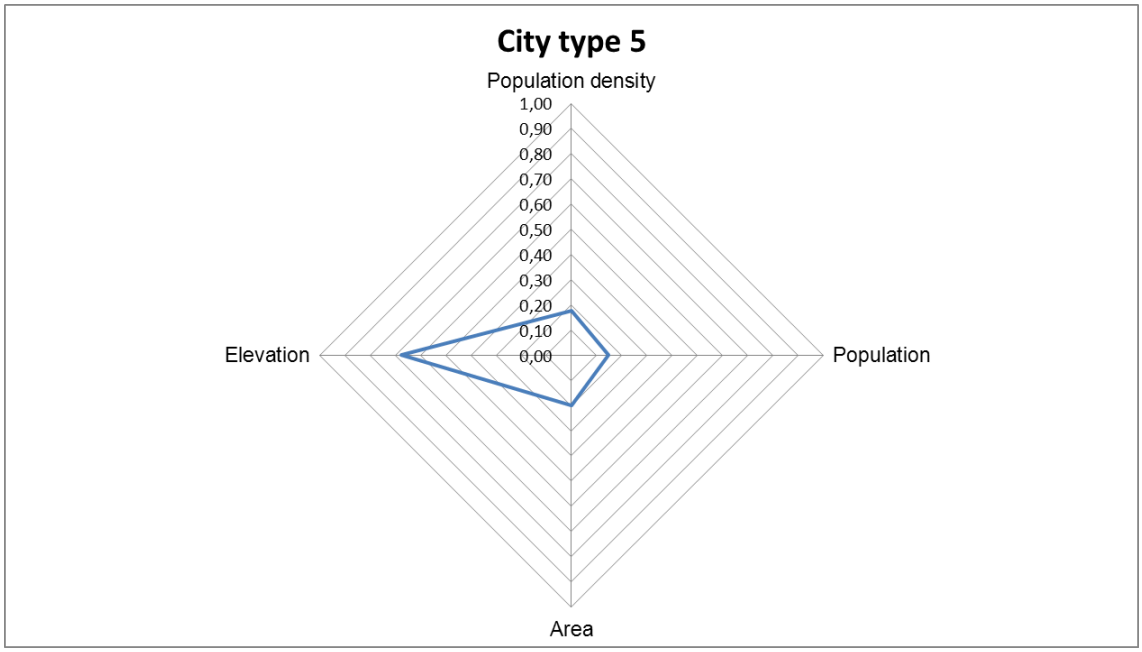


Figure 17: Management-Physical Characteristics city type 5

5.3.2 People and social characteristics

Table 22: Clusters for Management-People – List of cities

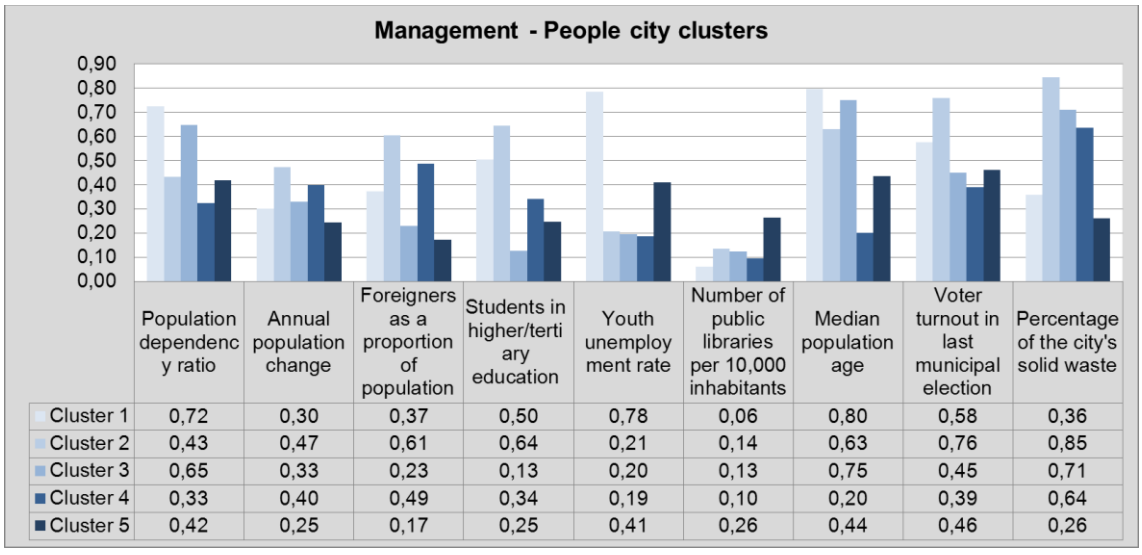
Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
San Sebastian-Donostia	Graz	Brugge	Cork	Tartu
Málaga	Innsbruck	Ruse	Utrecht	Jyväskylä
Sevilla	Ghent	Leipzig	Stavanger	Tampere
Valladolid	Liege	Rosenheim	Trondheim	Turku
Santa Cruz de Tenerife	Aachen	La Rochelle	Malmö	Poitiers
Firenze	Koeln/Köln	Bolzano	Nottingham	Thessaloniki
Genova	Stockholm	Eindhoven	Manchester	Miskolc
Porto	Gothenburg	Ljubljana	Bristol	Braga
			Oxford	

From these results, and using the z-normalisation for the centroids values of each cluster (that represents a city type for each of them), the values in the following table are obtained.

Table 23: Denormalised centroids for each cluster for the People and social characteristics clustering

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
MG_P1	35.0	30.2	33.7	28.4	30.0
MG_P2	1,331.1	5,231.5	2,007.6	3,557.5	76.3
MG_P3	7.4	12.1	4.6	9.7	3.5
MG_P4	42,206.0	53,294.5	12,309.9	29,305.1	21,692.9
MG_P5	49.0	15.7	15.0	14.6	27.3
MG_P6	0.4	0.8	0.7	0.6	1.4
MG_P7	43.3	40.3	42.5	32.6	36.9
MG_P8	64.3	75.7	56.3	52.6	57.1
MG_P9	31.8	51.4	46	43.1	28

The following figure represents the characterisation of these clusters according to their z-normalised centroids values.



	Population dependency ratio	Annual population change	Foreigners as a proportion of population	Students in higher/tertiary education	Youth unemployment rate	Number of public libraries per 10,000 inhabitants	Median population age	Voter turnout in last municipal election	Percentage of the city's solid waste
Cluster 1	0,72	0,30	0,37	0,50	0,78	0,06	0,80	0,58	0,36
Cluster 2	0,43	0,47	0,61	0,64	0,21	0,14	0,63	0,76	0,85
Cluster 3	0,65	0,33	0,23	0,13	0,20	0,13	0,75	0,45	0,71
Cluster 4	0,33	0,40	0,49	0,34	0,19	0,10	0,20	0,39	0,64
Cluster 5	0,42	0,25	0,17	0,25	0,41	0,26	0,44	0,46	0,26

Figure 18: Characterization of the clusters according to their z-normalised centroids values

Hence, and according to these results, the characterisation of the city types for this layer is included in the following sections.

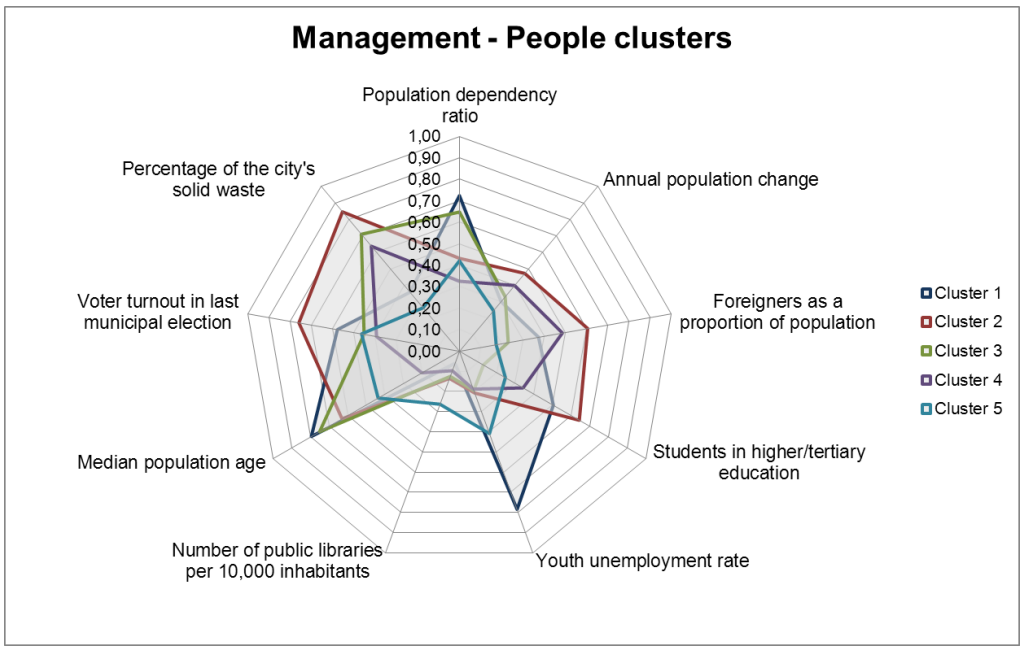


Figure 19: Radar representation of the management - People clusters

5.3.2.1 Management-People city type 1

The first of the city types in which San Sebastian, Málaga, Sevilla, Valladolid, Santa Cruz de Tenerife, Firenze, Genova, Porto are included (8 cities), is characterised mainly by a median population age (43 years) and a high rate of youth unemployment (49%). However, the rate of students in higher education is in a middle position and the annual population change is not very relevant. On the other hand, according to the data compiled, there is a lack of public libraries and a low rate of recycling practices. As a consequence, this type of cities could have a high potential for improving in cultural and environmental issues.

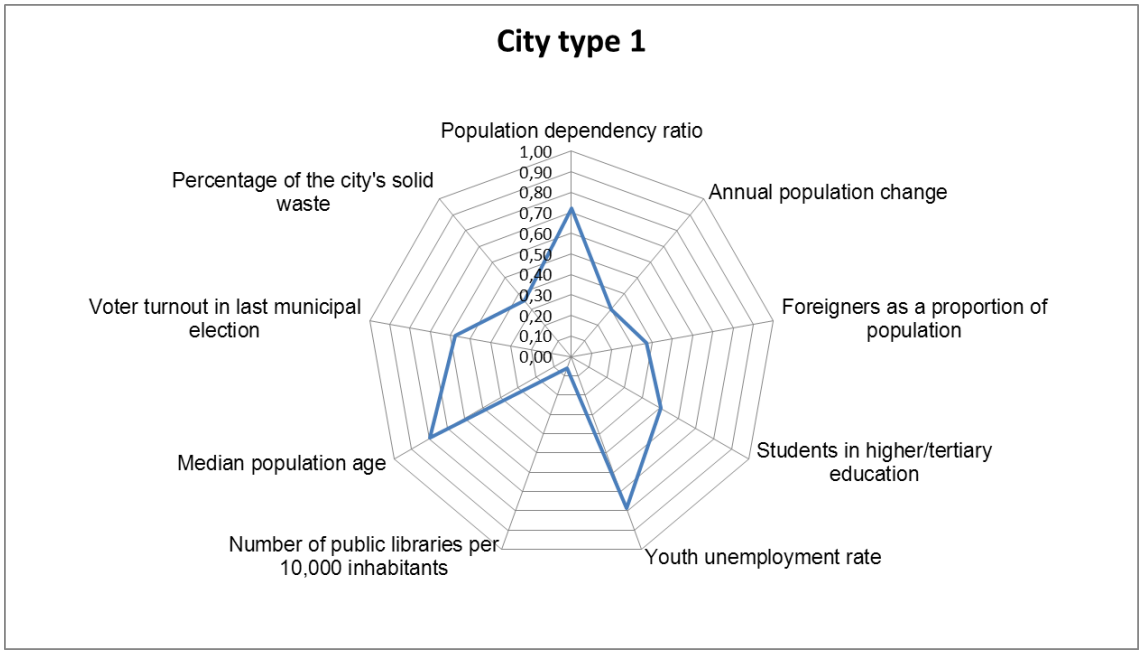


Figure 20: Management-People city type 1

5.3.2.2 Management-People city type 2

The second of the city types in which Graz, Innsbruck, Ghent, Liege, Aachen, Koeln/Köln, Stockholm and Gothenburg are included (8 cities), is characterised by a highest rate of recycling and a high level of participation in elections..

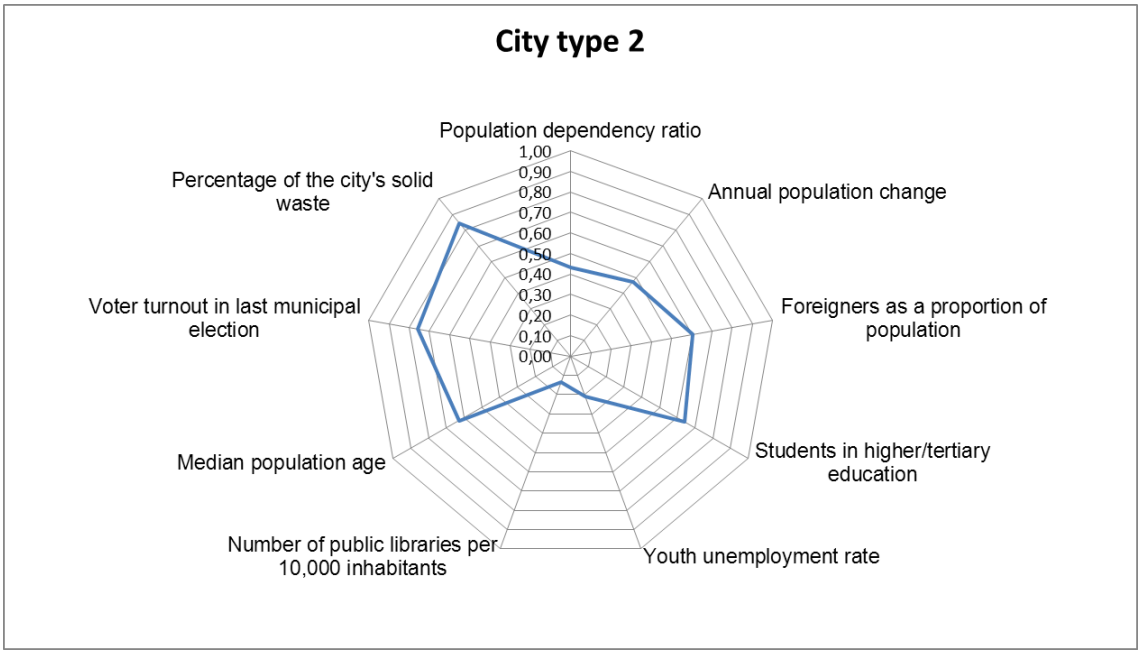


Figure 21: Management-People city type 2

Although the proportion of foreigners, the annual population change or the number of students in higher/tertiary education don't look very high in the graph, the highest values for these three indicators are in this type of cities.

5.3.2.3 Management-People city type 3

The third city type in which Brugge, Ruse, Leipzig, Rosenheim, La Rochelle, Bolzano, Eindhoven, Ljubljana are included (8 cities), is characterised by a population of median age (42.5 years) and a high rate of recycling (50%).

Concerning the youth unemployment rate, it should be highlighted that the value for this indicator is very low. Since, there is also few population which have higher education, an analysis to be done is the average disposable income in these cities. Finally, other important feature is the low voter turnover appreciated in these cities.

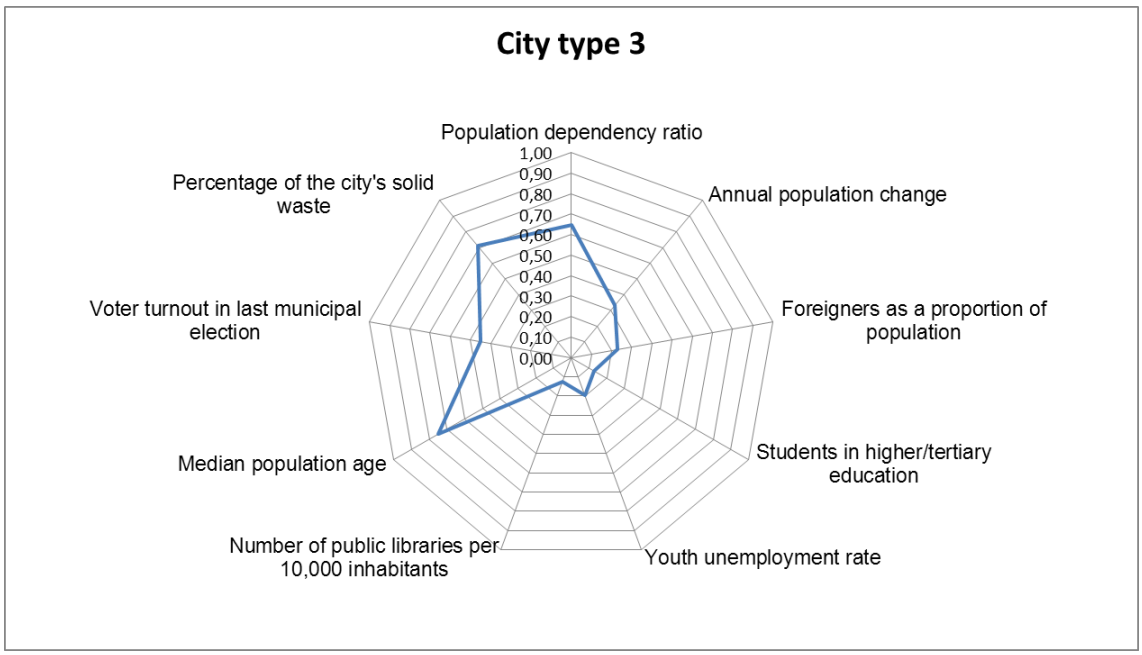


Figure 22: Management-People city type 3

5.3.2.4 Management-People city type 4

The fourth city cluster includes Cork, Utrecht, Stavanger, Trondheim, Malmö, Nottingham, Manchester, Bristol and Oxford (9 cities). This cluster is mainly characterized by the low median population age and the number of foreigners who are living in these cities. In addition, the movements of population are significant, mainly derived by young people. Given that this type of population are more receptive with sustainable practices (which it is confirmed by the high percentage of waste recycled), REMOURBAN model could have a high potential of replicability.

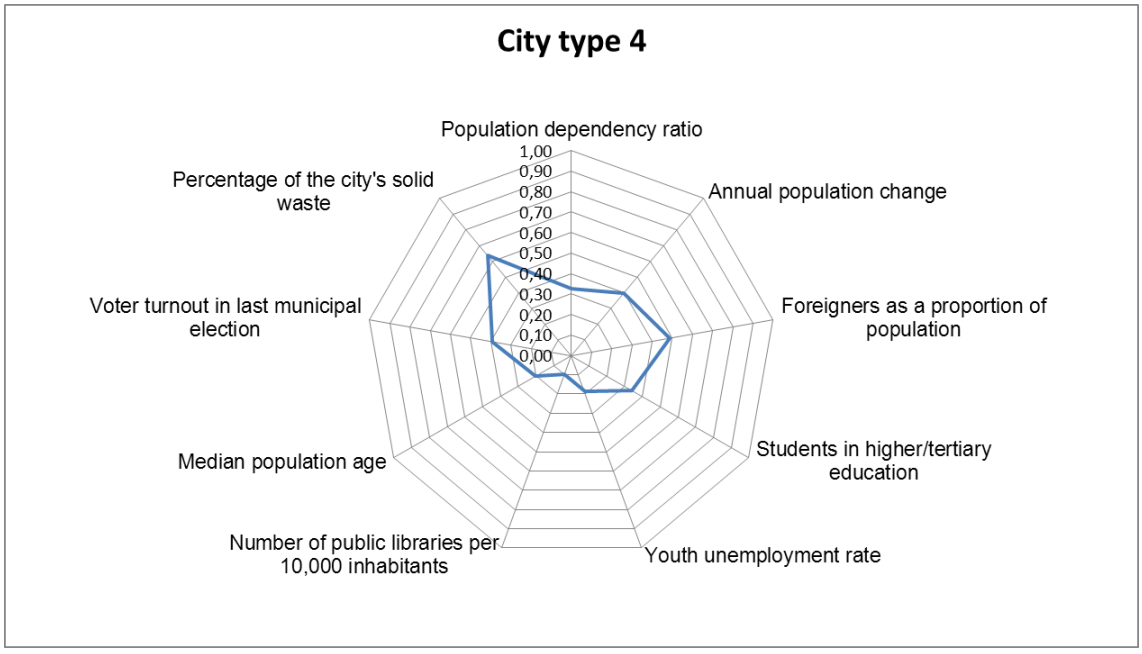


Figure 23: Management-People city type 4

5.3.2.5 Management-People city type 5

The fifth city type includes Tartu, Jyväskylä, Tampere, Turku, Poitiers, Thessaloniki, Braga and one of the follower Miskolc (8 cities).

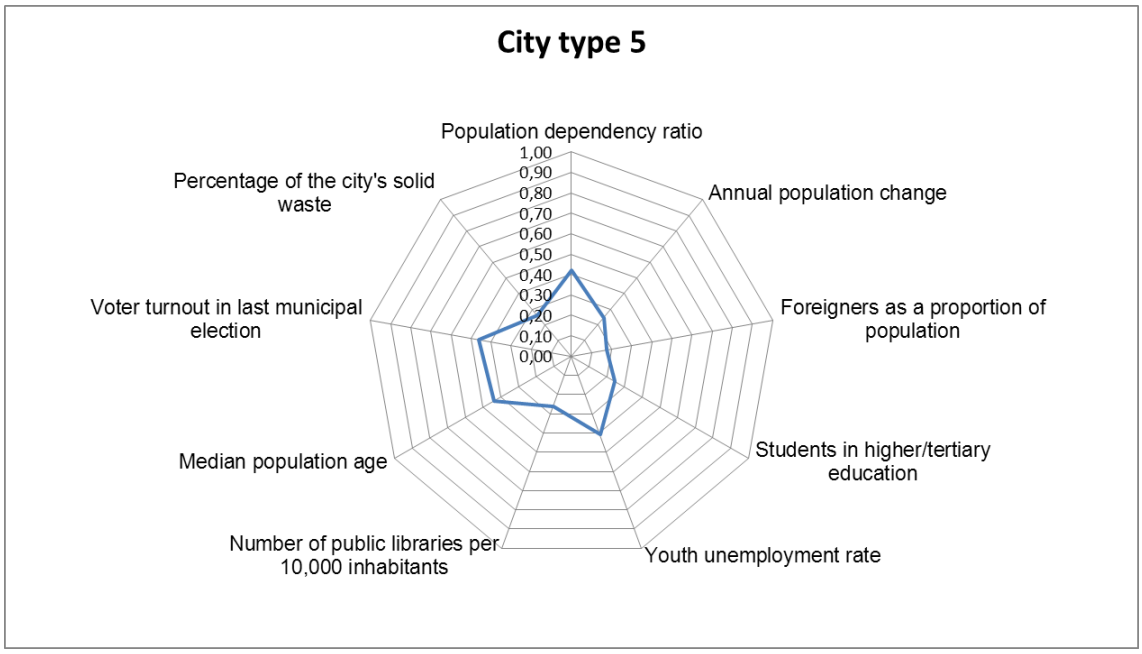


Figure 24: Management-People city type 5

This cluster is characterised by one of the lowest dependency ratio (30), an extremely low annual population change (10 times lower than other clusters), a rather high youth unemployment rate (27%), the highest number of public libraries per 10.000 inhabitants among the clusters (1.4), 57% of population who voted at the last municipal election and the lowest rate of wastes recycling.

These cities are offering a good potential for replicate smart strategies since there is a good willingness of municipalities in cultural practices (e.g. high number of libraries) which could extend also towards other fields. However, there is a bad predisposition of citizens for environmental practices given the low rate of recycling observed. Therefore, it would be interested to check how is the disposal income in the city, the energy behaviour of citizens in households and the sustainable practices already developed in these municipalities to understand better the replicability potential.

5.3.3 Governance and Sustainable and smart strategies –GSSS-

The “Governance and Sustainable and Smart Strategies” section of the management layer, has 6 indicators. These indicators are binomial and the values for three of them are 1 for all cities because all cities analysed have smart cities strategies, Agenda 21 and ICT citizen oriented platforms. For this reason, the clustering has been done using the other indicators, taking into account if the cities have local sustainability plans, mobility plans and if they have signed the Covenant of Mayors.

Taking into account these three indicators, four groups were generated: a first cluster including all cities whose values for all indicators are 0, a second group including cities that have not signed the Covenant of Mayor and have not submitted a local sustainability plan but they have mobility plans, the third group is very similar to the previous one, the only difference is that the cities in this group have signed the Covenant of Mayors and finally a fourth cluster whose cities have the value 1 for all indicators

The result of the clustering analysis can be found in the following table:

Table 24: Clusters for Governance and Sustainable and smart strategies – list of cities

Cluster 1	Cluster 2	Cluster 3	Cluster 4
Innsbruck	Graz	Brugge	Aachen
Liege	Ruse	Tartu	Koeln/Köln
Jyväskylä	Poitiers	Miskolc	San Sebastian
	Leipzig	Oxford	Málaga
	Rosenheim		Sevilla
			Valladolid
			Santa Cruz de Tenerife
			Tampere
			Turku
			La Rochelle
			Thessaloniki
			Cork
			Bolzano
			Firenze
			Genova
			Eindhoven
			Utrecht
			Stavanger
			Trondheim
			Porto
			Braga
			Stockholm
			Ljubljana
			Nottingham
			Manchester

			Bristol
			Ghent
			Gothenburg
			Malmö

Table 25: Reference values for the KPIs related to Governance and Sustainable and smart strategies for each cluster

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
MG_G1	0	0	0	1
MG_G2	1	1	1	1
MG_G3	1	1	1	1
MG_G4	0	0	1	1
MG_G5	0	1	1	1
MG_G6	1	1	1	1

The following figure represents the characterisation of these clusters.

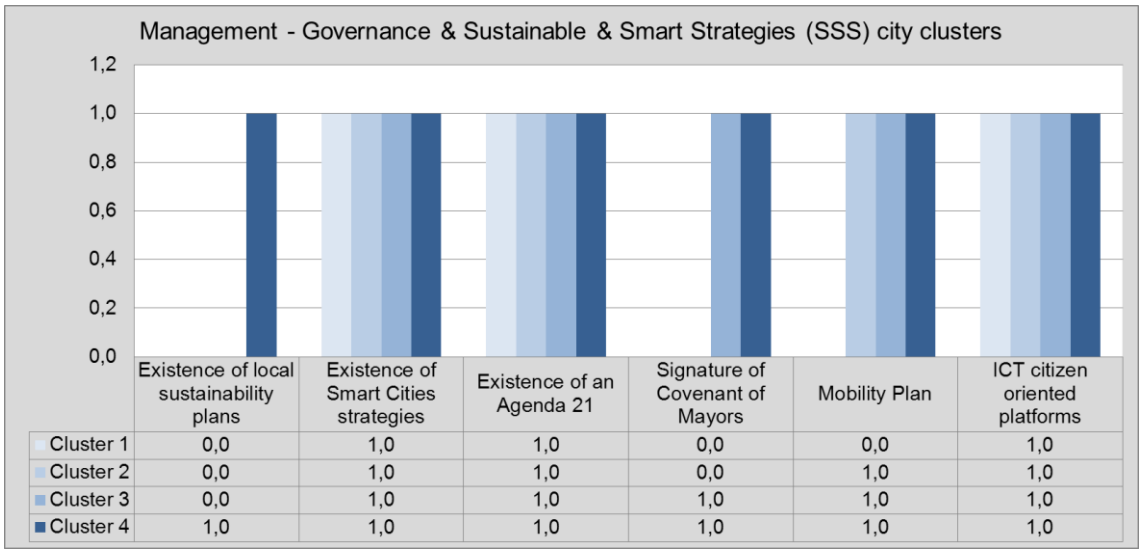


Figure 25: Characterization of the clusters according to their reference values

Hence, and according to these results, the characterisation of the city types for this layer is included in the following sections.

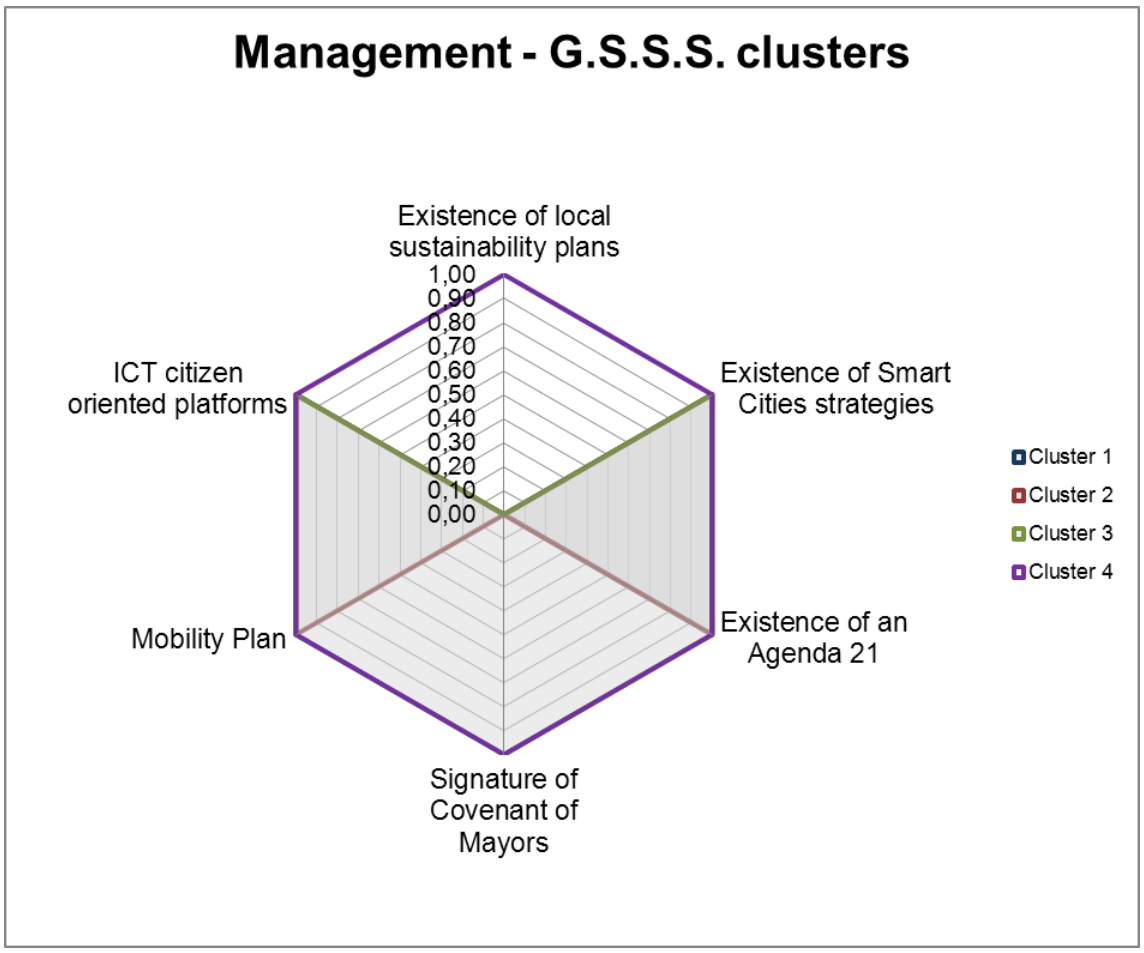


Figure 26: Radar representation of the Management – G.S.S.S. clusters

5.3.3.1 Management-GSSS city type 1

The first of the city types includes only 3 cities, Innsbruck, Liège and Jyväskylä.

This cluster is characterised by the lack of sustainability plans and mobility plans and because these cities have not signed the Covenant of Mayors. Regarding Liège, it can however be stated that the city recently undersigned the covenant of mayor and will, thanks to that, design a strategy and a dedicated plan to improve their sustainability.

This cluster will likely need to improve their sustainability strategies and are good potential cities for replication of REMOURBAN model. They represent the less advanced cluster, in terms of sustainability planning and smart development strategies.

