TECHNICAL REPORT

ESPON

Modeling territorial changes and time series database building process: empirical approach and applications

CONTENT

The problem of time series data is the lack of data a territorial unit either because the territorial unit has changed in the course of time or because data are simply missing.

Three complementary methods have been investigated: data collection in historical regional databases, NUTS changes modeling and missing values estimation.

The building of a dictionary of changes is a fundamental step to build harmonized spatiotemporal database. It consists to describing and modeling of territorial changes.

This theoretical framework was tested through data sets.

ESPON 2013 DATABASE

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Introduction

ESPON DB 2013 project aims to improve the access to time series data. The issue of time series is a recurring necessity for ESPON projects and several European institutions primarily DG REGIO and ESUROSTAT. In spite of it importance, this process has not very well initiated by the previous ESPON DB project (2006)1.

This brief technical report is for the purpose of providing a background to time series challenge of ESPON DB project during the timeframe December 2008 to December 2009. In this first period of the project, activities done are mainly conceptual. Some applications and operational results have been developed since November 2009 (figure 25).

The issue of time series data could be fundamentally assimilated to the lack of data for a territorial unit either because the territorial unit has changed in the course of time or because data are simply missing. Difficulties to build time series data can be related firstly to the lack of achieved databases EUROSTAT, as the principal provider of European statistics, does not archive its database versions. It keeps just the last version of database. Secondly, information about historical changes of NUTS is often missing or uncertain.

Time series approach can be organized in two main steps. Firstly, collection and exploration of historical data bases (NewCronos from EUROSTAT, cohesion reports from DG-REGIO…) was undertaken. This works aims to provide a review of continuous time-data series could be built form this data bases. Additionally, we have explored NUTS changes between 1995 and 2006. The dictionary of NUTS changes is the main result of this exploration. It allows a review of territorial changes (codes, names and geometries). But the most contribution of the dictionary of changes is the identification of the genealogy (lineage) of NUTS which is very useful for the harmonization of time-series data.

The result of this first step will be used to build continuous time-series data. The conceptual model and the implementation of the computing (automation) of the process is in progress.

[1] http://www.espon.eu/mmp/online/website/content/tools/832/index_EN.html

MAUP (First Interim Report 15/06/2006)

1.7 In what sense is the MAUP a problem? (p. 15)

[…]

The most important problem is about international and historical comparisons: do the elementary spatial units which are used for the analysis have the same meaning in two different countries? At two different time periods? It is not easy to determine if a difference in the results is due to a difference in the processes which are underlying the observed phenomena, or simply to a difference in the meaning of the spatial entities that are used for the observation.

http://www.espon.eu/mmp/online/website/content/projects/261/431/index_EN.html

Data Navigator 2 (Final Report, Part 1 – Handbook for data collection, January 2007)

4.3.4.1 Temporal integration

(p. 110)

[…] **Identificators or the geometries of the NUTS change strongly during the period**. These changes introduce very big difficulties in the survey of variables in the time. It doesn't exist any simple ties between two dates.

(p. 120)

Changes of geometry and changes of units identification, don't permit to get directly evolutions of population basing on initial data, as the shows following example:

We estimate an evolution for a middle time (1990-2000) and represent it for different geographical grids (NUTS 23 1988 and NUTS 23 1999) whereas data of population initial are the similar, calculations of evolution (1990-2000) defer very strongly from a geographical grid to the other.

http://www.espon.eu/mmp/online/website/content/tools/127/index_EN.html

Europe in the World (Final Interim Report, December 2007)

6.5. Conclusion (vol. 1 p 242)

The synthesis of the regional insertion of the ESPON region into the world economy and the typology of gateway cities that we have elaborated in this final section of the report cannot be considered as definitive results as their elaboration was based on a limited number of criteria. **Better results could be obtained in the future if, for example, international trades statistics can be obtain for the regional level or if coherent time series could be analyzed concerning the evolution of air traffic linking European cities to the rest of the World.** The current set of results does however uncover some important findings in accordance with the objectives of the ESDP.

http://www.espon.eu/mmp/online/website/content/projects/260/720/index_EN.html

1 Territorial changing information sources

Data availability and data quality are crucial for the understanding and the formalization of Nuts genealogy. Our attempt to harmonize NUTS versions is the result of a meticulous combination of several sources provided by European and national institutions.

1.1 Legal source: Official journal of the European Union

The Official Journal is the legal source. It constitutes the legal framework of regulation of NUTS since 2003. The regulation EC n° 1059/2003 defines the NUTS and states the conditions of their modifications. This information is very useful to understand and formalize the changes of NUTS. This founder juridical text is amended and updated when new countries joined the European Union (figure1).

Figure 1: *Example of regulations amendment following the accession of Czech Republic and Romania*

REGULATIONS

REGULATION (EC) No 176/2008 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 20 February 2008

amending Regulation (EC) No 1059/2003 on the establishment of a common classification of territorial units for statistics (NUTS) by reason of the accession of Bulgaria and Romania to the European Union

Annex I to Regulation (EC) No 1059/2003 is amended as follows:

1. the following table is inserted between BE — BELGIQUE/BELGIË and CZ — ČESKÁ REPUBLIKA:

'БЪЛГАРИЯ

CODE	NUTS 1	NUTS 2	NUTS 3
BG			
BG3	СЕВЕРНА И ЮГОИЗТОЧНА БЪЛГАРИЯ		
BG31		Северозападен	
BG311			Видин
BG312			Монтана
BG313			Враца
BG314			Плевен
BG315			Ловеч

1.2 Eurostat

Eurostat is the most valuable source. Many kinds of documents are produced by Eurostat2 allowing with NUTS changes, among which the most interesting is the description of changes occurring between each version. However, this description does not usually define types of changes. It is also, sometimes very imprecise, in the case of complex territorial modification, like the Danish territorial modification in 2006 which is described as follow: "Following an extensive regional reform in Denmark, where new administrative regions were created, Denmark will be divided into NUTS level 2 regions. The previous NUTS 3 regions do not generally correspond to the new NUTS level 2 regions. […] "The previous 15 administrative regions have been abolished and in their place, 11 new non administrative regions have been created by combining municipalities. Only two NUTS 3 level 3 regions remain intact".

Concerning the update and the of EUROSTAT database, EUROSTAT does not archive its database versions. First of all, it keeps just the last version of database. Secondly, information about historical changes of NUTS is often missing or uncertain.

Besides the data available on the Eurostat internet portal, we obtained a CDRom with the Windows-only New Cronos application (figure 2), i. e. the Eurostat archives. This CDRom was unsuitable for the needs of the project because of its web interface designed exclusively for data consultation and not for data exportation. The data were also stored on the CDRom in a specific file format unknown from us which led us to spend time on finding technical workarounds to finally extract and store these in a format we could handle.

The data appeared to be organised in 271 tables and 16 categories. We made an inventory of their content in order to have an idea of their completeness, so to say the time span covered and the territories covered. The nuts are from 1999, and all European countries that are currently EU members are represented, but this of course depending on the type of data, the nuts level, the years considered, and logically the completeness of these archive decreases with older data.

To provide here an exhaustive list of the content, even in a synthesised way, would be a non-sense because of the number of variables and parameters. The data currently available on the Eurostat internet portal and the data included in these archives are partially the same, except that they do not use the same nuts reference system.

These data will be included in the Database system but will depend on the time series conversion tool to mix them with the current Eurostat data. Reversely, since they refer to an older nuts genealogy (1999) they might be useful in the next step of the time series harmonisation challenge, but probably as a validation mean, to be compared with the values our tool will compute for the 1999 nuts references.

[2] http://ec.europa.eu/eurostat/ramon/nuts/splash_regions.html

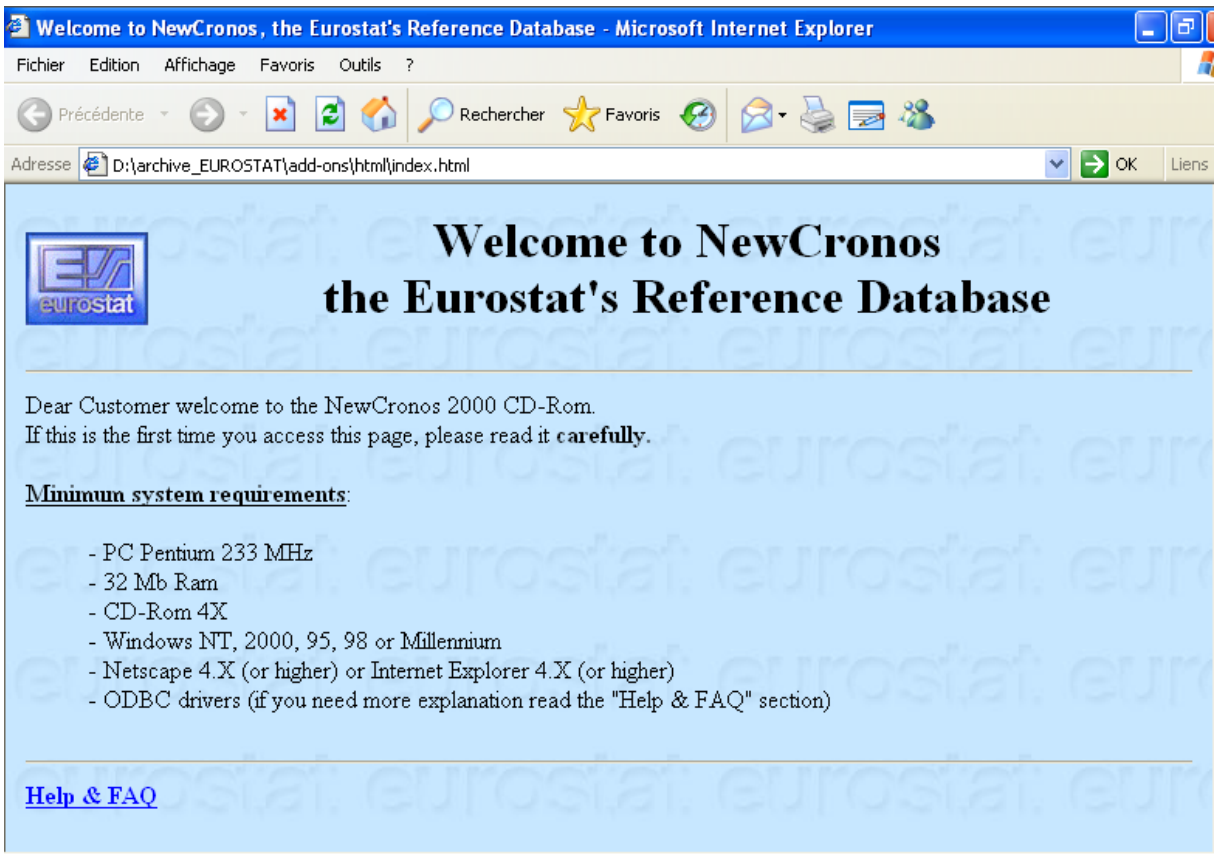


Figure 2: *NewCronos Web interface*

1.3 National Statistical Institutes

The European national statistical offices provide historical databases of national administrative boundaries. These sources are very useful for the understanding of local changes (national) which may affect geometry or structure of NUTS levels. National boundaries historical database is also very essential in the case of accessing new countries (EU15, EU25, and EU27) because EUROSTAT databases do not provide long term information about the historical administrative boundaries of these New Members.

