APPLYING URBAN COMPACTNESS METRICS ON PAN-EUROPEAN DATASETS

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KEY WORDS: Compact city, spatial metrics, Urban Atlas, Urban Audit.

ABSTRACT:

Urban compactness is measured for a number of medium sized European cities based on metrics available in the literature. The information used is a combination of Urban Atlas and Urban Audit data sets. The former is a source of spatial data whereas the latter of population data. These datasets that have been made recently available providing for the first time the opportunity to perform comparative analysis of urban compactness across European countries. The results provide an interesting insight of variation amongst cities in different countries. The analysis is limited however due to the quality and generalization of the datasets.

1. INTRODUCTION

The compact city is one of these concepts in planning that are hard to quantify (Burton 2000). The difficulty resides first of all in agreeing upon what exactly are the components of a compact city. But even if there is an exact answer to this question data availability in common standards would almost certainly force the measures to adapt from what should be measured but to what can be measured. Therefore, the quantification of a compact city is not an easy task. It is important however to be able to calculate urban compactness. The ability to measure it, as well as its change through time, is essential in monitoring cities. Even if intensification, i.e. increased compactness, is not planned but merely a spontaneous process planners should be able to have a clear view.

Compact city is an urban form that is alternative to urban sprawl (Besussi et al. 2010; Chin 2006). Compact city characteristics include high residential densities and increased mix of land uses as opposed to urban sprawl characterized by low densities and land use segregation (Neuman 2005). Some researches have proposed specific metrics to measure city compactness. Notably Burton (2002) proposed a metric of compactness that is composed of three poles (a) density (b) mix-of-use and (c) intensification. Each of these poles is measured as a combination of several indexes. The case study for this approach has been several medium sized cities in the UK. The objective of the present work is to try to apply a similar approach to European medium sized cities. Clearly the approach can only by partially applied due to data limitations based on the two standard datasets that cover the whole of the European Union, i.e. Urban Atlas and Urban Audit.

2. DATA

2.1 Urban Atlas

The spatial data for the cities come from Urban Atlas (European Union, 2011). It covers Large Urban Zones (LUZ) with more than 100,000 inhabitants. The data refer to the years 2005-7. It is suitable for 1:10,000 scale with a minimum mapping unit of 0.25 ha for artificial surfaces and 1 ha for all other classes. Its nominal thematic accuracy for the class referring to artificial surfaces is 85% or better. It is a product of interpretation of very high resolution earth observation data combined with locally available topographic and land use maps. Its original spatial structure is vector and it comes in Lambert Azimuthal Equal Area projection which maps conveniently the European continent. A useful property of this projection is that it does not distort areas. Consequently it is suitable for calculating densities in a pan-European dataset. An important aspect of Urban Atlas is its classification system (Table 1) which aligns with CORINE's system after the addition of a finer level (forth level). Despite this hierarchical alignment with CORINE it is not easy to combine it with Urban Atlas in time series analysis due to the very different reference scales (Prastacos et al. 2012).

code	Land use
11100	Continuous Urban Fabric
11210	Discontinuous Dense Urban Fabric
11220	Discontinuous Medium Density Urban Fabric
11230	Discontinuous Low Density Urban Fabric
11240	Discontinuous Very Low Density Urban Fabric
11300	Isolated structures
12100	Industrial,commercial, public, military & private units
12210	Fast transit roads and associated land
12220	Other roads and associated land
12230	Railways and associated land
12300	Port areas
12400	Airports
13100	Mineral extraction and dump sites
13300	Construction sites
13400	Land without current use
14100	Green urban areas
14200	Sports and leisure facilities
20000	Agricultural areas, semi-natural areas and wetlands
30000	Forests
50000	Water

Table 1. Land use classes in Urban Atlas.