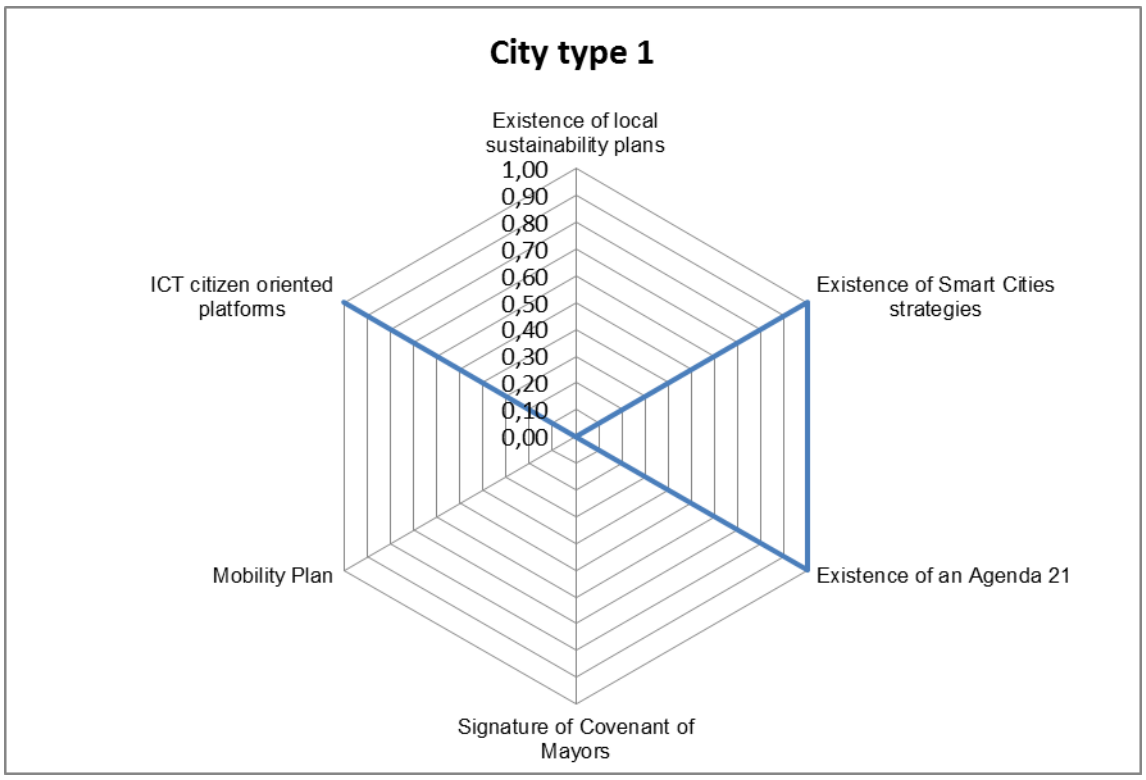


Figure 27: Management - G.S.S.S. city type 1

5.3.3.2 Management-GSSS city type 2

The second city type includes the cities of Graz, Ruse, Poitiers, Leipzig and Rosenheim.

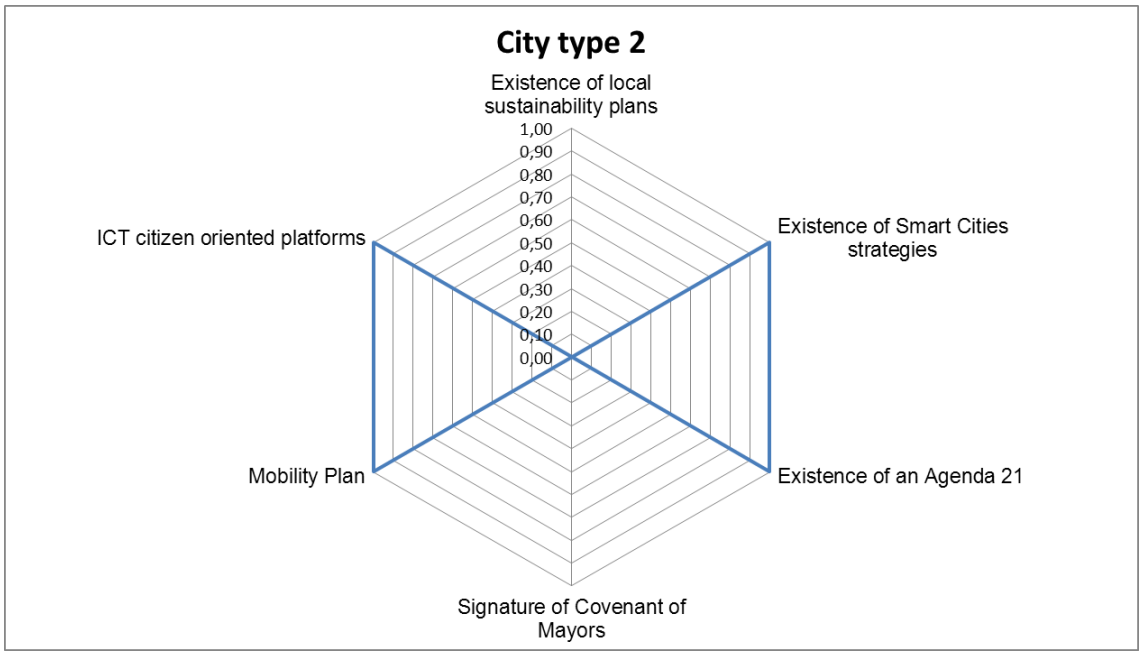


Figure 28: Management - G.S.S.S. city type 2

These cities have in common that they have not signed the Covenant of Mayors and they have not submitted a local sustainability action plan yet.

The cities included in this typology however, have got mobility plans, so their state is better than the state of the cities included in the first typology regarding the sustainable and smart strategies.

5.3.3.3 Management-GSSS city type 3

The third of the city types includes only 4 cities, Brugge, Tartu, Miskolc and Oxford.

These cities have already signed the Covenant of Mayors but they have not got a local sustainability plan, so this group of cities is in a good position in terms of governance because the values for the rest of indicators are 1.

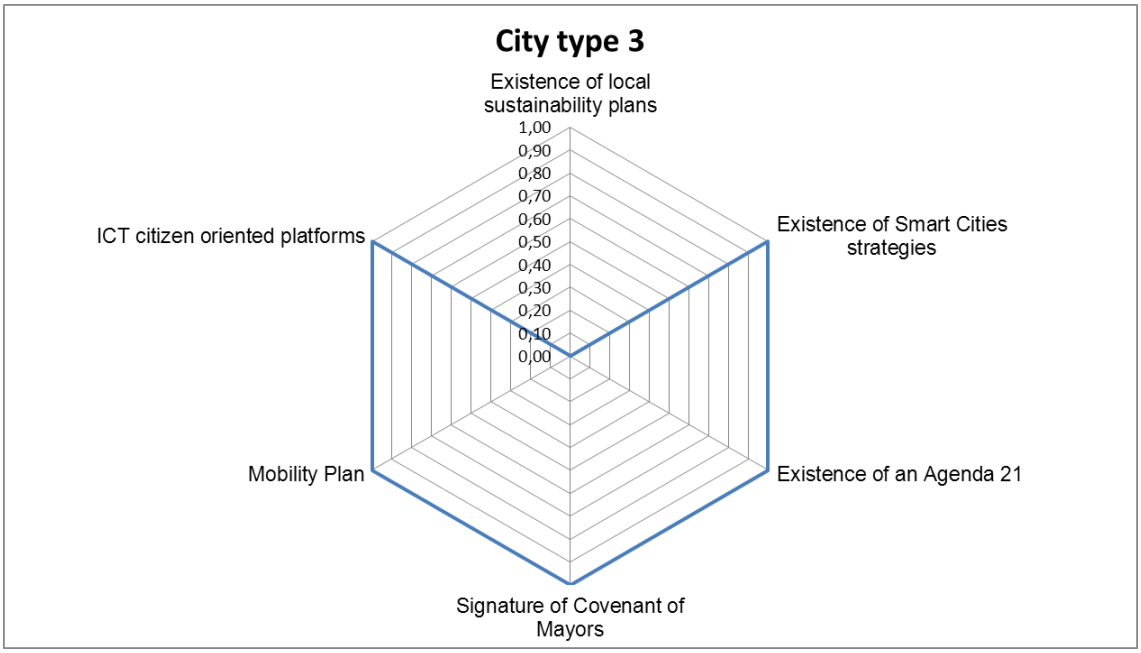


Figure 29: Management - G.S.S.S. city type 3

5.3.3.4 Management-GSSS city type 4

The fourth of the city types in this layer is very large as it includes all the other cities considered in this study (30).

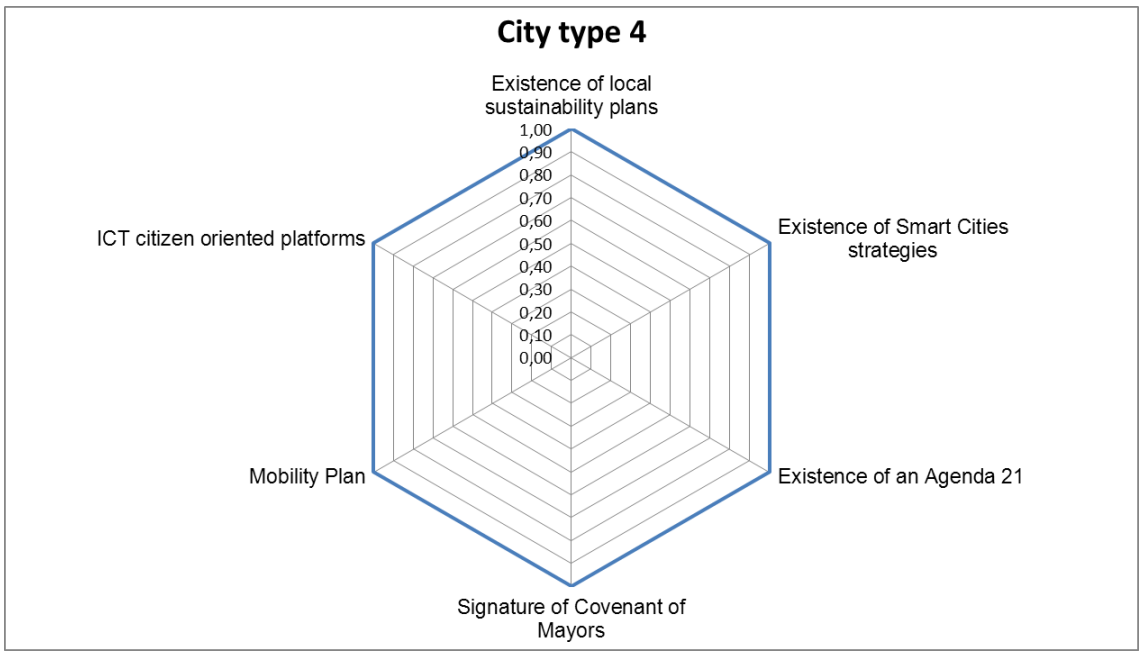


Figure 30: Management - G.S.S.S. city type 4

All the cities included in this cluster are in a very good position in term of governance and sustainable and smart strategies due to these 30 cities have a value 1 for all the proposed indicators.

6 Characterization of European cities by their finance features

This section analyses the European cities by their finance features according to the set of indicators selected.

6.1 Final list of indicators and databases

The following table define the final set of indicators, and the data sources where the information can be found, selected after the analysis of the data availability for the selected cities.

Table 26: Final set of indicators for Finance characterisation

INDICATOR	KPI_ID	FORMULA	UNIT	DESCRIPTION	DATABASE
GDP per inhabitant	FI1	Gross Domestic Product at market prices/ total city population	M€/inh	It is a measure for the economic activity of a city and it is defined as the value of all goods and services produced less the value of any goods or services used in their creation	Eurostat[72]
Average disposable income	FI2	Gross Domestic Product at market prices/ total city population	€/inh	The amount of money that households have available for spending and saving after income taxes have been accounted for	Eurostat[73]
City unemployment rate	FI3	Number of citizens unemployed / Total labour force x 100	%	Unemployed citizens in relation to employed and unemployed who are legally eligible to work	Eurostat[74]
Proportion of working age population with higher education	FI4	-	%	Proportion of working age population qualified at level 5 or 6 ISCED	Eurostat CEDUC[75]
GDP per	FI5	-	M€/inh	GDP per capita at current	Eurostat[76]

[72] http://ec.europa.eu/eurostat/en/web/products-press-releases/-/2-21062010-AP

76 http://ec.europa.eu/eurostat/web/products-datasets/-/nama_10r_3gdp

[73] http://ec.europa.eu/eurostat/en/web/products-statistical-working-papers/-/KS-RA-07-007

[74] http://ec.europa.eu/eurostat/web/products-datasets/-/lfst_r_urgau

[75] http://ec.europa.eu/eurostat/web/products-datasets/-/urb_leduc (Urban audit indicator : Proportion of working age population qualified at level 5 or 6 ISCED)

http://ec.europa.eu/eurostat/cache/RSI/#?vis=nuts3.economy&lang=en

[76] http://ec.europa.eu/eurostat/web/products-datasets/-/lfst_r_urgau

inhabitant in PPS				market prices in Purchasing Power Standards (PPS). It is a common currency that eliminates the differences in price levels between countries	

6.2 Data collection and aggregation for the cities

Table 27: Aggregated data for the finance layer

Code	City	KPI_FI1	KPI_FI2	KPI_FI3	KPI_FI4	KPI_FI5
		GDP per capita	Average disposable income	City unemployment rate	Proportion of working age population with higher education	GDP PPS per inhabitant
AT-01	Graz	144.76	20,400.00 €	6.50%	25.70%	40,400.00 €
AT-02	Innsbruck	138.97	20,300.00 €	4.20%	27.00%	37,200.00 €
BE-01	Ghent	138.24	18,500.00 €	7.00%	36.70%	36,300.00 €
BE-02	Liege	98.03	15,400.00 €	14.80%	33.10%	25,900.00 €
BE-03	Brugge	122	18,000.00 €	3.70%	33.00%	32,100.00 €
BG-01	Ruse	34.55	5,900.00 €	11.20%	22.70%	9,200.00 €
EE-01	Tartu	46.65	8,800.00 €	9.00%	37.60%	13,200.00 €
FI-01	Jyväskylä	95.11	23,015.00 €	12.90%	39.20%	24,800.00 €
FI-02	Tampere	109.62	15,600.00 €	12.60%	39.20%	29,300.00 €
FI-03	Turku	104.89	15,300.00 €	12.50%	38.10%	28,000.00 €
FR-01	La Rochelle	79.79	16,900.00 €	13.40%	26.00%	21,500.00 €
FR-02	Poitiers	91.53	16,900.00 €	12.90%	26.00%	24,000.00 €
DE-01	Aachen	110.34	19,900.00 €	7.00%	28.30%	29,600.00 €
DE-02	Koeln	181.1	19,900.00 €	7.20%	28.30%	47,400.00 €
DE-03	Leipzig	77.4	17,000.00 €	9.70%	30.00%	20,700.00 €
DE-04	Rosenheim	152.35	24,300.00 €	4.40%	37.10%	26,400.00 €

GR-01	Thessaloniki	68.79	11,100.00 €	12.00%	27.30%	16,800.00 €
HU-01	Miskolc	40.59	7,500.00 €	8.70%	17.10%	10,600.00 €
IR-01	Cork	158.63	10,224.00 €	19.70%	43.10%	44,200.00 €
IT-01	Bolzano	147.35	20,900.00 €	4.10%	16.20%	39,400.00 €
IT-03	Firenze	124.95	17,300.00 €	7.00%	17.40%	34,400.00 €
IT-04	Genova	109.34	18,300.00 €	7.70%	19.30%	32,300.00 €
NL-01	Eindhoven	137.95	15,800.00 €	4.20%	33.20%	39,300.00 €
NL-02	Utrecht	152.45	16,300.00 €	4.80%	45.60%	41,800.00 €
NW-01	Stavanger	160.04	18,700.00 €	3.20%	38.50%	44,600.00 €
NW-01	Trondheim	132.62	18,200.00 €	2.60%	40.70%	36,900.00 €
PT-01	Porto	78.33	10,600.00 €	17.60%	18.20%	19,700.00 €
PT-02	Braga	60.52	10,600.00 €	13.20%	18.20%	15,500.00 €
SI-01	Ljubljana	118.25	12,700.00 €	11.40%	33.10%	30,700.00 €
ES-01	San Sebastian - Donostia	133.74	18,900.00 €	10.70%	47.00%	33,600.00 €
ES-02	Málaga	73.44	11,200.00 €	31.40%	27.60%	18,300.00 €
ES-03	Sevilla	77.51	11,200.00 €	22.70%	27.60%	20,400.00 €
ES-04	Valladolid	102.84	14,400.00 €	16.80%	34.50%	25,100.00 €
ES-05	Santa Cruz de Tenerife	82.35	12,100.00 €	26.20%	27.00%	21,900.00 €
SE-01	Stockholm	172.74	19,800.00 €	6.50%	47.60%	46,800.00 €
SE-02	Gothenburg	120.31	16,600.00 €	9.30%	38.80%	32,500.00 €
SE-03	Malmö	107.94	15,800.00 €	14.30%	38.90%	28,400.00 €
UK-01	Nottingham	126.48	14,800.00 €	13.00%	34.80%	17,500.00 €
UK-02	Manchester	111.66	14,400.00 €	9.40%	37.60%	17,300.00 €
UK-03	Bristol	132.11	17,500.00 €	8.50%	44.70%	35,400.00 €
UK-04	Oxford	119.63	20,200.00 €	4.60%	51.00%	34,400.00 €

6.3 Definition of city types for the finance layer

From these results, and using the z-normalisation for the centroids values of each cluster (that represents a city type for each of them), the values included in the following table are obtained

Table 28: Clusters for finance – List of cities

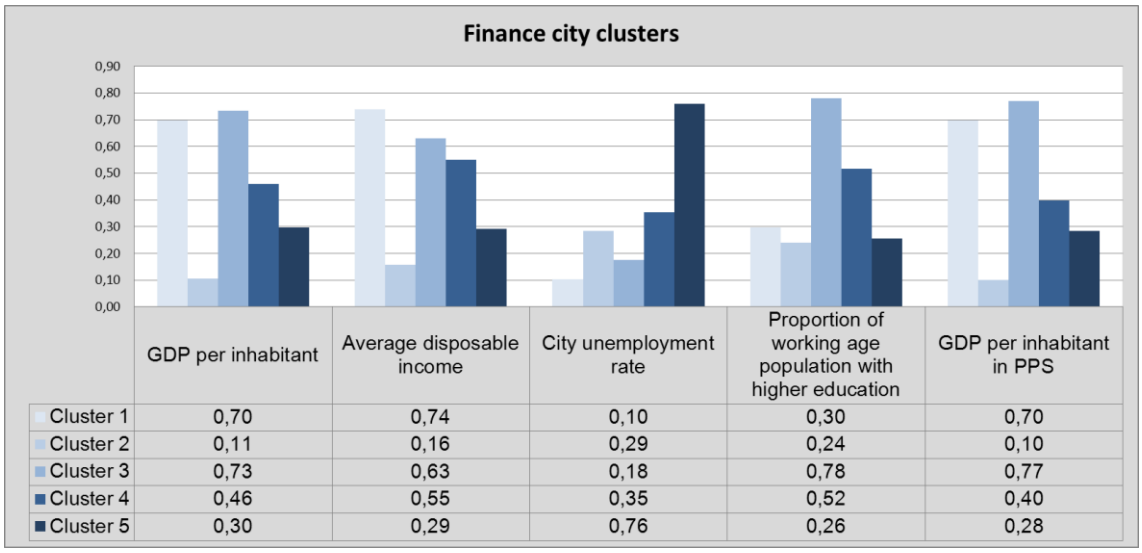
Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Graz	Ruse	Ghent	Liege	Málaga
Innsbruck	Tartu	San Sebastian-Donostia	Leipzig	Sevilla
Brugge	Thessaloniki	Cork	Valladolid	Santa Cruz de Tenerife
Aachen	Miskolc	Utrecht	Jyväskylä	Porto
Koeln/Köln	Braga	Stavanger	Tampere	
Rosenheim		Trondheim	Turku	
Bolzano		Stockholm	La Rochelle	
Firenze		Gothenburg	Poitiers	
Genova		Bristol	Malmö	
Eindhoven		Oxford	Ljubljana	
			Nottingham	
			Manchester	

From these results, and using the z-normalisation for the centroids values of each cluster (that represents a city type for each of them), the values included in the following table are obtained.

Table 29: Denormalised centroids for each cluster for the finance clustering

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
KPI_FI1	136,9	50,2	142,1	102,0	77,9
KPI_FI2	19510,0	8780,0	17492,4	16017,9	11275,0
KPI_FI3	5,6	10,8	7,7	12,8	24,5
KPI_FI4	26,6	24,6	43,4	34,2	25,1
KPI_FI5	35850,0	13060,0	38650,0	24433,3	20075,0

The following figure represents the characterisation of these clusters their z-normalised centroids values.



	GDP per inhabitant	Average disposable income	City unemployment rate	Proportion of working age population with higher education	GDP per inhabitant in PPS
Cluster 1	0,70	0,74	0,10	0,30	0,70
Cluster 2	0,11	0,16	0,29	0,24	0,10
Cluster 3	0,73	0,63	0,18	0,78	0,77
Cluster 4	0,46	0,55	0,35	0,52	0,40
Cluster 5	0,30	0,29	0,76	0,26	0,28

Figure 31: Characterization of the clusters according to their z-normalised centroids values

Hence, and according to these results, the characterisation of the city types for the finance layer is included in the following sections.

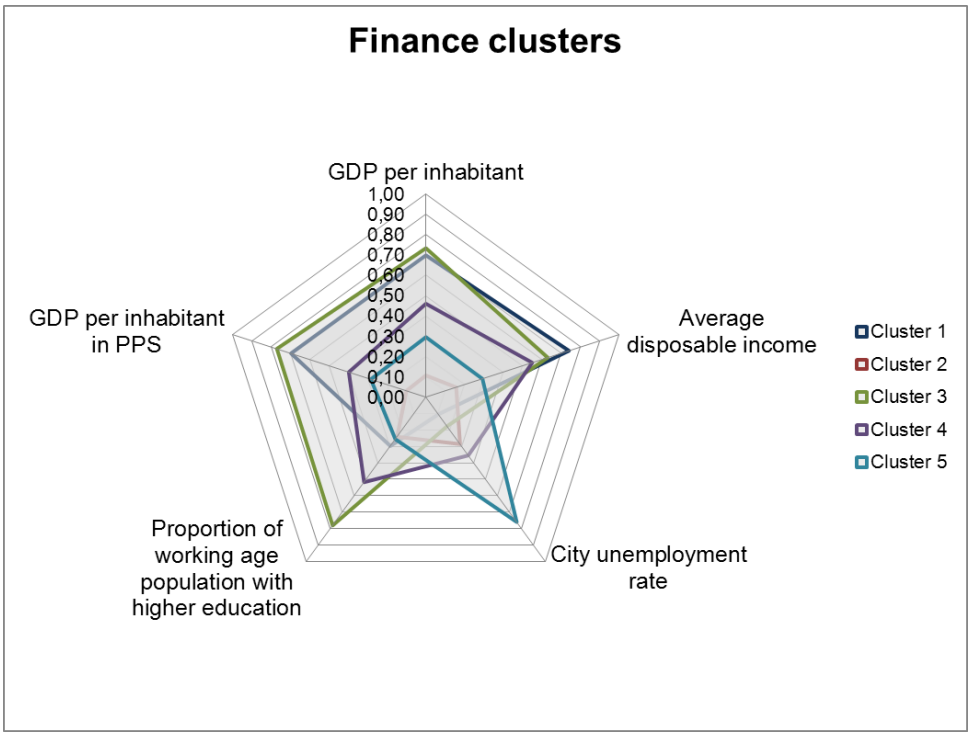


Figure 32: Radar representation of the finance clusters

6.3.1 Finance city type 1

The first of the city types in which Graz, Innsbruck, Brugge, Aachen, Koeln, Rossenheim, Bolzano, Firenze, Genova and Eindhoven are included (10 cities), is characterised by the highest disposable income and lowest unemployment rate. The economic activity is also relevant since this city cluster ranks second in GDP. However, the proportion of working age population with higher education could be considered at a low level compared with city types 3 or 4. These characteristics lead to conclude that given the better economic situation of citizens, this type of cities could implement sustainable practices with a reduced need of public funds

compared to other city types, while the main challenge could be in reaching a good level of social acceptance.

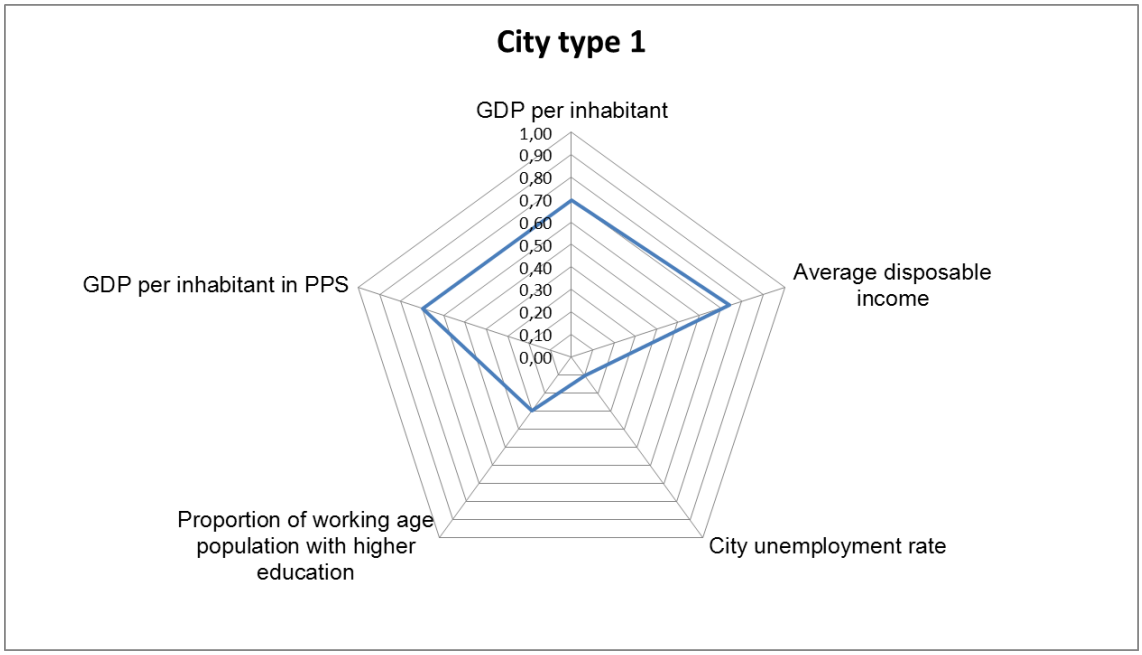


Figure 33: Finance city type 1

6.3.2 Finance city type 2

The second city type in which Ruse, Tartu, Thessaloniki, Miskolc and Braga (5 cities), is characterised by the worst economic conditions due to the lowest figures in GDP and disposable income.

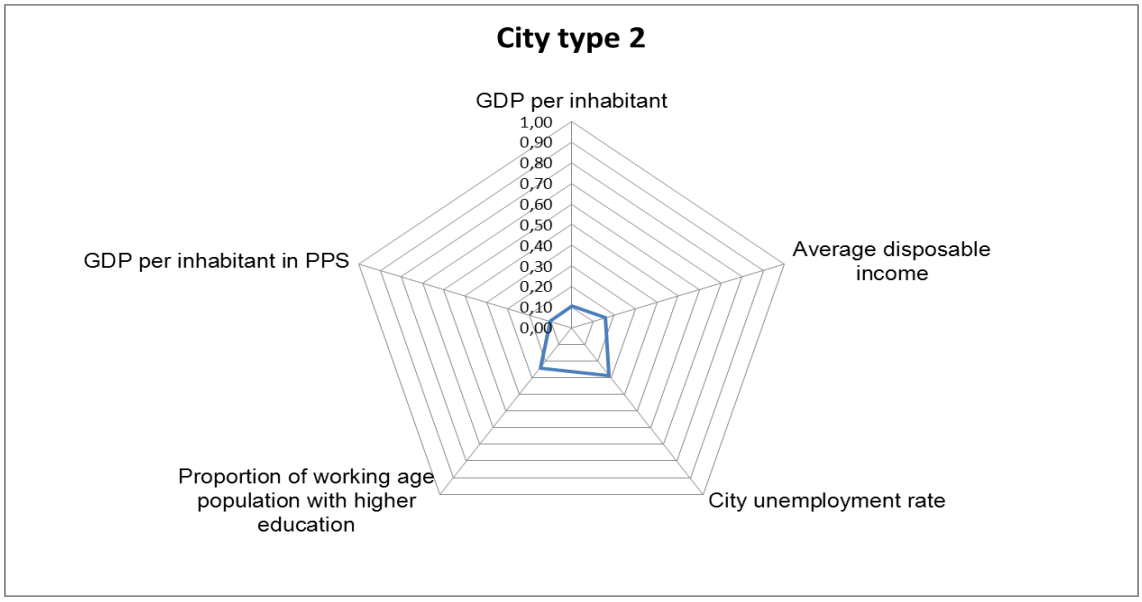


Figure 34: Finance city type 2

In addition, this city typology has the lowest proportion of working age population with higher education. However, the unemployment rate is not as relevant as in other city typologies. Therefore, the low income of residents could restrain the process of implementing some measures as citizens seem low suitable to face the high investment costs. Willingness of

municipalities for introducing sustainable practices in cities is decisive in this type of cities where REMOURBAN replicability is highly conditioned to a funded public support.

6.3.3 Finance city type 3

The third of the city types in which Ghent, San Sebastian, Cork, Utrecht, Stavanger, Trondheim, Stockholm, Gothenburg, Bristol and Oxford are included (10 cities), is characterised by a significant economic activity and a high rate of working population with higher education. Unemployment is not a big problem for these cities, since the rate is low. All this conditions presume that these cities have a high potential for replicating REMOURBAN model given the high possibilities of citizens and companies for finance the energy solutions.

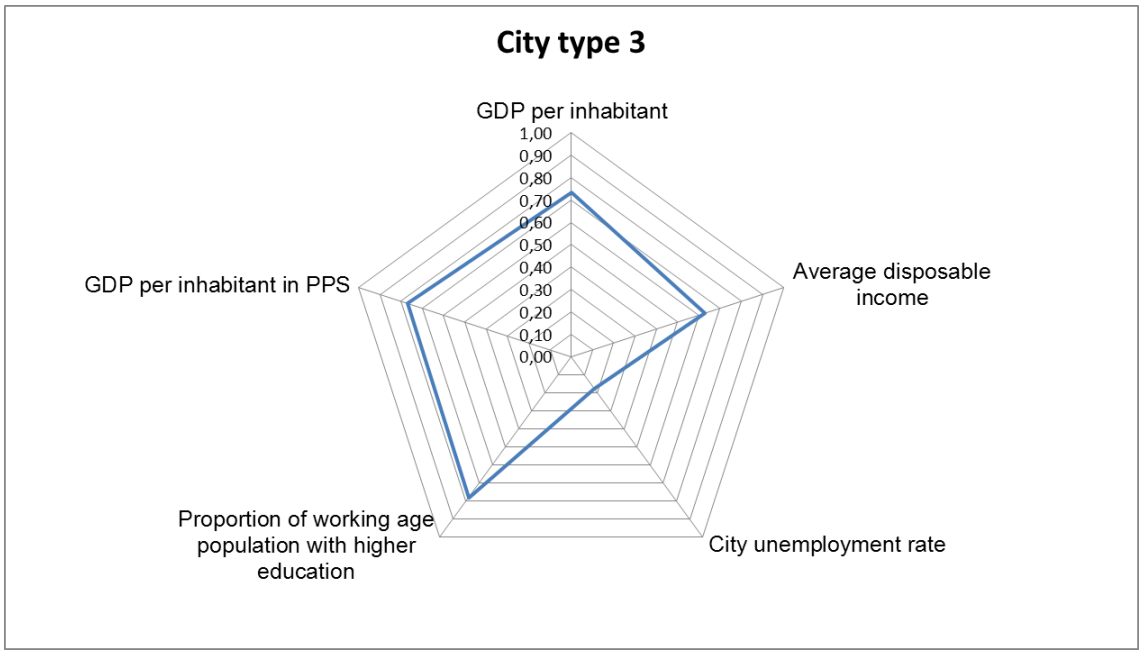


Figure 35: Finance city type 3

Maybe, some public finance is required to foster the implementation of sustainable practice, but not based only in subsidies but in other financial instruments (e.g. loans). Suitable business models practices can also afford the REMOURBAN replicability.