Although a relatively high numbers of countries describe the changes of their administrative boundaries, the attempt does not construct a real temporal database. The most frequent method is to list changes as events (juridical rules) without relations between administrative units states. Historical "communes" database in France, done by the INSEE, describe changes of the local level from 1930 until today. However, this database is not easily workable because of describing textual change (Figure 3)

ID MUNICIPALITY	DATE OF THE CHANGE	DESCRIPTION
51 261	14/12/1930	Fresnes-lès-Reims become Fresne-lès-Reims.
67 161	21/02/1948	Gottenhausen become Gottenhouse.
12 307	03/12/1952	Curan is created thanks to some areas of Salles-Curan.
51 136	01/03/2006	Châtillon-sur-Marne is separated from Cuisles.
21 551	01/01/2009	Saint-Germain-Source-Seine is merged to Blessey, which become Source-Seine

Figure 3: *Extract of the "Historical French communes' database" done by INSEE*

Danish National statistical Institute has built population time series data based in the current Nuts version (figure3). Earlier 2003 territorial nuts changes data sets are also available.

NUTS VERSION	CODE	NAME	1979	1980	...	2004	2005	2006	...	2009
NUTS 2003	DK001	Copenhagen	505974	498850	...	501664	502362	501158	...	No data
NUTS 2003	DK001	Frederiksberg	88835	88287	...	91721	91886	91855	...	No data
NUTS 2003	DK002	Copenhagen County	629928	627245	...	618407	618237	618529	...	No data
NUTS 2003	DK003	Frederiksborg County	325855	329141	...	373688	375705	378686	...	No data
NUTS 2003	DK004	Roskilde County	199672	202017	...	237089	239049	241523	...	No data
NUTS 2003	DK005	West Zealand County	275985	277833	...	302479	304761	307207	...	No data
NUTS 2003	DK006	Storstrøm County	259445	260081	...	261884	262144	262781	...	No data
NUTS 2003	DK007	Bornholm (excl. Christiansø)	47605	47780	...	43673	43347	43245	...	No data
NUTS 2003	DK008	Funen County	451727	452965	...	475082	476580	478347	...	No data
NUTS 2003	DK009	South Jutland County	248985	249949	...	252936	252980	252433	...	No data
NUTS 2003	DK00A	Ribe County	211492	212624	...	224595	224454	224261	...	No data
NUTS 2003	DK00B	Vejle County	323418	325774	...	355691	358055	360921	...	No data
NUTS 2003	DK00C	Ringkøbing County	261028	262751	...	274830	274574	275065	...	No data
NUTS 2003	DK00D	Århus County	571702	573916	...	653472	657671	661370	...	No data
NUTS 2003	DK00E	Viborg County	230536	231517	...	234659	234434	234896	...	No data
NUTS 2003	DK00F	North Jutland County	479349	481335	...	495669	495068	495090	...	No data
NUTS 2006	DK011	Province København by	No data	No data	...	No data	646986	645875	...	667228
NUTS 2006	DK012	Province Københavns omegn	No data	No data	...	No data	504634	504317	...	508183
NUTS 2006	DK013	Province Nordsjælland	No data	No data	...	No data	436570	440036	...	444215
NUTS 2006	DK014	Province Bornholm	No data	No data	...	No data	43445	43337	...	42659
NUTS 2006	DK021	Province Østsjælland	No data	No data	...	No data	228712	231150	...	233605
NUTS 2006	DK022	Province Vest- og sydsjælland	No data	No data	...	No data	577242	580361	...	587647
NUTS 2006	DK031	Province Fyn	No data	No data	...	No data	476580	478347	...	484346
NUTS 2006	DK032	Province Sydjylland	No data	No data	...	No data	707171	707504	...	715321
NUTS 2006	DK042	Province Østjylland	No data	No data	...	No data	792934	798671	...	820558
NUTS 2006	DK041	Province Vestjylland	No data	No data	...	No data	419853	421054	...	427174
NUTS 2006	DK050	Province Nordjylland	No data	No data	...	No data	577278	576807	...	580515

Figure 4: *Population 1979-2009 in the NUTS3 of Denmark (both NUTS 2003 and 2006 version, according to the Danish National Statistic Institute)*

Italian National statistical Institute proposes another example of time series handling. It provides information related to national territorial changes and its correspondence with regional (European) level (figure 5).

However, the Italian example may be considered as the best attempt because it provides much information to describe the change of administrative units: type of change, juridical texts and relation between versions of unit (genealogy). It allows also to analyse the effect of national administrative boundaries change on the NUTS geometry and hierarchy.

Cartografia: confini amministrativi e dei sistemi locali del lavoro

Censimento 2001, 31 dicembre 2008 e 1 gennaio 2010

L'Istat fornisce la **versione generalizzata dei confini amministrativi** (Regioni, Province e Comuni) **e dei sistemi locali del lavoro**. Gli strati informativi sono costituiti da tre livelli gerarchici a copertura nazionale per i limiti di regione, provincia e comune.

I dati sono in formato shapefile; tale formato dati è stato reso pubblico già da parecchi anni ed utilizzato per lo scambio di dati in ambito GIS (Geografic Information System). I dati cartografici forniti sono nel sistema di riferimento ED_1950_UTM zona 32; il dettaglio tecnico della proiezione è riportato nel file apposito, associato a ciascun file geografico.

La scala dei dati non è certificabile uniformemente dall'Istat, in quanto le basi di acquisizione utilizzate provengono da fonti e scale differenti, che variano dal 1:5.000 in ambito urbano fino 1:25.000 in ambito extraurbano. I dati sono stati inoltre generalizzati e semplificati nelle forme geometriche, per renderne disponibile una versione da utilizzare agevolmente, per la creazione di cartografia simbolica o di riferimento a livello nazionale.

I file geografici di regioni, province e comuni, già pubblicati alla data del Censimento del 2001, sono stati aggiornati comprendendo le variazioni (territoriali e di nome) intercorse tra la data del Censimento 2001 e il 31 dicembre 2008 e successivamente al 1 gennaio 2010. Sono stati quindi acquisiti i codici e le denominazioni delle tre nuove province (Monza e della Brianza, Fermo e Barletta-Andria-Trani) e le nuove codifiche dei comuni ad esse appartenenti. Inoltre sono state acquisite anche altre variazioni comunali (si veda la Struttura dei dati). Per una più approfondita descrizione delle variazioni amministrative e territoriali intervenute successivamente alla data del Censimento del 2001 si può consultare la pagina web con i codici dei comuni, delle province e delle regioni.

Sono inoltre forniti i confini dei Sistemi locali del lavoro e delle NUTS2 (Nomenclature of territorial units for statistics), che rappresenta l'articolazione ufficiale europea del territorio di livello 2 (Regioni e le Province autonome per l'Italia) finalizzata alla produzione di statistiche.

descrizione **dati**
- Struttura dei dati

confini amministrativi

Censimento 2001
- Regioni
- Province
- Comuni

31 dicembre 2008
- Regioni
- Province
- Comuni

1 gennaio 2010
- Regioni
- Province
- Comuni

altra **cartografia**
- Sistemi locali del lavoro
  Censimento 2001
- NUTS2
  2008

per informazioni

Informazioni territoriali e sistema informativo geografico
tel. 06 4673.4861
email int@istat.it

Figure 5: *Web Interface of Italian National statistical Institute*

Furthermore the National Statistical Institutes, other government departments such as the interior ministers could publish documents related to national territorial changes. The Danish ministry of the interior and social affairs has published guide paper to understand the local boundaries reforms, which have consequences on the definition of NUTS3 and NUTS2 units (figure 6). This kind of document is not usually available.

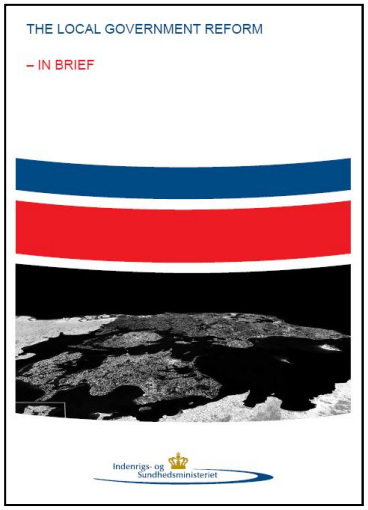


Figure 6: *Explanation of the Danish Reform on Territorial units*

1.4 Conclusion of the first part

Building NUTS temporal database is very complex for the following main reasons:

- NUTS changes vary greatly from country to country due to their different structures;
- The available data are very heterogeneous;
- Data quality varies largely;
- Lack of good practice and experiences of handling territorial boundaries.

Based on a compilation of several sources and methods, we will propose formalization adapted to the specificity of NUTS.

2 Nuts changes knowledge: from elementary to systemic approach of territorial changes

The benchmarking of sources and experiences has showed the complexity of NUTS territorial changes. Following Swianczny, (2000) who stated that: "In order to create a truly time integrative GIS, the focus has to change from spatial to temporal and from analyzing changes between events to the analysis of the change itself", we propose an appropriate approach to formalize the Nuts changes. This approach will be based on an explicit description of changes.

Based on the characteristics of NUTS, determined by regulations, we can distinguish the following changes: name, geometry, code and hierarchical level. These changes can occur at the same time because territorial changes are very complex. The changes analysis may be presented from tow angles: elementary approach and systemic approach.

2.1 Elementary changes

Elementary approach consists in describing the change of territorial units one undependably of the others (figure 7).

- Change of name: two cases can be distinguished. If the unit in question belongs to two levels (it is at the same time a NUTS 2 and a NUTS 3) the change of name can concern either one or the two levels.