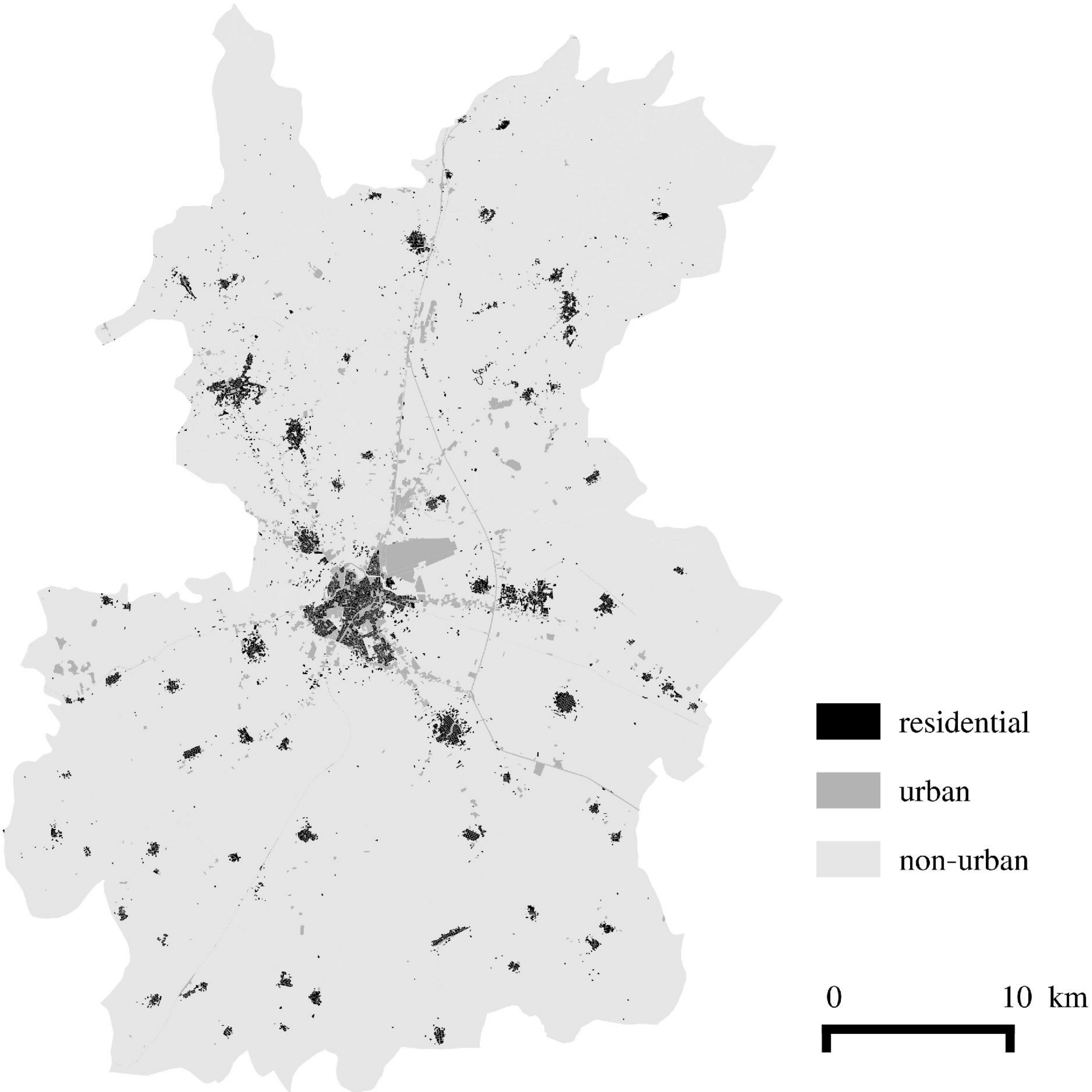

Figure 2. Urban Atlas data for the city of Larisa (gr005l_larisa).

In the following analysis Urban Atlas data was recoded to urban (codes 11100 – 14200), residential (codes 11100 – 11300) and non-urban (codes 20000 – 50000). One example is shown in Figure 2.

2.2 Urban Audit

Urban Audit is a database containing statistical information for European cities. It has been coordinated by the statistical office of the European Union (Eurostat). One important aspect of Urban Audit is that it provides data also for Larger Urban Zones (LUZs). But although LUZs should coincide with the functional urban region its limits have been adapted to coincide with administrative boundaries. This is definitely convenient for gathering socioeconomic data it is nevertheless probably the source of some problems in the dataset discussed in the following section. An other problem is that the most recent date for obtaining the total resident population within a Larger Urban Zone is the year 2004. For some cities the most recent year is even more distant. In specific, for all Bulgarian cities the most recent data is for 1991 whereas for Lincoln (UK) and Setubal (PT) it is 2001. Also other variables that would be useful in building indexes, such as the number of households and the number of dwellings, are not available for all the cities of the European Union.