6.3.4 Finance city type 4

The fourth city type in which Liege, Leipzig, Valladolid, Jyaskyla, Tampere, Turku, La Rochelle, Poitiers, Malmo, Ljubljana, Nottingham and Manchester are included (12 cities), is characterised by an intermediate position regarding the finance issue for all the variables analysed. This supposes that a proper replicability of REMOURBAN model could be produced if all the parties are willingness to adopt them. Improve access to information about economic savings for municipalities and citizens could be a good practice for helping to replicate REMOURBAN in these cities.

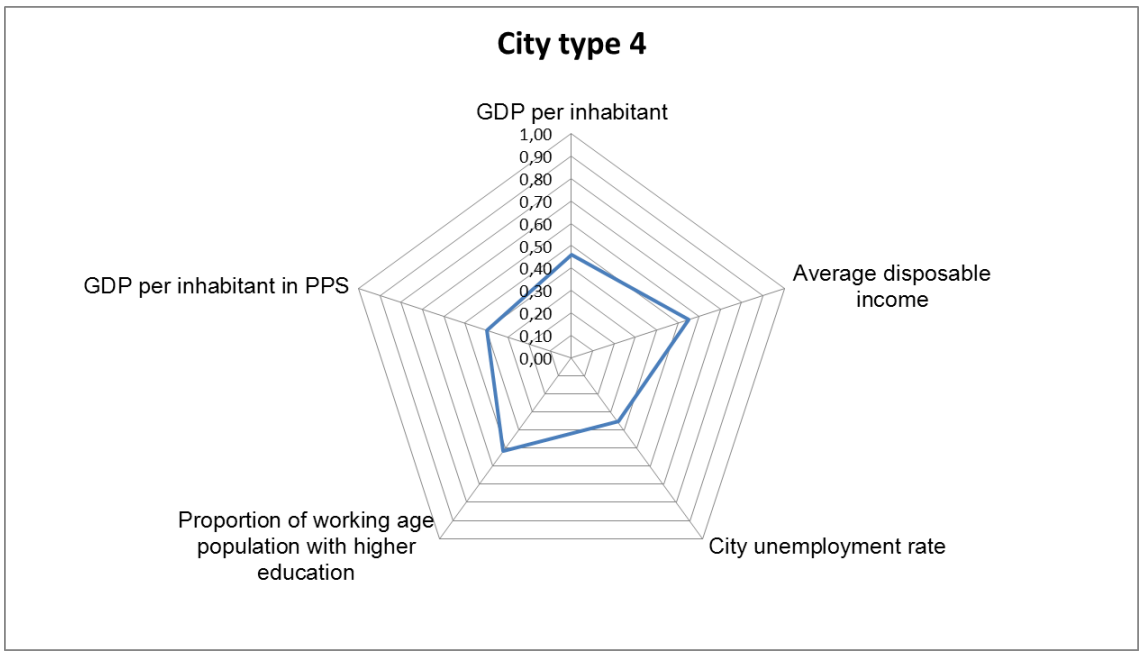


Figure 36: Finance city type 4

6.3.5 Finance city type 5

The fifth city type in which Málaga, Sevilla, Santa Cruz de Tenerife and Porto are included (5 cities) is characterised by a not suitable figure regarding finance.

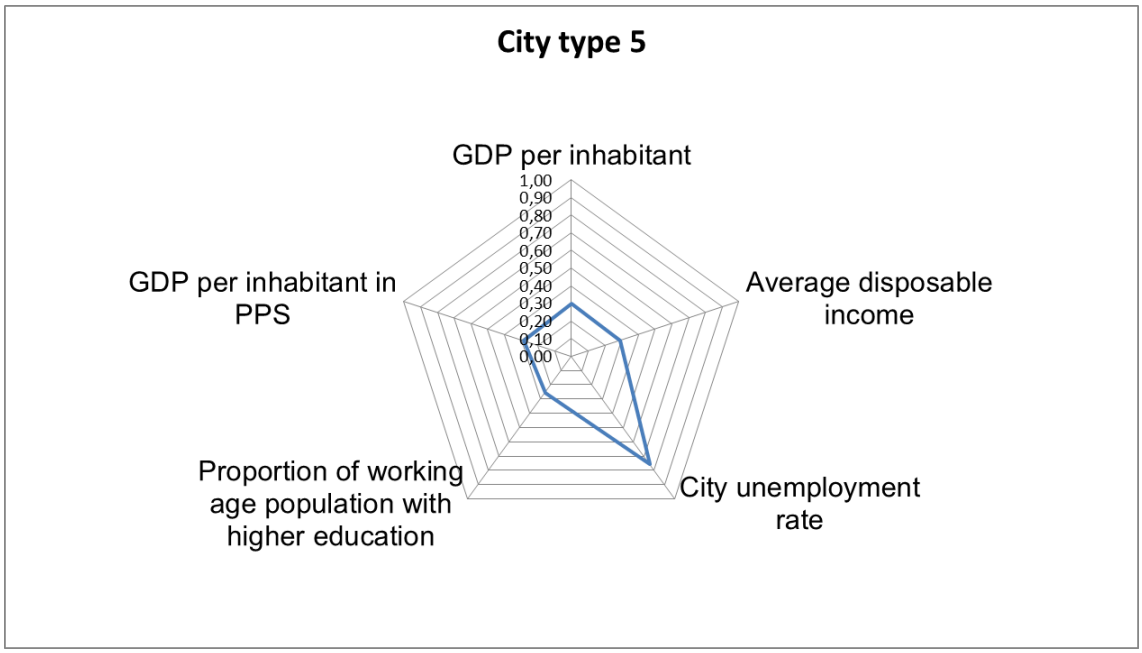


Figure 37: Finance city type 5

In addition, the unemployment rate is too high. Incentives devoted to residential buildings and sustainable urban mobility could help to replicate REMOURBAN. Thus, it is needed to lead dissemination actions to the public sector for fostering the engagement of these municipalities in urban transformation in order these cities start to prioritise the sustainable practices in the city planning. In the case of Málaga, which is one of the most active smart cities, these informative actions are not required. A workshop held in Project CITyFiED on which non-technical barriers

were analysed by the case of Málaga conducted towards the diversification of available public funds in order to avoid concentrating in subsidies as in the past, since this has not been successful.

7 Characterisation of European cities by their energy features

This section analyses the European cities by their energy features according to the set of indicators selected. As it can be observed, the characterization is done with national data since there is not enough information at city level.

7.1 Final list of indicators and databases

The following table define the final set of indicators, and the data sources where the information can be found, selected after the analysis of the data availability for the selected cities.

Table 30: Final set of indicators for Energy characterization

INDICATOR	KPI_ID	FORMULA	UNIT	DESCRIPTION	DATA BASE
Share of electricity in final energy consumptions in households	EN1	-	%	Energy derived from electricity related to the final energy in households	Eurostat[77]
Share of gas in final energy consumptions in households	EN2	-	%	Energy derived from gas related to the final energy in households	Eurostat[78]
Share of Renewable Energies in final energy consumption in households	EN3	-	%	Energy derived from energy renewable sources related to the final energy in households	Eurostat[79]
Final energy consumption per inhabitant	EN4	-	MWh/inh	It covers consumption of private households, commerce, public	Eurostat[80]

[77] http://ec.europa.eu/eurostat/web/products-datasets/-/t2020_rk210 and CoM Final energy consumption per capita (http://www.covenantofmayors.eu/search_en.html?q=+Final+energy+consumption+per+capita+&x=27&y=9) Search in every signatories Action Plan.

[78] http://ec.europa.eu/eurostat/web/products-datasets/-/t2020_rk210 and CoM Final energy consumption per capita (http://www.covenantofmayors.eu/search_en.html?q=+Final+energy+consumption+per+capita+&x=27&y=9) Search in every signatories Action Plan.

[79] http://ec.europa.eu/eurostat/web/products-datasets/-/t2020_rk210 and CoM Final energy consumption per capita (http://www.covenantofmayors.eu/search_en.html?q=+Final+energy+consumption+per+capita+&x=27&y=9) Search in every signatories Action Plan.

[80] http://ec.europa.eu/eurostat/tgm/refreshTableAction.do?tab=table&plugin=1&pcode=tsdpc320&language=en

				administration, services, agriculture and fisheries	
GHG emissions per inhabitant	EN5	1000 tonnes of CO2 eq / Total National Population	Mton CO_2 eq/Million of inhabitant	GHG emissions from buildings (residential and public)	Eurostat[81]

7.2 Data collection and aggregation for the cities

The Table 31 shows the data obtained for the indicators related to the energy field. As it can be seen, national data have been used for the characterisation of cities regarding energy features due to the lack of local data for most cities. In order to be able to work with a complete matrix of data, it was necessary to change the final list of indicators in order to adapt it to the available information and use national data instead of local data.

Using national data, all cities from the same country have the same values for all indicators, as expected, these cities were included in the same group, so the clustering and the calculation of the centroids are influenced by the number of cities from a same country within the list. For this reason, the clustering was repeated but in second case only one city per country was taken into account to generate the groups. The indicators used for this second analysis can be seen in the Table 32.

[81] http://ec.europa.eu/eurostat/en/web/products-statistical-books/-/KS-37-01-647 and/or http://www.covenantofmayors.eu/. Search in every signatories Action Plan.

Table 31: Aggregated data for the energy layer

Code	City	KPI_EN1	KPI_EN2	KPI_EN3	KPI_EN4	KPI_EN5
		Share of electricity in final energy consumption in households	Share of gas in the final energy consumption in households	Share of Renewable Energies in final energy consumption in households	Final energy consumption per inhabitant (housholds)	GHG emissions per inhabitant (households)
AT-01	Graz	23.1	19	27.9	9.04	1820.16
AT-02	Innsbruck	23.1	19	27.9	9.04	1820.16
BE-01	Ghent	19	41.3	7	9.32	2387.32
BE-02	Liege	19	41.3	7	9.32	2387.32
BE-03	Brugge	19	41.3	7	9.32	2387.32
BG-01	Ruse	40.3	2	33.8	14.37	3680.39
EE-01	Tartu	17.2	5.6	40	8.21	877.74
FI-01	Jyväskylä	36.3	0.6	24.5	10.89	1083.47
FI-02	Tampere	36.3	0.6	24.5	10.89	1083.47
FI-03	Turku	36.3	0.6	24.5	10.89	1083.47
FR-01	La Rochelle	33.1	29.1	18.4	7.69	1916.95
FR-02	Poitiers	33.1	29.1	18.4	7.69	1916.95
DE-01	Aachen	19.6	37.7	10.4	0.62	100.93
DE-02	Koeln/ Koln	19.6	37.7	10.4	0.62	100.93

DE-03	Leipzig	19.6	37.7	10.4	0.62	100.93
DE-04	Rosenheim	19.6	37.7	10.4	0.62	100.93
GR-01	Thessaloniki	39.9	6.2	26.6	3.97	1321.40
HU-01	Miskolc	18.8	51.9	15.4	5.69	1471.05
IR-01	Cork	24.4	21.6	1.4	7.10	2565.40
IT-01	Bolzano	16.8	52.8	19.7	6.65	1702.24
IT-03	Firenze	16.8	52.8	19.7	6.65	1702.24
IT-04	Genova	16.8	52.8	19.7	6.65	1702.24
NL-01	Eindhoven	20.1	73.5	3.1	7.46	2402.50
NL-02	Utrecht	20.1	73.5	3.1	7.46	2402.50
NW-01	Stavanger	80.9	0.1	13.4	9.01	1032.45
NW-01	Trondheim	80.9	0.1	13.4	9.01	1032.45
PT-01	Porto	40.1	9.3	30.8	2.93	1246.75
PT-02	Braga	40.1	9.3	30.8	2.93	1246.75
SI-01	Ljubljana	24	9.9	43.3	6.53	840.78
ES-01	San Sebastian-Donostia	41.5	21.3	18.2	3.70	1309.12
ES-02	Malaga	41.5	21.3	18.2	3.70	1309.12

ES-03	Sevilla	41.5	21.3	18.2	3.70	1309.12
ES-04	Valladolid	41.5	21.3	18.2	3.70	1309.12
ES-05	Santa Cruz de Tenerife	41.5	21.3	18.2	3.70	1309.12
SE-01	Stockholm	46.8	0.5	14.5	8.51	1006.15
SE-02	Gothenburg	46.8	0.5	14.5	8.51	1006.15
SE-03	Malmo	46.8	0.5	14.5	8.51	1006.15
UK-01	Nottingham	24.3	66.3	1.3	7.30	2108.41
UK-02	Manchester	24.3	66.3	1.3	7.30	2108.41
UK-03	Bristol	24.3	66.3	1.3	7.30	2108.41
UK-04	Oxford	24.3	66.3	1.3	7.30	2108.41

Table 32: Aggregated data for the energy layer (Only one city per country)

Code	Country	KPI_EN1	KPI_EN2	KPI_EN3	KPI_EN4	KPI_EN5
		Share of electricity in final energy consumption in households	Share of gas in the final energy consumption in households	Share of Renewable Energies in final energy consumption in households	Final energy consumption per inhabitant (housholds)	GHG emissions per inhabitant (households)
AT	Austria	23.1	19	27.9	9.04	1820.16
BE	Belgium	19	41.3	7	9.32	2387.32
BG	Bulgaria	40.3	2	33.8	14.37	3680.39
EE	Estonia	17.2	5.6	40	8.21	877.74
FI	Finland	36.3	0.6	24.5	10.89	1083.47
FR	France	33.1	29.1	18.4	7.69	1916.95
DE	Germany	19.6	37.7	10.4	0.62	100.93
GR	Greece	39.9	6.2	26.6	3.97	1321.40
HU	Hungary	18.8	51.9	15.4	5.69	1471.05
IR	Ireland	24.4	21.6	1.4	7.10	2565.40
IT	Italy	16.8	52.8	19.7	6.65	1702.24
NL	Netherlands	20.1	73.5	3.1	7.46	2402.50
NW	Norway	80.9	0.1	13.4	9.01	1032.45
PT	Portugal	40.1	9.3	30.8	2.93	1246.75

SI	Slovenia	24	9.9	43.3	6.53	840.78
ES	Spain	41.5	21.3	18.2	3.70	1309.12
SE	Sweden	46.8	0.5	14.5	8.51	1006.15
UK	United Kingdom	24.3	66.3	1.3	7.30	2108.41

7.3 Definition of city types for the energy layer

For the energy layer and as was mentioned above, the characterization of cities was made using national data and the clustering was made twice. In the first analysis, all cities of the list were taken into account and in the second analysis only one city per country was included in the study in order to avoid the influence of the number of cities from the same country of the list, because the list include countries represented by several cities (Germany, Spain…) and others represented only by one city (Ireland, Greece…)

7.3.1 Energy city type definition

Taking into account the assumptions indicated in the previous section, the first clustering was done with all cities of the list. The result of this first clustering can be seen in the Table 33. As expected and can be seen in the table, all cities from the same country are included in the same group because all their KPIs have the same values.

Table 33: Clusters for energy I (taking into account all cities)

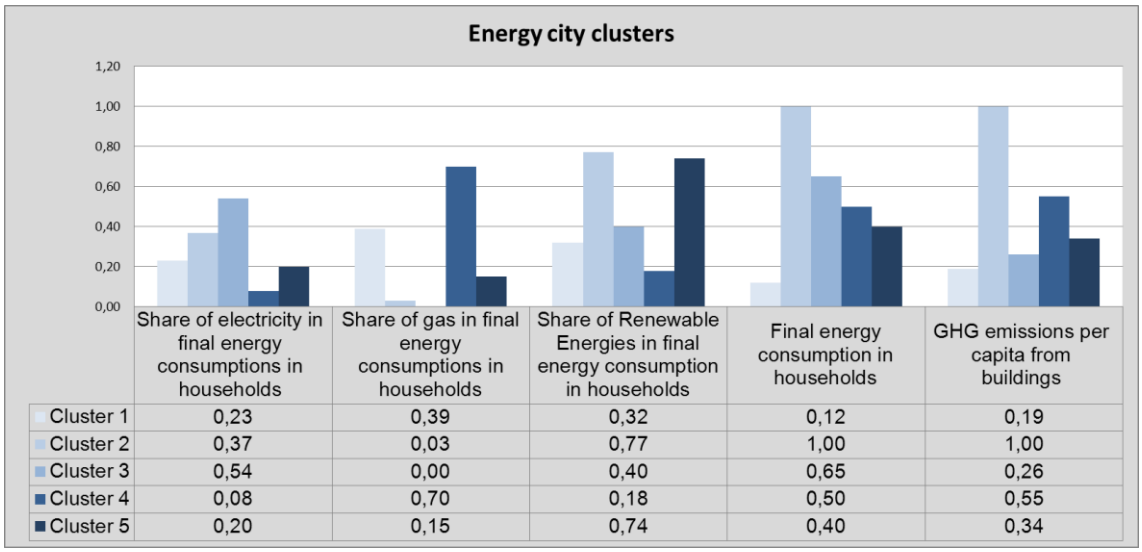
Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Aachen	Ruse	Jyväskylä	Ghent	Graz
Koeln/Köln		Tampere	Liege	Innsbruck
Leipzig		Turku	Brugge	Tartu
Rosenheim		Stavanger	La Rochelle	Thessaloniki
San Sebastian-Donostia		Trondheim	Poitiers	Porto
Málaga		Stockholm	Miskolc	Braga
Sevilla		Gothenburg	Cork	Ljubljana
Valladolid		Malmö	Bolzano	
Santa Cruz de Tenerife			Firenze	
			Genova	
			Eindhoven	
			Utrecht	
			Nottingham	
			Manchester	
			Bristol	
			Oxford	

From these results, and using the z-normalisation for the centroids values of each cluster (that represents a city type for each of them), the values included in the following table are obtained.

Table 34: Denormalised centroids for each cluster for the energy clustering I

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
KPI_EN1	31.8	40.3	51.4	22.1	29.6
KPI_EN2	28.6	2.0	0.4	51.6	11.2
KPI_EN3	14.7	33.8	18,0	9.1	32.5
KPI_EN4	2.3	14.4	9,5	7.5	6.1
KPI_EN5	772.1	3680.4	1041,7	2086.1	1310.5

The following represents the characterisation of these clusters according to their z-normalised centroids.



	Share of electricity in final energy consumptions in households	Share of gas in final energy consumptions in households	Share of Renewable Energies in final energy consumption in households	Final energy consumption in households	GHG emissions per capita from buildings
Cluster 1	0,23	0,39	0,32	0,12	0,19
Cluster 2	0,37	0,03	0,77	1,00	1,00
Cluster 3	0,54	0,00	0,40	0,65	0,26
Cluster 4	0,08	0,70	0,18	0,50	0,55
Cluster 5	0,20	0,15	0,74	0,40	0,34

Figure 38: Characterization of the clusters according to their z-normalised centroids values

The second clustering was done using only a city per country but in each cluster, shown in the table below, all cities of the REMOURBAN list have been included taking into account the group where their country were included.

Comparing both tables (Table 33 and Table 35), the clusters are very similar. The cities from Finland are the only difference between these tables. In the first analysis Jyväskylä, Tampere and Turku are in the cluster 3 with Stavanger, Trondheim, Stockholm, Gothenburg and Malmö, and in the second analysis, these cities are in the cluster 5 with the cities from Austria, Estonia, Greece, Portugal and Slovenia.

On the other hand, if the centroids are compared (Table 34 and Table 36), can be seen that the values are not the same although the lists of cities in both groups are identical. This is because the number of cities from each country has influence in the calculation of the centroids. In the case of the cluster 4 (analysis I) and cluster 1 (analysis II), the same list of cities are part of both clusters, but the values of the centroids for these clusters are different because in these clusters there are one country represented by four cities (United Kingdom), two countries with three

cities (Belgium and Italy), two countries represented by two cities (France and Netherlands) and two countries with only one city (Hungary and Ireland).

Although the values are very similar, finally and taking into account that in both analysis all used values are national data, the characterization of cities have been made using the second analysis in order to avoid the influence of the number of cities considered in the study when the centroids are calculated.

Table 35: Clusters for energy II (one city per country)

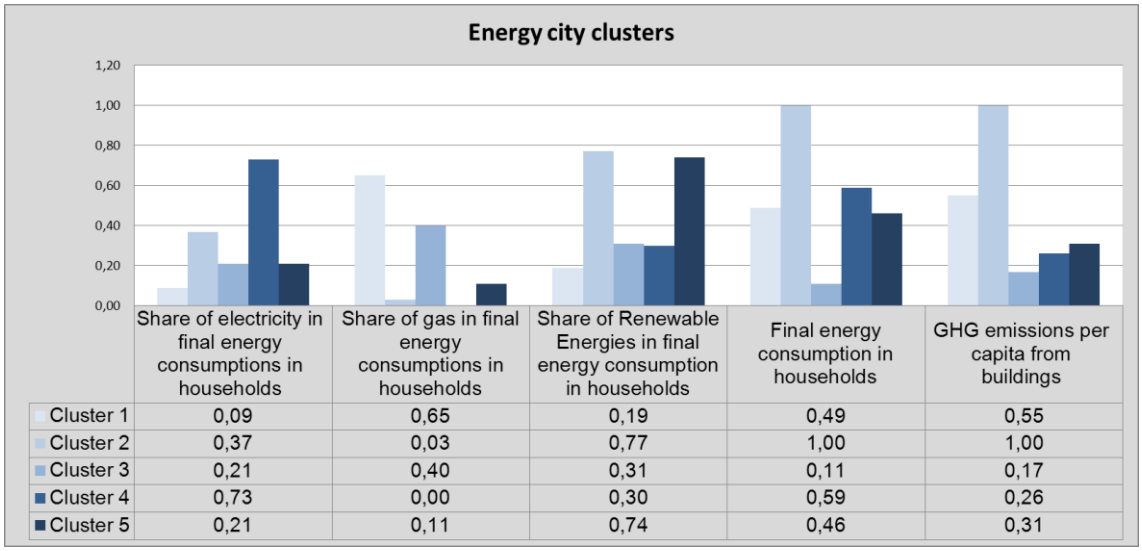
Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Ghent	Ruse	Aachen	Stavanger	Graz
Liege		Koeln/Köln	Trondheim	Innsbruck
Brugge		Leipzig	Stockholm	Tartu
La Rochelle		Rosenheim	Gothenburg	Jyväskylä
Poitiers		San Sebastian-Donostia	Malmö	Tampere
Miskolc		Málaga		Turku
Cork		Sevilla		Thessaloniki
Bolzano		Valladolid		Porto
Firenze		Santa Cruz de Tenerife		Braga
Genova				Ljubljana
Eindhoven				
Utrecht				
Nottingham				
Manchester				
Bristol				
Oxford				

From these results, and using the z-normalisation for the centroids values of each cluster (that represents a city type for each of them), the values included in the following table are obtained.

Table 36: Denormalised centroids for each cluster for the energy clustering II (one city per country)

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
KPI_EN1	22,4	40,3	30,6	63,9	30,1
KPI_EN2	48,1	2,0	29,5	,3	8,4
KPI_EN3	9,5	33,8	14,3	14,0	32,2
KPI_EN4	7,3	14,4	2,2	8,8	6,9
KPI_EN5	2079,1	3680,4	705,0	1019,3	1198,4

The following represents the characterisation of these clusters according to their z-normalised centroids.



	Share of electricity in final energy consumptions in households	Share of gas in final energy consumptions in households	Share of Renewable Energies in final energy consumption in households	Final energy consumption in households	GHG emissions per capita from buildings
Cluster 1	0,09	0,65	0,19	0,49	0,55
Cluster 2	0,37	0,03	0,77	1,00	1,00
Cluster 3	0,21	0,40	0,31	0,11	0,17
Cluster 4	0,73	0,00	0,30	0,59	0,26
Cluster 5	0,21	0,11	0,74	0,46	0,31

Figure 39: Characterization of the clusters according to their z-normalised centroids values

The following figure represents the characterisation of these clusters their z-normalised centroids. Hence, and according to these results, the characterisation of the city types for the energy layer is included in the following sections.

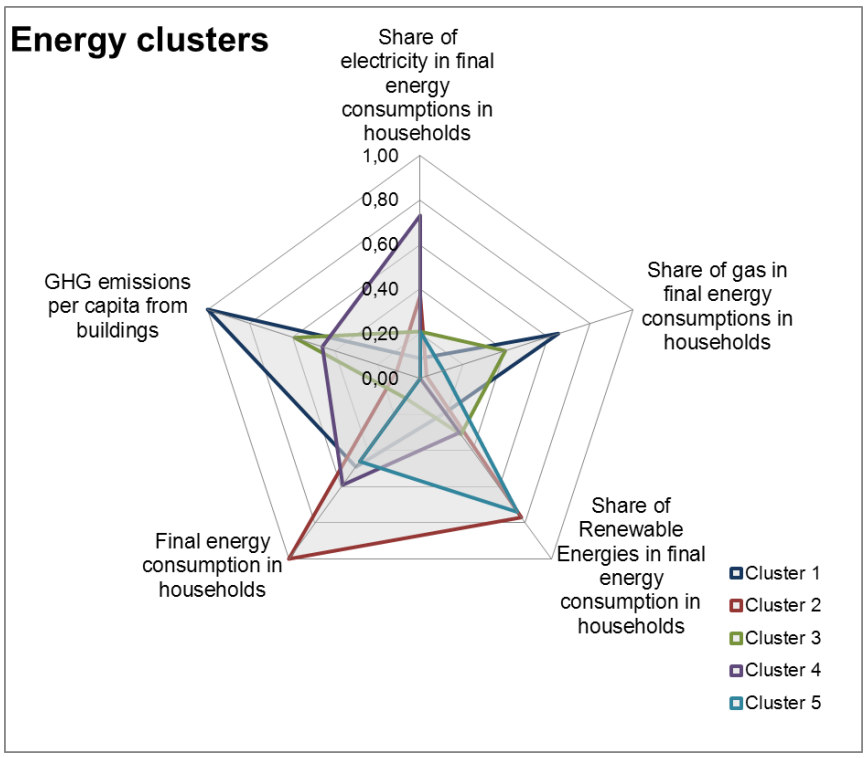


Figure 40: Radar representation of the energy clusters (national level)

7.3.2 Energy city type 1

In this case, the first city type is the largest, with sixteen cities including all cities from Belgium, France, Hungary (Miskolc), Ireland, Italy, Holland, and UK. Characterised by the lowest value in electricity in the final energy consumption, the lowest rate also in RES, the highest in gas and with a good average in final energy consumption in households, but still a high GHG emissions average ratio, all these cities have still a long way to go to become fully sustainable.

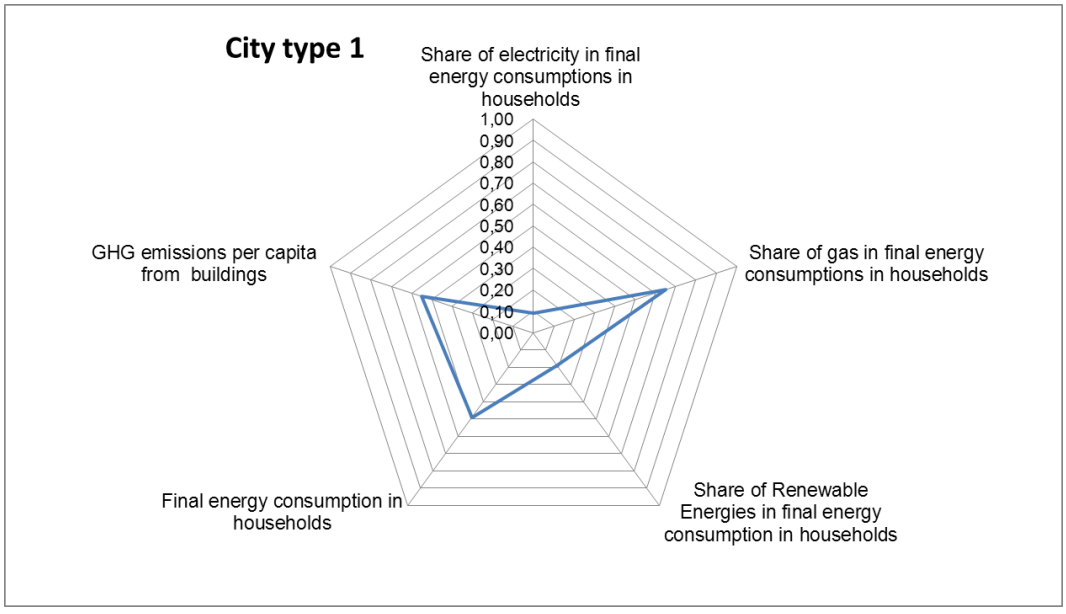


Figure 41: Energy city type 1

7.3.3 Energy city type 2

Only one city has been included in the city type number 2. This city is Ruse.

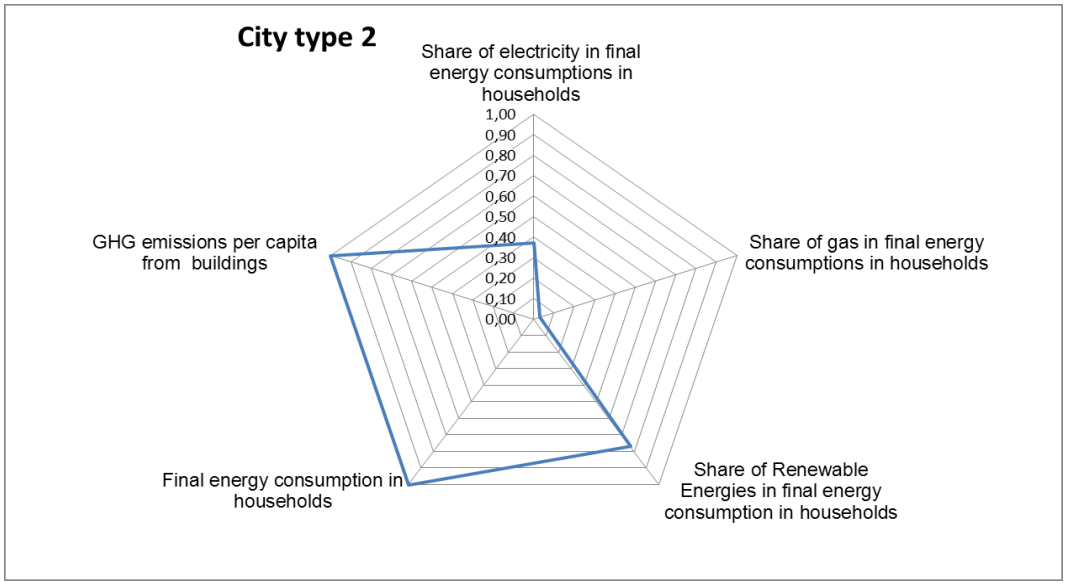


Figure 42: Energy city type 2

The main characteristics of this cluster from the point of view of energy are the highest rate in final energy consumption and in GHG emissions. However, a high rate in renewable energy comes to balance these results a little.

7.3.4 Energy city type 3

In this case, the third cluster includes all cities from Germany and Spain. This cluster is characterized by the lowest energy consumption in households (not very surprising for a Southern country such as Spain, but more remarkable for Germany), and a low value for GHG emissions.