  1999: BE31 Brabant Wallon
  2003: B310 Arrondissement Nivelles

- Change of code: it may result from different types of territorial modifications: political decision, territorial reorganisation. In the first case, we can list many changes of NUTS 2 level in 2003. In the second case, we point the code changing of Italian NUTS 2 and NUTS 3 units since 2003 due to regional reorganisation of NUTS 1.
- Change of geometry: It is the most complicated change type. Generally, the deformation of a spatial unit can be done in three different ways: the loss of area, the gain of area, or the redistribution of boundaries even while keeping the same area value. Most of the time, there is no relation between the different versions of the NUTS, like in Poland (figure 9). This kind of situation makes the harmonisation very difficult to implement.
- Change of hierarchy: it consists to the change of the territorial reference or of belonging. As shown by the figure 7, Italian Nuts 2 level have changed their Nuts 1 units of belonging because of territorial reforms of nuts 1 level in 2003.

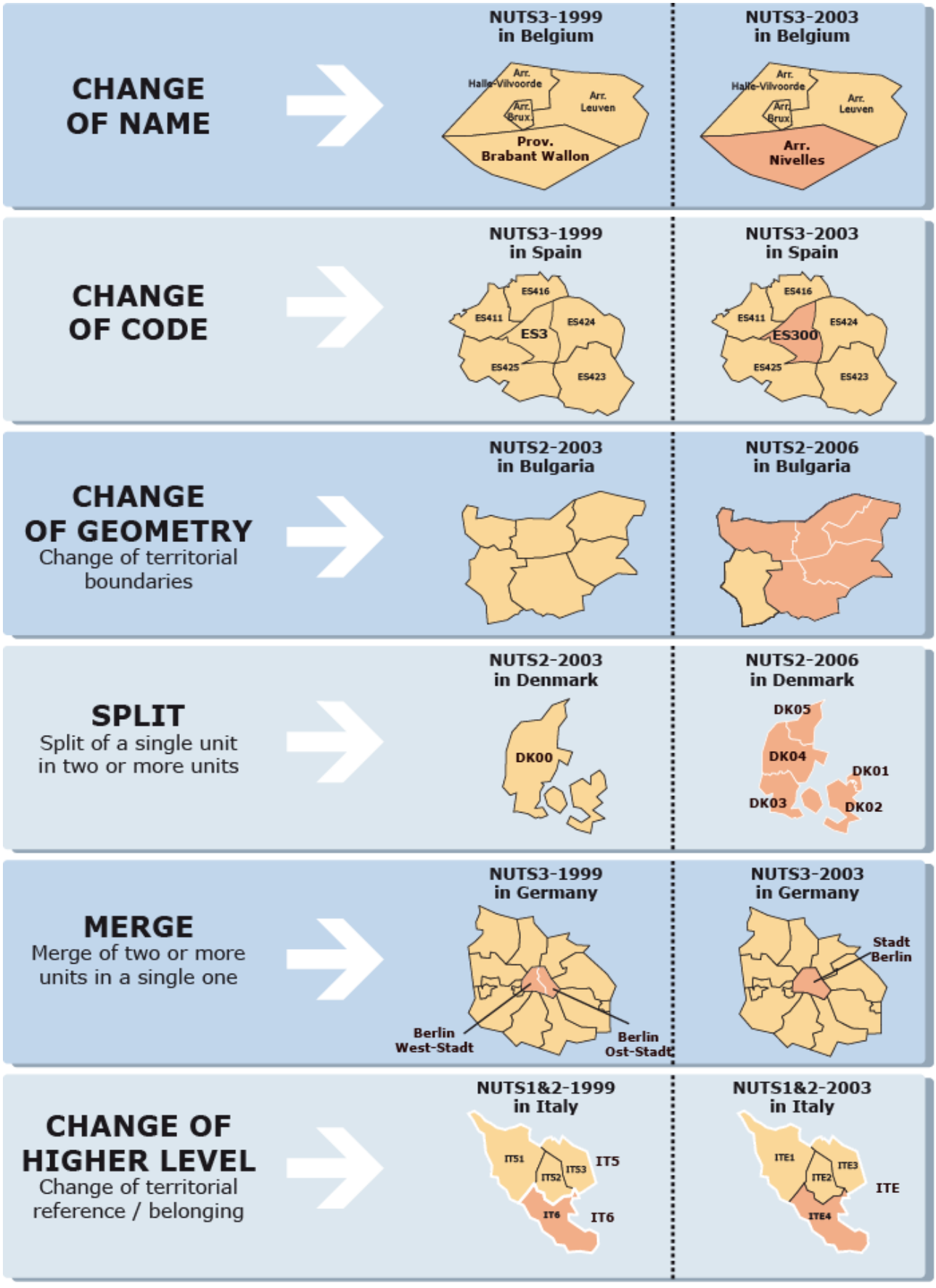


Figure 7: *Examples of elementary Nuts changes*

CODE 1999	CODE 2003	Name 1999	Name 2003	Status
ES3	ES3	Comunidad de Madrid	Comunidad de Madrid	No change
ES3	ES30	Comunidad de Madrid	Comunidad de Madrid	Changed
ES3	ES300	Comunidad de Madrid	Comunidad de Madrid	Changed
IT1	ITC	Nord Ovest	Nord Ovest	Changed
IT11	ITC1	Piemonte	Piemonte	Changed
IT111	ITC11	Torino	Torino	Changed
IT112	ITC12	Vercelli	Vercelli	Changed
IT113	ITC13	Biella	Biella	Changed
IT114	ITC14	Verbano-Cusio-Ossola	Verbano-Cusio-Ossola	Changed
IT115	ITC15	Novara	Novara	Changed
IT116	ITC16	Cuneo	Cuneo	Changed
IT117	ITC17	Asti	Asti	Changed
IT118	ITC18	Alessandria	Alessandria	Changed

Figure 8: *Examples of changing of unit's code in Italy and Spain from 1999 to 2003*

Considering the characteristics of Nuts units which are mentioned, limiting the investigation to basic (elementary) changes does not allow to reconstruct genealogy of Nuts. To achieve this, we have considered nuts structure as a system and we have focused on the relationship between changes.

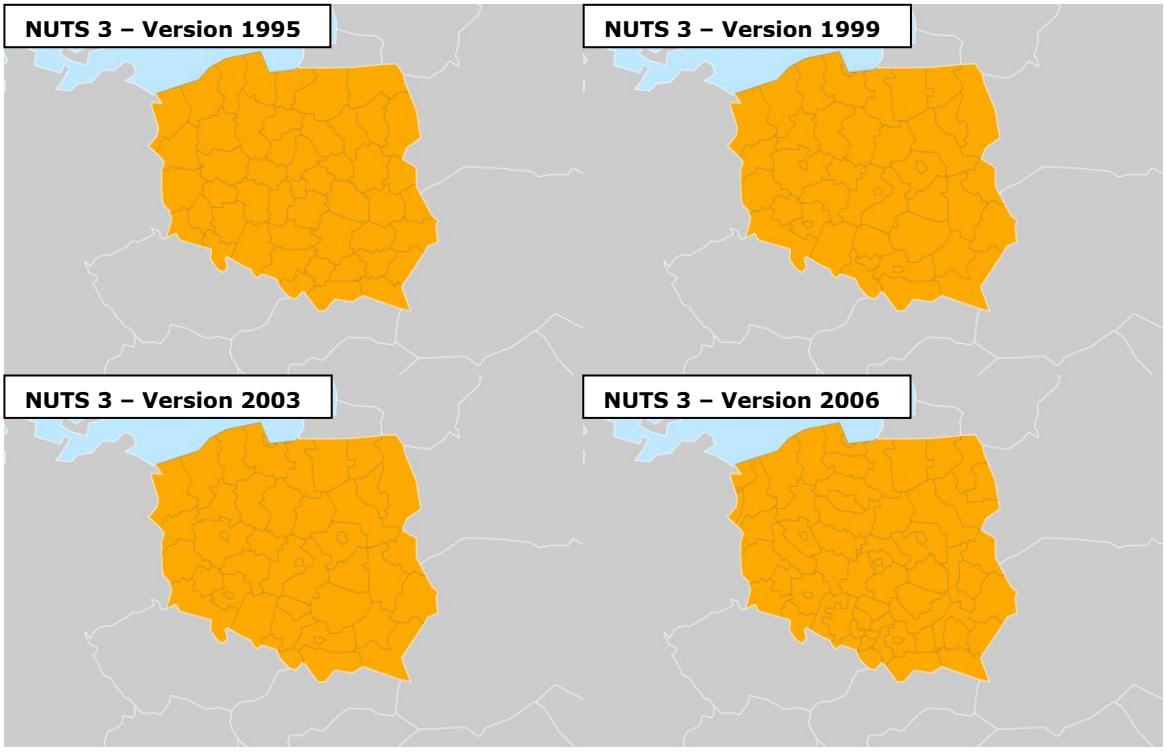


Figure9: *Complex geometry change in Polish nuts 3 units*

2.2 Systemic approach of NUTS changes

Because the formalization of Nuts changes is complex and has to take into account several parameters (type of changes, temporal period and scalar dimension), we propose a cubic model which emphasizes the relationships between these parameters. This means that the result of territorial modifications depends on the type of changes (name, code, and geometry), the period of time and the territorial level. Thus, we used the concept of systemic approach.
The systemic conception emphasizes the relationships between the changes:

- A change affecting a unit may have implications on the other units.
- A change happening on a given level may have implications on the other levels.