2.3 Data quality

To a large extent the nominal accuracy of the datasets used in the study have been taken for granted in order to focus on the use of metrics. A systematic assessment of data quality is clearly out of the scope of the present work. However, there is evidence that some checking needs to be done in the future. To mention one example, the population of the LUZ of Volos (gr006l_volos) given in Urban Audit is significantly less compared to that given by official national statistics. An other problem is the delineation of urban zones in Urban Atlas. For example despite the fact that in terms of population the city of Ioannina (gr007l_ioannina) is seven times smaller compared to Thessaloniki (gr002l_thessaloniki) their zone acreage in Urban Atlas is surprisingly approximately the same.

3. METHOD

3.1 Selection of cities

In any comparison between cities great differences in size can make results difficult to interpret. For that reason only medium sized cities are selected here for comparison. In specific the cities that qualify for comparison are those having a LUZ with total resident inhabitants between 80,000 and 220,000. The exact population limits are identical to those used by Burton (2002).

3.2 Metrics

The metrics used here are taken from Burton (2002). The author there assembles quite a large number of metrics. The data requirements for these metrics might be possible to be met at national scale, at least for some European countries, but is not possible to be met for a cross-European analysis. In fact by using the only European-wide available datasets, i.e. Urban Atlas and Urban Audit, only a few of these metrics can be used. In specific, and using the names proposed by Burton (2002), in terms of density only the following indexes can be used:

- densgr1 = resident population in zone / total zone acreage (persons per hectare).
- densblt1 = residential population in zone / built-up acreage (persons per hectare). The correspondence of built-up area in Urban Atlas schema is given in section 2.1. Note that built-up includes residential.
- densres1 = resident population in zone / residential area acreage (persons per hectare).

With respect to the mix of use only the following index can be used:

- supfacs2 = residential / non-residential urban land.

No metric can be used with respect to intensification, that is the change of city compactness throughout time. The reason is that currently both Urban Atlas and the Urban Audit do not offer a second point in time with pan-European coverage in order to estimate change.

The metrics have been standardized based on the following formula:

$$standardized\ value = \frac{value - mean}{standard\ deviation} \qquad (1)$$

They were then combined to yield an overall density measure (dens) by averaging densblt1 and densres1. Index densgr1 is shown on Table 2 but has been omitted in calculating the overall density measure (dens). The reason is that, as explained in section 2.3 there is evidence that the delineation of LUZ is not consistent. The delineation of urban and residential areas is much more objective, especially when very high resolution satellite images are available, and thus more reliable. The overall mix-of-use index (mixuse) has only one component. Moreover, the intensification component is absent as already explained. An overall metric, termed compactness (compact), is calculated by averaging the overall density (dens) and mix-of-use (mixuse) measures.

4. RESULTS

The results of the process are shown on Table 2 shorted on compactness. Population refers to total resident persons in the LUZ, zone area refers to total acreage of the LUZ, the correspondence of built-up and residential areas are given in section 2.1, code refers to Urban Atlas codes of cities and "compact" is the total metric of compactness. A more interesting view of the results is shown on figure 2. In this scatterplot it becomes evident that the vast majority of the cities are clustered approximately around mean density and mix-of-use values, i.e. where the two axes cross. There are however some interesting deviations.

Looking at the outliers in the rightmost part of this diagram, there is a cluster of values of over 2 or more standard deviations. This cluster is exclusively composed of Romanian cities with only one exception. This exception is the the most dens city namely Kavala (gr008). The other end of density is dominated by Swedish cities. Finally three cities are substantially more mixed compared to the average (pl020, hu003, pt004).

Overall the variation of compactness values at the European level is significant providing adequate contrast as opposed to data reported at national scale (Burton 2002). A further reason for this increased variation is perhaps that each pole of compactness (density and mix-of-use) has been calculated by very few components and thus the effect of averaging is inevitably minimized.

