

# Annex B (informative)

## Management of connections at international boundaries

### B.1 Introduction

Requirements about connections between spatial objects at international boundaries (i.e. edge-matching) come from the Directive, Article 10 (2): in order to ensure that spatial data relating to a spatial object the location of which spans the frontier between two Member States are coherent, Member States shall, where appropriate, decide by mutual consent on the depiction and position of such common spatial objects.

The challenge is to match two data sets on the same theme; the two data sets have already been transformed in the common application schemas, in the same CRS (generally ETRS89 for planimetry and EVRF2000 for altimetry, if any), their levels of detail are the same (or almost the same) and they come from two neighbour countries.

Two issues can be distinguished: a) the issue of representing national boundaries and b) the issue of edge-matching national data. It would be possible to edge-match national data (except administrative units, cadastral parcels and statistical units) even though there is not always a precise and agreed representation of the boundary. However, matching precisely at the national boundary is the ideal solution.

NOTE 1: There might be also edge-matching issues within countries, e.g. in federally organised countries. This point is not specifically considered in this chapter.

Generally, it is assumed that the country has already some organisation to solve the issue (and so, may provide interesting feed-back to INSPIRE from their experience on this topic). If not, most of the recommendations given in this chapter may also apply for edge-matching within a Member State.

NOTE 2: This chapter provides some recommendations for edge-matching and gives examples, generally from EuroGeographics experience. The numeric values given as thresholds in the example apply only for the given example. Furthermore, these numeric values are often used only for automatic processing of edge-matching.

It will be to each "Thematic Working Group" to define the appropriate thresholds, if required, in a given data product specification, for each case of edge-matching.

### B.2 Which spatial objects have to be matched?

The issue is not exactly the same for vector data and for coverages.

#### B.2.1 Vector data

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Spatial objects have to be matched if they represent the same real-world phenomena along or across the national boundary.

- they must have the same spatial object type and the same geometric primitive (e.g. lines, polygons, ...).
- they must be close to each other, geometrically and/or semantically.
  - for geometry, the condition may be given by a threshold which will be function of the database accuracy
  - for semantics, spatial objects having the same code or same name (if the 2 neighbour countries have the same language) or corresponding geographical names (i.e the endonym in one database being an exonym in the neighbour database, if the 2

neighbour countries do not have the same language ) : they may be considered as representing the same real-world phenomena

NOTE 1 the use of distance threshold is convenient to enable some automation of the process. Nevertheless, the main point is that in the real world the two spatial object lines (or areas) are really connecting (or they are not) or that the two point features are really the same

Each “Thematic Working Group” will have to specify more in detail what is meant by “being close to each other”.

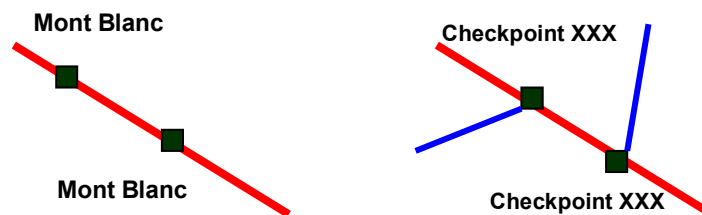
The main points to be decided:

- the threshold to be applied, at least to enable some automatic procedure
- the attributes to be taken into account.

NOTE 2 as general rule, the threshold has to be defined by the “Thematic Working Group” taking in account the accuracy of the required database and the source databases. Nevertheless, some adaptation may be required, when matching two neighbour countries, taking in account the accuracy of existing data on each side and (at least for large scale data), the alterations implied by the CRS transformation.