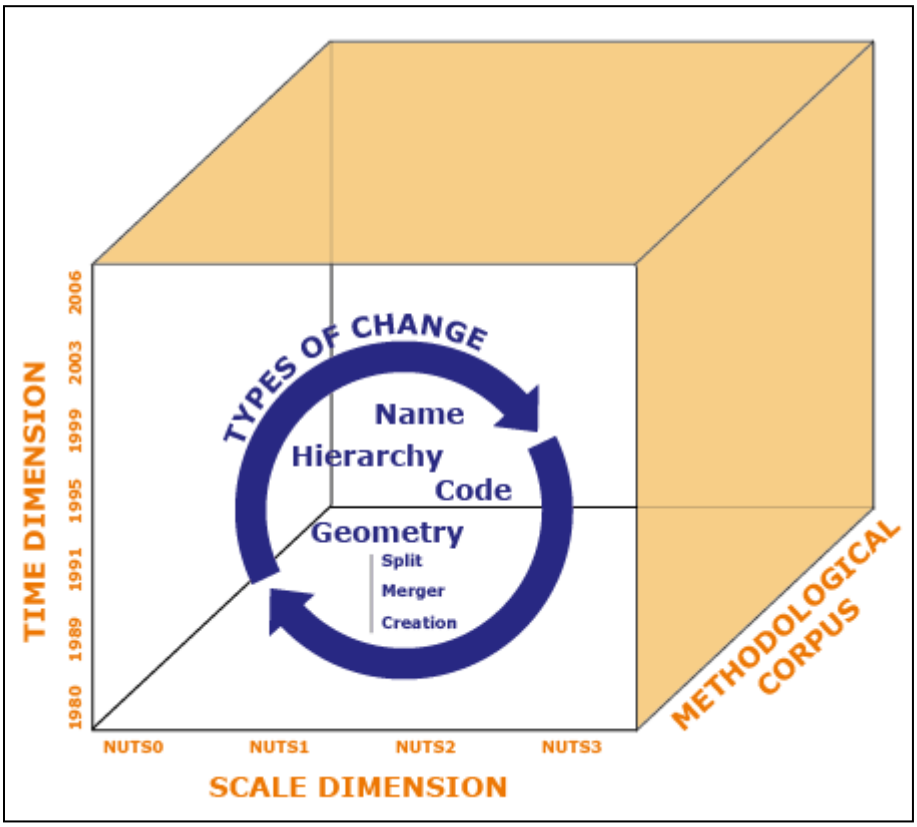


***Figure 10**: Cube structure of NUTS formalisation*

We demonstrate our approach through the analysis of the example of Italian Nuts between 1995 and 2006 (figure 10):
Concerning the temporal dimension, tow orders can be distinguished:

- The period of time determines the degree of discontinuity of the data sets. Indeed, the extension of the period increases the discontinuity because of the complexity of changes that may have occurred. In the case of Italian Nuts, if we consider the whole period (1995-2006), we can see a big discontinuity in the data sets. However, the data set will be complete between 2003 and 2006.
- The building of time series data could be considered in either a prospective or retrospective territorial approach. The prospective view consists in transposing old data sets onto a recent version of Nuts (data 1995 onto Nuts 2006 for example). However, the retrospective view consists in transposing recent data sets onto old Nuts versions (data 2006 to Nuts 1995). Each approach requires a

different methodology. For example, 2003 version data should be disaggregated to be integrated in Italian Nuts 1 level 1999 version. However, the 1995 version data should be aggregated.

- As for the Scalar dimension, it is linked to the hierarchical structure of Nuts (Nuts 1 level is subdivided into Nuts 2 level which is in turn subdivided into Nuts 3 level). In fact, the changes which occur in higher levels (1 and 2) have various consequences on lower territorial levels. As it was shown by the figure 7, the territorial reform of Italian Nuts 1 level in 2003, consisting in merging and changing codes of units, has caused a change of codes of Nuts 2 and Nuts 3 units. Moreover, reforms of higher Nuts levels (Nuts 1 and Nuts 2) could have more complex implications on lower levels. The creation of 5 new Nuts 2 units in Denmark in 2003, by splitting DK00, has caused very complex territorial reorganization on Nuts 3 level units (Figure 7).

Regarding Relationships between changes, the change of geometry is a determining factor in the time series data building process. On the whole, three types of unit spatial changes can be identified: the loss of area, the gain of area and deformation (which means territorial boundaries redistribution without loss of area). Based on these primary types of changes, we have developed a conceptual corpus to describe further types of changes (dictionary of changes). The dictionary of changes aims to answer the following questions: what happened? How did it happen? And what were the results?
For example, the Danish territorial reforms in 2003 could be described as follows:

Nuts 1 level: there are no changes

Nuts 2 level:

- The Split of DK00 (change of geometry)
- Official disappearance of DK00
- Creation of 5 new Nuts 2 units: DK01, DK02, DK03, DK04 and DK05

Nuts 3 level:

- Change of code which means change of belonging to a superior unit (hierarchy): Funy DK008 (2003) and DK031 (2006), Bornholm DK007 (2003) and DK014 (2006)
- Complex changes of geometry for the rest of units which have caused the disappearance of 12 units and the creation of 10 new units

3 Building historical database of territorial changes: from conceptual approach to operational solutions

This process of formalization of Nuts changes is not an end in itself. Aiming to build continuous time series data, its first objective is to understand how spatial units have been changed. Information describing Nuts changes represent a very useful metadata. In this final section of this technical report, we will examine how these results could be presented to the users. A first application made on cohesion reports will also be presented.

The results of this exploration may be presented in different ways depending on the users' needs. The examples that we present illustrate the progress of the complexity of the issue of nuts changes formalization. Location of change, identification of change and genealogy (lineage) of spatial units are the most important information that could be allowed to the users at this stage of work.

3.1 Improved Snapshot model (presentation)

One of the simplest spatio-temporal data models is the snapshot model (Armstrong 1988). Temporal information was incorporated into this spatial data model by time-stamping layers. Every layer shows the states of NUTS at different times without explicit relation between versions. Changes and genealogy cannot be depicted. This prevents harmonized database to be built.

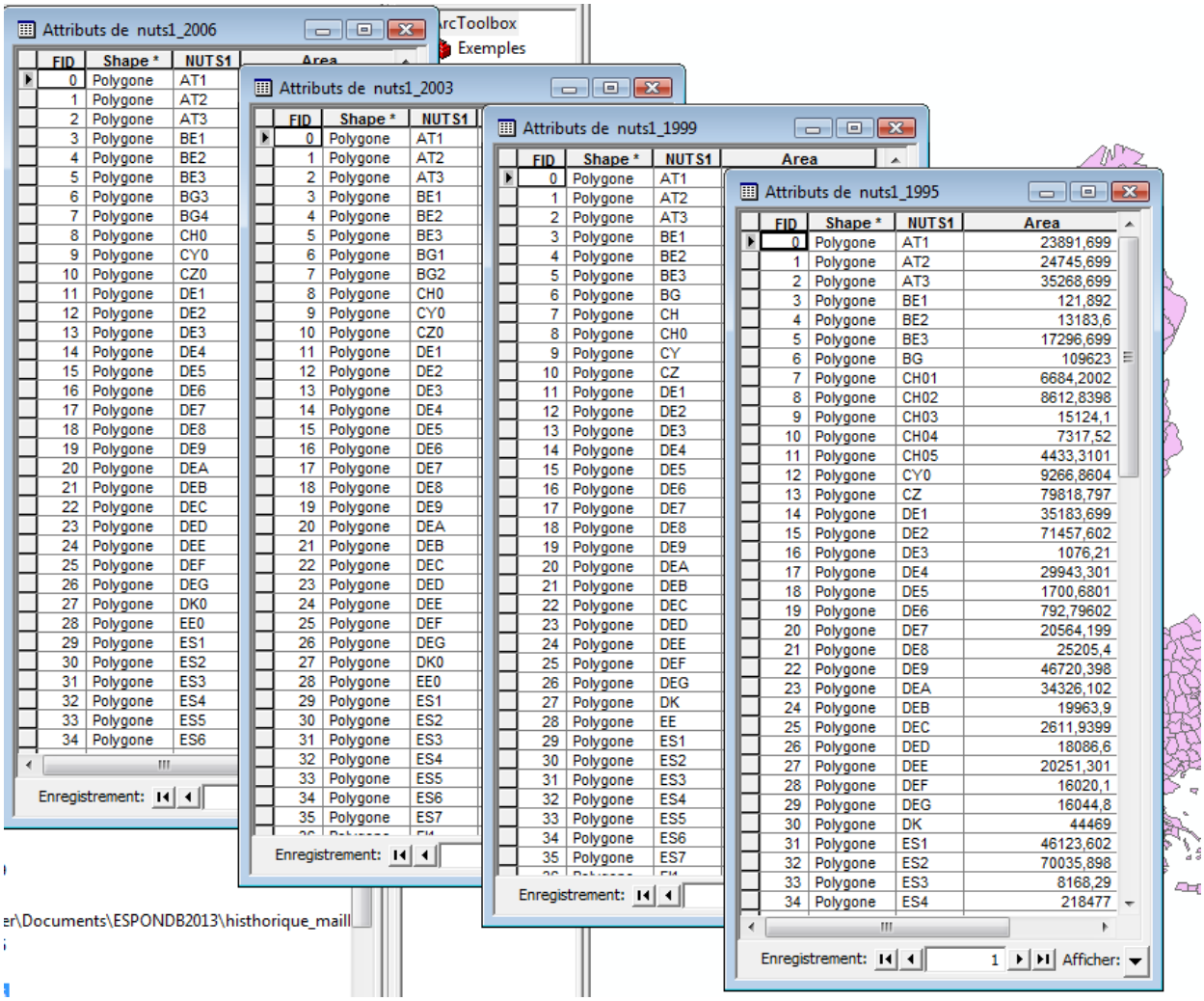


Figure 11: *Snapshot of NUTS versions between 1995 and 2006 (example of Nuts 1 level)*

This method could be improved by location of changes occurred. A binary code was attributed to the state of Nuts: 0 for stability and 1 in case of change. This simple coding can identify potential discontinuities in the time series. The figure 11 shows an extract of tables covering all Nuts levels.

Code 2006	NUTS0	NUTS level 1	NUTS level 2	NUTS level 3	Change	Change since 2003
DK0		DANMARK			same	0
DK01			Hovedstaden		changed	1
DK011				Byen København	changed	1
DK012				Københavns omegn	changed	1
DK013				Nordsjælland	changed	1
DK014				Bornholm	changed	1
DK02			Sjælland		changed	1
DK021				Østsjælland	changed	1
DK022				Vest- og Sydsjælland	changed	1
DK03			Syddanmark		changed	1
DK031				Fyn	changed	1
DK032				Sydjylland	changed	1
DK04			Midtjylland		changed	1
DK041				Vestjylland	changed	1
DK042				Østjylland	changed	1
DK05			Nordjylland		changed	1
DK050				Nordjylland	changed	1

Figure 12: *Extract of table of location of changes: Danish Nuts between 2006 and 2003*

The figure 12 shows more developed stage of change describing process. Identifying kinds of change and the consequences, even in scalar dimension and relationship between changes, were added to the location of change.

- The column Check: change/no change
- The column Change: identify the initial change
- The column Life: indicates if units exists (E) or did not exist (D: deleted)
- The column Hierarchy : change of geometry (0/1)
- The column Geometry: specifies the change of geometry of the unit

Semantic describing changes (code) should be improved. A table of Metadata will be established when this semantic description will be consolidated.