5. CONCLUSIONS

In conclusion the two datasets currently available can be used along with the metrics for the compact city that have already proposed to provide an insight on the current state of the cities. The two data sources are far from perfect. Nevertheless this is the only option currently available to anyone how would like to do a pan-European study of cities.

Only a few of the metrics originally proposed by Burton (2002) can be used with these data sources. The results are definitely limited in that respect. But this limitation is also valuable as a conclusion by itself. It shows that currently there are no reliable datasets to study European cities based on common standards.

The same finding can also be viewed differently. When studying European cities the metrics used should be more adapted to pan-European datasets rather than using methods that rely on country-specific datasets. Metrics could adapt to CORINE's and Urban Atlas' classes and scales. This is also an opportunity to shift the nature of metrics from statistical to spatial.

In addition, the realization of the lack of data to monitor European cities should also alert planners and policy makes since it is an indication that this field does not receive due attention despite of the fact that it is critical and that it affects the environment and the economy in multiple ways. This could mean that monitoring the cities should rely more on top down methods, such as remote sensing (Stathakis et al. 2012; Stathakis and Faraslis, to appear), rather than bottom-up data gathering.

An open research question is whether it is feasible to devise new metrics adapted to pan-European datasets that can better capture the dynamics of compactness and its evolution through time. That is currently a very interesting topic for further research. The other question is whether European institutions can become more active in producing reliable datasets for urban areas.