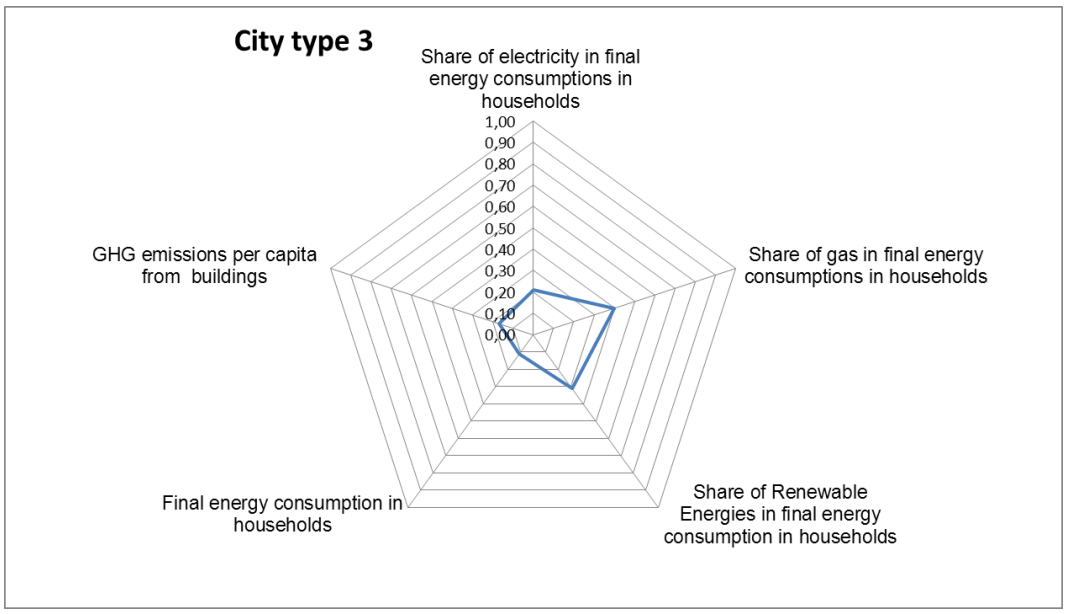


Figure 43: Energy city type 3

7.3.5 Energy city type 4

All cities from Norway and Sweden are included in this fourth city type.

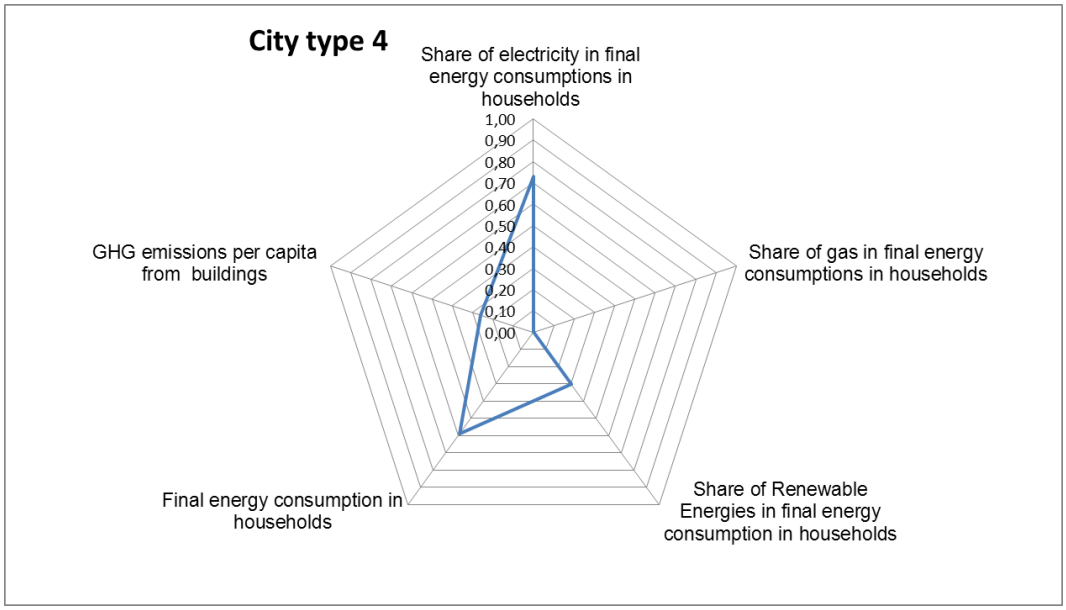


Figure 44: Energy city type 4

These cities have almost no gas share in their final consumption in residential sector, but quite a high rate of electricity used, and one of the lowest GHG emissions of all energy clusters.

7.3.6 Energy city type 5

This cluster is characterised by a rather high share in renewable energies in final energy consumption in households. All the cities of Austria, Estonia, Greece, Portugal, Slovenia and Finland are in this cluster.

With a low gas and electricity shares, and a good result in GHG emissions, this cluster may be considered in a good position in terms of energy efficiency and should strengthen their efforts.

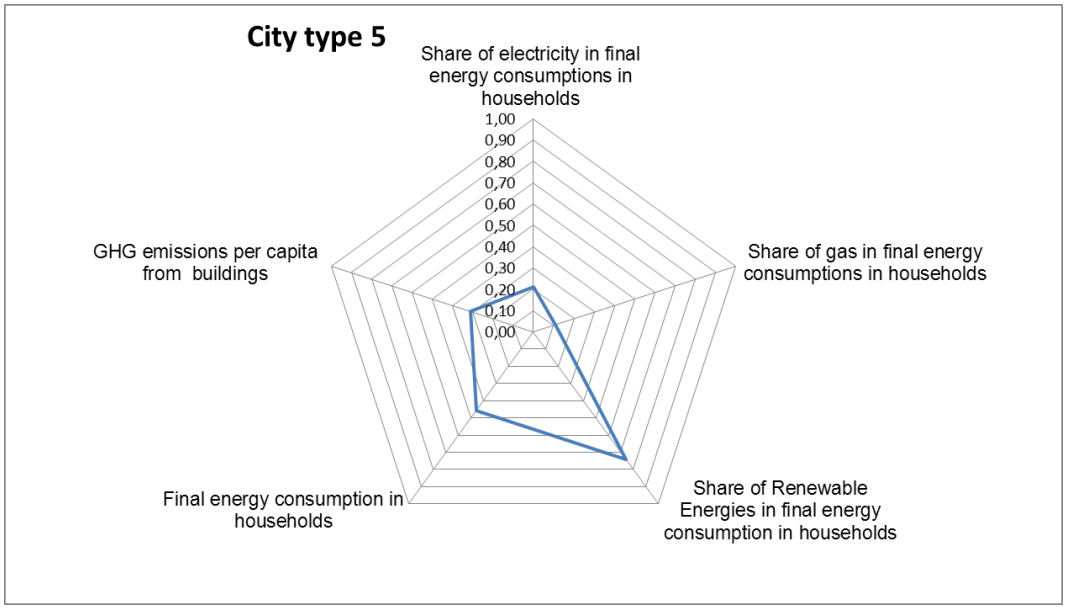


Figure 45: Energy city type 5

8 Characterisation of European cities by their mobility features

This section analyses the European cities by their mobility features according to the set of indicators selected. It has to point that data for indicators MO7 and MO8 are at national level.

8.1 Final list of indicators and databases

The following table define the final set of indicators, and the data sources where the information can be found, selected after the analysis of the data availability for the selected cities.

Table 37: Final set of indicators for Mobility characterization

INDICATOR	KPI_ID	FORMULA	UNIT	DESCRIPTION	DATA BASE
Private car ratio	MO1	Total number of private cars x 1000 inhabitants/population	Number of cars / 1000 inhabitants	Total number of private cars (excluding automobiles, trucks and vans used for the delivery of goods and services by commercial enterprises), related to the total number of inhabitants	Eurostat CTRAN[82]
People killed in road accidents (per 10000 population)	MO2	People killed in road accidents x 10000 inhabitants/population	People killed in road accidents/ 1000 inhabitants	People killed in road accidents	Eurostat CTRAN [83]
Modal Split. Use of private motor vehicle	MO3	-	%	Percentage of trips using a private motor vehicle as type of transportation	Modal TEMS - The EPOMM Modal Split Tool[84] Eurostat CTRAN[85]
Modal Split. Walk	MO4	-	%	Percentage of trips walking as type of transportation	Modal TEMS - The EPOMM Modal Split Tool[86]

[82] http://ec.europa.eu/eurostat/web/products-datasets/-/urb_ctran (Data 14 sheet)

[83] http://ec.europa.eu/eurostat/web/products-datasets/-/urb_ctran (Data 15 sheet) and http://ec.europa.eu/eurostat/web/products-datasets/-/tps00165

[84] http://www.epomm.eu/tems/cities.phtml

[85] Idib.

[86] http://www.epomm.eu/tems/cities.phtml

					Eurostat CTRAN[87]
Modal Split. Bike	MO5	-	%	Percentage of trips using a bike as type of transportation	Modal TEMS - The EPOMM Modal Split Tool[88] Eurostat CTRAN [89]
Modal Split. Passenger transport	MO6	-	%	Percentage share of each mode of transport in total inland transport, expressed in passenger-kilometers (pkm)	Modal TEMS - The EPOMM Modal Split Tool[90] Eurostat CTRAN [91]
Percentage of Electrical Vehicle (EV)	MO7	Total number of all type EV Total number vehicles	%	Number of electric vehicles related to total number of vehicles	McKinsey Report[92]
GHG emissions per capita from transportation	MO8	Annual Tonnes of CO2 eq / Total City Population	Annual tonnes CO_2 eq / Hab.	According to the Global Protocol for Community Scale GHG Emissions (GPC)	Eurostat[93]

[87] Idib.

[88] http://www.epomm.eu/tems/cities.phtml

[89] Idib.

[90] http://www.epomm.eu/tems/cities.phtml

[91] Idib.

[92] http://www.mckinsey.com/~/media/McKinsey%20Offices/Netherlands/Latest%20thinking/PDFs/Electric-Vehicle-Report-EN_AS%20FINAL.ashx Exhibit 1.1

[93] http://ec.europa.eu/eurostat/web/products-datasets/-/t2020_rd300 (Country level only) and http://ec.europa.eu/eurostat/web/products-datasets/-/med_en1

8.2 Data collection and aggregation for the cities

Table 38: Aggregated data for the mobility layer

Code	City	KPI_MO1	KPI_MO2	KPI_MO3	KPI_MO4	KPI_MO5	KPI_MO6	KPI_MO7	KPI_MO8
		nº of registered cars per 1000 population	People killed in road accidents (per 10,000 population)	Modal Split. Private motor vehicle	Modal Split. Walk	Modal Split. Bike	Modal Split. Passenger transport	Percentage of EV	GHG per capita from transportation
AT-01	Graz	535,80	0.16	47	19	14	20	0.86	2.57
AT-02	Innsbruck	535,80	0.17	43	27	14	16	0.86	2.57
BE-01	Ghent	415,80	0.443	47	24	20	9	0.75	2.25
BE-02	Liege	409,50	0.504	76	6	2	16	0.75	2.25
BE-03	Brugge	463,10	0.256	43	11	28	18	0.75	2.25
BG-01	Ruse	593,10	0.868	33	44	2	21	0	1.15
EE-01	Tartu	278,20	0.41	28	40	5	27	1.60	1.72
FI-01	Jyväskylä	498,40	0.382	58	22	14	6	0.28	2.35
FI-02	Tampere	441,50	0.1	46	27	10	17	0.28	2.35
FI-03	Turku	469,60	0.169	48	30	13	9	0.28	2.35
FR-01	La Rochelle	558,60	0.203	75	11	6	8	1	2.05
FR-02	Poitiers	563,10	0.074	63	18	5	13	0.70	2.05

DE-01	Aachen	340,20	0.348	51	23	11	15	0.61	1.90
DE-02	Koeln	354,30	0.32	43	24	12	21	0.61	1.90
DE-03	Leipzig	332,60	0.153	40	27	14	19	0.61	1.90
DE-04	Rosenheim	420,20	0,00	54	22	18	6	0.61	1.90
GR-01	Thessaloniki	460,50	0.67	55	10	10	25	0,01	1.45
HU-01	Miskolc	260,10	0.536	22	19	5	53	0.03	1.09
IR-01	Cork	491,60	0.253	76	15	2	7	0,5	2.38
IT-01	Bolzano	519,60	0.673	34	29	29	8	0.1	1.79
IT-02	Firenze	562,90	0.404	62	16	5	17	0.1	1.79
IT-03	Genova	464,70	0.345	49	21	0	31	0.1	1.79
NL-01	Eindhoven	410,40	0.417	42	13	40	5	5.51	2.03
NL-02	Utrecht	306,20	0.321	41	17	26	16	5.51	2.03
NW-01	Stavanger	453,10	0.159	61	23	5	11	5.51	3.04
NW-02	Trondheim	429,60	0.115	53	28	9	10	5.51	3.04
PT-01	Porto	446,40	0.798	44	30	1	25	0.18	1.61
PT-02	Braga	446,40	0.386	52	30	1	17	0.18	1.61
SI-01	Ljubljana	434,10	0.25	58	19	10	13	0,12	2.81

ES-01	San Sebastian-Donostia	410,40	0.323	29	43	3	25	0.13	1.72
ES-02	Málaga	471,40	0.517	49	38	1	12	0.13	1.72
ES-03	Sevilla	483,10	0.387	35	37	6	22	0.13	1.72
ES-04	Valladolid	445,60	0.578	57	22	1	20	0.13	1.72
ES-05	Santa Cruz de Tenerife	561,10	0.25	65	18	0.1	16.9	0.13	1.72
SE-01	Stockholm	361,60	0.127	47	17	1	35	1.62	2.02
SE-02	Gothenburg	342,90	0.173	50	15	9	26	1.62	2.02
SE-03	Malmö	352,90	0.132	42	15	22	21	1.62	2.02
UK-01	Nottingham	252,00	0.033	54	23	1	21	0.67	1.82
UK-02	Manchester	234,30	0.318	53	15	4	28	0.67	1.82
UK-03	Bristol	368,20	0.257	49	21	14	16	0.67	1.82
UK-04	Oxford	283,90	0.066	41	19	19	21	0.67	1.82

8.3 Definition of city types for the mobility layer

Table 39: Clusters for mobility – List of cities

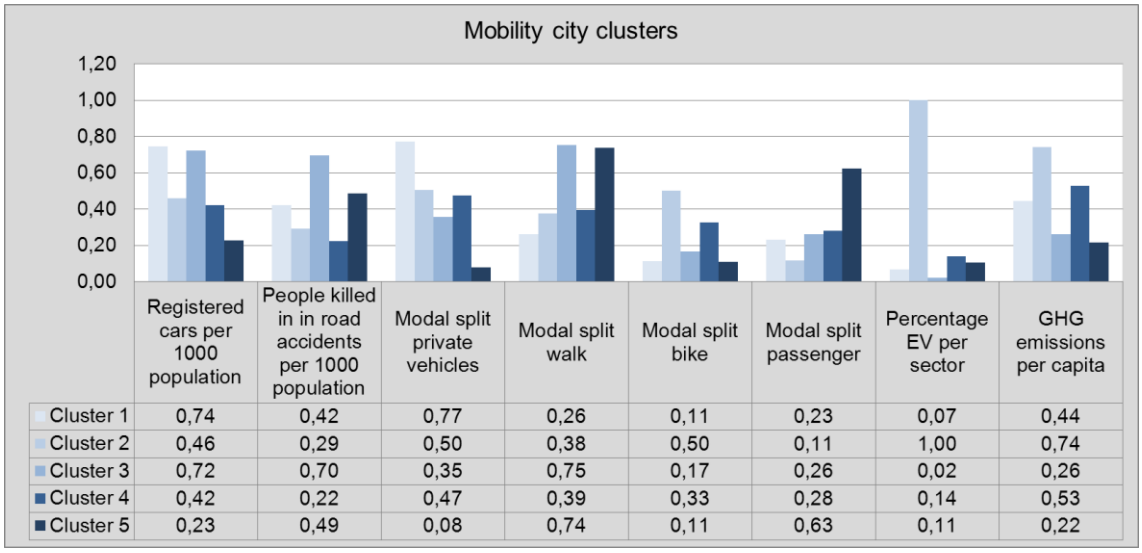
Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Liege	Eindhoven	Ruse	Graz	Tartu
Valladolid	Utrecht	Málaga	Innsbruck	San Sebastian-Donostia
Santa Cruz de Tenerife	Stavanger	Sevilla	Ghent	Miskolc
Jyväskylä	Trondheim	Bolzano	Brugge	
La Rochelle		Porto	Aachen	
Poitiers		Braga	Koeln/Köln	
Thessaloniki			Leipzig	
Cork			Rosenheim	
Firenze			Tampere	
Genova			Turku	
			Stockholm	
			Gothenburg	
			Malmö	
			Ljubljana	
			Nottingham	
			Manchester	
			Bristol	
			Oxford	

From these results, and using the z-normalisation for the centroids values of each cluster (that represents a city type for each of them), the values included in the following table are obtained.

Table 40: Denormalised centroids for each cluster for the mobility clustering

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
KPI_MO1	501.6	399.8	493.3	385.5	316.2
KPI_MO2	0.4	0.3	0.6	0.2	0.4
KPI_MO3	63.6	49.3	41.2	47.6	26.3
KPI_MO4	15.9	20.3	34.7	21.0	34.0
KPI_MO5	4.5	20.0	6.7	13.0	4.3
KPI_MO6	16.0	10.5	17.5	18.4	35.0
KPI_MO7	0.4	5.5	0.1	0.8	0.6
KPI_MO8	2.0	2.5	1.6	2.1	1.5

The following figure represents the characterisation of these clusters according to their z-normalised centroids values.



	Registered cars per 1000 population	People killed in in road accidents per 1000 population	Modal split private vehicles	Modal split walk	Modal split bike	Modal split passenger	Percentage EV per sector	GHG emissions per capita
Cluster 1	0,74	0,42	0,77	0,26	0,11	0,23	0,07	0,44
Cluster 2	0,46	0,29	0,50	0,38	0,50	0,11	1,00	0,74
Cluster 3	0,72	0,70	0,35	0,75	0,17	0,26	0,02	0,26
Cluster 4	0,42	0,22	0,47	0,39	0,33	0,28	0,14	0,53
Cluster 5	0,23	0,49	0,08	0,74	0,11	0,63	0,11	0,22

Figure 46: Representation of the absolute values of the z-normalised centroids for the mobility clusters

Hence, and according to these results, the characterisation of the city types for the mobility layer is included in the following sections.

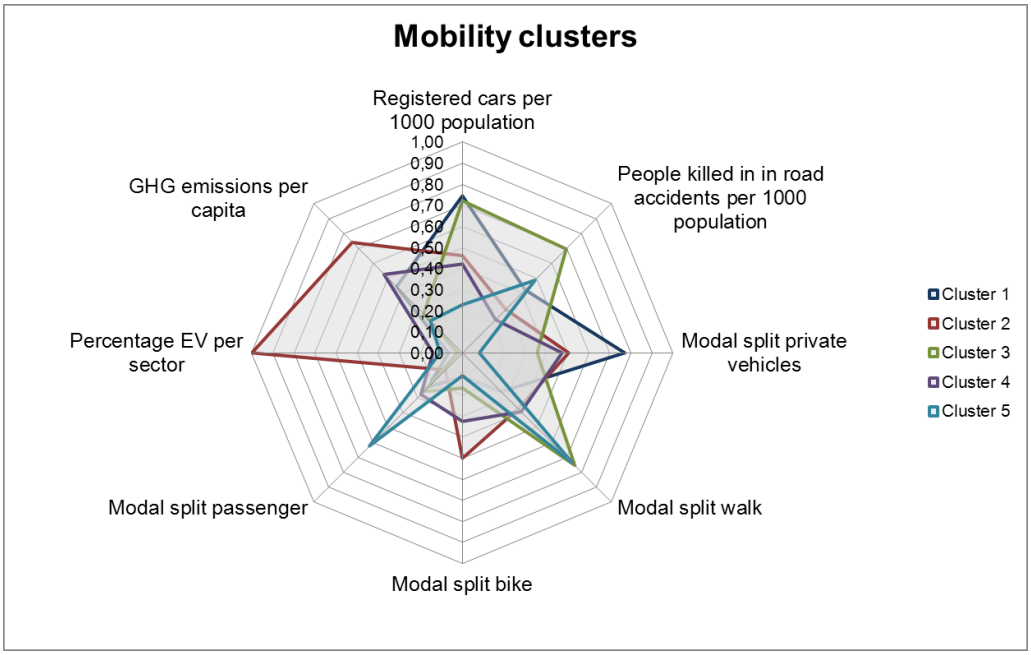


Figure 47: Radar representation of the mobility clusters

8.3.1 Mobility city type 1

The first of the city types includes 10 cities: Liege, Santa Cruz de Tenerife, Jyväskylä, La Rochelle, Poitiers, Thessaloniki, Cork, Firenze, Genova and Valladolid (one of the lighthouse cities of REMOURBAN).

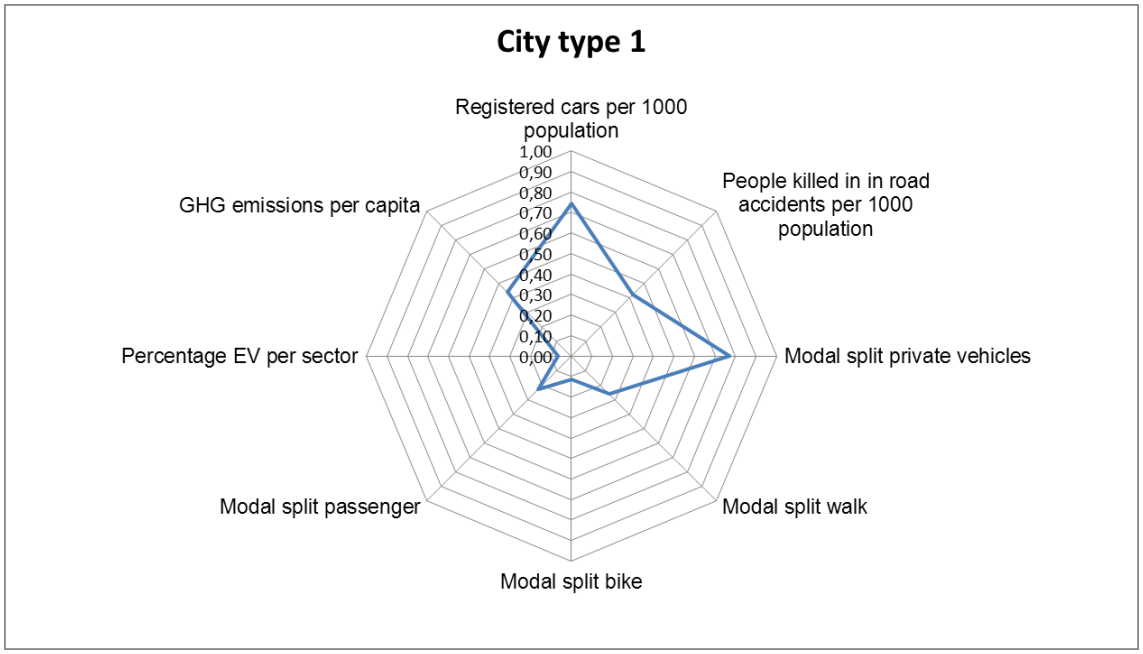


Figure 48: Mobility city type 1: low transport safety and sustainability

This cities cluster is characterised by a very high number of registered cars per 1000 population (top value) with an average value of 501.6 vehicles/1000 inhabitants (One vehicle for 2 inhabitants), and the highest value in use of private vehicles. Consequently, the GHG emissions are high, being this city typology in the 3rd position among the cluster analysed. The average of the cluster is still poor in EV and use of bike.

8.3.2 Mobility city type 2

The second city type includes only 4 cities: Eindhoven, Utrecht, Stavanger and Trondheim.

This cluster 2 is characterised by a peak in EV penetration and a good result in the use of bikes. But, on the other hand, this group has the highest GHG emissions; probably this is because they have the lowest percentage of use of passenger transport and a low value for the percentage of people walking.

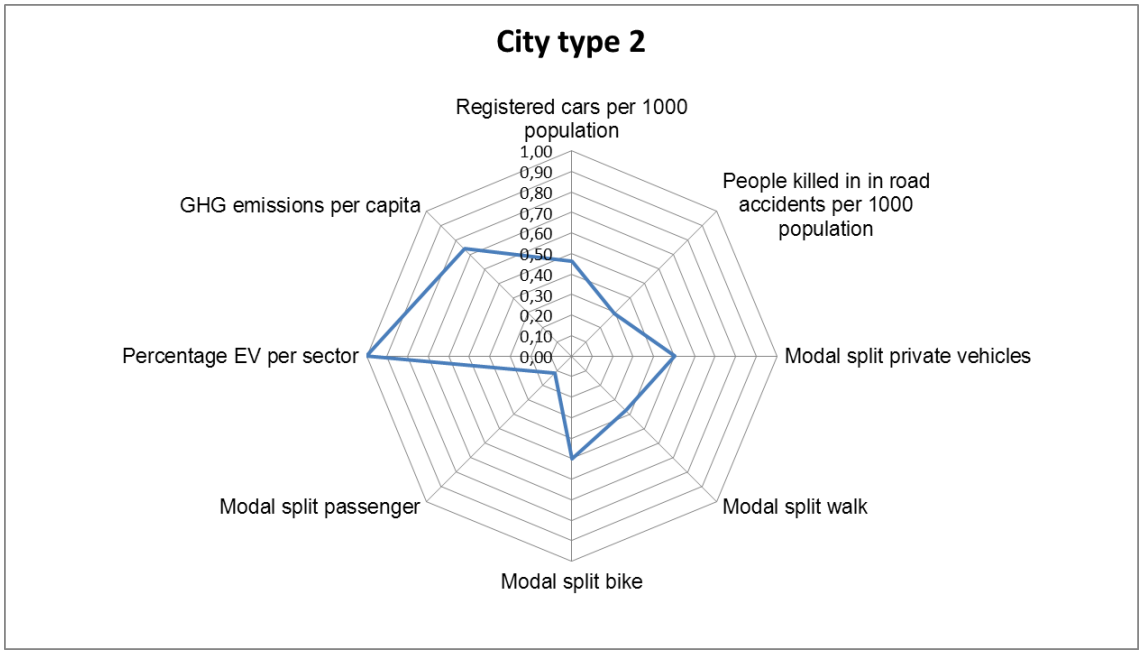


Figure 49: Mobility city type 2

8.3.3 Mobility city type 3

The third city type includes a total of six cities: Ruse, Málaga, Sevilla, Bolzano, Porto and Braga.

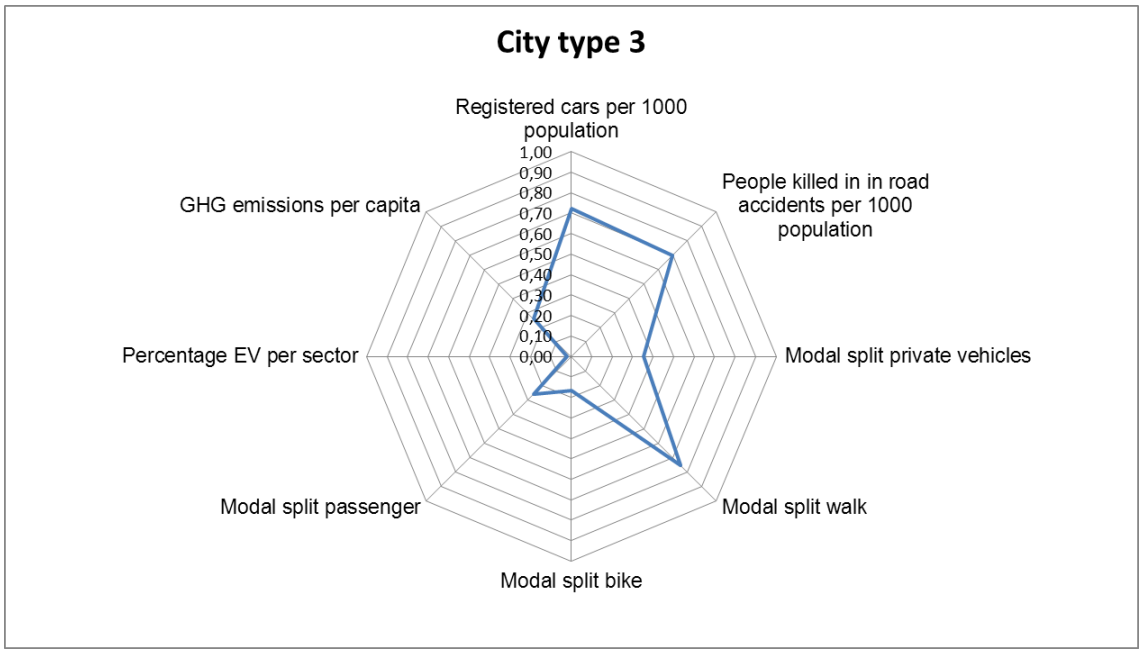


Figure 50: Mobility city type 3

In this type of cities it is relevant the high number of registered cars and, unfortunately a significant number of people killed in road accidents.

On the other hand, they have the highest percentage of people walking and a medium position for people using bikes and passenger transport. This helps to achieve the low GHG emissions that these cities have. Other relevant characteristic for this city type is the lowest penetration of EV.

8.3.4 Mobility city type 4

The city type 4 is the largest one, with 14 cities. This cluster includes Graz, Innsbruck, Ghent, Brugge, Aachen, Koeln/Köln, Leipzig, Rosenheim, Tampere, Turku, Stockholm, Gothenburg, Malmö, Ljubljana, Manchester, Bristol, Oxford, and Nottingham, one of the REMOURBAN lighthouse cities.

The main characteristic for this group of cities regarding its mobility features is there are not very relevant values for any of the considered indicators.

Analysing these values, it can be seen the good characteristics of these cities regarding the “green mobility”, with very good values for walking, biking and public transportation (Nottingham is a good example), and promising progress in EV penetration.

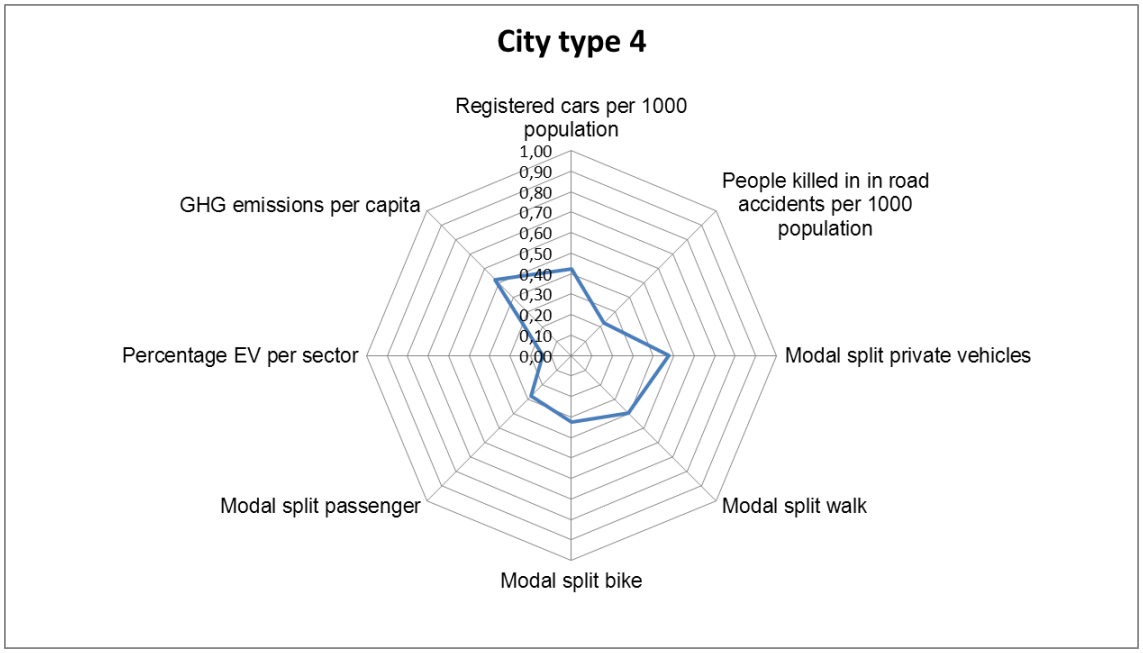


Figure 51: Mobility city type 4

8.3.5 Mobility city type 5

This city type is the smallest one, since it only includes three cities, Tartu, San Sebastian and one of the two follower cities of REMOURBAN project, Miskolc.

This cluster is characterised by the low rate in use and purchase of private vehicles. On the other hand, as can be seen in the following figure, the percentage of people using passenger transport or walking is very high, so as expected, the GHG emissions are the lowest of all generated clusters.