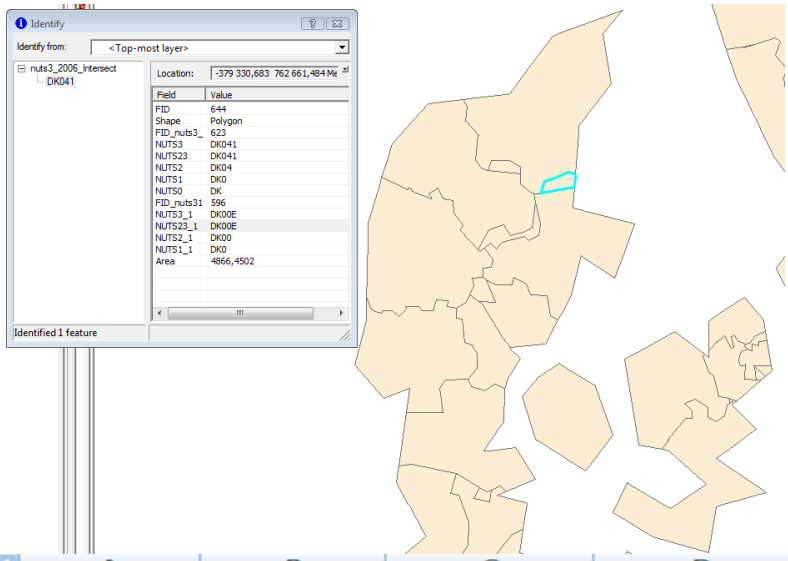
Code 2003	Code 2006	Country	NUTS level 1	NUTS level 2	NUTS level 3	CHECK	CHANGE	LIFE	HIERARCHY	GEOMETRY
	DK01			Hovedstaden		**changed**	GEOM	N	0	GEOM+
	DK011				Byen København	**changed**	GEOM	N	0	GEOM+
	DK012				Københavns omegn	**changed**	GEOM	N	0	GEOM+
	DK013				Nordsjælland	**changed**	GEOM	N	0	GEOM+
DK007	DK014				Bornholm	**changed**	GEOM	N	0	GEOM+
	DK02			Sjælland		**changed**	GEOM	N	0	GEOM+
	DK021				Østsjælland	**changed**	GEOM	N	0	GEOM+
	DK022				Vest- og Sydsjælland	**changed**	GEOM	N	0	GEOM+
	DK03			Syddanmark		**changed**	GEOM	N	0	GEOM+
DK008	DK031				Fyn	**changed**	GEOM	N	0	GEOM+
	DK032				Sydjylland	**changed**	GEOM	N	0	GEOM+
	DK04			Midtjylland		**changed**	GEOM	N	0	GEOM+
	DK041				Vestjylland	**changed**	GEOM	N	0	GEOM+
	DK042				Østjylland	**changed**	GEOM	N	0	GEOM+
	DK05			Nordjylland		**changed**	GEOM	N	0	GEOM+
	DK050				Nordjylland	**changed**	GEOM	N	0	GEOM+
DK00				*Danmark*		**changed**	GEOM	D	0	0
DK001					*København og Frederiksberg kommuner*	**changed**	GEOM	D	0	0
DK002					*Københavns amt*	**changed**	GEOM	D	0	0
DK003					*Frederiksborg amt*	**changed**	GEOM	D	0	0
DK004					*Roskilde amt*	**changed**	GEOM	D	0	0
DK005					*Vestsjællands amt*	**changed**	GEOM	D	0	0
DK006					*Storstrøms amt*	**changed**	GEOM	D	0	0
DK009					*Sønderjyllands amt*	**changed**	GEOM	D	0	0
DK00A					*Ribe amt*	**changed**	GEOM	D	0	0
DK00B					*Vejle amt*	**changed**	GEOM	D	0	0
DK00C					*Ringkøbing amt*	**changed**	GEOM	D	0	0
DK00D					*Århus amt*	**changed**	GEOM	D	0	0
DK00E					*Viborg amt*	**changed**	GEOM	D	0	0
DK00F					*Nordjyllands amt*	**changed**	GEOM	D	0	0

Figure 13: *Extract of table of identification of changes: Danish Nuts between 2006 and 2003*

3.2 The space-time composite model: reconstructing genealogy of Nuts versions

This model was proposed by Langran (1992). It consists to decompose NUTS, geometries through time by intersecting different versions (1995-1999-2003-2006). Small spatio-temporal entities (polygons) are created as the results of this intersection. It represents the lowest common denominator.

As it is shown by the figure 13 the intersection of geometries of Danish NUTS 3 2003 and 2006 versions results 22 polygons. The belonging to NUTS is defined as a temporal attribute. For example, the polygon n°11 (table and selected in the maps) belong to DK00E unit in 2003 and to DK041 unit in 2006. In fact, genealogy of units can be deducted and may be represented by a graph.



	A	B	C	D
1	Polygons	NUTS3-2003	NUTS3-2006	Area
2	p1	DK001	DK011	50,8357
3	p2	DK002	DK011	32,7178
4	p3	DK002	DK012	321,644
5	p4	DK002	DK013	71,7531
6	p5	DK003	DK013	774,849
7	p6	DK004	DK021	863,461
8	p7	DK005	DK022	3171,58
9	p8	DK006	DK022	4059,64
10	p9	DK007	DK014	614,29
11	p10	DK00C	DK041	5227,71
12	p11	DK00E	DK041	4866,45
13	p12	DK00B	DK041	183,677
14	p13	DK00D	DK042	4056,62
15	p14	DK00E	DK042	335,029
16	p15	DK00B	DK042	1459,76
17	p16	DK00D	DK050	186,306
18	p17	DK00E	DK050	147,482
19	p18	DK00F	DK050	6069,42
20	p19	DK008	DK031	2659,36
21	p20	DK00A	DK032	4063,59
22	p21	DK009	DK032	3891,81
23	p22	DK00B	DK032	1351,82

Figure 14: *Space time composite model*

We have improved this cartographic method by quantifying lineage of Nuts. Information collected through the exploration of sources has allowed us to establish a relationship between spatial units. We tried to quantify this genealogy by calculating the proportion of area transferred in case of change. The proportion of the population transferred will also be tested. This method is very useful for estimating missing data because of territorial changes

The figure 14 illustrates the table built. It does not yet cover all the ESPON area because of lack of accurate data especially for the new member countries.

NAME	code 2006	% Geom	code 2003	% Geom	code 1999	% Geom	code 1995	NAME
Denmark	0	*0*	DK00	*100*	DK00	*100*	DK00	Danmark
	DK01	*4,2*	DK00	*4,2*	DK00	*4,2*	DK00	Hovedstaden
	DK02	*18,2*	DK00	*18,2*	DK00	*18,2*	DK00	Sjælland
	DK03	*26,9*	DK00	*26,9*	DK00	*26,9*	DK00	Syddanmark
	DK04	*36,3*	DK00	*36,3*	DK00	*36,3*	DK00	Midtjylland
	DK05	*14,4*	DK00	*14,4*	DK00	*14,4*	DK00	Nordjylland

Figure 15: *Extract of table of genealogy of Nuts: Danish Nuts2 level between 2006 and 1995*

Another simple approach is to tag every object (NUTS) with a pair of timestamps, one for the time of creation and one for the time of cessation. Current objects have their cessation time given by a special value "NOW", "CURRENT", or "NULL".

To conclude this section, we emphasize that these applications were developed in the following time periods: 2006-2003; 2006-1999; 2006-1995, 2003-1999; 2003-1995 and 1999-1995.

3.3 Towards a NUTS changes mapping

A cartographic display of the results of formalization would be very useful for the better understanding of Nuts territorial changes. However the visualization of changes is as complex as the formalization and it depends on all parameters prsented in the previous section. We propose the following thoughts.

3.3.1 A general view

The map of static units distinguishes static units (no change observed) from changed units as shown by the figure 15. Yellow units are static. However, white units have been changed since 1995.

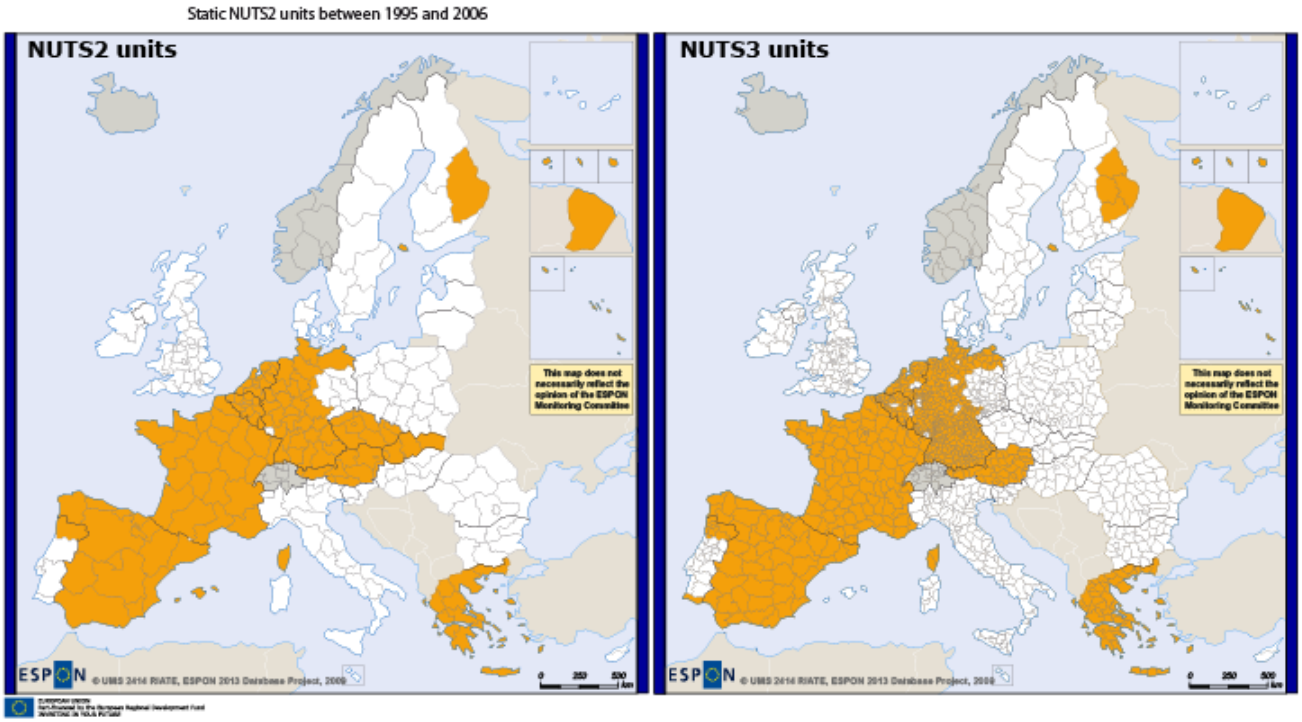


***Figure 16*:** Static NUTS 2 and Nuts 3 units between 1995 and 2006 (all criteria).

3.3.2 *Typology of changes*

These maps give more information about changes. It aims to emphasize on the diversity of changes. The most important kinds of changes are: name, code, geometry and hierarchy.