Example 1 for point features (EGM, accuracy ≈ 1000 m):

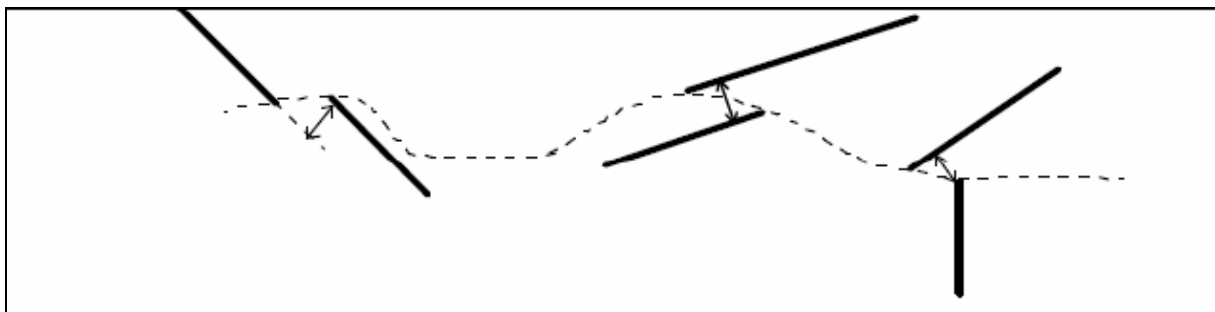
If the same point or node feature type is portrayed in adjacent layers more than once, only one of these features is left to the final, combined database. For automatic edge-matching, points and nodes are considered to be the same feature if they have the same feature type and if the distance between features is less than (about) 250 meters. However, in some special case it's obvious that the two features are the same even if the distance is more than 250 meters.



**Figure 19 – Same point/node feature duplicated in layers ELEVATION POINT and TRANSPORT**

Example 2 for line features (EGM, accuracy ≈ 1000 m):

Two line features will only be moved automatically to match each other if they are of the same feature type and if the gap is no greater than approximately 1000 meters. The gap between two line features along the edge matching boundary is the shortest distance between the edges (not necessarily between nodes) composing the line features.



**Figure 20 – Measuring gap between lines**

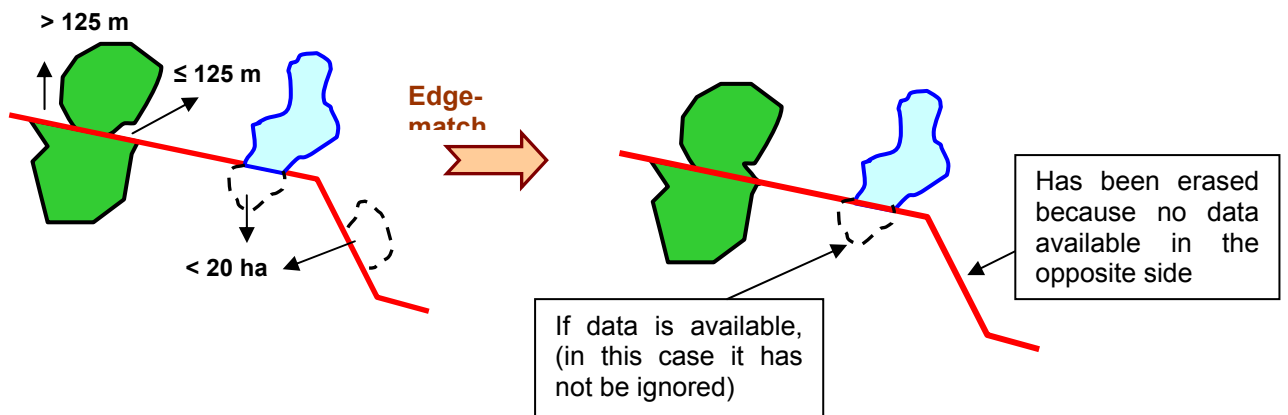
Rules for edge-matching are less obvious for the area features, because quite depending on the selection criteria and generalisation criteria used to portray the area features.

Example 3 (ERM, accuracy  $\approx$  125 m, scale range of 1: 250 000) for area features:

Edge-matching can only be performed at a distance not exceeding the geometrical resolution accuracy of the data set, and the minimum area size resolution.

The matching distance between borderlines of area feature is a maximum of 125m (accuracy resolution). If bigger distance is noticed, it is not needed to do the edge-matching. An exception is done for the water bodies and islands because it is a tremendous condition to get a continuous water network.

When the extended part to be added to the spatial object is less than 20 ha (for area feature: minimum area size resolution) this can be ignored and not added.



**Figure 21**

Of course, this geometrical resolution accuracy and minimum area size values will vary according to the scale range of Level of Detail.