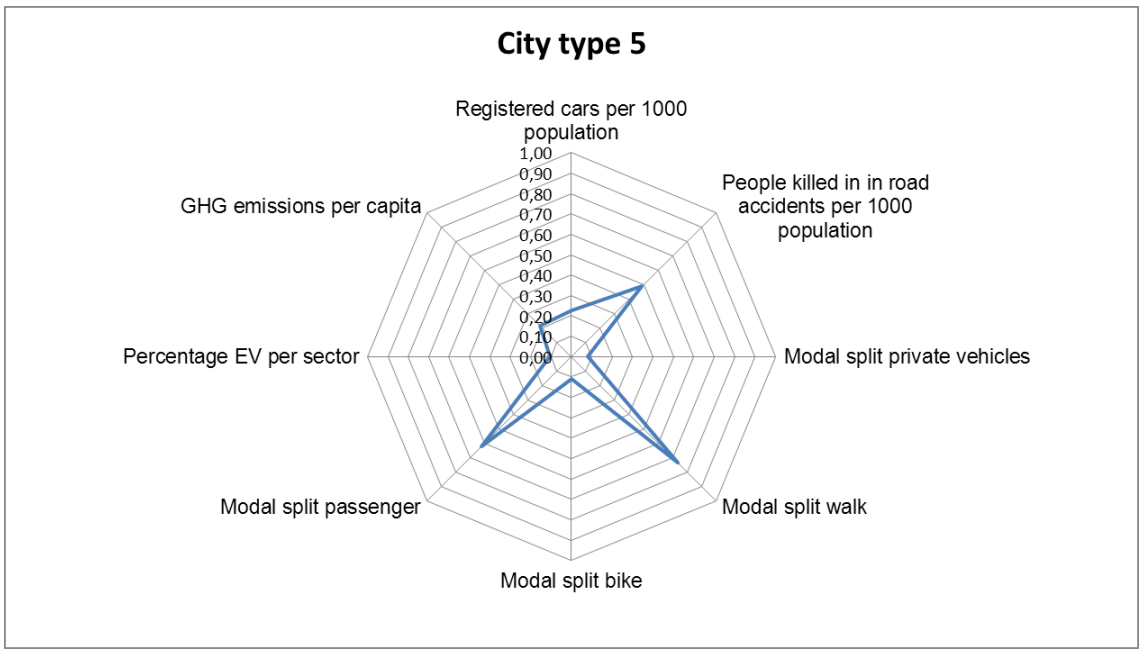


Figure 52: Mobility city type 5

9 Characterization of European Cities by their infrastructures features

This section analyses the European cities by their infrastructures features according to the set of indicators selected. As it can be observed, the characterization is done with national data since there is not enough information at city level for all cities.

9.1 Final list of indicators and databases

The following table define the final set of indicators, and the data sources where the information can be found, selected after the analysis of the data availability for the selected cities.

Table 41: Final set of indicators for Infrastructures characterization

INDICATOR	KPI_ID	FORMULA	UNIT	DESCRIPTION	DATABASES
Smartphone penetration	IN1	Number of smartphones / Total mobile phones	%	Number of smartphones in relation to total mobile phones	The International Telecommunication Union. Wikipedia
Fixed wired internet subscriptions	IN2	Number of fixed wired internet subscriptions/ Total Country Population	%	Percentage of a country's population which have fixed wired internet subscription	The International Telecommunication Union. Wikipedia
Broadband internet subscriptions: Mobile-cellular	IN3	% of a country's population that are subscribers to a public mobile telephone service	%	Number of subscriptions to a public mobile telephone service. High- speed access to the public internet	The International Telecommunication Union. Wikipedia
Percentage of internet users	IN4	Number of people who has access to Internet at home. This indicator does not record use, or frequency of use, but only access	%	Number of people who has access to Internet at home. This indicator does not record use, or frequency of use, but only access	The International Telecommunication Union. Wikipedia

9.2 Data collection and aggregation for the cities

The Table 42 shows the data obtained for the indicators related to the infrastructures field. As can be seen, national data have been used for the characterization of cities regarding infrastructures features due to the lack of local data for most cities. In order to be able to work with a complete matrix of data and following the same method used in the section about energy (Section 7), it was necessary to change the final list of indicators in order to adapt it to the available information and use national data instead of local data.

Using national data, all cities from the same country have the same values for all indicators, as expected, these cities were included in the same group, so the clustering and the calculation of

the centroids are influenced for the number of cities from a same country within the list. For this reason, the clustering was repeated but in second case only one city per country was taken into account to generate the groups. The indicators used for this second analysis can be seen in Table 43.

Table 42: Aggregated data for the infrastructures layer

Code	City	KPI_INf1	KPI_INF2	KPI_INF3	KPI_INF4
		Smartphone penetration	Penetration ratio. Number of broadband internet subscriptions		Number of internet users (%)
			Fixed-broadband	Mobile	
AT-01	Graz	48	25.2	55.5	80.62
AT-02	Innsbruck	48	25.2	55.5	80.62
BE-01	Ghent	33.5	34.1	33.7	82.17
BE-02	Liege	33.5	34.1	33.7	82.17
BE-03	Brugge	33.5	34.1	33.7	82.17
BG-01	Ruse	33	17.6	40.3	53.06
EE-01	Tartu	43	25.7	72.5	80
FI-01	Jyväskylä	45.5	30.4	106.5	91.51
FI-02	Tampere	45.5	30.4	106.5	91.51
FI-03	Turku	45.5	30.4	106.5	91.51
FR-01	La Rochelle	42.3	37.8	52.2	81.92
FR-02	Poitiers	42.3	37.8	52.2	81.92
DE-01	Aachen	39.8	34	41	83.96
DE-02	Koeln	39.8	34	41	83.96
DE-03	Leipzig	39.8	34	41	83.96
DE-04	Rosenheim	39.8	34	41	83.96
GR-01	Thessaloniki	32.5	23.5	44.5	59.87
HU-01	Miskolc	34.4	22.9	23.1	72.64
IR-01	Cork	57	22.7	64.2	78.25
IT-01	Bolzano	41.3	22.1	51.8	58.46
IT-03	Firenze	41.3	22.1	51.8	58.46
IT-04	Genova	41.3	22.1	51.8	58.46
NL-01	Eindhoven	52	39.4	61	93.96

NL-02	Utrecht	52	39.4	61	93.96
NW-01	Stavanger	67.5	36.9	84.6	95.05
NW-01	Trondheim	67.5	36.9	84.6	95.05
PT-01	Porto	32.1	22.3	32.5	62.1
PT-02	Braga	32.1	22.3	32.5	62.1
SI-01	Ljubljana	27.6	24.6	37.1	72.68
ES-01	San Sebastian	55.4	24.3	53.2	71.57
ES-02	Málaga	55.4	24.3	53.2	71.57
ES-03	Sevilla	55.4	24.3	53.2	71.57
ES-04	Valladolid	55.4	24.3	53.2	71.57
ES-05	Santa Cruz de Tenerife	55.4	24.3	53.2	71.57
SE-01	Stockholm	62.9	32.2	101.3	94.78
SE-02	Gothenburg	62.9	32.2	101.3	94.78
SE-03	Malmö	62.9	32.2	101.3	94.78
UK-01	Nottingham	62.2	34	72	89.84
UK-02	Manchester	62.2	34	72	89.84
UK-03	Bristol	62.2	34	72	89.84
UK-04	Oxford	62.2	34	72	89.84

Table 43: Aggregated data for the infrastructure layer (Only one city per country)

Code	Country	KPI_INF1	KPI_INF2	KPI_INF3	KPI_INF4
		Smartphone penetration	Penetration ratio. Number of broadband internet subscriptions		Number of internet users (%)
			Fixed-broadband	Mobile	
AT	Austria	48	25.2	55.5	80.62
BE	Belgium	33.5	34.1	33.7	82.17
BG	Bulgaria	33	17.6	40.3	53.06
EE	Estonia	43	25.7	72.5	80
FI	Finland	45.5	30.4	106.5	91.51
FR	France	42.3	37.8	52.2	81.92

DE	Germany	39.8	34	41	83.96
GR	Greece	32.5	23.5	44.5	59.87
HU	Hungary	34.4	22.9	23.1	72.64
IR	Ireland	57	22.7	64.2	78.25
IT	Italy	41.3	22.1	51.8	58.46
NL	Netherlands	52	39.4	61	93.96
NW	Norway	67.5	36.9	84.6	95.05
PT	Portugal	32.1	22.3	32.5	62.1
SI	Slovenia	27.6	24.6	37.1	72.68
ES	Spain	55.4	24.3	53.2	71.57
SE	Sweden	62.9	32.2	101.3	94.78
UK	United Kingdom	62.2	34	72	89.84

9.3 Definition of city types for the infrastructure layer

As was mentioned above, the characterization of cities taking into account their ICT features, was made using national data instead of local data due to the lack of information for most of the cities included in the list.

Following the same methodology used for the energy characterization, two analyses were done. In the first analysis, all cities of the list were taken into account and in the second analysis only one city per country was included in the study in order to avoid the influence of the number of cities from the same country of the list, because the list include countries represented by several cities (Germany, Spain…) and others represented only by one city (Ireland, Greece…).

9.3.1 Infrastructure city type definition

Taking into account the assumptions indicated in the previous section, the first clustering was done with all cities of the list. The result of this first clustering can be seen in the Table 44. As expected and can be seen in the table, all cities from the same country are included in the same group because all their KPIs have the same values.

Table 44: Clusters for infrastructure I (taking into account all cities)

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Graz	Jyväskylä	Ghent	Eindhoven	Ruse
Innsbruck	Tampere	Liege	Utrecht	Thessaloniki
Tartu	Turku	Brugge	Stavanger	Miskolc
Cork	Stockholm	La Rochelle	Trondheim	Bolzano

San Sebastian	Gothemburg	Poitiers	Nottingham	Firenze
Málaga	Malmö	Aachen	Manchester	Genova
Sevilla		Koeln	Bristol	Porto
Valladolid		Leipzig	Oxford	Braga
Santa Cruz de Tenerife		Rosenheim		Ljubljana

From these results, and using the z-normalisation for the centroids values of each cluster (that represents a city type for each of them), the values included in the following table are obtained.

Table 45: Denormalised centroids for each cluster for the infrastructure clustering I

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
KPI_INF1	52,6	54,2	38,3	61,0	35,1
KPI_INF2	24,5	31,3	34,9	36,1	22,2
KPI_INF3	57,1	103,9	41,1	72,4	40,6
KPI_INF4	75,3	93,1	82,9	92,2	62,0

The following figure represents the characterisation of these clusters using their z-normalised centroids values.

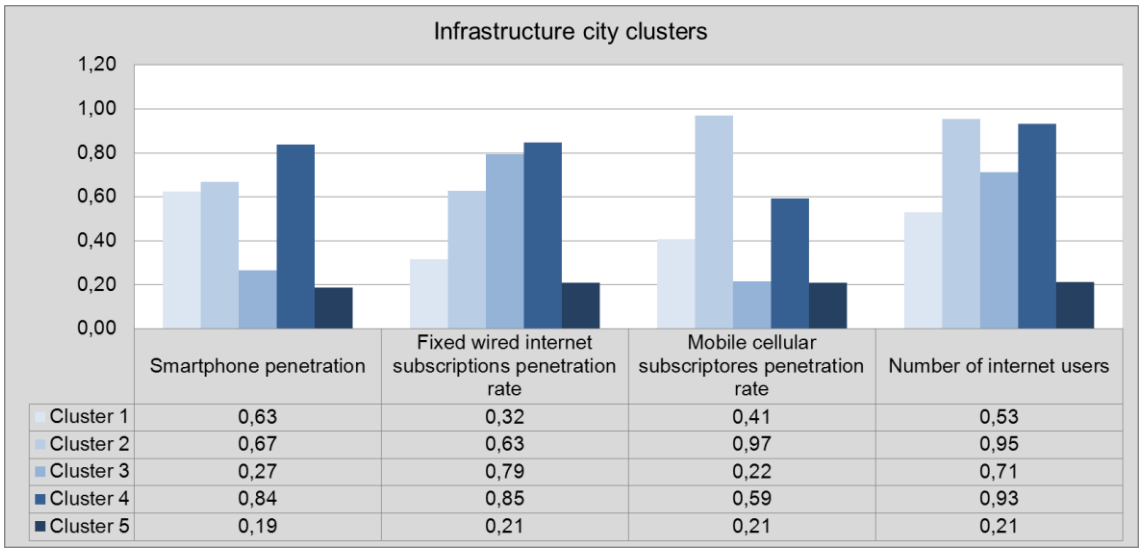


Figure 53: Representation of the absolute values of the z-normalised centroids for the infrastructure city clusters (I)

The second clustering was done using only a city per country but in each cluster, shown in the table below, all cities of the REMOURBAN list have been included taking into account the group where their country were included.

Comparing both tables (Table 44 and Table 46), the generated clusters are identical, but, as expected, the centroids are different (Table 45 and Table 47) due to the influence of the number of cities from each country in the same group.

In the case of cluster 2 (analysis I) and cluster 1 (analysis II), cities and centroids are identical because in these groups 3 cities from Finland and 3 cities Sweden are included, but for example, if the centroids of cluster 1 (analysis I) and cluster 3 (analysis II) are compared, there are a great influence of the Spanish values because in these groups there are two cities from Austria, one from Estonia, one from Ireland and five from Spain.

In order to avoid the influence of the number of cities, the characterization of cities was done using the second analysis, calculating the centroids taking into account one city per country.

Table 46: Clusters for infrastructure II (taking into account one city per country)

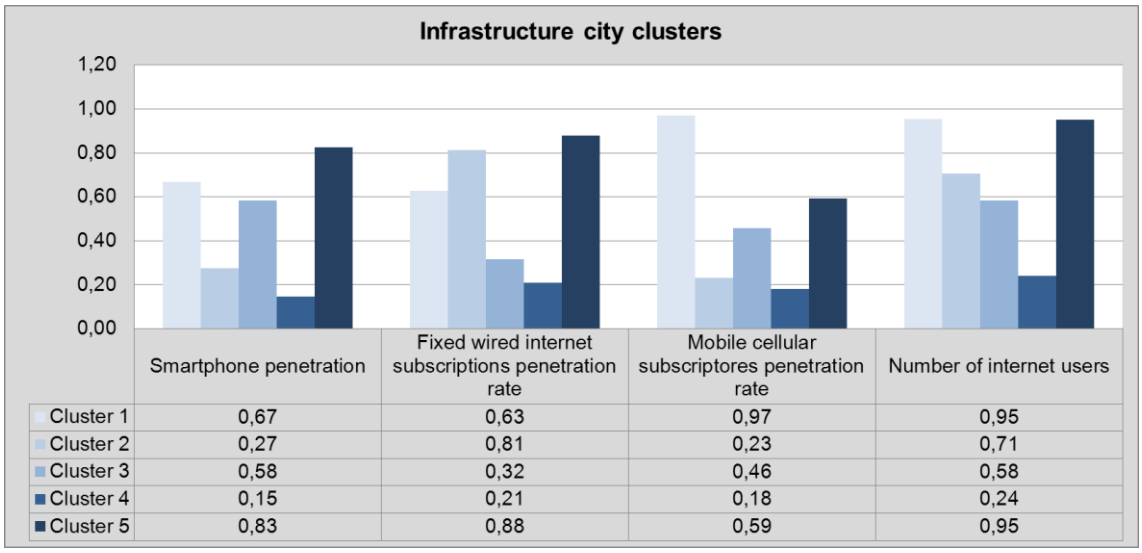
Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Jyväskylä	Ghent	Graz	Ruse	Eindhoven
Tampere	Liege	Innsbruck	Thessaloniki	Utrecht
Turku	Brugge	Tartu	Miskolc	Stavanger
Stockholm	La Rochelle	Cork	Bolzano	Trondheim
Gothenburg	Poitiers	San Sebastian-Donostia	Firenze	Nottingham
Malmö	Aachen	Málaga	Genova	Manchester
	Koeln/Köln	Sevilla	Porto	Bristol
	Leipzig	Valladolid	Braga	Oxford
	Rosenheim	Santa Cruz de Tenerife	Ljubljana	

From these results, and using the z-normalisation for the centroids values of each cluster (that represents a city type for each of them), the values included in the following table are obtained.

Table 47: Denormalised centroids for each cluster for the infrastructure clustering II

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
KPI_INF1	54,2	38,5	50,9	33,5	60,6
KPI_INF2	31,3	35,3	24,5	22,2	36,8
KPI_INF3	103,9	42,3	61,4	38,2	72,5
KPI_INF4	93,1	82,7	77,6	63,1	93,0

The following figure represents the characterisation of these clusters using their z-normalised centroids values based on the data at national level only.



	Smartphone penetration	Fixed wired internet subscriptions penetration rate	Mobile cellular subscriptores penetration rate	Number of internet users
Cluster 1	0,67	0,63	0,97	0,95
Cluster 2	0,27	0,81	0,23	0,71
Cluster 3	0,58	0,32	0,46	0,58
Cluster 4	0,15	0,21	0,18	0,24
Cluster 5	0,83	0,88	0,59	0,95

Figure 54: : Representation of the absolute values of the z-normalised centroids for the infrastructure city clusters (II)

Hence, and according to these results, the characterisation of the city types for the infrastructure layer is included in the following sections.

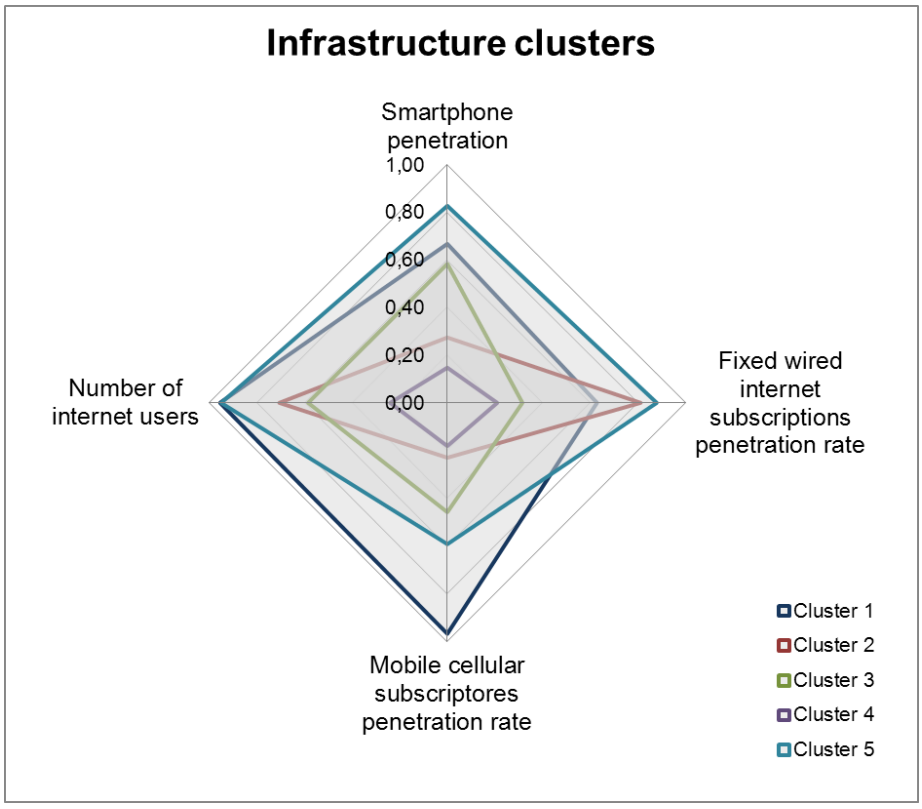


Figure 55: Radar representation of the infrastructure clusters

In the following sections, the interpretation of the clustering is based on data at national level.

9.3.2 Infrastructure city type 1

The first of the infrastructure city types includes six cities, three cities from Finland and three from Sweden.

This cluster is characterised by the highest number of Internet users and the highest subscriptions to high-speed mobile access to public internet. With a good penetration of smartphones, the cities included in this cluster, count on a good ICT infrastructure.

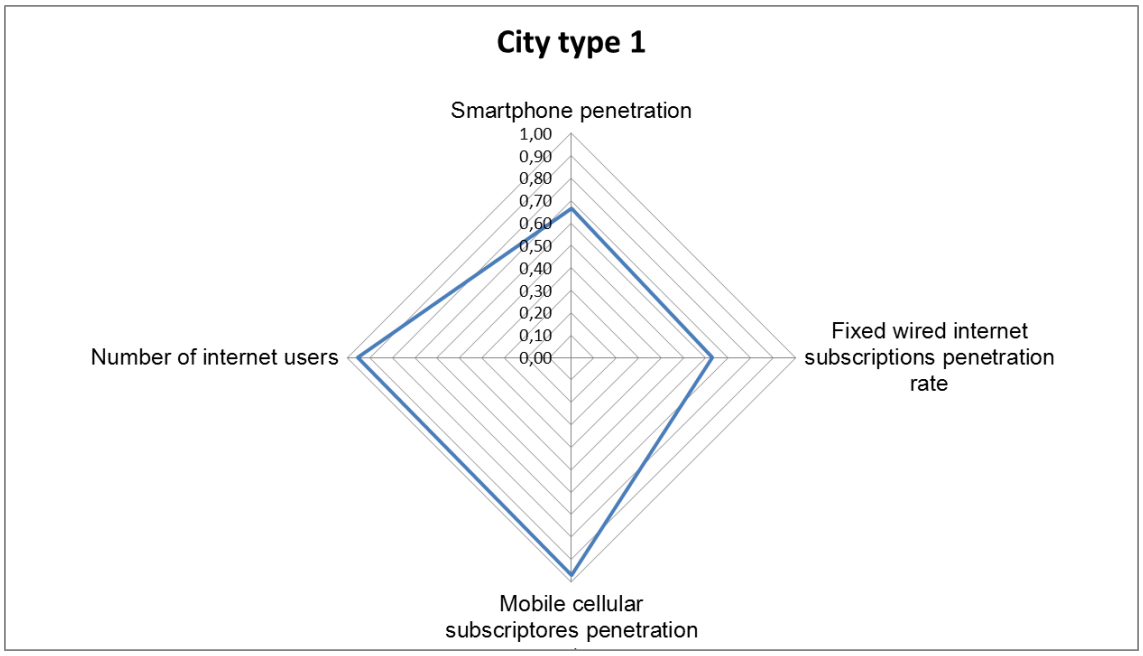


Figure 56: Infrastructure city type 1

9.3.3 Infrastructure city type 2

This infrastructure city type 2 includes all the cities of Belgium, France and Germany.

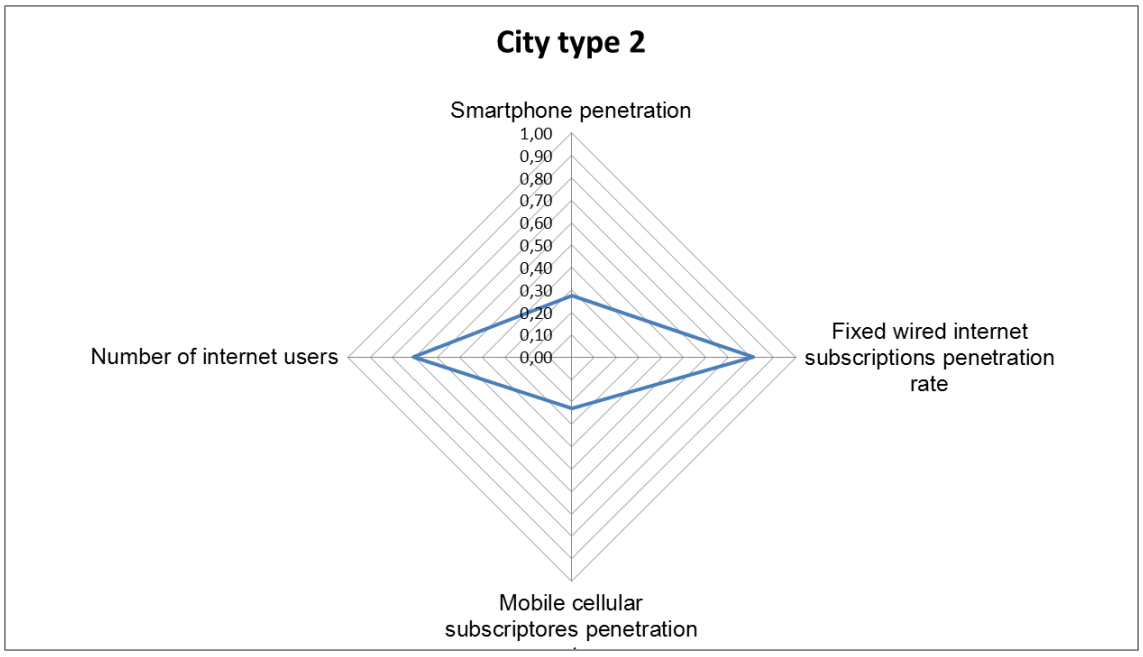


Figure 57: Infrastructure city type 2

These countries have a very good position regarding their broadband internet subscriptions using fixed broadband but analysing the graphs and the data, these cities have a lower penetration of smartphones and subscriptions to high-speed mobile access to public internet than other European cities. The reason of these values is that although the total number of

subscriptions, for example in Germany, is very high if the high population of this country is taken into account, the % of penetration is less than other European countries.

9.3.4 Infrastructure city type 3

All cities of Austria, Estonia, Ireland and Spain are into this infrastructure city type 3.

Analysing the values and the graphs of this type of cities, it can be seen that the representative values for the indicators are medium-low values, with a low number of internet users compared with the other clusters and a low penetration of fixed wired internet. Their values regarding penetration of smartphones or high-speed mobile access to public internet are also medium values compared with the other generated clusters.

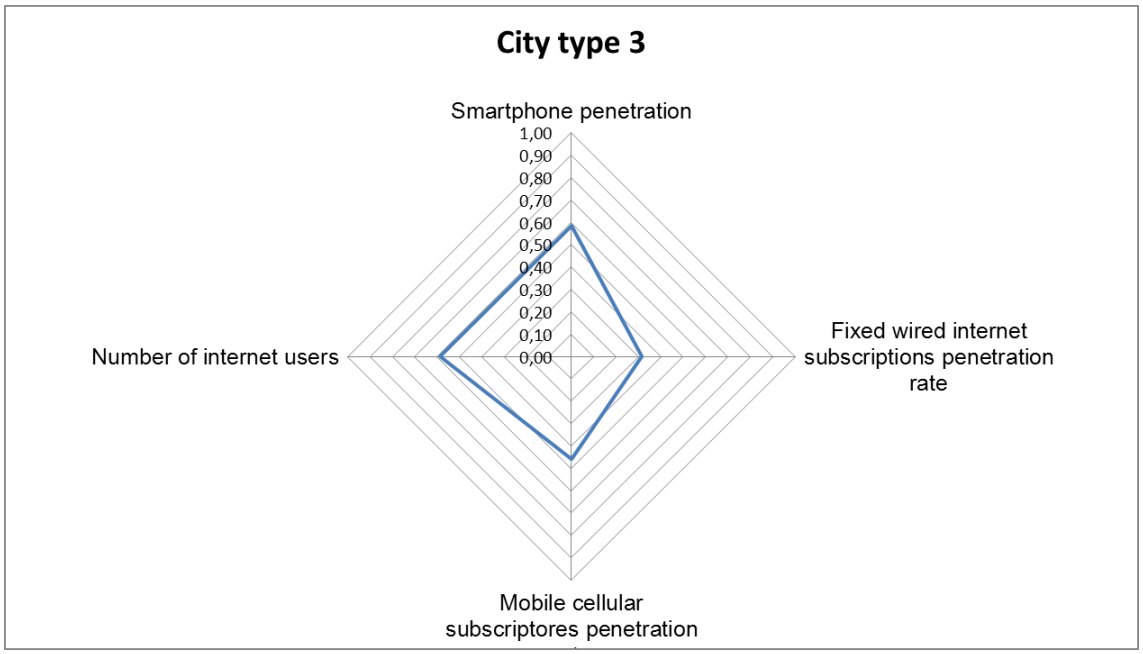


Figure 58: Infrastructure city type 3

9.3.5 Infrastructure city type 4

The infrastructure city type 4 includes all cities of Bulgary, Greece, Hungary, Italy, Portugal and Slovenia, meaning from the South and South-Eastern part of Europe.

This cluster is characterised by the lowest values in every of the four indicators of this ICT section. These cities should set up a strong ICT strategy in order to improve their situation regarding their infrastructures features.

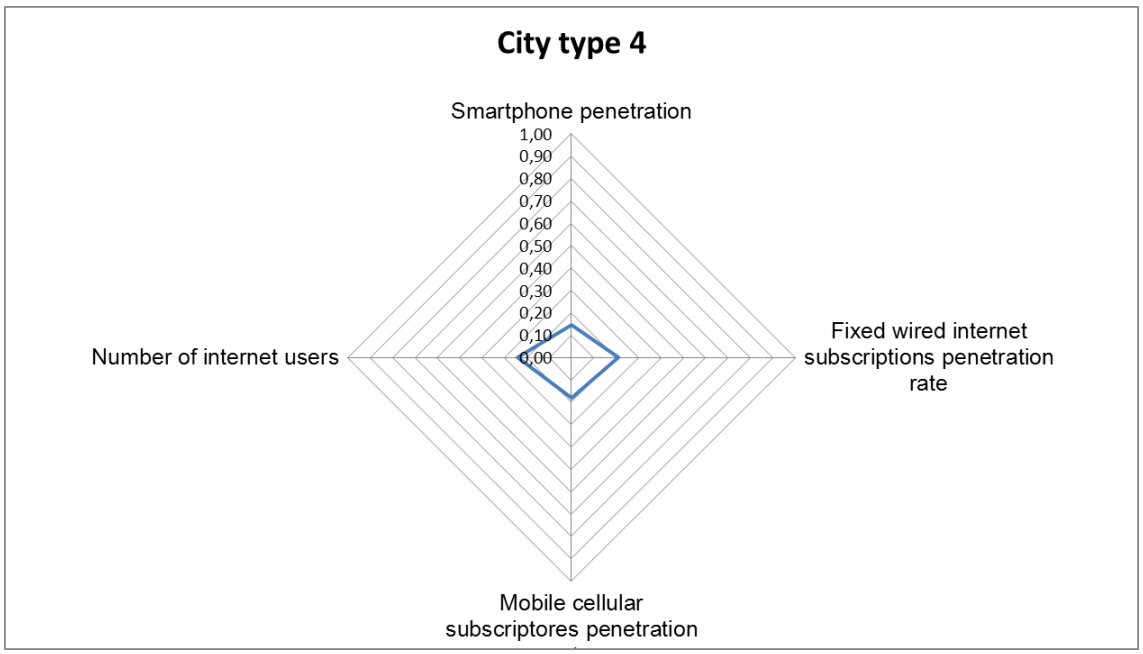


Figure 59: Infrastructure city type 4

9.3.6 Infrastructure city type 5

This fifth infrastructure city type includes all remaining cities, meaning all cities of Netherlands, Norway and UK.

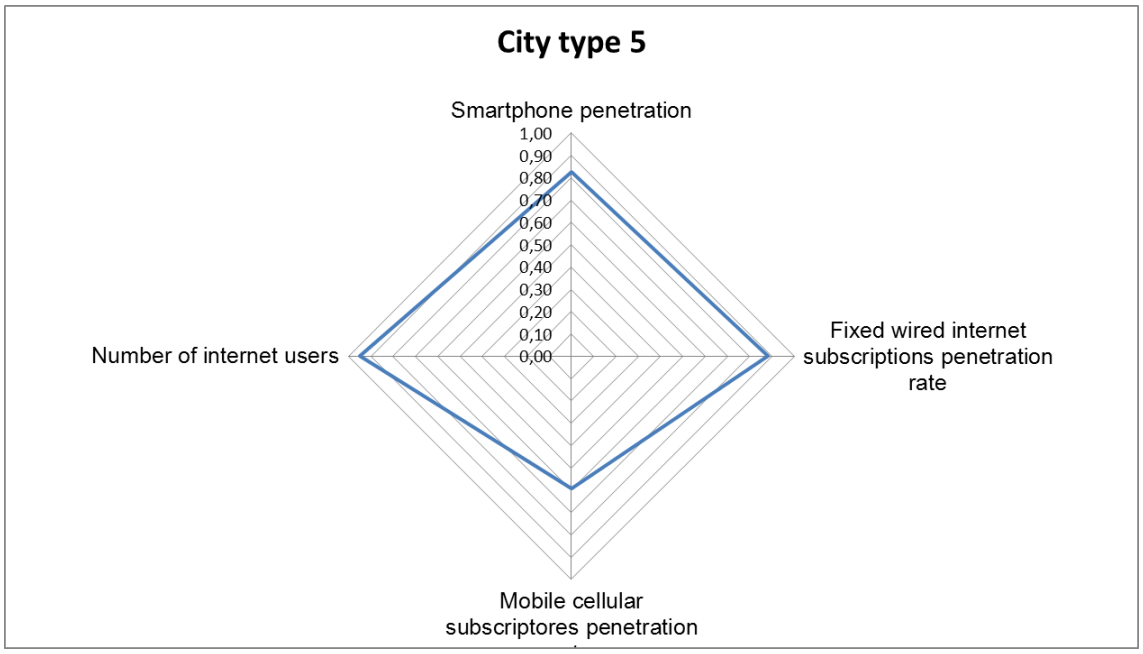


Figure 60: Infrastructure city type 5

This one is characterized by the highest results in all of the indicators. This is, therefore, the cluster where are included the most technological cities considering the selected indicators.