3.3.3 *Maps by times intervals*

The interval of time (period) is a very important parameter for building time series database. Naturally, the enlargement of the covered period makes the building process more difficult. Mapping changes by period of time could help users in their building time series process.

3.3.4 *Examples of lineage (genealogy) visualization*

The attempt is to propose a graphic visualization of the units' genealogy. We selected the most demonstrative examples in order to emphasize in the complexity of Nuts changes. These patterns are in an early stage implementation and should be improved.

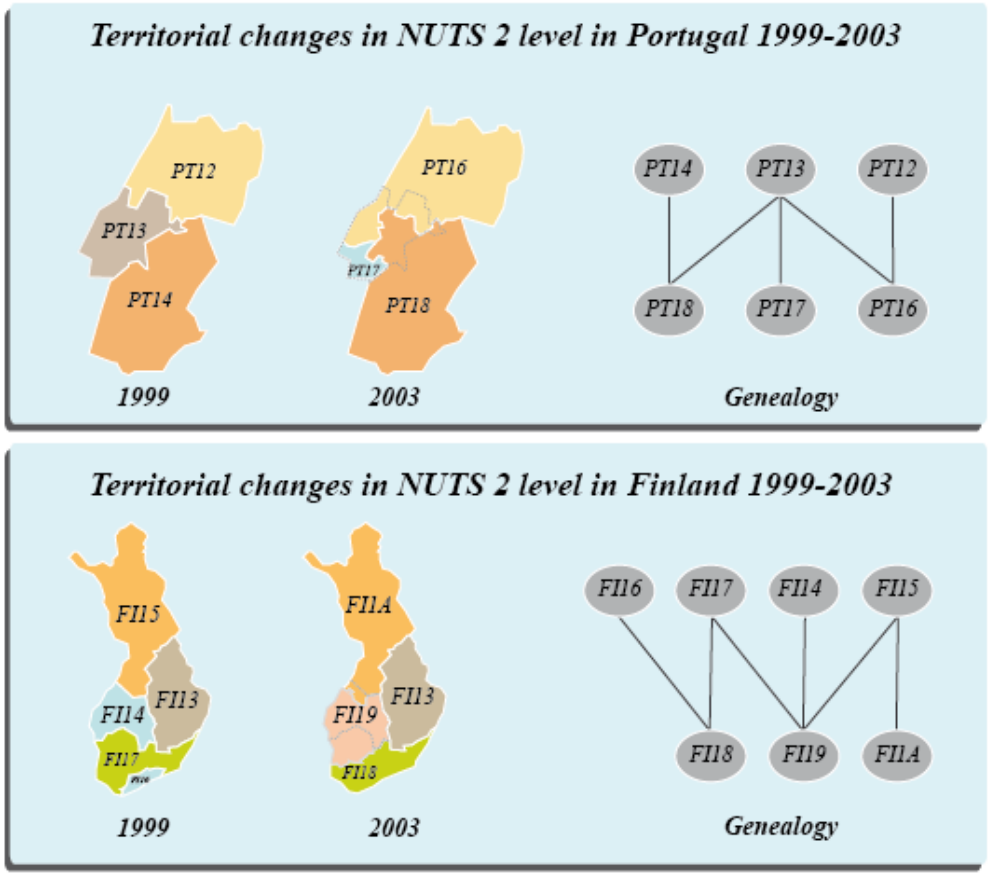


Figure 17: examples of NUTS genealogy visualization

3.4 Tables structure of NUTS changes

Table structuring of NUTS changes is a very challenging topic. The aim of this topic is to provide a very friendly using data about territorial changes. The complexity of NUTS changes requires simplifying the information to be useful and comprehensive by a large public dealing with time series data implementation.

We propose a several ways of structuring change tables. Theses tables are complementary and propose different visions of territorial changes that meet to needs of many users in terms of spatiotemporal databases.

3.4.1 Changes location tables

It is a binary description of NUTS situation between each version: 1995-1999, 1999-2003 and 2003-2006 (more time intervals combinations are possible). The aim of this table is to locate changes regarding all analysis criteria (name, code, geometry and belonging to a higher level).

Code 2006	NUTS0	NUTS level 1	NUTS level 2	NUTS level 3	Change since 2003
DK	DANMARK				0
DK0		DANMARK			0
DK01			Hovedstaden		1
DK011				Byen København	1
DK012				Københavns omegn	1
DK013				Nordsjælland	1
DK014				Bornholm	1
DK02			Sjælland		1
DK021				Østsjælland	1

Figure 18: extract of change location table (Danish Nuts between 2003 and 2006)

3.4.2 Changes typology tables

These tables give more detailed information about changes. The identification of nuts changes is very helpful for understanding territorial changes. It could contribute to the database harmonization. Regarding to nuts changes formalization presented in the previous section (2.2), we identified four kinds of change: name, code, geometry and belonging to a higher level.

Code 2003	Code 1999	NUTS level 1	NUTS level 2	NUTS level 3	OP	CHANGE	LIFE	HIERARCHY	GEOMETRY
DE3	DE3	BERLIN			0	0	E	0	0
DE30	DE3		Berlin		CODE	CODE	E	1	0
0	DE300			Berlin	MERGER	NO	D	0	NO
DE301	0			Berlin-West, Stadt	MERGER	NO	N	0	GEOM+
DE302	0			Berlin-Ost, Stadt	MERGER	NO	N	0	GEOM+
DE4	DE4	BRANDENBURG			SPLIT	H	D	1	NO
0	DE4		Brandenburg		SPLIT	NO	D	0	NO
DE41	0			Brandenburg - Nordost	SPLIT	NO	N	0	GEOM+
DE42	0			Brandenburg - Südwest	SPLIT	NO	N	0	GEOM+
DE411	DE403			Frankfurt (Oder), Kreisfreie Stadt	SPLIT	CODE	E	2	0
DE412	DE405			Barnim	SPLIT	CODE	E	2	0
DE413	DE409			Märkisch-Oderland	SPLIT	CODE	E	2	0
DE414	DE40A			Oberhavel	SPLIT	CODE	E	2	0
DE415	DE40C			Oder-Spree	SPLIT	CODE	E	2	0
DE416	DE40D			Ostprignitz-Ruppin	SPLIT	CODE	E	2	0
DE417	DE40F			Prignitz	SPLIT	CODE	E	2	0
DE418	DE40I			Uckermark	SPLIT	CODE	E	2	0

Figure 19: extract of change typology table (German Nuts between 2003 and 1999)

3.4.3 "Units life" tables

The aim of these tables is to provide a general view of the official existence of units in each nuts version. The use of legal definition of statistical units (Official journal of the European Union) avoided the several interpretations of the notion of "life". We regroup in one table all units from 1995 to 2006 and we indicate each version, by binary description, if it exists or it was deleted.

Code 2003	Code 1999	NUTS level 1	NUTS level 2	NUTS level 3	OP	LIFE
DE3	DE3	BERLIN			0	1
DE30	DE3		Berlin		CODE	1
0	DE300			Berlin	MERGER	0
DE301	0			Berlin-West, Stadt	MERGER	1
DE302	0			Berlin-Ost, Stadt	MERGER	1
DE4	DE4	BRANDENBURG			SPLIT	0
0	DE4		Brandenburg		SPLIT	0
DE41	0			Brandenburg - Nordost	SPLIT	1
DE42	0			Brandenburg - Südwest	SPLIT	1
DE411	DE403			Frankfurt (Oder), Kreisfreie Stadt	SPLIT	1
DE412	DE405			Barnim	SPLIT	1
DE413	DE409			Märkisch-Oderland	SPLIT	1
DE414	DE40A			Oberhavel	SPLIT	1
DE415	DE40C			Oder-Spree	SPLIT	1
DE416	DE40D			Ostprignitz-Ruppin	SPLIT	1
DE417	DE40F			Prignitz	SPLIT	1
DE418	DE40I			Uckermark	SPLIT	1

Figure 20: extract of "Units life" table (German Nuts between 2003 and 1999)

3.4.4 "genealogy units" tables

It is the most complicated table and the most innovative. It provides a conversion keys between nuts versions in order to harmonize temporal databases. To emphasize on the lineage of units, we have defined tow possible kinds of proportionalities: area and population. The proportionality of area transferred is very useful for the conversion of environmental indicators (figure 15). However the proportionality of population is useful for social economic indicators conversion.

4 Example of time series data building process: the European regional cohesion indicators

This section presents a harmonization use-case based on the formalization previously developed. It emphasizes on the contribution of time series data building and harmonization to the thematic analysis. The analysis of the European regional cohesion spatio-temporal evolution offers a very interesting example of methodological demonstration of the time-series building process. The analysis focused on data attached to the three latest reports on territorial cohesion, which include all methodological difficulties such as missing values and mixture of NUTS versions.