When possible, trans-border spatial objects should be treated as one spatial object at least when it comes to quantitative measurements.

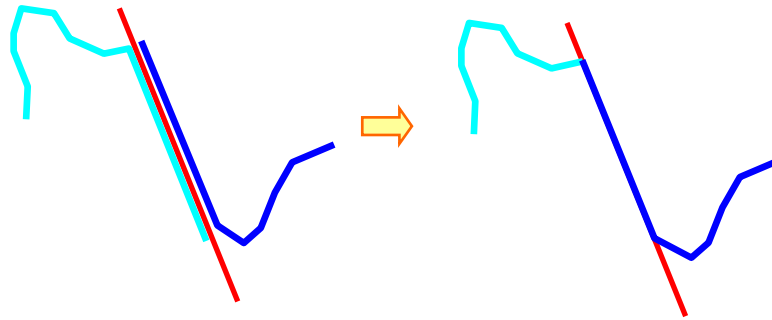
Example: There might be rules (minimum surface) for including a lake in a map/database. Applying these rules only on national parts might lead to erroneous results.

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- When a line segment (for example a watercourse) is consistent with the national boundary, the segment should have exactly the same geometry in both national components.

In other words, the geometry of the linear feature should fit the geometry of the national boundary, knowing that this national boundary has been preliminary portrayed in a unique manner in both countries.

The fact that the watercourse is consistent with the national boundary should be proofed by the boundary treaty.



**Figure 22**

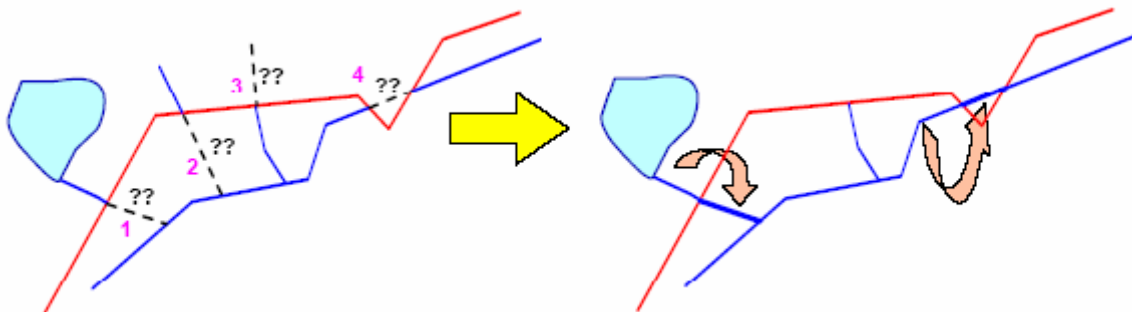
When real world objects are effectively continuous in cross-border areas, selection and representation criteria should be consistent in the different data sets of similar LoDs (same spatial object type and geometric primitive).

This is mainly important for linear features in order to assure a continuous network all over national boundaries.

When discrepancy appears in the selection criteria of linear features, it may be also necessary to do some edge-matching to ensure network continuity. It may imply to add or to delete some small size spatial objects.

#### Example ERM and EGM:

When a spatial object is obviously stopped at the national boundary with no counterpart at the other side, the decision whether to erase it or to extend it should be decided in common agreement between neighbour countries.



**Figure 23 – Two new short lines (1, 4) added. Lines 2 and 3 are too long or too uncertain. Existing line above the missing line number 2 removed. New spatial objects get attributes from those lines they are joined to (existing dangling node).**

The threshold to authorise adding or deleting spatial objects will have to be defined for each product (at least, for each theme and for each scale range) by each “Thematic Working Group”.

### **B.2.2 Coverage data**

At least, elevation and orthoimages (and may be, other INSPIRE themes) are concerned by this type of data.

Let us assume that the coverages in two neighbour Member States are already harmonised (same grid type, same grid size, same CRS, same function).

The first point to be decided is how to make the mosaic between the two countries:

- should we cut the data set exactly at the national boundary?
- is it enough to adopt some rectangular "cutting" along the national boundary (e.g. keep tiles of 1 km<sup>2</sup> or 100 km<sup>2</sup>).