10 Characterisation report as basis for replication

This section deals with the definition of cities types when a global analysis is conducted taking into account all the indicators and layers. As a result, 5 groups of cities have been identified. Table below shows the cities which take part from each cluster.

Table 48: Cities' clusters in the global analysis

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Thessaloniki	Ghent	Ruse	Tampere	Graz
Porto	La Rochelle	Tartu	Turku	Innsbruck
Braga	Poitiers	Miskolc	Eindhoven	Liege
San Sebastian-Donostia	Aachen		Utrecht	Brugge
Málaga	Koeln		Stavanger	Jyväskylä
Sevilla	Cork		Trondheim	Leipzig
Valladolid	Bolzano		Stockholm	Rosenheim
Santa Cruz de Tenerife	Firenze		Nottingham	Gothenburg
	Genova		Manchester	Malmö
	Ljubljana		Bristol	Oxford

First conclusion which can be taken is the linkage of the clusters with European geographic areas as follows:

- **Cluster 1** corresponds with cities located in countries of the South of Europe (Greece, Portugal and Spain).
- **Cluster 2** corresponds with cities located mainly in countries of the Centre of Europe (France, Italy, Slovenia, and Belgium). This cluster also involves other countries such as Germany and Ireland.
- **Cluster 3** corresponds with cities located in countries of the East of Europe (Bulgaria, Estonia and Hungary).
- **Cluster 4** corresponds with cities located in Scandinavian countries (Finland, Norway, Sweden), UK and Netherlands.
- **Cluster 5** corresponds with cities located in diverse geographic zones. North countries (Austria, Germany), Scandinavian area (Sweden, Finland), Belgium and UK.

In order to characterize these clusters, centroid values for each performance indicator are shown in Table 49, where the minimum and maximum values for each indicator have been identified in each cluster with the objective of finding the potential and failures of the cities analysed.

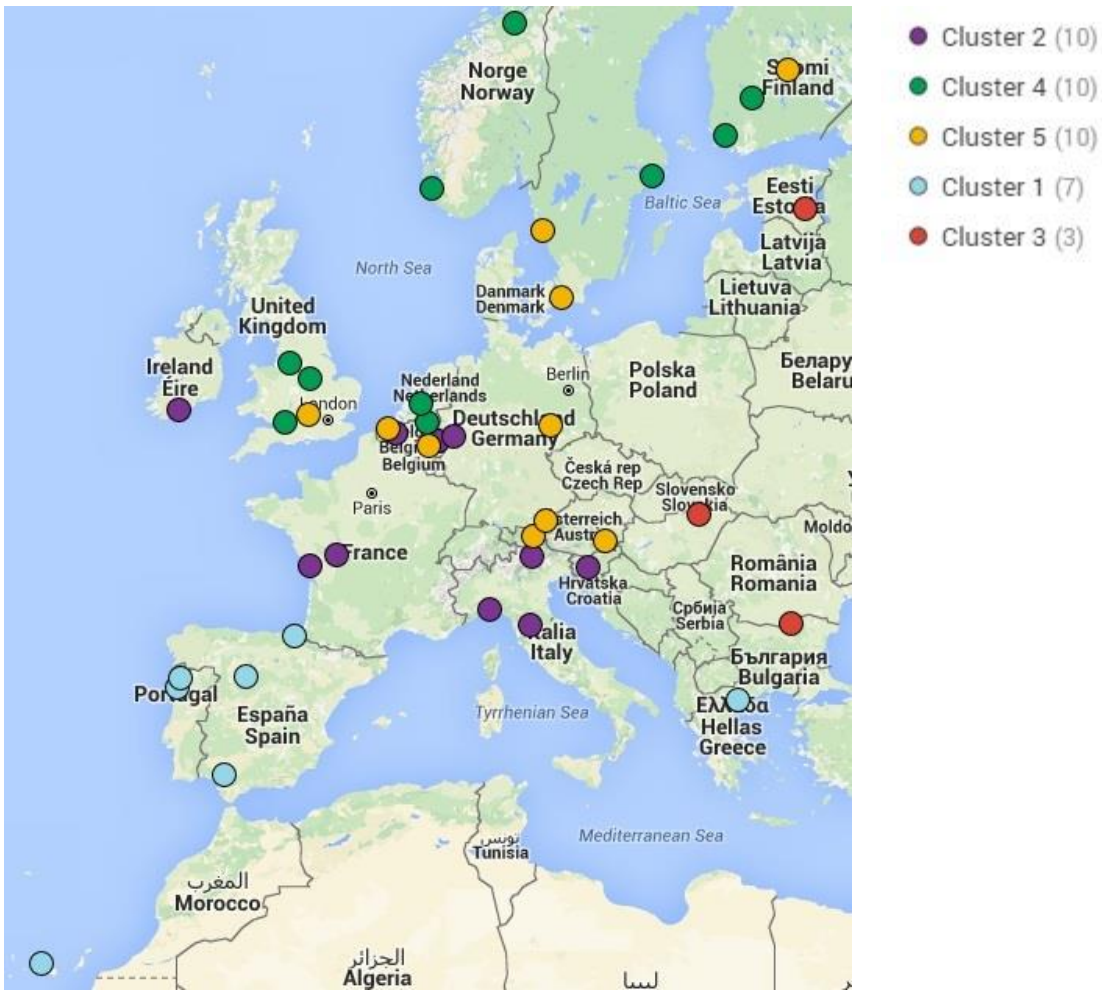


Figure 61: Map representing the global clusters

As a result of representing the best and worst values in green and red colours, respectively, table below is obtained. Intermediate values are shown in orange.

Most positive values	
Intermediate values	
Less positive values	

It has to be mentioned that in some cases, green colour is used for highest values whereas in other cases, this colour is linked with lowest values. The same occurs for red colour. On the other hand, there are some exceptions (e.g. population, area, foreigners) that highest values are being underlined with green, but it does not represent a positive value. Concerning the indicators of governance, given that data are not quantitative; these are being unified for a better understanding.

Table 49: Denormalised centroids for each cluster

KPI		Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Population density	MG_PC1	3.265,09	2.324,38	1.515,38	2.614,38	1.785,11
Population	MG_PC2	395.193,13	312.499,50	139.830,33	331.817,90	236.411,80
Area	MG_PC3	160,66	139,18	134,21	184,72	152,97
Elevation	MG_PC4	130,38	95,50	77,73	36,15	179,90
Population dependency ratio	MG_P1	31,76	33,52	31,25	29,16	31,15
Annual population change	MG_P2	-2.089,75	4.154,58	-880,33	4.697,70	3.202,60
Foreigners as a proportion of population	MG_P3	6,04	9,44	2,11	5,80	10,02
Students in higher education	MG_P4	34.339,50	35.805,00	14.849,67	33.294,00	28.951,70
Youth unemployment rate	MG_P5	50,08	21,81	21,83	14,87	15,46
Number of public libraries	MG_P6	0,27	0,82	1,43	0,44	1,25
Median population age	MG_P7	41,36	41,76	38,86	34,50	38,80
Voter turnout in last municipal election	MG_P8	61,54	62,13	54,36	51,51	70,87
Percentage of the city's solid waste that it is recycled	MG_P9	27,61	41,63	32,93	42,25	48,80

Governance: Existence of local initiatives/plans	**MG_G1**	-	-	-	-	-
GDP per inhabitant	**FI1**	84,69	125,95	40,60	134,06	117,65
Average disposable income	**FI2**	12.512,50	17.152,40	7.400,00	16.640,00	19.101,50
City unemployment rate	**FI3**	18,83	9,74	9,63	7,73	8,44
Proportion of working age population with higher education	**FI4**	28,43	27,44	25,80	40,00	35,38
GDP per inhabitant in PPS	**FI5**	21.412,50	33.980,00	11.000,00	33.690,00	30.280,00
Share of electricity in final energy consumptions in households	**EN1**	40,95	22,32	25,43	39,43	27,76
Share of gas in final energy consumptions in households	**EN2**	16,41	36,48	19,83	34,78	26,39
Share of Renewable Energies in final energy consumption in households	**EN3**	22,40	16,84	29,73	10,04	14,54
Final energy consumption in households	**EN4**	3,54	5,95	9,42	8,51	7,32
GHG emissions for households	**EN5**	1.295,06	1.493,60	2.009,73	1.636,82	1.382,10
Private car ratio	**MO1**	465,61	470,49	377,13	372,65	417,51
People killed in road accidents (per 10000 population)	**MO2**	0,49	0,33	0,60	0,20	0,20
Modal Split. Use of private motor vehicle	**MO3**	48,25	55,80	27,67	49,40	49,40

Modal Split. Walk	**MO4**	28,50	20,00	34,33	21,40	18,30
Modal Split. Bike	**MO5**	2,89	10,00	4,00	12,30	15,40
Modal Split. Passenger transport	**MO6**	20,36	14,20	33,67	16,80	16,90
Percentage of Electrical Vehicle (EV)	**MO7**	0,13	0,46	0,54	2,62	0,86
GHG emissions per capita from transportation	**MO8**	1,66	2,07	1,32	2,23	2,17
Smartphone penetration	**IN1**	46,71	40,62	36,80	57,95	47,61
Fixed wired internet subscriptions	**IN2**	23,70	29,13	22,07	34,76	31,54
Mobile cellular subscriptions	**IN3**	46,94	47,68	45,30	82,15	64,15
Number of internet users	**IN4**	67,74	74,02	68,57	92,53	86,44

Finally, with the aim to reflect how replicable REMOURBAN is, table below has been drawn with the aim to identify from each city cluster which sectors (energy, mobility and ICT) have a better opportunity for the urban transformation as well which are the key enablers (people, governance and financing issues).

Thus, taking into account the characterization of each indicator, as well as the data obtained in the other clusters, each layer has been typified in a colour code (green, orange and red) according with the prevalence of positive or negative features.

Most positive values

Intermediate values

Less positive values

It should be noted that physical layer has not been included since the physical features of a city (i.e. area, population) do not show any good or bad position in the way towards the urban transformation.

Table 50: Characterization of European Cities by layers

	People	Governance	Finance	Mobility	Energy	Infrastructures
Cluster 1						
Cluster 2						
Cluster 3						
Cluster 4						
Cluster 5						

Finally, next tables summaries the main characteristics of each cluster for each layer.

Table 51: Characterization of European Cities belong to Cluster 1

Cluster 1 (South)	Descriptions
People	(-) Cities which lost population. High youth unemployment ratio. Low recycling ratio (+) High ratio of population with higher education
Governance	Cities which have developed a large number of plans and strategies for a sustainable urban model
Finance	High ratio of unemployment, bad position in GDP and disposable income
Mobility	Modal split: private motor vehicle. Scarce use of bike or electrical vehicle.

	High private car ratio
Energy	Cities with low energy consumption in households and good position in use of RES. Electricity as main final energy consumption. Low GHG emissions.
Infrastructures	Low number of internet users. Intermediate position in Smartphone use.

Table 52: Characterization of European Cities belong to Cluster 2

Cluster 2 (Centre)	Descriptions
People	Cities which gain population. High ratio of population with higher education Also, cities with aging population
Governance	Cities which have developed a large number of plans and strategies for a sustainable urban model
Finance	Good position in GDP and disposable income
Mobility	Cities with highest private car ratio. Predominance of car in the modal split.
Energy	Cities with low energy consumption in households and intermediate position in use of RES. Gas natural as main final energy consumption.
Infrastructures	Intermediate position in use of internet and smartphone

Table 53: Characterization of European Cities belong to Cluster 3

Cluster 3 (East)	Descriptions
People	Cities which lost population. Low ratio of population with higher education. Low voter ratio
Governance	Cities which have developed some plans and strategies for a sustainable urban model
Finance	Bad position in GDP and disposable income. Intermediate unemployment ratio. Low proportion of working age population with higher education
Mobility	Predominance of walking as type of transportation. Scarce use of car, but high frequency of accidents
Energy	Cities with low energy consumption in households and good position in use of RES.
Infrastructures	Bad position in use of internet, mobiles or smartphone

Table 54: Characterization of European Cities belong to Cluster 4

Cluster 4 (Scandinavia)	Descriptions
People	Cities which gain population. Low youth unemployment. Low voter ratio. Less aging population
Governance	Cities which have developed a large number of plans and strategies for a sustainable urban model
Finance	Good position in GDP and intermediate disposable income. Low unemployment ratio. High proportion of working age population with higher education
Mobility	Cities with lowest private car ratio and intermediate use of private car. Intermediate share of bike and walking. Good position in use of Electrical Vehicle
Energy	Cities with higher energy consumption in households and worst position in use of RES. Prevalence of gas natural as fuel
Infrastructures	Good position in use of internet, mobiles or smartphone

Table 55: Characterization of European Cities belong to Cluster 5

Cluster 5 (Scandinavia + North)	Descriptions
People	Cities which gain population. Low youth unemployment. High voter and recycling ratio. Less aging population
Governance	Most cities have developed some plans and strategies for a sustainable urban model. Three cities with a few plans and strategies (Agenda 21, Smart Cities strategies)
Finance	Intermediate position in GDP and good disposable income.
Mobility	Cities with highest bike ratio and intermediate use of private car. Scarce practice of walking. Intermediate position in car purchase. Low GHG emissions
Energy	Cities with intermediate energy consumption in households and bad position in use of RES. Similar share for gas natural and electricity in the final energy consumption
Infrastructures	Intermediate position in use of internet, mobiles or smartphone

These tables, which describe the potentials and barriers found in the European cities analysed, provide an initial approach about which actions should be taken in order to conduct these cities towards the sustainability.

Finally, it has been analysed if there is any correlation among the two procedures for the characterization of the cities: analysis by separate layers and global analysis. Tables below pretend to identify the linkage of clusters with geographic areas and if the same cities and countries are merged in the same groups.

Table 56: Analysis of correlation among characterization procedures concerning geographic areas

Cluster	Global analysis	People	Governance	Finance	Mobility	Energy	Infrastructures
Cluster 1	**CITIES** Thessaloniki Porto Braga San Sebastian-Donostia Málaga Sevilla Valladolid Santa Cruz de Tenerife	**CITIES** San Sebastian-Donostia Málaga Sevilla Valladolid Santa Cruz de Tenerife Firenze Genova Porto	**CITIES** Innsbruck Liege Jyväskylä	**CITIES** Graz Innsbruck Brugge Aachen Koeln/Köln Rosenheim Bolzano Firenze Genova Eindhoven	**CITIES** Liege Valladolid Santa Cruz de Tenerife Jyväskylä La Rochelle Poitiers Thessaloniki Cork Firenze	**CITIES** Ghent Liege Brugge La Rochelle Poitiers Miskolc Cork Bolzano Firenze Genova Eindhoven Utrecht Nottingham Manchester Bristol Oxford	**CITIES** Jyväskylä Tampere Turku Stockholm Gothenburg Malmö
	Greece, Portugal, Spain **"South countries"**	Portugal, Spain, Italy **"South countries"**	Belgium, Austria, Finland **"North/Centre/ Scandinavia"**	Belgium, Netherland Germany, Austria, Italy, **"North/Centre countries"**	Belgium, Austria, France, Italy, Finland, Ireland **"North/Centre/ Scandinavia"**	Belgium, France, Hungary, Ireland, Italy, Netherland, UK "North, Centre, East"	Finland, Sweden **"Scandinavian countries"**

Cluster 2	**CITIES** Ghent La Rochelle Poitiers Aachen Koeln/Köln Cork Bolzano Firenze Genova Ljubljana	**CITIES** Graz Innsbruck Ghent Liege Aachen Koeln/Köln Stockholm Gothenburg	**CITIES** Graz Ruse Leipzig Rosenheim Poitiers	**CITIES** Ruse Tartu Thessaloniki Miskolc Braga	**CITIES** Eindhoven Utrecht Stavanger Trondheim	**CITIES** Ruse	**CITIES** Ghent Liege Brugge La Rochelle Poitiers Aachen Koeln/Köln Leipzig Rosenheim
	Belgium, Germany, France, Italy, Slovenia, Ireland **"North/Centre"**	Belgium, Austria, Germany, Sweden **"North/Centre/ Scandinavia"**	Austria, Germany, France, Bulgaria **"All geographic areas"**	Bulgaria, Estonia, Hungary, Greece, Portugal **"East/South"**	Norway, Netherlands **"North/ Scandinavia"**	Bulgaria **"East"**	Belgium, Germany, France **"North countries"**
Cluster 3	**CITIES** Miskolc Ruse Tartu	**CITIES** Brugge Ruse Leipzig Rosenheim La Rochelle Bolzano Eindhoven Ljubljana	**CITIES** Brugge Tartu Miskolc Oxford	**CITIES** Ghent San Sebastian-Donostia Cork Utrecht Stavanger Trondheim Stockholm Gothenburg Bristol Oxford	**CITIES** Ruse Málaga Sevilla Bolzano Porto Braga	**CITIES** Aachen Koeln/Köln Leipzig Rosenheim San Sebastian-Donostia Málaga Sevilla Valladolid Santa Cruz de Tenerife	**CITIES** Graz Innsbruck Tartu Cork San Sebastian-Donostia Málaga Sevilla Valladolid Santa Cruz de Tenerife

	Hungary, Bulgaria, Estonia **"East"**	Belgium, Netherland, Germany, France, Italy, Bulgaria, Slovenia **"North, Centre, East"**	Belgium, Estonia, Hungary, UK **"All geographic areas"**	Norway, Sweden, UK, Ireland, Belgium, Spain **"Scandinavia, North, South"**	Bulgaria, Italy, Spain, Portugal **"East, South, Centre"**	Germany, Spain **"North, South"**	Austria, Estonia, Ireland, Spain **"North, South, East"**
Cluster 4	**CITIES** Tampere Turku Eindhoven Utrecht Stavanger Trondheim Stockholm Nottingham Manchester Bristol	**CITIES** Cork Utrecht Stavanger Trondheim Malmö Nottingham Manchester Bristol Oxford	**CITIES** Aachen Koeln/Köln San Sebastian Málaga Sevilla Valladolid Santa Cruz de Tenerife Tampere Turku La Rochelle Thessaloniki Cork Bolzano Firenze Genova Eidnhoven Utrecht	**CITIES** Liege Leipzig Valladolid Jyväskylä Tampere Turku La Rochelle Poitiers Malmö Ljubljana Nottingham	**CITIES** Graz Innsbruck Ghent Brugge Aachen Koeln/Köln Leipzig Rosenheim Tampere	**CITIES** Stavanger Trondheim Stockholm Gothenburg Malmö	**CITIES** Ruse Thessaloniki Miskolc Bolzano Firenze Genova Porto Braga Ljubljana
	Finland, Norway Sweden, Netherlands U.K. **"Scandinavia, UK"**	Norway, Sweden, Netherland, Ireland, UK **"Scandinavia, Ireland"**		Finland, Sweden, Belgium, Germany, France, Slovenia, Spain, UK **"Scandinavia, North, Centre, South"**	Finland, Belgium, Austria, Germany **"Scandinavia, North, Centre"**	Norway, Sweden **"Scandinavian countries"**	Bulgaria, Greece, Hungary, Italy, Portugal, Slovenia **"East, South, Centre"**

Cluster 5	**CITIES** Graz Innsbruck Liege Brugge Jyväskylä Leipzig Rosenheim Gothenburg Malmö Oxford	**CITIES** Tartu Jyväskylä Tampere Turku Poitiers Thessaloniki Miskolc Braga	Stavanger Trondheim Porto Stockholm Ljubljana Nottingham Manchester Bristol Ghent Gothenburg Malmö	**CITIES** Málaga Sevilla Santa Cruz de Tenerife Porto	**CITIES** Tartu San Sebastian-Donostia Miskolc	**CITIES** Graz Innsbruck Tartu Jyväskylä Tampere Turku Thessaloniki Porto Braga Ljubljana	**CITIES** Eindhoven Utrecht Stavanger Trondheim Nottingham Manchester Bristol Oxford
	Finland, Sweden, Austria, Belgium, Germany, U.K. **"Scandinavia, centre, UK"**	Finland, France, Estonia, Hungary, Portugal and Greece **"Scandinavia, centre, south, east"**	Finland, Belgium, Germany, France, Italy, Greece, Spain, Ireland, Sweden, UK, Portugal, Slovene **"Scandinavia, North, Centre, South**	Spain, Portugal **"South"**	Spain, Estonia, Hungary **"South, East"**	Austria, Estonia, Finland, Greece, Portugal, Slovenia **"North, South, Centre, Scandinavia"**	Netherland, Norway, UK **"North, Scandinavian countries"**

Table 57: Summary of two clustering levels for the cities

CLUSTER 1								
Global Cluster		**Management**			**Finance**	**Energy**	**Mobility**	**Infrastructures**
		Physical Char.	**People**	**Governance**				
Cluster 1	**Global**	-						
	Thessaloniki	PC2 Very high population density with low area	P5 Very low dependency population dependency ratio and extremely low level of population change	G4 CoM signed with sustainability and mobility plans	F2 Very low disposable income and very low economic activity with a relatively low city unemployment rate	E5 Very high rate of RES with medium level of final energy consumption in households resulting in low GHG emissions	M1 Very high rate of vehicles and very high value of private vehicles with low EV and bike use resulting in a high level of GHG emissions	I4 Very low number of internet users and very low levels of mobile and smartphone penetration
	Porto	PC2 Very high population density with low area	P1 High rate of youth unemployment and low level of public libraries	G4 CoM signed with sustainability and mobility plans	F5 Very low disposable income, very low economic activity and very high unemployment rate	E5 Very high rate of RES with medium level of final energy consumption in households resulting in low GHG emissions	M3 Very high rate of vehicles and very low level of road safety but with a high level of walking and public transport modes resulting in a low level of GHG emissions	I4 Very low number of internet users and very low levels of mobile and smartphone penetration

CLUSTER 1								
Global Cluster		**Management**			**Finance**	**Energy**	**Mobility**	**Infrastructures**
		Physical Char.	**People**	**Governance**				
	Braga	PC3 Low population density and small city area	P5 Very low dependency population dependency ratio and extremely low level of population change	G4 CoM signed with sustainability and mobility plans	F2 Very low disposable income and very low economic activity with a relatively low city unemployment rate	E5 Very high rate of RES with medium level of final energy consumption in households resulting in low GHG emissions	M3 Very high rate of vehicles and very low level of road safety but with a high level of walking and public transport modes resulting in a low level of GHG emissions	I4 Very low number of internet users and very low levels of mobile and smartphone penetration
	San Sebastian	PC3 Low population density and small city area	P1 High rate of youth unemployment and low level of public libraries	G4 CoM signed with sustainability and mobility plans	F3 Very high disposable income, very low unemployment rate with relevant economic activity with a high level of working age population with higher education	E3 Relatively low rate of RES with a very low final energy consumption in households resulting in low GHG emissions	M5 Very low rate of vehicles and very high level of walk and public transport modes with a relatively low level of road safety	I3 Medium level of internet users with relatively high levels of mobile and smartphone penetration

CLUSTER 1								
Global Cluster		Management			Finance	Energy	Mobility	Infrastructures
		Physical Char.	People	Governance				
	Málaga	PC4 Low population density and big city area	P1 High rate of youth unemployment and low level of public libraries	G4 CoM signed with sustainability and mobility plans	F5 Very low disposable income, very low economic activity and very high unemployment rate	E3 Relatively low rate of RES with a very low final energy consumption in households resulting in low GHG emissions	M3 Very high rate of vehicles and very low level of road safety but with a high level of walking and public transport modes resulting in a low level of GHG emissions	I3 Medium level of internet users with relatively high levels of mobile and smartphone penetration
	Sevilla	PC2 Very high population density with low area	P1 High rate of youth unemployment and low level of public libraries	G4 CoM signed with sustainability and mobility plans	F5 Very low disposable income, very low economic activity and very high unemployment rate	E3 Relatively low rate of RES with a very low final energy consumption in households resulting in low GHG emissions	M3 Very high rate of vehicles and very low level of road safety but with a high level of walking and public transport modes resulting in a low level of GHG emissions	I3 Medium level of internet users with relatively high levels of mobile and smartphone penetration

CLUSTER 1								
Global Cluster		**Management**			**Finance**	**Energy**	**Mobility**	**Infrastructures**
		Physical Char.	**People**	**Governance**				
	Valladolid	PC5 Low population density and small city area in very elevated areas	P1 High rate of youth unemployment and low level of public libraries	G4 CoM signed with sustainability and mobility plans	F4 Medium disposable income and medium economic activity with a relevant rate of unemployment	E3 Relatively low rate of RES with a very low final energy consumption in households resulting in low GHG emissions	M1 Very high rate of vehicles and very high value of private vehicles with low EV and bike use resulting in a high level of GHG emissions	I3 Medium level of internet users with relatively high levels of mobile and smartphone penetration
	Santa Cruz de Tenerife	PC3 Low population density and small city area	P1 High rate of youth unemployment and low level of public libraries	G4 CoM signed with sustainability and mobility plans	F5 Very low disposable income, very low economic activity and very high unemployment rate	E3 Relatively low rate of RES with a very low final energy consumption in households resulting in low GHG emissions	M1 Very high rate of vehicles and very high value of private vehicles with low EV and bike use resulting in a high level of GHG emissions	I3 Medium level of internet users with relatively high levels of mobile and smartphone penetration

CLUSTER 2								
Global Cluster		Management			Finance	Energy	Mobility	Infrastructures
		Physical Char.	People	Governance				
Cluster 2	Global	-						
	Ghent	PC3 Low population density and small city area	P2 Low youth unemployment rate and very high rate of recycling	G4 CoM signed with sustainability and mobility plans	F3 Very high disposable income, very low unemployment rate with relevant economic activity with a high level of working age population with higher education	E1 Low rate of RES with a relatively low final energy consumption in households and high GHG emissions	M4 Medium rate of vehicles with a very low EV penetration resulting in a relatively high level of GHG emissions	I2 Very high number of internet users with relatively low levels of mobile and smartphone penetration
	La Rochelle	PC3 Low population density and small city area	P3 Low youth unemployment rate and low level of students in higher/tertiary education	G4 CoM signed with sustainability and mobility plans	F4 Medium disposable income and medium economic activity with a relevant rate of unemployment	E1 Low rate of RES with a relatively low final energy consumption in households and high GHG emissions	M1 Very high rate of vehicles and very high value of private vehicles with low EV and bike use resulting in a high level of GHG emissions	I2 Very high number of internet users with relatively low levels of mobile and smartphone penetration

CLUSTER 2								
Global Cluster		Management			Finance	Energy	Mobility	Infrastructures
		Physical Char.	People	Governance				
	Poitiers	PC3 Low population density and small city area	P5 Very low dependency population dependency ratio and extremely low level of population change	G2 CoM not signed and lack of sustainability plans	F4 Medium disposable income and medium economic activity with a relevant rate of unemployment	E1 Low rate of RES with a relatively low final energy consumption in households and high GHG emissions	M1 Very high rate of vehicles and very high value of private vehicles with low EV and bike use resulting in a high level of GHG emissions	I2 Very high number of internet users with relatively low levels of mobile and smartphone penetration
	Aachen	PC3 Low population density and small city area	P2 Low youth unemployment rate and very high rate of recycling	G4 CoM signed with sustainability and mobility plans	F1 Very high disposable income, very low unemployment rate, relevant GDP with low level of working people with higher education	E3 Relatively low rate of RES with a very low final energy consumption in households resulting in low GHG emissions	M4 Medium rate of vehicles with a very low EV penetration resulting in a relatively high level of GHG emissions	I2 Very high number of internet users with relatively low levels of mobile and smartphone penetration

CLUSTER 2								
Global Cluster		Management			Finance	Energy	Mobility	Infrastructures
		Physical Char.	People	Governance				
	Koeln	PC1 High population and big city area	P2 Low youth unemployment rate and very high rate of recycling	G4 CoM signed with sustainability and mobility plans	F1 Very high disposable income, very low unemployment rate, relevant GDP with low level of working people with higher education	E3 Relatively low rate of RES with a very low final energy consumption in households resulting in low GHG emissions	M4 Medium rate of vehicles with a very low EV penetration resulting in a relatively high level of GHG emissions	I2 Very high number of internet users with relatively low levels of mobile and smartphone penetration
	Cork	PC3 Low population density and small city area	P4 Low median population age and high number of foreigners with very high levels of population movement	G4 CoM signed with sustainability and mobility plans	F3 Very high disposable income, very low unemployment rate with relevant economic activity with a high level of working age population with higher education	E1 Low rate of RES with a relatively low final energy consumption in households and high GHG emissions	M1 Very high rate of vehicles and very high value of private vehicles with low EV and bike use resulting in a high level of GHG emissions	I3 Medium level of internet users with relatively high levels of mobile and smartphone penetration

CLUSTER 2								
Global Cluster		Management			Finance	Energy	Mobility	Infrastructures
		Physical Char.	People	Governance				
	Bolzano	PC3 Low population density and small city area	P3 Low youth unemployment rate and low level of students in higher/tertiary education	G4 CoM signed with sustainability and mobility plans	F1 Very high disposable income, very low unemployment rate, relevant GDP with low level of working people with higher education	E1 Low rate of RES with a relatively low final energy consumption in households and high GHG emissions	M3 Very high rate of vehicles and very low level of road safety but with a high level of walking and public transport modes resulting in a low level of GHG emissions	I4 Very low number of internet users and very low levels of mobile and smartphone penetration
	Firenze	PC2 Very high population density with low area	P1 High rate of youth unemployment and low level of public libraries	G4 CoM signed with sustainability and mobility plans	F1 Very high disposable income, very low unemployment rate, relevant GDP with low level of working people with higher education	E1 Low rate of RES with a relatively low final energy consumption in households and high GHG emissions	M1 Very high rate of vehicles and very high value of private vehicles with low EV and bike use resulting in a high level of GHG emissions	I4 Very low number of internet users and very low levels of mobile and smartphone penetration

CLUSTER 2								
Global Cluster		**Management**			**Finance**	**Energy**	**Mobility**	**Infrastructures**
		Physical Char.	**People**	**Governance**				
	Genova	PC1 High population and big city area	P1 High rate of youth unemployment and low level of public libraries	G4 CoM signed with sustainability and mobility plans	F1 Very high disposable income, very low unemployment rate, relevant GDP with low level of working people with higher education	E1 Low rate of RES with a relatively low final energy consumption in households and high GHG emissions	M1 Very high rate of vehicles and very high value of private vehicles with low EV and bike use resulting in a high level of GHG emissions	I4 Very low number of internet users and very low levels of mobile and smartphone penetration
	Ljubljana	PC5 Low population density and small city area in very elevated areas	P3 Low youth unemployment rate and low level of students in higher/tertiary education	G4 CoM signed with sustainability and mobility plans	F4 Medium disposable income and medium economic activity with a relevant rate of unemployment	E5 Very high rate of RES with medium level of final energy consumption in households resulting in low GHG emissions	M4 Medium rate of vehicles with a very low EV penetration resulting in a relatively high level of GHG emissions	I4 Very low number of internet users and very low levels of mobile and smartphone penetration

CLUSTER 3								
Global Cluster		Management			Finance	Energy	Mobility	Infrastructures
		Physical Char.	People	Governance				
Cluster 3	Global	-						
	Ruse	PC3 Low population density and small city area	P3 Low youth unemployment rate and low level of students in higher/tertiary education	G2 CoM not signed and lack of sustainability plans	F2 Very low disposable income and very low economic activity with a relatively low city unemployment rate	E2 High rate of RES with a very high final energy consumption in households resulting in very high GHG emissions	M3 Very high rate of vehicles and very low level of road safety but with a high level of walking and public transport modes resulting in a low level of GHG emissions	I4 Very low number of internet users and very low levels of mobile and smartphone penetration
	Tartu	PC3 Low population density and small city area	P5 Very low dependency population dependency ratio and extremely low level of population change	G3 CoM signed and lack of sustainability plans	F2 Very low disposable income and very low economic activity with a relatively low city unemployment rate	E5 Very high rate of RES with medium level of final energy consumption in households resulting in low GHG emissions	M5 Very low rate of vehicles and very high level of walk and public transport modes with a relatively low level of road safety	I3 Medium level of internet users with relatively high levels of mobile and smartphone penetration