4.1 Data collection and temporal series maps

Based on the results of the exploration of nuts changes, the first step of the time series data building process is to collect data and to identify the latest version of nuts. The aim of this work is to produce thematic maps based on the 2003 and 2006 Nuts version (figure 16 and figure 17). These data sets were delivered at ESPON Coordination Unit in November (ESPON DB Update) and were presented at ESPON seminar in Malmö (2-4 December 2009).

id	level	name	NUTS_VER	source
TEMPORAL_START			1999	
TEMPORAL_END			2006	
BE	NUTS0	België/Belgique	2006	1
BE10	NUTS2	Région de Bruxelles-Capitale / Brussels Hoofdstedelijk Gewest	2006	1
BE2	NUTS1	Vlaams Gewest	2006	1
BE21	NUTS2	Prov. Antwerpen	2006	1
BE22	NUTS2	Prov. Limburg (BE)	2006	1
BE23	NUTS2	Prov. Oost-Vlaanderen	2006	1
BE24	NUTS2	Prov. Vlaams-Brabant	2006	1
BE25	NUTS2	Prov. West-Vlaanderen	2006	1
BE3	NUTS1	Région Wallonne	2006	1
BE31	NUTS2	Prov. Brabant Wallon	2006	1
BE32	NUTS2	Prov. Hainaut	2006	1
BE33	NUTS2	Prov. Liège	2006	1
BE34	NUTS2	Prov. Luxembourg (BE)	2006	1
BE35	NUTS2	Prov. Namur	2006	1
BG	NUTS0	Bulgaria	2006	1

Figure 21: Nuts version identification of spatial units used by the 4th Cohesion report

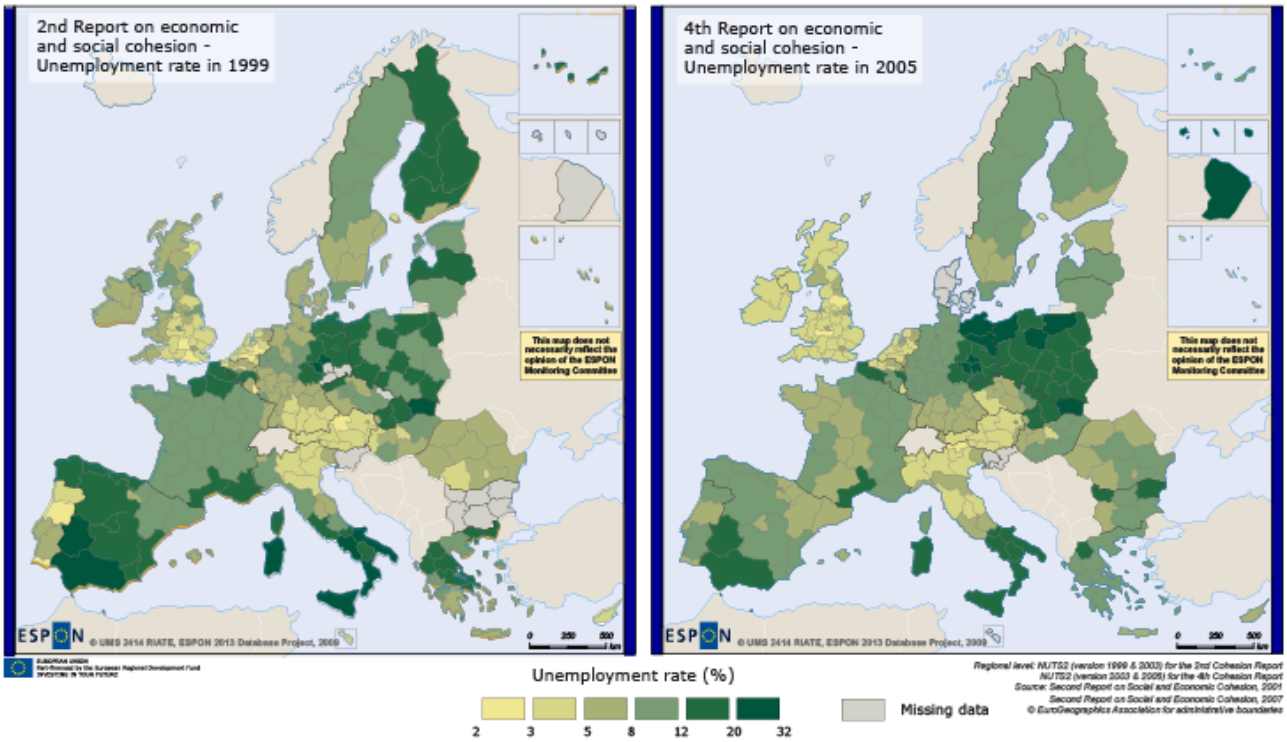


Figure 22: Mapping the Unemployment rate in 1999 and 2005

This task aims to provide data users and policy makers with maps allowing the comparison between two situations of unemployment in the European regions. Mapping is an important added value.

4.2 Building a harmonized temporal data base for the European regional cohesion analysis

The harmonization of time series data is a fundamental step for a more advanced temporal analysis and mapping. The built of time-series data can be done by two complementary approaches: The ESTI framework for estimating missing values is one of them1 and the modelling of NUTS changes.

The methodology consisted on these main steps:

- Based on the dictionary of changes of territorial units, we defined the versions of NUTS. The 2003 NUTS version was considered as a reference. The data were transposed into this version.
- Missing data were estimated using the ESTI framework methods
- Selected indicators cover the following sectors: economy, demography, unemployment and GDP per capita
- We proceed first to a hierarchical cluster on the second report data and we allocate the results to third and fourth reports data

These steps will be developed in the next sections.

4.2.1 Cohesion reports datasets exploration: missing values and lack of compatibility between NUTS versions

The exploration of data at NUTS 2 level shows the lack of compatibility of NUTS between datasets. Indeed, the collected data is a mixture of nuts versions from 1995 to 2006. If we look at the NUTS 2 level, we can observe many kinds of change. We illustrate some of them by the following tables.

ID (CR2)	name	ID (CR3)	name
IT11	PIEMONTE	ITC1	Piemonte
IT12	VALLE D'AOSTA	ITC2	Valle d'Aosta/Vallée d'Aoste
IT13	LIGURIA	ITC3	Liguria
IT20	LOMBARDIA	ITC4	Lombardia
IT31	TRENTINO-ALTO ADIGE	IT31	*Trentino-Alto Adige*
		ITD1	Provincia Autonoma Bolzano/Bozen
		ITD2	Provincia Autonoma Trento
IT32	VENETO	ITD3	Veneto
IT33	FRIULI-VENEZIA GIULIA	ITD4	Friuli-Venezia Giulia
IT40	EMILIA-ROMAGNA	ITD5	Emilia-Romagna
IT51	TOSCANA	ITE1	Toscana
IT52	UMBRIA	ITE2	Umbria
IT53	MARCHE	ITE3	Marche
IT60	LAZIO	ITE4	Lazio
IT71	ABRUZZO	ITF1	Abruzzo
IT72	MOLISE	ITF2	Molise
IT80	CAMPANIA	ITF3	Campania
IT91	PUGLIA	ITF4	Puglia
IT92	BASILICATA	ITF5	Basilicata
IT93	CALABRIA	ITF6	Calabria
ITA	SICILIA	ITG1	Sicilia
ITB	SARDEGNA	ITG2	Sardegna

Figure 23: The lack of compatibility between Italians NUTS2 units between 1999 and 2003.

ID (CR2)	name	ID (CR3)	name
FI14	VÄLI-SUOMI	FI18	Etelä-Suomi
FI15	POHJOIS-SUOMI	FI19	Länsi-Suomi
FI16	UUSIMAA (SUURALUE)	FI1A	Pohjois-Suomi
FI17	ETELÄ-SUOMI		

Figure 20: A complicated territorial change of NUTS2 level in Finland

Concerning the missing values, we can distinguish between cases caused by changes of NUTS and cases of non-available data. Depending of these types we use the adequate framework of estimation.

id	level	name	NUTS_VER	GDP_head_av	Emp_agri	Emp_ind	Emp_serv	Unemp	Unemp_LT	Pop_tot
BG31	NUTS2	Severozapaden	2006	25,6				12,1		983
BG32	NUTS2	Severen tsentralen	2006	26,4				12,1		963
BG33	NUTS2	Severoiztochen	2006	29,3				12,1		1004
BG34	NUTS2	Yugoiztochen	2006	29,9				8,3		1143
BG42	NUTS2	Yuzhen tsentralen	2006	25,6				11,0		1576
CY0	NUTS2	KYPROS	2006	78,9	10,2	23,2	66,6	3,1		741
DE41	NUTS2	Brandenburg - Nor	2006	68,4						1177
DE42	NUTS2	Brandenburg - Süd	2006	77,8						1419
DED1	NUTS2	CHEMNITZ	2006	60,5					41,4	1690
DED2	NUTS2	DRESDEN	2006	71,1					44,7	1762
DED3	NUTS2	LEIPZIG	2006	76,5					42,2	1112
ES63	NUTS2	Ciudad Autónoma	2006							75
ES63	NUTS2	Ciudad Autónoma d	2006	90,4				19,7	51,5	71
ES64	NUTS2	Ciudad Autónoma	2006							67
ES64	NUTS2	Ciudad Autónoma d	2006	87,9				13,9	36,7	67
FI16	NUTS2	UUSIMAA (SUUR	1999	130,6	1,06	22,34	76,27	7	28,7	1336
FI17	NUTS2	ETELÄ-SUOMI	1999	91,4	6,32	32,94	60,48	12,3	24,5	1815
FI18	NUTS2	Etelä-Suomi	2006	133,3						2537
FI19	NUTS2	Länsi-Suomi	2006	99,9						1319
FI1A	NUTS2	Pohjois-Suomi	2006	97,7						628

Missing value in the 4 cohesion report
Missing value in the 3 cohesion report
Missing value in the 2 cohesion report

Figure 24: An extract of the summary table of missing values of the 2, 3 and 4 cohesion reports.

4.2.2 NUTS harmonisation process

After the identification of NUTS version (Figure 17), the second step of database harmonisation consists to define a reference version of NUTS depending of the complexity of territorial changes. In this reference we will transpose all indicators. Theoretically, three formalizations are possible:

- Prospective approach consists to consider the oldest version of nuts as the spatial reference.
- Retrospective approach consists to consider the most recent version as a spatial reference.
- Intermediary approach uses the intermediary version as a reference: the lowest common denominator

Based on the dictionary of changes (figure 15), we considered the 2003 NUTS2 version as a reference because it allows building the most complete temporal database. Selected indicators were transposed in this NUTS version.
We selected 13 indicators covering economic sectors, Unemployment, demography, education and GDP.
The following figure illustrates the structure of the built temporal database.

Codes_Unit	Indicator 1	.....	Indicator 13
AT1-CR2			
AT11-CR2			
AT12-CR2			
AT13-CR2			
AT2-CR2			
AT1-CR3			
AT11-CR3			
AT12-CR3			
AT13-CR3			
AT2-CR3			
AT1-CR4			
AT11-CR4			
AT12-CR4			
AT13-CR4			
AT2-CR4			

Figure 25: Theoretical structure of the complete temporal database based on 2, 3 and 4 cohesion reports.