The second issue is the edge-matching of the function values along the boundary: probably, some inconsistencies will appear when gathering data. For instance, for DEM, there may be artificial 'cliffs' and 'steps' at the edges of the national contributions.

Each "Thematic Working Group" will have to decide if it is necessary or not to do some smoothing at national boundaries.

#### Example 1: about DEM (BKG):

Experience at BKG has shown that the most effective method for edge-matching between DEM is to re-calculate the border area from the original measurements, putting together the information from both sides of the national border. Only in cases where the original measurements are not available, a blending algorithm may be applied on the edge between the interpolated DEM files.

In case two DEMs overlap, a blending method has been proposed by Norbert Pfeifer (TU Vienna) and provides good results for DEM with different accuracy (see his powerpoint slides from the joint EuroGeographics / EuroSDR workshop on "NMCAs and GMES", 5 - 6 September 2006, at the BKG in Frankfurt am Main:

[http://www.eurogeographics.org/eng/documents/08\\_Pfeifer\\_DTMquality.pdf](http://www.eurogeographics.org/eng/documents/08_Pfeifer_DTMquality.pdf))

Generally, edge-matching has to be done by agreement between two neighbour countries but, in some cases, it may be necessary to have it done at centralised level.

#### Example 2: radar rainfall

Radar edge matching occurs on the overlap between circular radar images. The edge matching is dependent on different radar properties and even on the specific weather. Here data exchange mechanisms happen as frequently as every 2 minutes, while the European Composite Radar is delivered every 30 minutes. This has to be a centralised service due to the data exchange overload: the merged data is centrally provided, even if it is supplied through different routes by individual EUMETNET members.

In fact this is a specialised procedure and so has to be done once, and by a central system, not only because of the time constraints. In a way, this is a generalisation of the borders issue. Here it isn't one data provider having to match between another, but all data providers submitting to standards and having the data centrally adapted.

### **B.3 How to match spatial objects?**

It is still an open issue whether if it is necessary to undertake geometric edge-matching for each pair of corresponding spatial objects or if it is enough to establish the link between the two spatial objects (e.g. by using their identifiers).

- The first solution will fulfil more requirements, as it ensures continuity across the boundary, both for computers and for human beings (visualisation). However, it may lead to significant deformations, especially if the two neighbour data sets are not at the same level of detail (and so, not at the same accuracy). This can normally be accommodated where both parties agree the need to resolve both the match and the geometric fidelity, there are examples where topographic objects are matched seamlessly. The advantage is that once this is achieved it is resolved for the remainder of time and is reusable.

- The second solution may be enough e.g. for itinerary computation (it is more or less the solution chosen by EuroRoadS, with its border nodes, each node “knowing” the identifier of the border node on the other side). It ensures continuity only for computers, not for the human beings.

Connecting (or border) nodes or edges are required with the second solution, they may be useful also even with the first solution.

### B.3.1 Geometry edge-matching:

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To achieve geometric edge-matching, spatial objects will be moved according to the following rules:

- Both spatial objects will be moved to reach the middle position if the two sources used for capturing the data are of the same quality level.
- If one of the two sources used is of higher quality, the positions of spatial objects captured from this source will be preserved and the other spatial objects will be moved toward the best source.

NOTE : “higher quality source” has to be understood as the most reliable data source ; it generally and mainly involves geometric accuracy and data currency.

When displacing the spatial objects, we must take care that the relative position of the other spatial objects will be preserved (e.g. a river located on one side of a road should remain on the same side of the road after edge matching).

#### Rules for points:

The only points to be matched are the points located on the boundary. A common position has to be agreed and this common position must be on the agreed national boundary.

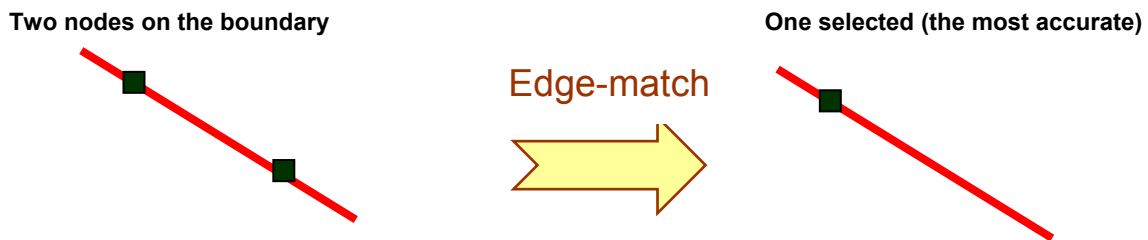


Figure 24 – The matching location may be a choice between the two locations.