CLUSTER 3								
Global Cluster		Management			Finance	Energy	Mobility	Infrastructures
		Physical Char.	People	Governance				
	Miskolc	PC3 Low population density and small city area	P5 Very low dependency population dependency ratio and extremely low level of population change	G3 CoM signed and lack of sustainability plans	F2 Very low disposable income and very low economic activity with a relatively low city unemployment rate	E1 Low rate of RES with a relatively low final energy consumption in households and high GHG emissions	M5 Very low rate of vehicles and very high level of walk and public transport modes with a relatively low level of road safety	I4 Very low number of internet users and very low levels of mobile and smartphone penetration

CLUSTER 4								
Global Cluster		Management			Finance	Energy	Mobility	Infrastructures
		Physical Char.	People	Governance				
Cluster 4	Global	-						
	Tampere	PC4 Low population density and big city area	P5 Very low dependency population dependency ratio and extremely low level of population change	G4 CoM signed with sustainability and mobility plans	F4 Medium disposable income and medium economic activity with a relevant rate of unemployment	E5 Very high rate of RES with medium level of final energy consumption in households resulting in low GHG emissions	M4 Medium rate of vehicles with a very low EV penetration resulting in a relatively high level of GHG emissions	I1 Very high number of internet users and very high mobile and high smartphone penetration
	Turku	PC3 Low population density and small city area	P5 Very low dependency population dependency ratio and extremely low level of population change	G4 CoM signed with sustainability and mobility plans	F4 Medium disposable income and medium economic activity with a relevant rate of unemployment	E5 Very high rate of RES with medium level of final energy consumption in households resulting in low GHG emissions	M4 Medium rate of vehicles with a very low EV penetration resulting in a relatively high level of GHG emissions	I1 Very high number of internet users and very high mobile and high smartphone penetration

CLUSTER 4								
Global Cluster		Management			Finance	Energy	Mobility	Infrastructures
		Physical Char.	People	Governance				
	Eindhoven	PC3 Low population density and small city area	P3 Low youth unemployment rate and low level of students in higher/tertiary education	G4 CoM signed with sustainability and mobility plans	F1 Very high disposable income, very low unemployment rate, relevant GDP with low level of working people with higher education	E1 Low rate of RES with a relatively low final energy consumption in households and high GHG emissions	M2 Medium rate of vehicles with a very high EV penetration but low level of walking or bike transport modes resulting in a high level of GHG emissions	I5 Very high number of internet users and high mobile and very high smartphone penetration
	Utrecht	PC3 Low population density and small city area	P4 Low median population age and high number of foreigners with very high levels of population movement	G4 CoM signed with sustainability and mobility plans	F3 Very high disposable income, very low unemployment rate with relevant economic activity with a high level of working age population with higher education	E1 Low rate of RES with a relatively low final energy consumption in households and high GHG emissions	M2 Medium rate of vehicles with a very high EV penetration but low level of walking or bike transport modes resulting in a high level of GHG emissions	I5 Very high number of internet users and high mobile and very high smartphone penetration

CLUSTER 4								
Global Cluster		Management			Finance	Energy	Mobility	Infrastructures
		Physical Char.	People	Governance				
	Stavanger	PC3 Low population density and small city area	P4 Low median population age and high number of foreigners with very high levels of population movement	G4 CoM signed with sustainability and mobility plans	F3 Very high disposable income, very low unemployment rate with relevant economic activity with a high level of working age population with higher education	E4 Non-gas consuming cities with a relatively high final energy consumption in households covered with a medium rate of RES resulting in low GHG emissions	M2 Medium rate of vehicles with a very high EV penetration but low level of walking or bike transport modes resulting in a high level of GHG emissions	I5 Very high number of internet users and high mobile and very high smartphone penetration
	Trondheim	PC4 Low population density and big city area	P4 Low median population age and high number of foreigners with very high levels of population movement	G4 CoM signed with sustainability and mobility plans	F3 Very high disposable income, very low unemployment rate with relevant economic activity with a high level of working age population with higher education	E4 Non-gas consuming cities with a relatively high final energy consumption in households covered with a medium rate of RES resulting in low GHG emissions	M2 Medium rate of vehicles with a very high EV penetration but low level of walking or bike transport modes resulting in a high level of GHG emissions	I5 Very high number of internet users and high mobile and very high smartphone penetration

CLUSTER 4								
Global Cluster		Management			Finance	Energy	Mobility	Infrastructures
		Physical Char.	People	Governance				
	Stockholm	PC2 Very high population density with low area	P2 Low youth unemployment rate and very high rate of recycling	G4 CoM signed with sustainability and mobility plans	F3 Very high disposable income, very low unemployment rate with relevant economic activity with a high level of working age population with higher education	E4 Non-gas consuming cities with a relatively high final energy consumption in households covered with a medium rate of RES resulting in low GHG emissions	M4 Medium rate of vehicles with a very low EV penetration resulting in a relatively high level of GHG emissions	I1 Very high number of internet users and very high mobile and high smartphone penetration
	Nottingham	PC2 Very high population density with low area	P4 Low median population age and high number of foreigners with very high levels of population movement	G4 CoM signed with sustainability and mobility plans	F4 Medium disposable income and medium economic activity with a relevant rate of unemployment	E1 Low rate of RES with a relatively low final energy consumption in households and high GHG emissions	M4 Medium rate of vehicles with a very low EV penetration resulting in a relatively high level of GHG emissions	I5 Very high number of internet users and high mobile and very high smartphone penetration

CLUSTER 4								
Global Cluster		Management			Finance	Energy	Mobility	Infrastructures
		Physical Char.	People	Governance				
	Manchester	PC2 Very high population density with low area	P4 Low median population age and high number of foreigners with very high levels of population movement	G4 CoM signed with sustainability and mobility plans	F4 Medium disposable income and medium economic activity with a relevant rate of unemployment	E1 Low rate of RES with a relatively low final energy consumption in households and high GHG emissions	M4 Medium rate of vehicles with a very low EV penetration resulting in a relatively high level of GHG emissions	I5 Very high number of internet users and high mobile and very high smartphone penetration
	Bristol	PC2 Very high population density with low area	P4 Low median population age and high number of foreigners with very high levels of population movement	G4 CoM signed with sustainability and mobility plans	F3 Very high disposable income, very low unemployment rate with relevant economic activity with a high level of working age population with higher education	E1 Low rate of RES with a relatively low final energy consumption in households and high GHG emissions	M4 Medium rate of vehicles with a very low EV penetration resulting in a relatively high level of GHG emissions	I5 Very high number of internet users and high mobile and very high smartphone penetration

CLUSTER 5								
Global Cluster		Management			Finance	Energy	Mobility	Infrastructures
		Physical Char.	People	Governance				
Cluster 5	Global	-						
	Graz	PC5 Low population density and small city area in very elevated areas	P2 Low youth unemployment rate and very high rate of recycling	G2 CoM not signed and lack of sustainability plans	F1 Very high disposable income, very low unemployment rate, relevant GDP with low level of working people with higher education	E5 Very high rate of RES with medium level of final energy consumption in households resulting in low GHG emissions	M4 Medium rate of vehicles with a very low EV penetration resulting in a relatively high level of GHG emissions	I3 Medium level of internet users with relatively high levels of mobile and smartphone penetration
	Innsbruck	PC5 Low population density and small city area in very elevated areas	P2 Low youth unemployment rate and very high rate of recycling	G1 CoM not signed and lack of sustainability and mobility plans	F1 Very high disposable income, very low unemployment rate, relevant GDP with low level of working people with higher education	E5 Very high rate of RES with medium level of final energy consumption in households resulting in low GHG emissions	M4 Medium rate of vehicles with a very low EV penetration resulting in a relatively high level of GHG emissions	I3 Medium level of internet users with relatively high levels of mobile and smartphone penetration

CLUSTER 5								
Global Cluster		Management			Finance	Energy	Mobility	Infrastructures
		Physical Char.	People	Governance				
	Liege	PC3 Low population density and small city area	P2 Low youth unemployment rate and very high rate of recycling	G1 CoM not signed and lack of sustainability and mobility plans	F4 Medium disposable income and medium economic activity with a relevant rate of unemployment	E1 Low rate of RES with a relatively low final energy consumption in households and high GHG emissions	M1 Very high rate of vehicles and very high value of private vehicles with low EV and bike use resulting in a high level of GHG emissions	I2 Very high number of internet users with relatively low levels of mobile and smartphone penetration
	Brugge	PC3 Low population density and small city area	P3 Low youth unemployment rate and low level of students in higher/tertiary education	G3 CoM signed and lack of sustainability plans	F1 Very high disposable income, very low unemployment rate, relevant GDP with low level of working people with higher education	E1 Low rate of RES with a relatively low final energy consumption in households and high GHG emissions	M4 Medium rate of vehicles with a very low EV penetration resulting in a relatively high level of GHG emissions	I2 Very high number of internet users with relatively low levels of mobile and smartphone penetration

CLUSTER 5								
Global Cluster		Management			Finance	Energy	Mobility	Infrastructures
		Physical Char.	People	Governance				
	Jyväskylä	PC3 Low population density and small city area	P5 Very low dependency population dependency ratio and extremely low level of population change	G1 CoM not signed and lack of sustainability and mobility plans	F4 Medium disposable income and medium economic activity with a relevant rate of unemployment	E5 Very high rate of RES with medium level of final energy consumption in households resulting in low GHG emissions	M1 Very high rate of vehicles and very high value of private vehicles with low EV and bike use resulting in a high level of GHG emissions	I1 Very high number of internet users and very high mobile and high smartphone penetration
	Leipzig	PC4 Low population density and big city area	P3 Low youth unemployment rate and low level of students in higher/tertiary education	G2 CoM not signed and lack of sustainability plans	F4 Medium disposable income and medium economic activity with a relevant rate of unemployment	E3 Relatively low rate of RES with a very low final energy consumption in households resulting in low GHG emissions	M4 Medium rate of vehicles with a very low EV penetration resulting in a relatively high level of GHG emissions	I2 Very high number of internet users with relatively low levels of mobile and smartphone penetration

CLUSTER 5								
Global Cluster		Management			Finance	Energy	Mobility	Infrastructures
		Physical Char.	People	Governance				
	Rosenheim	PC5 Low population density and small city area in very elevated areas	P3 Low youth unemployment rate and low level of students in higher/tertiary education	G2 CoM not signed and lack of sustainability plans	F1 Very high disposable income, very low unemployment rate, relevant GDP with low level of working people with higher education	E3 Relatively low rate of RES with a very low final energy consumption in households resulting in low GHG emissions	M4 Medium rate of vehicles with a very low EV penetration resulting in a relatively high level of GHG emissions	I2 Very high number of internet users with relatively low levels of mobile and smartphone penetration
	Gothenburg	PC4 Low population density and big city area	P2 Low youth unemployment rate and very high rate of recycling	G4 CoM signed with sustainability and mobility plans	F3 Very high disposable income, very low unemployment rate with relevant economic activity with a high level of working age population with higher education	E4 Non-gas consuming cities with a relatively high final energy consumption in households covered with a medium rate of RES resulting in low GHG emissions	M4 Medium rate of vehicles with a very low EV penetration resulting in a relatively high level of GHG emissions	I1 Very high number of internet users and very high mobile and high smartphone penetration

CLUSTER 5								
Global Cluster		Management			Finance	Energy	Mobility	Infrastructures
		Physical Char.	People	Governance				
	Malmö	PC3 Low population density and small city area	P4 Low median population age and high number of foreigners with very high levels of population movement	G4 CoM signed with sustainability and mobility plans	F4 Medium disposable income and medium economic activity with a relevant rate of unemployment	E4 Non-gas consuming cities with a relatively high final energy consumption in households covered with a medium rate of RES resulting in low GHG emissions	M4 Medium rate of vehicles with a very low EV penetration resulting in a relatively high level of GHG emissions	I1 Very high number of internet users and very high mobile and high smartphone penetration
	Oxford	PC3 Low population density and small city area	P4 Low median population age and high number of foreigners with very high levels of population movement	G3 CoM signed and lack of sustainability plans	F3 Very high disposable income, very low unemployment rate with relevant economic activity with a high level of working age population with higher education	E1 Low rate of RES with a relatively low final energy consumption in households and high GHG emissions	M4 Medium rate of vehicles with a very low EV penetration resulting in a relatively high level of GHG emissions	I1 Very high number of internet users and very high mobile and high smartphone penetration

11 Future directions

11.1 Development of a model for replication potential

In the frame of the next task 5.2: Development of a model for replication potential, follower cities will collaborate with the development of the Urban Regeneration Model (WP1) to define necessary adaptations in order to make the model applicable for each group of cities identified within this deliverable 5.1.

Special attention will be paid to second tier cities in order to maximise the multiplier effects of REMOURBAN project and establish synergies with other financial means.

During the development of the replicable model, an iterative and collaborative approach will be applied. Within this Work Package, there are several connection points. As an example, the surveyed cities willingness and openness to adapt the developed model will be mapped and this exercise will contribute to the exploitation of the project results. The output of this task will be a model for replication potential. In turn, the replication model will form the basis of replication plans to be outlined in Task 5.4 for each follower city. Testing of the replication model will be performed in the framework of Task 5.3 with the model modified and finalised on the results of the testing phase, if needed.

To assist in these next steps, the creation of interactive tool(s) for cities to assist them in their characterisation and set up their own strategic plan for getting smarter is being considered.

The survey conducted during the task 5.1 to help characterising the European cities is a first tangible tool and should conduct to a more dynamic way to evaluate the smartness characterisation of cities in Europe.

All these activities are linked through the Dissemination Cascade Plan established within D7.3, where it is defined how interested cities for replication of the Urban Regeneration Model and other end-users will be involved through a set of cooperation and business proposals.

11.2 Basis of model for replication potential

The current REMOURBAN D5.1 focuses on classifying EU cities based on their socio-economic and technical data published in the EU databases, to identify their replication capability. There are some implicit assumptions in this approach, for example:

- Cities of similar size to our Lighthouse cities are more likely to replicate the model. Therefore they will be targeted first.
- Replication will be around all or some of the REMOURBAN model and the socio-economic data may allow us to identify the cities “readiness” for replication.

“How cities innovate and uptake low carbon best practices?” is a question which is fairly new in Europe. There is little knowledge base to suggest any types of models and approaches to this question. REMOURBAN has started its journey based on one approach; however the project will scrutinise and improve this approach during the project.

Some open questions in the REMOURBAN approach include:

- Can the Lighthouse cities’ *regions* be a likely candidate for uptake of best practices, or is the model limited to the cities?
- Can the smaller EU towns and villages replicate some best practices? In reality some of these small towns have very limited internal resources for learning and would benefit from external facilitation.
- Cities of similar size to REMOURBAN, which are identified in the current classification in REMOURBAN, are likely to have existing initiatives or priorities. Why would these

cities replicate the REMOURBAN model as opposed to other initiatives? Could this lead to "initiative fatigue"? Can our approach be plagued by "not invented here" phenomena?
- Does the local authority's (LA) leadership style influence their capability to innovate and replicate good practice?
- Does the degree of local "power" which the LAs have, influence their ability to replicate?

There are EU reports, which allude to the limitations of the socio-economic characterisation of EU cities. The State of the European Cities Report[94] explains that this report is based on "typology of cities" with criteria such as size, economic structure, economic performance, and drivers of competitiveness. The report argues that this approach has advantages but there are also some disadvantages:

- EU data characterises EU cities by their core boundaries and cities may recognise themselves in more than one grouping. The data should therefore be used as a complimentary tool for better understanding the urban dynamics.
- The extent to which particular city authorities can shape the future of their cities depends on their Individual cities' power in terms of influencing structure and governance, as well as raising finance. The report[1] has tried to develop an index of the relative "power" of city governments in the EU, which may prove useful in the development of the REMOURBAN model. For example the power of municipalities in the Nordic countries and Italy are high because the proportional weight of local government expenditure and local taxes are the highest in the EU. In contrast, city authorities in Greece, Malta, Cyprus and Ireland, where the role of local government is more restricted, emerge as among the least powerful in the Union. The current devolution agenda of the UK government promises to substantially increase the governance and decision making powers of their cities and regions.
- Individual cities can swim against the current, formulate and implement strategies and oversee investments that make a difference, based on their leadership.

The report[1] summarises that:

> *"Needs will be stronger if socio-economic conditions are adverse – as they place extra demands on services, reduce locally-raised income and pose serious challenges to local leaders. Our report highlights a need for detailed research at the level of individual cities in order to fully understand the "room for manoeuvre" possessed by cities and their leaders. However, the ability of city leaders to seize the opportunities available to them will often be determinant for cities' future development."*

Therefore the REMOURBAN model can use the socio-economic data to understand where there are adverse conditions. In addition, the model needs to take heed of the leadership qualities of the LAs to enable transformations, and establish the city's "power level" to understand how much they can influence their environment.

11.3 City Power Levels

The State of the EU Cities Report[1] argues that the degree of decentralisation in policy-making and delivery varies greatly between EU Member States and there is by no means a consensus on the most appropriate balance between central and local responsibility.

A complex range of factors and questions come into play when it comes to considering the most appropriate role for city governments including:

[94] EU Regional Policy, State of European Cities Report- Adding value to the European Urban Audit, May 2007, http://ec.europa.eu/regional_policy/sources/docgener/studies/pdf/urban/stateofcities_2007.pdf

- The *territory and structure* of city government – Where do we draw city boundaries? How will the city territory relate to other levels of local government? Do we need to create government for the "city region"? Over what scale?
- The *resources* of city government – How will the city's activities be financed? Can it raise finance? Should cities be able to raise their own taxes? If so, how much? Should public services be delivered directly by the city authority or delegated to other actors?
- The *responsibilities* accorded to city government – Which public sector tasks should the city administration (as opposed to other levels of government) deal with? How much freedom should they have to shape their own policies and initiatives? How do these relate to the roles of other levels of government?

The report[1] seeks to assess the relative "power" of city governments between and within Member States. Measuring the "power" of cities in an effective manner pre-supposes both a clear definition of what is meant by "power" in this instance and adequate and appropriate information to measure this. Neither of these elements is readily available and the report does not claim to have found perfect solutions. However, their working definition of "power" in relation to city governments comprises of two components:

- Relative "weight" of city governments in the national governance system (resources and responsibilities of city government as a proportion of all public sector resources and responsibilities) and;
- Relative "flexibility" of city governments to influence their resources and the way they discharge their responsibilities (the level of autonomy they have over taxation or other income and in the focus and design of policy interventions).

Taking into account the key factors of territory, structure, resources and responsibilities mentioned previously, the report identifies four main areas where quantitative measurement is possible:

1. *Size* – common sense and experience suggest that larger cities (and their governments) carry more weight in national political contexts than smaller cities – even if many other factors may have a greater impact on real city power.
2. *Structure and status* – not all cities have the same governance structures and political status, even within the same country. Some may be city regions, others merely subdivisions of larger local or regional government entities;
3. *Spending power* – the size of the budget and resources controlled by the city authority. This can be measured both in absolute terms and as a proportion of overall public spending in a particular country.
4. *Control over income* – the ability to influence income levels, notably through local taxes and charges is widely seen as a key element of local government autonomy. When viewed alongside overall income and expenditure levels, the proportion of income obtained from local taxes provides a basic measure of local financial autonomy.

The relevance of these findings for REMOURBAN are that our replication model has to understand how much decision making power the receiving cities have to formulate strategy and fund low carbon transformations. Though most EU cities will have the authority to implement low carbon initiatives to meet EU targets, the REMOURBAN model still needs to understand where to draw the city boundaries and what aspects of the best practices the city can replicate. In addition, for replication at an international level, the model may require adaptations based on national policies and governance structures.

11.4 LA Leadership & Innovation

In the UK, the substantial budget cuts for LAs in conjunction with the devolution agenda has diverted much focus on the leadership innovative capacity of the LAs. Guidelines for LAs confirm that[95]:

> *"… Councils recognise that radical service transformation is required and that they have a key role to play in promoting and facilitating local economic growth. …*
>
> *There is wide recognition that the right mind set – an entrepreneurial approach, a willingness to take managed risks and 'think outside of the box' are at least as important as the existence of a power or otherwise in enabling innovation."*

Innovations are defined as changes to services or products or ways of working or organisational arrangement or democratic approaches that are both:

- New to the council and;
- Deliver additional value for its residents, service users and/or local businesses.

A major research project Accelerating Innovation in Local Government[96] undertook a major consultation to understand which factors influence the innovative capacity of LAs. The results were published in a framework, which is presented in Annex A. Local Authority Innovation Framework: a European Cities Survey

Though the power structures and the socio-economic conditions of all EU countries are different, REMOURBAN can extract some generic questions and criteria for its model from the above framework, tailoring it to the EU settings as well as the core objectives of the lighthouse cities in integrating of low carbon transport, energy and built environment infrastructures.

11.5 Future Directions

REMOURBAN will take account of the current deliverable for the characterisation of the EU cities, as one complimentary tool for better understanding the urban dynamics and creating a replication framework for its findings. This deliverable provides the overview of which cities have adverse conditions in meeting their energy, transport and climate change targets.

For future deliverables, the project will also consider two other criteria:

- "Power index" of the cities and regions. This may mean adaptations of the model, based each EU member state; and
- Innovative capacities of LAs.

More detailed studies will be conducted with the shortlisted cities, in cooperation with the Dissemination Cascade activities (please, refer to D7.3) to understand their replication "readiness". The follower cities will guide the way as how to create a replication framework which is user friendly and fit for purpose.

In Annex A. Local Authority Innovation Framework: a European Cities Survey, more information about the LA innovation framework and the European Cities Survey proposed by the "Accelerating innovation in local government" research project is included as a reference for the future investigation about the power index and innovative capacities of Local Authorities.

[95] Local Government Association, "The General Power of Competence Empowering Councils to Make a Difference", July 2013, http://www.local.gov.uk/c/document_library/get_file?uuid=83fe251c-d96e-44e0-ab41-224bb0cdcf0e&groupId=10180

[96] Joan Munro (2015) Accelerating innovation in local government, Public Money & Management, 35:3, 219-226, DOI: 10.1080/09540962.2015.1027498

12 Conclusions and recommendations

This deliverable 5.1 provides the basis for supporting the development and facilitating the replication of the urban regeneration model developed in REMOURBAN project in order to improve the sustainability and smartness of European Cities –leveraging the convergence area among energy, mobility and ICTs, integrated with strategies to involve the Smart City enablers–. Main achievements of this report are provided below as conclusions of this first activity within the replicability framework, which covers the characterisation of existing cities:

- A methodology has been developed in this report for the characterisation of cities as the first step for replicating the urban regeneration model in European cities. This approach consists of a list of indicators which define the main features of cities, data sources where to find this information and the statistical procedures to be conducted for obtaining a classification of cities typologies. This model is the result of a deep analysis on which the key indicators for describing the cities in terms of management, finance, mobility, energy and ICTs were collected. As an outcome of this exercise, also the data availability for this characterisation was analysed, identifying a remarkable gap in the accuracy (the non-reliability of the data in some cases produces some uncertainty in the identification of patterns of cities) and the difficulty for characterising some of the cities given the lack of data at city level in the existing data sources (e.g. indicators for energy and infrastructure are only available at regional or national level). In addition, not all the data can be collected for the same annuity. Consequently, one of our recommendations is the need of making efforts in improving the compilation of data at city level given the importance of knowing the baseline of the cities for taking decisions about which actions must be conducted for addressing them towards the sustainability.
- A sample of 41 middle-size European cities has been characterised utilising quantitative and qualitative indicators following the previous methodology. As a result, different typologies of cities for each layer analysed in the application domain of the REMOURBAN regeneration model (management, finance, mobility, energy and ICTs) have been defined and characterised. As a result, it is possible to identify which are the adverse conditions and potential features of these cities by each domain (energy, mobility, ICT) and enablers (people, governance and finance).
- Further to the layer-by-layer analysis, a second analysis has been performed where five geographic areas have been detected in Europe as a result of applying a clustering approach for characterising the cities in a global analysis in which all the indicators are considered: North, Centre, South, East and Scandinavian countries (UK and Ireland are not included in these identified areas). Contrary to the outcomes obtained in the analysis by layers, in the global evaluation cities have been grouped into regions with a clear correlation with their location.
- As a result of crossing both analyses, it can be easily identified the correlation among the global cluster and the layer-by-layer evaluation, where it is clearly shown how although cities belong to the same global cluster (which is mostly distributed in clear geographical areas), they usually have different conditions for some of the layers, which makes more precise the layer-by-layer evaluation in order to define how the urban regeneration model can be adapted to these existing conditions.

As a result of all these outcomes, and despite of the uncertainty derived from the data accuracy, the main objective of this deliverable relies on the definition of the city types, and not the cities classification itself. This city types' definition will allow the adaptation of the urban regeneration model as it is defined in REMOURBAN, establishing specific implementation possibilities according to the cities' conditions in each of the application domains. Therefore, the following activities within the replicability framework of the project will define how the model can be

applicable to each group of cities and the development of the strategies to create Integrated Urban Plans following the REMOURBAN approach.

On the other hand, and as an essential part of the replicability strategy, the outcomes of this report will support the development of specific tools to assess the current status of the cities, providing recommendations to identify the cities' baseline (the cluster they belong to) in order to better identify the key strategies for the urban regeneration model implementation.

As a final conclusion, and as depicted in the future developments' dedicated chapter the power of Local Authorities will be further explored in the generation of the replicability strategy, whose role in achieving significant energy savings is acknowledged by the Energy Efficiency Directive (EED, 2012/27/EU).

13 References

[01] EUROSTAT. (n.d.). *Population Database.* Retrieved from http://ec.europa.eu/eurostat/web/population-demography-migration-projections/population-data/main-tables

[02] PLEEC - Rudolf Giffinger, G. H. (January 2014). *Typology of cities - WP2 - Deliverable 2.2.* Vienna: TUWIEN Team.

[03] Rheinisch-Westfälisches Institut für Wirtschaftsforschung. (November 2010). *Second State of European Cities Report.* Research Project for the European Commission, DG Regional Policy. Essen, Germany: Policy Research & Consultancy – PRAC.

[04] EIP-SCC – the Market Place of the European Innovation Partnership on Smart Cities and Communities – EU projects page (https://eu-smartcities.eu/eu-projects)

[05] http://ec.europa.eu/eurostat/en/web/products-statistics-in-focus/-/KS-SF-08-082

[06] http://ec.europa.eu/eurostat/web/main/home

[07] http://www.covenantofmayors.eu/

[08] The European Innovation Partnership on Smart Cities and Communities - http://ec.europa.eu/eip/smartcities/

[09] https://eu-smartcities.eu/

[10] http://www.concerto-project.org/

[11] http://www.citykeys-project.eu/citykeys/home

[12] http://www.cityfied.eu/

[13] http://celsiuscity.eu/

[14] http://ec.europa.eu/eurostat/web/products-datasets/-/urb_cpopcb (Population by citizenship and country of birth - cities and greater cities)

[15] European Smart cities ranking by Vienna University of Technology - http://www.smart-cities.eu/

[16] Joan Munro (2015) Accelerating innovation in local government, Public Money & Management, 35:3, 219-226, DOI: 10.1080/09540962.2015.1027498

[17] EU Regional Policy, State of European Cities Report- Adding value to the European Urban Audit, May 2007, http://ec.europa.eu/regional_policy/sources/docgener/studies/pdf/urban/stateofcities_2007.pdf

Annex A. Local Authority Innovation Framework: a European Cities Survey

This framework and the European Cities Survey included below was first published in April 2012, and updated in May 2014, by the "Accelerating Innovation in Local Government" Research Project.

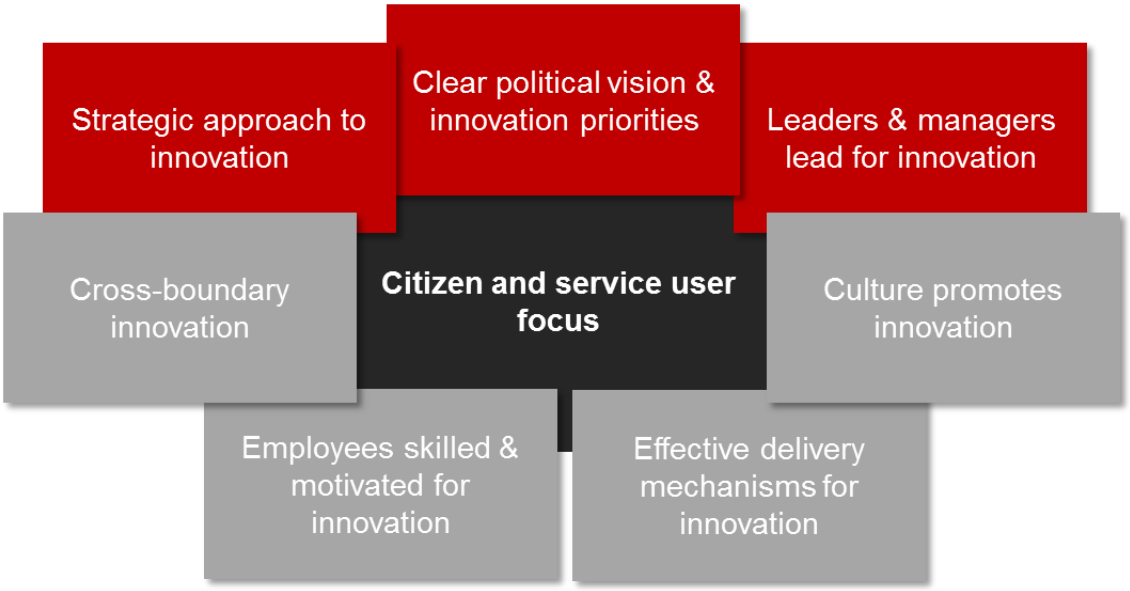


Figure 62: Local Councils' innovation framework

KEY QUESTIONS

Central Focus:

- Are citizens' and service users' priorities and aspirations central to the council's approach to innovation?

Key Drivers:

- Is the council's political vision, and its priority areas for innovation, clear?
- Are leaders and managers leading for innovation?
- Is the council taking a strategic approach to innovation?

Key Enablers:

- Does the council's organisational culture promote innovation?
- Are cross-boundary approaches generating significant innovations?
- Are employees motivated and skilled for innovation?
- Does the council have effective, disciplined, delivery mechanisms for innovations?

Are citizens' and service users' priorities and aspirations central to the council's approach to innovation?

For example, in the innovation priority areas, could the council do more to:

- Understand service users' aspirations, needs and priorities more deeply?
- Develop innovations with service users, and other local residents, to get their support, and to help to change their expectations and behaviours?
- Unlock and develop more capacity for innovation within local communities?

Is the council's political vision, and its priority areas for innovation clear?

For example:

- Is the vision ambitious and inspiring, but attainable, in the unfolding strategic context?
- Have politicians agreed the innovation priority areas in the medium and longterm?
- Are politicians prepared for experimentation, considered risk taking and necessary failures?

Are leaders and managers leading for innovation?

For example, are leaders and managers…?

- Trusted by managers and staff?
- Bold, forward-looking and united?
- Focusing enough time and effort on innovation?
- Convincing communicators, personally selling the need for innovation?
- Involving all key stakeholders, including middle managers, in discussing critical future issues, and plans for innovations?
- Listening and responding to feedback, including from critics and mavericks?
- Devolving decision-making appropriately?
- Moving forward at a brisk, but sustainable, pace?
- Persisting until innovations are delivered?

Is the council taking a strategic approach to innovation?

For example, does the council have:

- Clear plans and accountability for innovations, and effective project leaders?
- Sufficient resources and time devoted to innovations?
- Innovation processes being given sufficient freedom to experiment (and not being held back by unnecessary bureaucratic barriers)?
- The flexibility to seize new opportunities, and to adapt when experiments fail?
- The expertise to fully exploit the latest new technologies?

Does the council's organisational culture promote innovation?

For example, is innovation promoted through:

- Leaders' and managers' everyday behaviours, practices and stories?
- Values, norms and working practices?
- Safeguarding time for reflection and creative thinking?
- Healthy debates, that challenge and test accepted assumptions?
- Pro-actively looking elsewhere for fresh ideas, from other councils, other organisations (including those in other countries)?
- Celebrating innovations?

Are cross-boundary approaches generating significant innovations?