city	population [1]	zone area (ha) [2]	Built-up (ha) [3]	Residential (ha) [4]	densgr1 [1]/[2]	densblt1 [5]=[1]/[3]	densres1 [6]=[1]/[4]	supfacs2 [7]=[4]/([3]-[4])	code	dens [8]=([5]+[6])/2	mixuse [7]	compact ([8]+[7])/2
Nowy Sacz	158,620	44,835	7,636	5,467	0.41	0.07	-0.61	4.39	pl020	-0.27	4.39	2.06
Targu Mures	172,642	14,135	3,224	1,763	3.99	3.25	2.37	0.67	ro010	2.81	0.67	1.74
Piatra Neamt	124,194	14,671	2,561	1,452	2.44	2.76	1.84	0.96	ro011	2.30	0.96	1.63
Funchal	190,014	26,095	6,234	4,037	1.96	1.01	0.17	2.46	pt004	0.59	2.46	1.52
Bacau	203,559	22,078	4,235	2,246	2.76	2.72	2.06	0.45	ro007	2.39	0.45	1.42
Kavala	129,567	35,148	2,505	1,101	0.47	3.07	3.23	-0.52	gr008	3.15	-0.52	1.31
Nyíregyháza	218,153	143,765	17,861	12,109	-0.42	-0.76	-1.09	3.21	hu003	-0.93	3.21	1.14
Iraklio	202,426	60,447	6,179	3,399	0.33	1.23	0.71	0.72	gr004	0.97	0.72	0.85
Oradea	218,276	20,110	5,307	2,425	3.43	2.04	2.03	-0.36	ro006	2.04	-0.36	0.84
Sibiu	186,803	58,814	4,694	2,152	0.26	1.92	1.89	-0.35	ro009	1.90	-0.35	0.78
Alba Iulia	97,745	25,882	3,053	1,643	0.51	1.16	0.71	0.55	ro014	0.93	0.55	0.74
Pécs	178,190	57,066	8,857	5,242	0.24	0.01	-0.40	1.36	hu004	-0.20	1.36	0.58
Calarasi	83,441	24,578	2,149	762	0.35	1.82	2.88	-1.19	ro012	2.35	-1.19	0.58
Jelenia Góra	127,382	58,565	6,267	3,587	-0.15	0.03	-0.33	1.05	pl019	-0.15	1.05	0.45
Arad	189,099	51,978	6,623	3,350	0.45	0.82	0.58	0.15	ro008	0.70	0.15	0.43
Namur	139,024	39,741	9,424	5,640	0.39	-0.51	-0.80	1.47	be007	-0.66	1.47	0.41
Zlin	193,068	103,207	10,153	5,755	-0.28	-0.10	-0.42	0.96	cz011	-0.26	0.96	0.35
Szeged	197,417	75,292	10,799	6,154	0.03	-0.17	-0.48	1.01	hu006	-0.33	1.01	0.34
PREŠOV	163,743	93,455	8,012	4,355	-0.33	0.04	-0.24	0.63	sk005	-0.10	0.63	0.26
Nitra	163,764	87,020	9,516	5,261	-0.27	-0.28	-0.52	0.76	sk004	-0.40	0.76	0.18
Ajaccio	83,026	101,502	6,502	3,740	-0.71	-0.71	-0.91	1.09	fr027	-0.81	1.09	0.14
Suwalki	82,539	61,833	4,211	2,227	-0.50	-0.04	-0.26	0.43	pl021	-0.15	0.43	0.14
Setubal	113,811	17,283	4,253	1,927	1.67	0.65	0.69	-0.40	pt006	0.67	-0.40	0.14
Aveiro	112,873	27,335	6,351	3,391	0.65	-0.22	-0.43	0.50	pt008	-0.32	0.50	0.09
Faro	111,782	48,217	5,415	2,760	-0.09	0.06	-0.11	0.20	pt009	-0.03	0.20	0.09
Kecskemét	170,452	148,304	16,229	9,348	-0.58	-0.93	-1.08	1.10	hu008	-1.00	1.10	0.05
Catanzaro	146,730	76,141	6,356	3,008	-0.25	0.29	0.24	-0.20	it024	0.27	-0.20	0.03
Ancona	208,235	40,844	8,351	3,729	1.05	0.47	0.55	-0.46	it017	0.51	-0.46	0.03
Žilina	156,869	81,391	7,814	3,870	-0.25	0.00	-0.11	0.03	sk006	-0.06	0.03	-0.01
Ruse	201,410	89,261	7,374	2,664	-0.12	0.70	1.41	-1.14	bg006	1.06	-1.14	-0.04
Foggia	196,072	104,812	7,128	2,012	-0.28	0.72	2.35	-1.63	it031	1.54	-1.63	-0.05
Valletta	208,542	24,671	8,815	3,900	2.44	0.35	0.45	-0.50	mt001	0.40	-0.50	-0.05
Vidin	85,974	51,750	4,462	2,181	-0.36	-0.08	-0.16	-0.04	bg007	-0.12	-0.04	-0.08
Ponto Delgada	119,571	53,714	5,859	2,780	-0.13	0.03	-0.01	-0.19	pt007	0.01	-0.19	-0.09
Trento	185,452	77,916	8,168	3,614	-0.07	0.26	0.35	-0.50	it014	0.31	-0.50	-0.10
Gorzów Wielkopolski	190,251	130,538	9,552	4,531	-0.45	-0.01	-0.05	-0.19	pl017	-0.03	-0.19	-0.11
Trencín	112,515	67,404	6,002	2,877	-0.36	-0.13	-0.17	-0.14	sk008	-0.15	-0.14	-0.14