CR	id	NUTS_VER	GDP_head_av	Emp_agri	Emp_ind	Emp_serv	Unemp	Unemp_LT	Pop_tot
CR2	BE10	2006	170,3	0,21	13,42	86,38	14	62,0	952
CR2	BE21	2006	137,5	2,15	28,07	69,79	6,5	53,2	1637
CR2	BE22	2006	109,4	2,09	34,52	63,39	7	53,7	782
CR3	BE10	238,5	0,1	13,1	86,9	14,5	55,1	17,8	65,4
CR3	BE21	135,9	1,2	29,7	69,2	5,5	44,0	17,2	65,9
CR3	BE22	98,7	1,6	32,9	65,5	5,3	32,5	17,4	68,8
CR4	BE10	248,3	0,2	11,1	88,7	16,3	56,4	18,2	66,1
CR4	BE21	144,5	1,7	28,4	69,9	6,2	44,0	16,8	65,7
CR4	BE22	101,5	1,8	32,2	66,0	7,1	44,2	16,5	68,3
CR4	BE23	111,0	2,0	28,4	69,6	4,9	37,1	16,4	65,8

Figure 26: An extract of the complete temporal database based on 2, 3 and 4 cohesion reports.

4.3 Spatio-temporal analysis of the European regional cohesion

This section shows that it is possible to analyze the evolution of spatial patterns of regional inequalities with changing territorial units, through the example of a cross analysis of statistical annexes of 2nd, 3rd and 4th Cohesion Reports. The built temporal dataset allows implementing a temporal hierarchical cluster analysis.

The territorial cohesion of the European regions is organised along four main groups. Each group can be either central or peripheral (Figure 27):

- *North-western European type*:
    - Central: it is characterized mainly by: a very high education level, a very high rate of the service sector employments and a high rate of elderly people.

    - Peripheral: it is characterised by a relative decrease in the level of education and service sector employments.
    - Ultra-peripheral: it is characterised by a very high rate of young population. There is also an important decrease in education and service sector employments levels.
- *Southern European type*:
    - Central: it is characterized mainly by a high rate of elderly people, an important rate of industry sector employment and a low education level.
    - Peripheral: it is characterised by a relative decrease in the rate of elderly people and an increase in the rate of the agriculture sector employment.
- *Central European type:*
    - Central: it is characterized mainly by an important rate of adult population, a high education rate and the primacy of service sector employments rate.
    - Peripheral: it is characterised by the decrease the rate of high education level and an increase in the rate of the industry sector employment.
- Eastern European type:
    - Central: it is characterised by an important rate of the industry and the agriculture sectors employment and an important rate of adult population.
    - Peripheral: it is characterised by the primacy of the rate of the agriculture sectors employment and the increase of the rate of young population rate.

This organization is very stable through time. Indeed, no major changes happened.

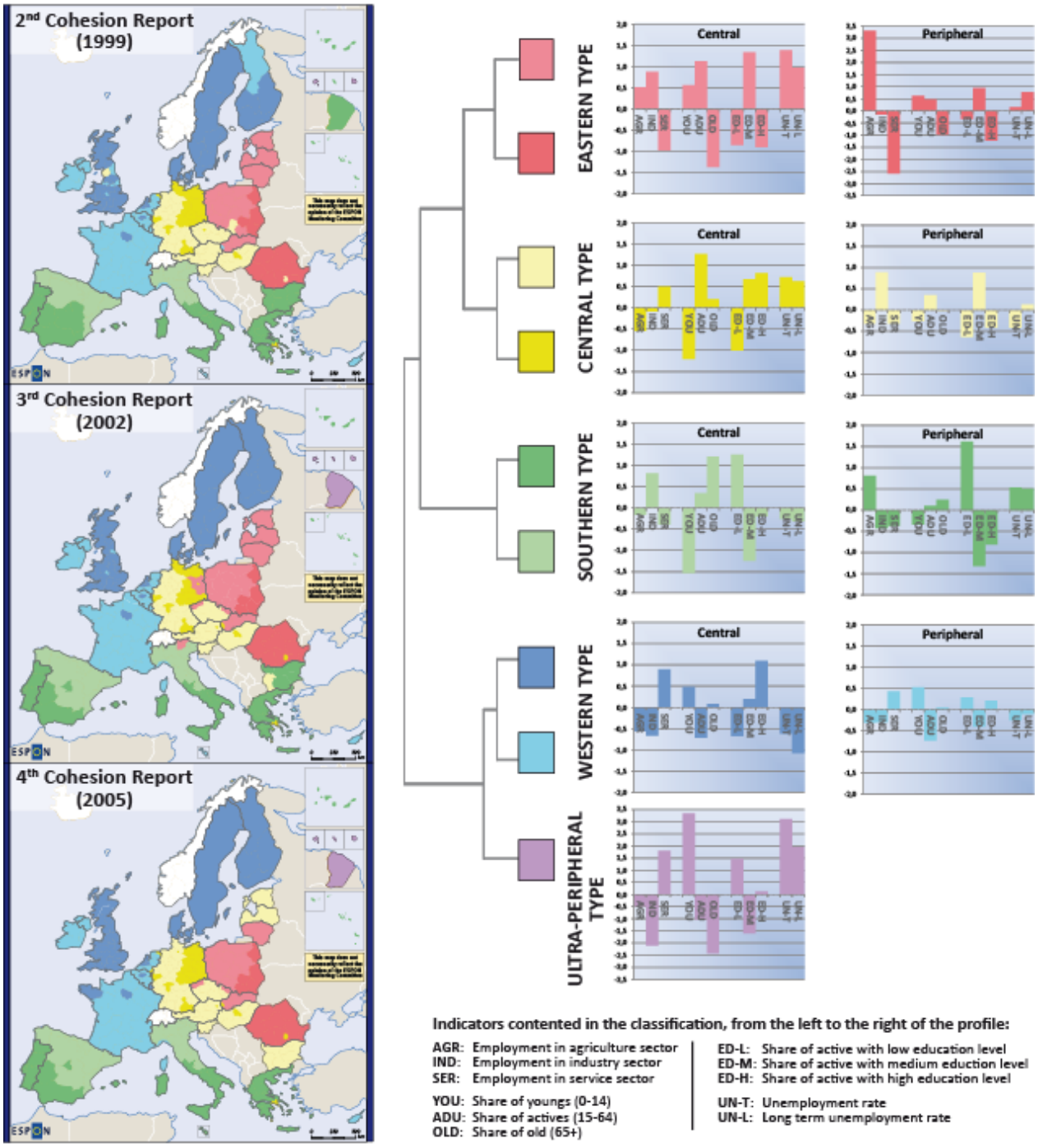


Figure 27: An extract of the complete temporal database based on 2, 3 and 4 cohesion reports.

Conclusion

The contribution of the change analysis based-approach to the topic of time-series is very important. The theoretical formalization and modelling allow the building of a complete temporal database (figure 24). They provide a key of conversion between NUTS versions. This formalization is not a normative approach, but rather it requires an improvement.
The improvement perspectives could be oriented in the following directions:

- The enlargement of the temporal period to the beginning of 1980. The archived New-Cronos database of Eurostat is a very relevant case study.
- The integration of a various geographic objects like cities and grids could have a very potential contribution to the time series building process. It could also affine and improve the thematic analysis
- The automation of the dictionary of changes and the estimation methods

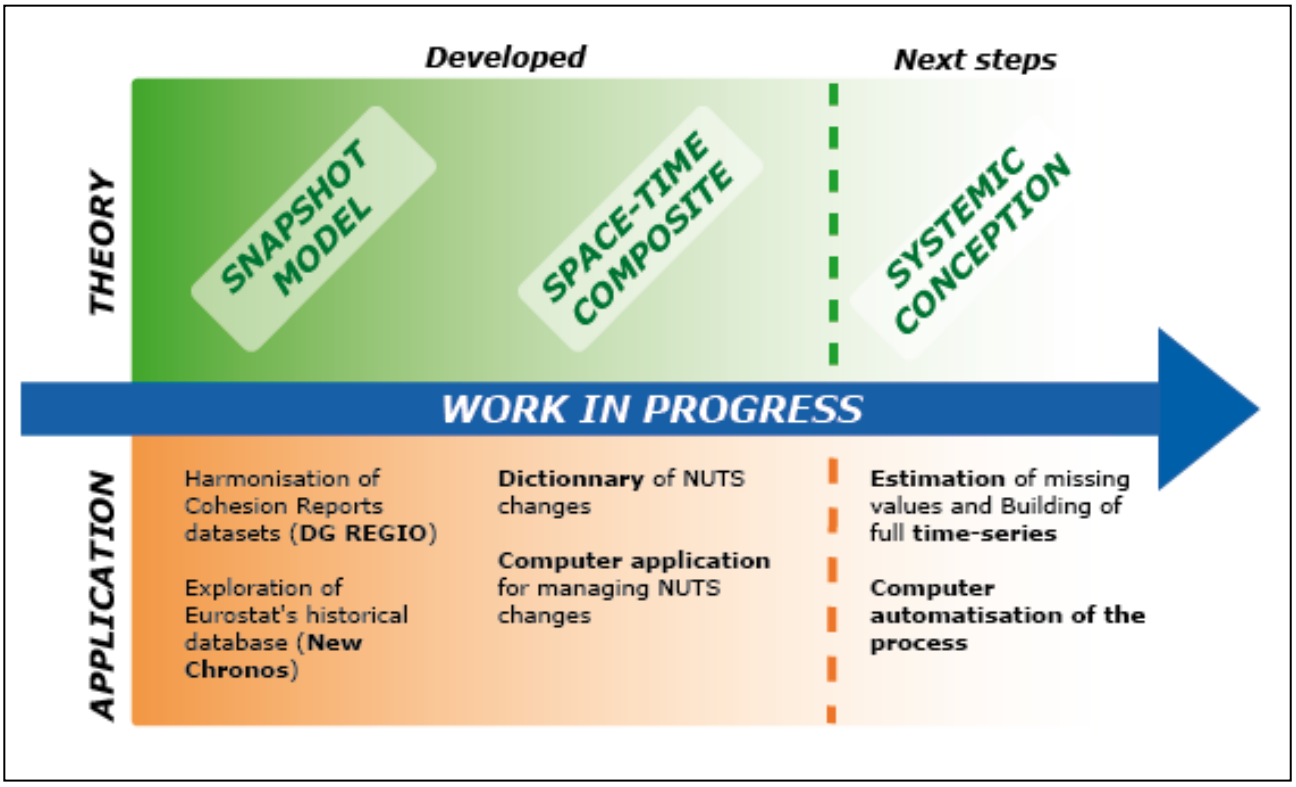


Figure 28: Synthesis of the work of the "time-series" group.

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