For example, is the council successfully delivering innovations through:

- Cross-council working?
- Partnerships with external organisations?
- Its commissioning and contract management arrangements?

Are the council's employees motivated and skilled for innovation?

For example, does the council:

- Have enough employees with the attitudes and skills needed to deliver innovations?
- Encourage employees to develop better ways of doing things?

- Involve frontline employees in innovation processes?
- Recognise and reward employees for innovating?
- Respond to employees' concerns about innovations?
- Deal with job losses or role changes fairly?

Does the council have effective, disciplined, delivery mechanisms for innovations?

For example, does the council have:

- Effective ways of tracking and delivering innovations?
- Sufficient innovation expertise to support the delivery of major innovations?
- A straightforward approach to evaluating and learning from successful and unsuccessful innovations?

Example of an innovation process:

1. Understand the key issues, underlying problems and the strategic context (including: politicians' views and ambitions; service users' and citizens' needs, priorities and aspirations).
2. Agree the outcomes you want to achieve.
3. Generate fresh ideas for tackling the issues, including by looking for successful innovations in other councils, and other organisations (including those from other countries).
4. Select the most promising ideas, right for the organisation and the strategic context.
5. Test, prototype and evaluate these ideas. Learn from what does not work.
6. Choose the best idea(s) to implement.
7. Develop and implement the idea(s), addressing barriers, persisting, adapting and learning, until they work in practice.
8. Evaluate how successful the innovation has been, over time, against your ambitions.
9. Build on and spread successful innovations, learn from failures, and disseminate the ideas and learning to others.

For major innovations involve politicians, middle managers, frontline employees, service users, other local residents, and partners at key stages in the process. In practice innovation processes may move backwards and forward between the different stages.

Annex B. List of Indicators Discarded

In the following table, can be seen the list of indicators which are not available in databases at city level and were finally discarded for our study. For the case of indicators for energy and infrastructure, some of them were included since they are only available for regional and national level.

LAYER	INDICATOR	DESCRIPTION
Management	Affordability of housing	Percentage of population living in affordable housing
	Residential Land occupation	Urbanised area of the municipality: residential areas in the extension covered by the city
	Satisfaction with city quality of life	Percentage of population satisfied with their city's quality of life
	Green areas	Green areas in the extension covered by the city
	Average life expectancy	Average number of years to be lived by a group of people born in the same year, if health and living conditions at the same through their lives.
	Waste generated per capita	Municipal waste shall refer to waste collected by or on behalf of municipalities (by private of regional associations founded for that purpose).
	Percentage of the city's solid waste that is recycled	Percentage of the city's solid waste that is recycled
	Number of local associations per capita	Total number of citizen associations in the city
	R&D expenditure per capita	The running cost which a city employed for research and development issues by inhabitant
	Existence of public incentives to promote energy efficient districts	Are there any specific public incentives for promoting of energy efficient districts in the city?
	Existence of public incentives to promote sustainable mobility	Are there any specific public incentives for promoting of sustainable mobility in the city?
	Percentage of the ICT sector on GDP	Gross value added (at basic prices) minus other taxes less other subsidies on production on ICT sector (based on NACE Rev. 2)
Finance	-	-
Energy	Annual final energy consumption of buildings	Final energy consumption of buildings for all usages (heat and water heating, cooling, lighting, cooking ventilation and other ancillary services, electrical appliances) per m^2 of buildings
	Residential energy consumption per capita	Final energy consumption of residential users for all usages (heat and water heating, cooling, lighting, cooking, ventilation and other ancillary services, electrical appliances)
	Total residential electrical energy use per capita	Residential electricity consumption

LAYER	INDICATOR	DESCRIPTION
	Energy consumption of public buildings per year	Electricity consumption by public buildings
	The percentage of total energy derived from renewable sources	Energy derived from energy renewable sources related to the total energy
	Share of gas in final energy consumptions in households	Energy derived from gas related to the final energy in households
	GHG emissions per capita from buildings	GHG emissions from buildings (residential and public) according to the Global Protocol for Community Scale GHG Emissions (GPC)
Mobility	Kilometres of high capacity public transport system per 100 000 population	Length of high capacity public transport network (heavy rail metro, subway and commuter rail systems)
	Kilometres of light passenger public transport system per 100 000 population	Length of light capacity public transport network (light rail streetcars, tramways, bus, trolleybus and other)
	Kilometres of bicycle paths and lanes per 100 000 population	Length of bicycle paths (independent roads or parts of a road designated for cycles and signed-posted as such) and lanes (part of carriageways designated for cycles and distinguished from the rest by longitudinal road markings)
	Percentage of EV per sector (private, public and service(taxi and first mile))	Number of electric vehicles related to total number of vehicles
	GHG emissions per capita from transportation	According to the Global Protocol for Community Scale GHG Emissions (GPC)
Infrastructure	Smartphone penetration	Number of smartphones in relation to total mobile phones
	Mobile cellular subscriptions	Number of subscriptions to a public mobile telephone service
	Availability of Internet access in households	Percentage of households with Internet access for any household member via a fixed or mobile network at any given time in relation to total households
	Percentage of households having access to high speed internet of above 30 Mbps	Coverage/availability of high speed internet in households
	Percentage of the population covered by at least a 3G mobile network	Percentage of the population covered by at least a 3G mobile network
	Number of internet users	Number of people who has access to Internet at home. This indicator does not record use, or frequency of use, but only access
	Fixed wired internet subscriptions	Percentage of a country's population which have fixed wired internet subscription
	Number of infrastructure	The components cover the traffic, public transit

LAYER	INDICATOR	DESCRIPTION
	components with installed sensors	demand, parking, waste, water and public lighting
	Number of services integrated in a singular operations centre leveraging real-time data	The services include ambulance, emergency/disaster response, fire, police, weather, transit and air quality

Annex C. Hierarchical Method

C.1. Clusters and dendrogram for Management-Physical Characterization

Clusters are constructed using SPSS, and the cluster distribution is given in the following table.

Table 58: City distribution to the clusters for Management (Physical Characterization)

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Graz	Liege	Ruse	Koeln	Leipzig
Innsbruc	Thessaloki		Stockholm	Genova
Ghent	Firenze			Málaga
Brugge	Bristol			Sevilla
Tartu				Gothenburg
Jyväskyl				Manchester
Tampere				
Turku				
La Roche				
Poitiers				
Aachen				
Rosenhein				
Miskolc				
Cork				
Bolzano				
Eindhoven				
Utrecht				
Stavanger				
Trondheim				
Porto				
Braga				
Ljubljana				

San Sebastian				
Valladolid				
Santa Cruz de Tenerife				
Malmö				
Nottingham				
Oxford				

Table 59: The average values of the indicators for each cluster for Management (Physical Characterization)

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
MG_PC1	18.554.293	44.444.975	860.60	48.785.000	29.564.250
MG_PC2	191769.71	392565.75	147817	949249.50	570847.17
MG_PC3	1.989.068	279.960.975	187124.00	2.965.750	2.739.117
MG_PC4	1.381.679	582.500	45.00	185.000	335.000

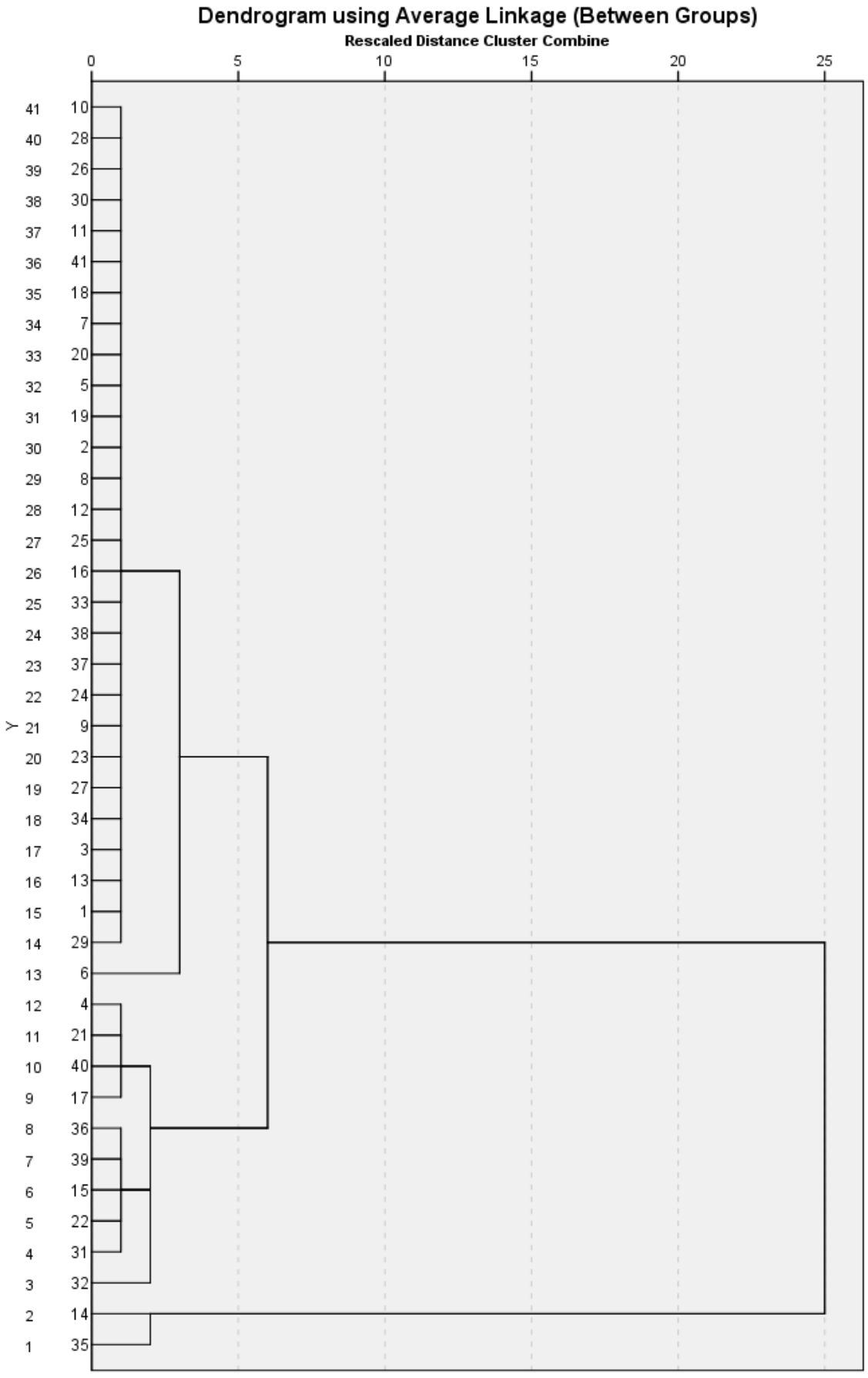


Figure 63: Dendrogram for Management (Pysical Characterization)

C.2. Clusters and dendrogram for Management-People

Table 60: City distribution to the clusters for Management (People)

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Graz	Innsbruck	Ghent	Brugge	Firenze
Porto	Liege	Koeln	Ruse	Stockholm
Nottingham	Tampere	Sevilla	Tartu	
	Turku	Manchester	Jyväskylä	
	Aachen		La Rochele	
	Leipzig		Poitiers	
	Genova		Rosenheim	
	Utrecht		Thessaloniki	
	Málaga		Miskolc	
	Gothenburg		Cork	
	Oxford		Bolzano	
			Eindhoven	
			Stavanger	
			Trondheim	
			Braga	
			Ljubljana	
			San Sebastian	
			Valladolid	
			Santa Cruz de Tenerife	
			Malmö	
			Bristol	

Table 61: The average values of the indicators for each cluster for Management (People)

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
MG_P1	322.333	309.550	311.525	312.386	323.750
MG_P2	3.626.667	42.160.833	31.645.000	5.858.952	142.095.000
MG_P3	75.800	92.892	86.475	60.114	118.700
MG_P4	56824.33	34664.83	77008.50	14970.43	54604.50
MG_P5	198.667	233.583	263.750	241.905	286.000
MG_P6	0.2867	0.7767	0.3700	0.9619	0.4650
MG_P7	385.000	385.350	388.175	390.148	402.500
MG_P8	522.733	664.392	665.625	574.248	746.700
MG_P9	423.333	439.167	432.000	371.571	442.000

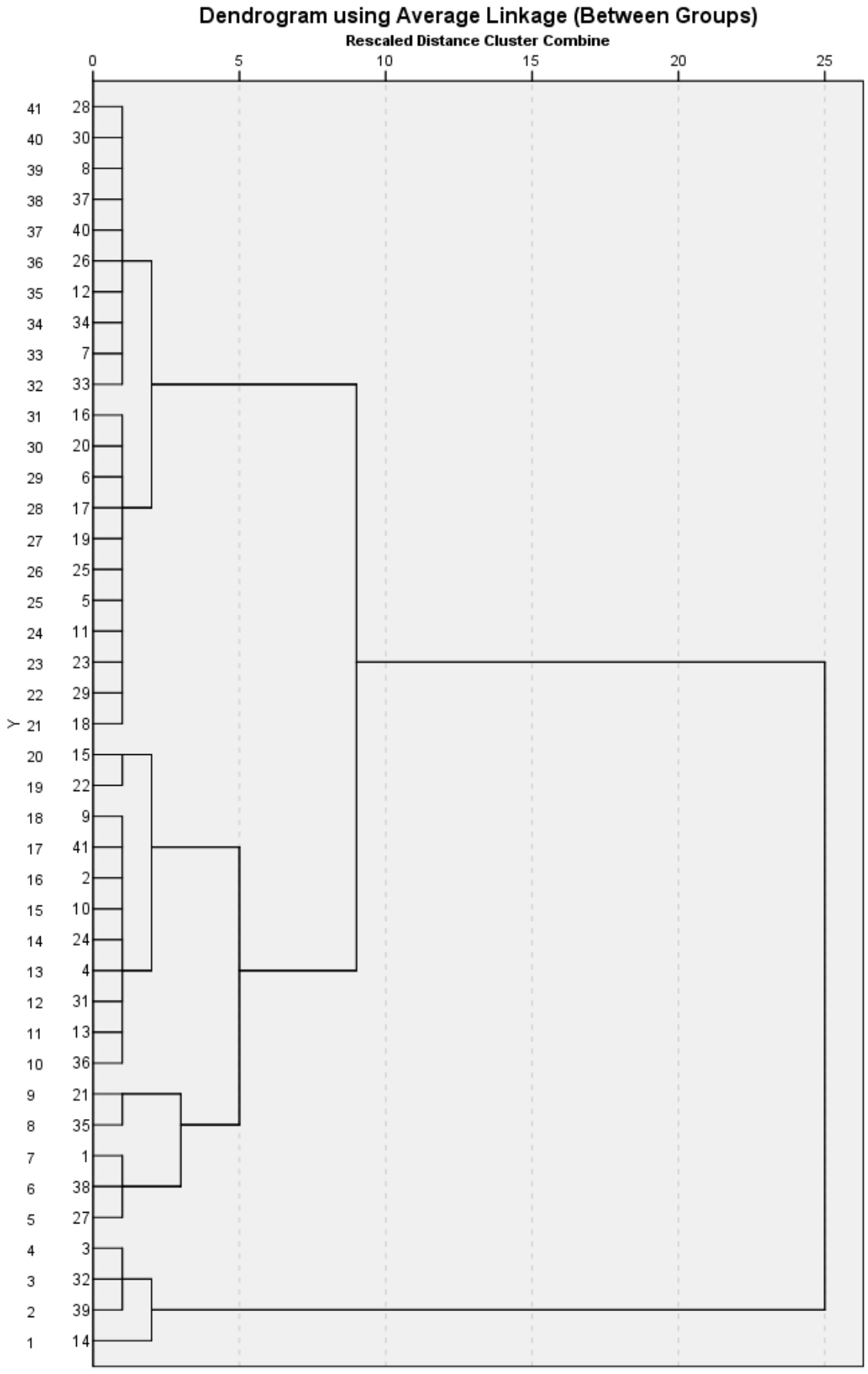


Figure 64: Dendrogram for management (people)

C.3. Clusters and dendrogram for Management-Governance and Sustainable and Smart City Strategies

The indicators for Governance & Sustainable and Smart City Strategies are binomial, in other words, only take 0 or 1. That means we cannot conduct cluster analysis in order to group the cities for this field. On the other hand three of the indicators take only “1”s. Hence these are not variables. To classify the cities, the following table was constructed which shows the cities in 5 different cluster. The first cluster constructed by the cities which have “0”s for G1, G4 and G5. Other descriptions are given in the table below:

Table 62: City distribution to the clusters for Management (Governance & Sustainable and Smart Cities Strategies)

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
KPI1=0 KPI4=0 KPI5=0	KPI1=0 KPI4=0 KPI5=1	KPI1=1 KPI4=0 KPI5=1	KPI1=1 KPI4=1 KPI5=0	KPI1=1 KPI4=1 KPI5=1
Innsbruc	Graz	Ghent	Santa Cruz de Tenerife	Nottingham
Liege	Brugge			Manchester
Gothenburg	Ruse			Bristol
Oxford	Tartu			Stockholm
	Leipzig			Cork
	Rosenheim			Bolzano
	Miskolc			Firenze
				Genova
				Eindhoven
				Utrecht
				Stavanger
				Trondheim
				Porto
				Braga
				Ljubljana
				San Sebastian
				Málaga
				Sevilla
				Valladolid

				Thessaloniki
				Tampere
				Turku
				La Rochele
				Poitiers
				Aachen
				Koeln

C.4. Clusters and dendrogram for Finance

Table 63: City distribution to the clusters for Finance

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Graz	Liege	Ruse	Tartu	Cork
Innsbruc	Jyväskylä	Miskolc	Thessaloniki	Stavanger
Ghent	Tampere		Porto	Stockholm
Brugge	Turku		Braga	
Aachen	La Rochele		Málaga	
Bolzano	Poitiers		Sevilla	
Firenze	Leipzig		Santa Cruz de Tenerife	
Genova	Rosenheim		Nottingham	
Eindhoven	Ljubljana		Manchester	
Utrecht	Valladolid			
Trondheim	Malmö			
San Sebastian				
Gothenburg				
Bristol				
Oxford				

Table 64: The average values of the indicators for each cluster for Finance

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
KPI_FI1	1.309.840	1.034.318	37.57	806.367	1.681.275
KPI_FI2	18473.33	17028.64	6700	11644.44	17156
KPI_FI3	61.267	123.364	9.95	171.667	9.15
KPI_FI4	33.64	341.091	19.9	284.333	39.375
KPI_FI5	35706.67	25890.91	9900	17844.44	45750

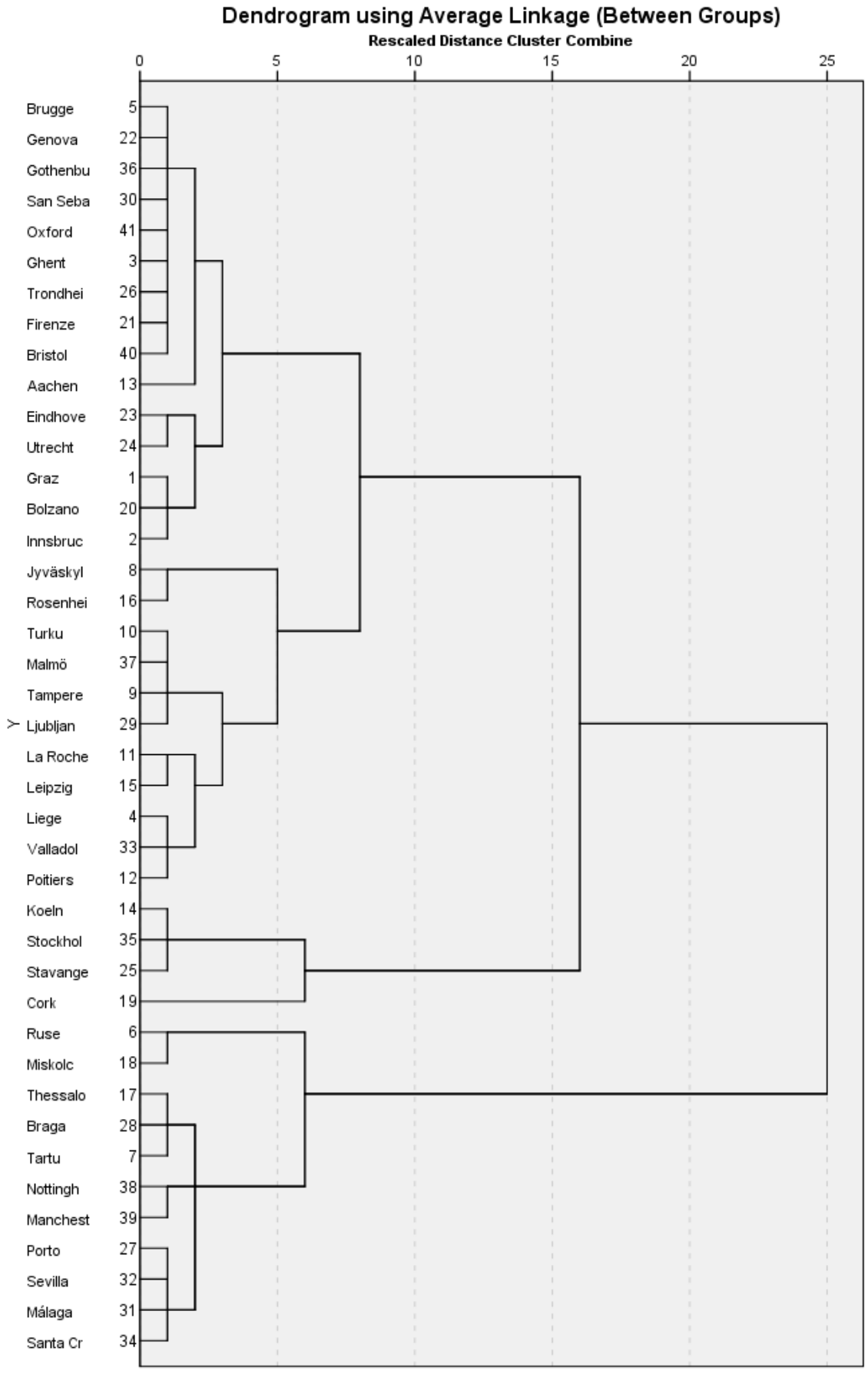


Figure 65: Dendrogram for Finance

C.5. Clusters and dendrogram for Energy

Dendrogram is not given here for Energy, since the clusters are not far away from each other on the graph.

C.6. Clusters and dendrogram for Mobility

Table 65: City distribution to the clusters for Mobility

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Graz	Ghent	Tartu	Aachen	Santa Cruz de Tenerife
Innsbruc	Liege	Miskolc	Koeln	
Ruse	Brugge	Utrecht	Leipzig	
La Roche	Jyväskylä	Nottingham	Stockholm	
Poitiers	Tampere	Manchester	Gothenburg	
Bolzano	Turku	Oxford	Malmö	
Firenze	Rosenheim		Bristol	
	Thessaloniki			
	Cork			
	Genova			
	Eindhoven			
	Stavanger			
	Trondheim			
	Porto			
	Braga			
	Ljubljana			
	San Sebastian			
	Málaga			
	Sevilla			
	Valladolid			

Table 66: The average values of the indicators for each cluster for Mobility

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
KPI_MO1	5.527.000	4.393.095	2.691.167	3.503.857	561.10
KPI_MO2	0.36457	0.36133	0.28067	0.21571	0.250
KPI_MO3	51.00	50.19	39.83	46.00	65
KPI_MO4	23.43	23.33	22.17	20.29	18
KPI_MO5	10.71	9.48	10.00	11.86	1
KPI_MO6	14.71	17.00	27.67	21.86	169
KPI_MO7	0.5171	10.414	15.250	10.514	0.13
KPI_MO8	19.957	20.681	17.167	19.400	1.72

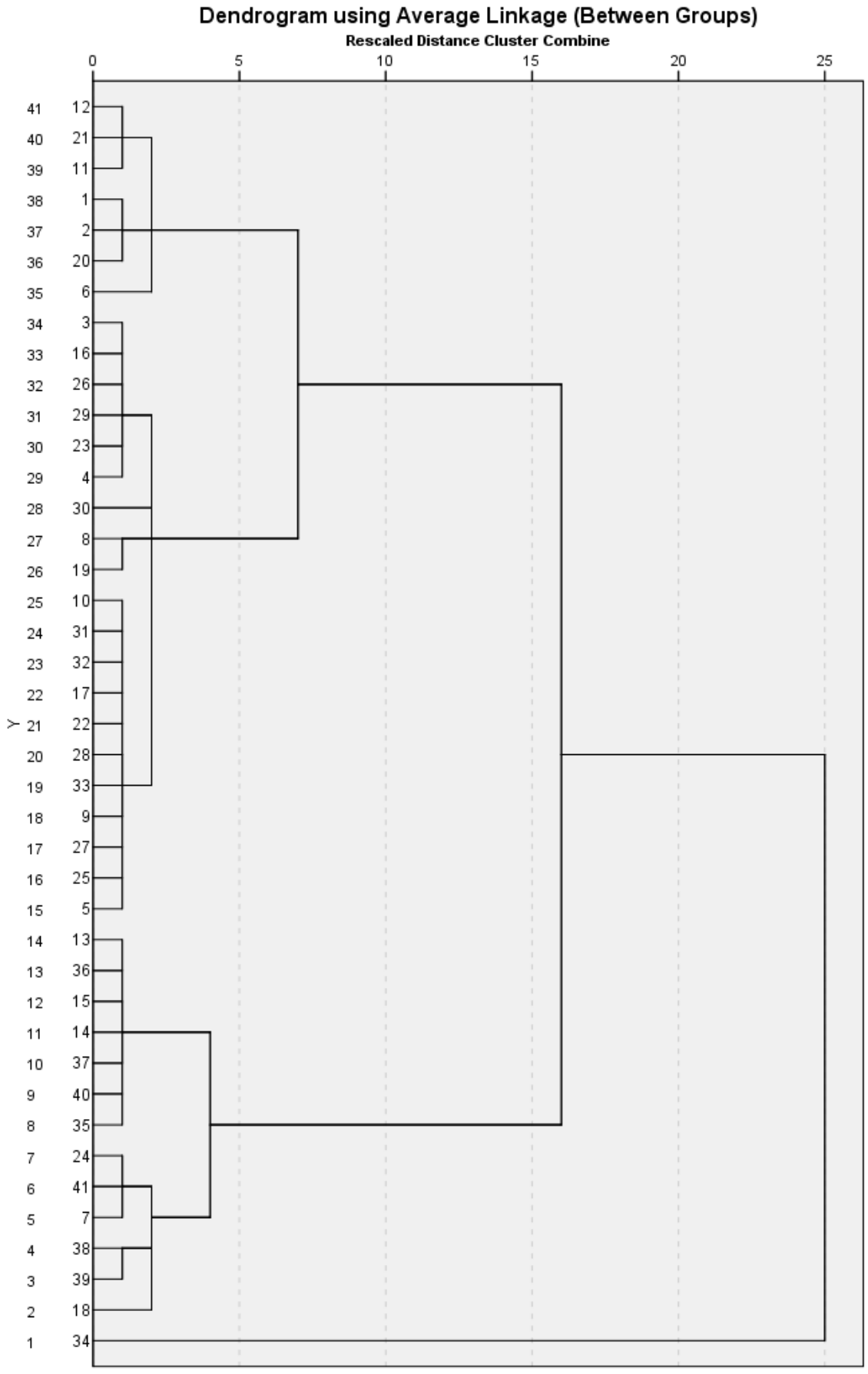


Figure 66: Dendrogram for Mobility

C.7. Clusters and dendrogram for Infrastructures

Table 67: City distribution to the clusters for infrastructures

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Graz	Ghent	Ruse	Jyväskyla	Eindhoven
InnsbrucK	Liege	Thessaloniki	Tampere	Utrecht
Tartu	Brugge	Firenze	Turku	Stavanger
Cork	La Rochele	Genova	Stockholm	Trondheim
San Sebastian	Poitiers	Porto	Gothenburg	Nottingham
Málaga	Aachen	Braga	Malmö	Manchester
Sevilla	Koeln			Bristol
Valladolid	Leipzig			Oxford
Santa Cruz de Tenerife	Rosenheim			Eindhoven
	Miskolc			Utrecht
	Ljubljana			

Table 68: The average values of the indicators for each cluster for Infrastructures

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
KPI_INF1	525.556	369.364	362.286	54.2	60.975
KPI_INF2	244.778	328.545	217.143	31.3	36.075
KPI_INF3	570.778	390.636	43.6	103.9	72.4
KPI_INF4	75.26	810.464	58.93	93.145	921.725

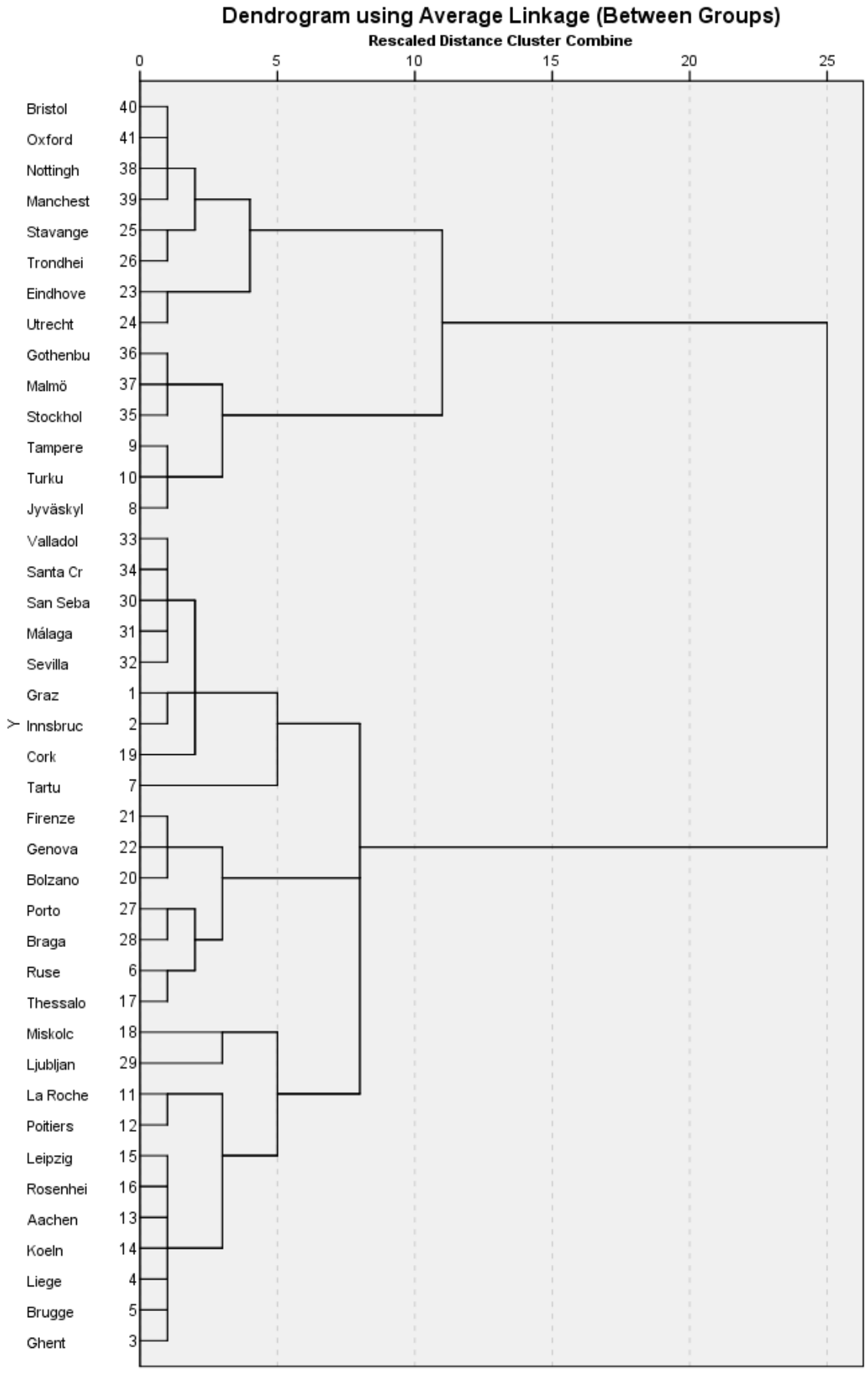


Figure 67: Dendrogram for Infrastructures