Banska Bystrica	111,419	80,887	4,907	2,079	-0.48	0.26	0.45	-0.66	sk003	0.35	-0.66	-0.15
Konin	143,305	75,844	8,337	4,097	-0.27	-0.28	-0.35	-0.01	pl022	-0.32	-0.01	-0.16
Hradec Kralove	159,293	87,600	10,146	5,030	-0.30	-0.42	-0.50	0.04	cz009	-0.46	0.04	-0.21
Székesfehérvár	155,877	114,417	11,685	6,031	-0.49	-0.65	-0.75	0.28	hu009	-0.70	0.28	-0.21
Campobasso	116,507	130,868	9,613	5,049	-0.68	-0.77	-0.87	0.39	it020	-0.82	0.39	-0.22
Apeldoorn	212,948	62,505	11,832	5,551	0.36	-0.20	-0.21	-0.24	nl014	-0.20	-0.24	-0.22
Santiago de Compostela	186,332	135,165	17,203	9,168	-0.48	-0.90	-0.99	0.49	es011	-0.94	0.49	-0.23
Perugia	207,569	80,602	11,612	5,433	0.01	-0.21	-0.21	-0.25	it016	-0.21	-0.25	-0.23
Brugge	165,743	41,228	10,260	4,953	0.61	-0.38	-0.42	-0.10	be006	-0.40	-0.10	-0.25
Pleven	206,936	179,197	11,400	5,236	-0.57	-0.18	-0.16	-0.34	bg005	-0.17	-0.34	-0.25
Sassari	200,554	122,648	12,326	5,903	-0.37	-0.37	-0.40	-0.14	it026	-0.38	-0.14	-0.26
Leeuwarden	158,883	45,205	7,870	3,313	0.40	0.01	0.21	-0.69	nl015	0.11	-0.69	-0.29
Zielona Góra	207,451	162,701	11,222	4,862	-0.52	-0.15	-0.02	-0.58	pl018	-0.09	-0.58	-0.33
Koszalin	171,469	175,106	9,248	3,983	-0.65	-0.15	0.00	-0.60	pl028	-0.08	-0.60	-0.34
Lincoln	164,418	72,378	10,076	4,528	-0.11	-0.36	-0.30	-0.43	uk019	-0.33	-0.43	-0.38
Tartu	148,872	300,056	15,269	7,858	-0.85	-1.00	-1.05	0.26	ee002	-1.02	0.26	-0.38
TRNAVA	126,822	74,092	7,678	3,412	-0.34	-0.34	-0.26	-0.48	sk007	-0.30	-0.48	-0.39
Pardubice	159,981	89,091	11,266	5,187	-0.31	-0.57	-0.53	-0.33	cz010	-0.55	-0.33	-0.44
Jihlava	108,292	117,869	7,668	3,518	-0.67	-0.58	-0.54	-0.34	cz014	-0.56	-0.34	-0.45
l'Aquila	100,592	158,778	8,637	4,165	-0.79	-0.82	-0.82	-0.11	it018	-0.82	-0.11	-0.46
Ceske Budejovice	179,369	162,455	13,847	6,440	-0.59	-0.69	-0.66	-0.28	cz008	-0.68	-0.28	-0.48
Poitiers	216,847	176,075	21,018	10,144	-0.54	-0.95	-0.94	-0.10	fr021	-0.94	-0.10	-0.52
Panevezys	160,656	222,822	12,981	5,972	-0.75	-0.75	-0.70	-0.33	lt003	-0.72	-0.33	-0.53
Weimar	153,353	88,949	9,241	3,669	-0.34	-0.34	-0.06	-0.88	de030	-0.20	-0.88	-0.54
Örebro	178,748	368,777	22,975	11,409	-0.85	-1.19	-1.19	0.05	se008	-1.19	0.05	-0.57
Logroño	171,599	143,702	9,401	2,232	-0.56	-0.17	1.46	-1.86	es018	0.64	-1.86	-0.61
Oulu	196,096	376,836	21,387	10,179	-0.84	-1.06	-1.03	-0.17	fi004	-1.05	-0.17	-0.61
Potenza	145,337	149,847	11,470	4,948	-0.65	-0.72	-0.60	-0.60	it023	-0.66	-0.60	-0.63
Cremona	132,159	66,133	8,132	2,892	-0.22	-0.37	0.11	-1.18	it013	-0.13	-1.18	-0.66
Ioannina	139,522	132,632	9,364	3,575	-0.62	-0.50	-0.18	-1.00	gr007	-0.34	-1.00	-0.67
Larissa	187,831	155,570	11,651	4,023	-0.55	-0.38	0.15	-1.25	gr005	-0.11	-1.25	-0.68
Liepaja	131,788	365,731	11,136	4,529	-0.90	-0.80	-0.61	-0.80	lv002	-0.70	-0.80	-0.75
Umeå	139,588	981,210	25,950	12,494	-0.99	-1.42	-1.39	-0.11	se005	-1.40	-0.11	-0.76
Jönköping	148,693	347,332	18,894	8,138	-0.87	-1.18	-1.08	-0.60	se004	-1.13	-0.60	-0.87
Linköping	183,221	423,193	23,690	9,989	-0.87	-1.20	-1.07	-0.68	se007	-1.14	-0.68	-0.91
Karlovy Vary	121,430	162,137	11,246	4,109	-0.74	-0.90	-0.59	-1.11	cz013	-0.74	-1.11	-0.93
Toledo	167,036	361,635	15,387	4,411	-0.86	-0.89	-0.23	-1.61	es016	-0.56	-1.61	-1.08

Table 2. Compactness and other data per LUZ. The most recent population data for Setubal and Lincoln is 2001 whereas for Pleven, Vidin and Ruse is 1991

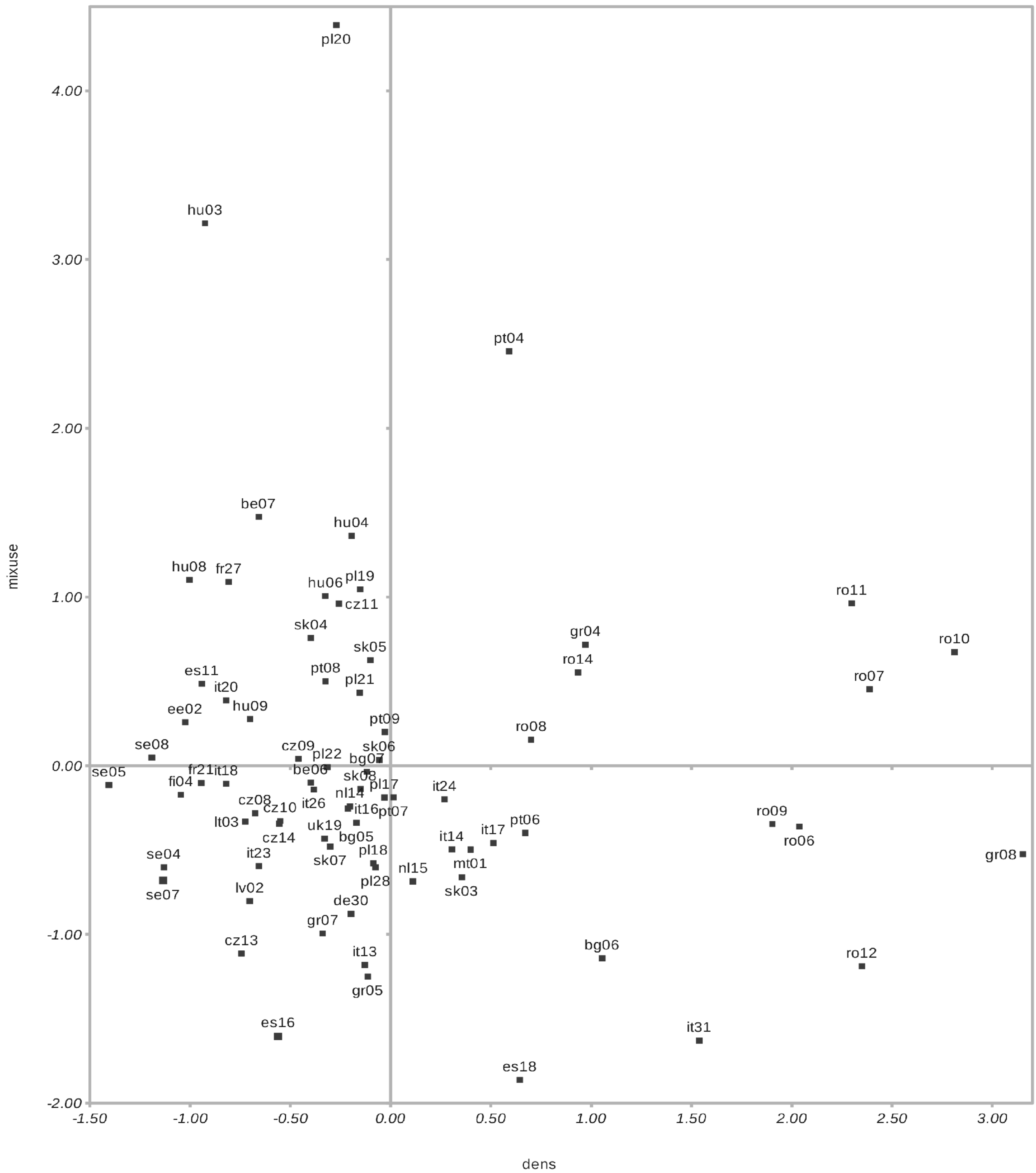

Figure 2. Compactness of cities based on density and mix-of-use.

6. ACKNOWLEDGEMENT

The Urban Atlas dataset is a property of the European Commission (Directorate-General Enterprise and Industry and Directorate-General for Regional Policy).

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Revised March 2013