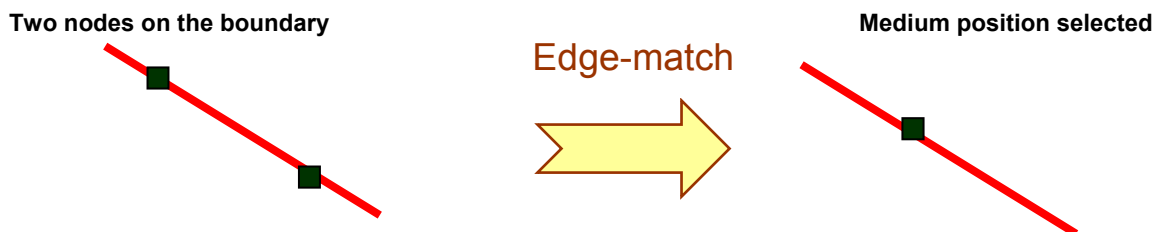
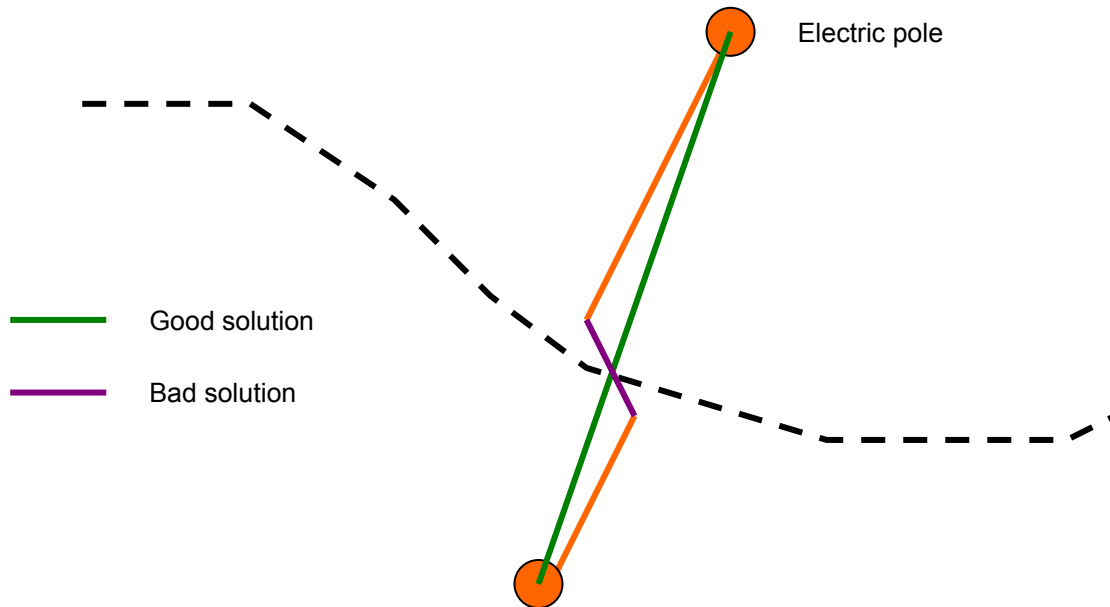


Figure 25 – The matching location may be a medium position between the two locations (the middle between the two locations).

Rules for lines crossing the national boundary:

The edge-matching must be done:

- respecting the characteristics of the spatial object.
- as near as possible to the national boundary.



**Figure 26 – Electric lines are straight lines between two poles.**

In other cases, it may be quite better to have some elastic deformation. Specific geometric methods can be used to recognise homologous points and to stretch the spatial objects geometry one to another. Rubber sheeting is a famous method to stretch data one to another (see for example Laurini 1996; Haurert 2005).

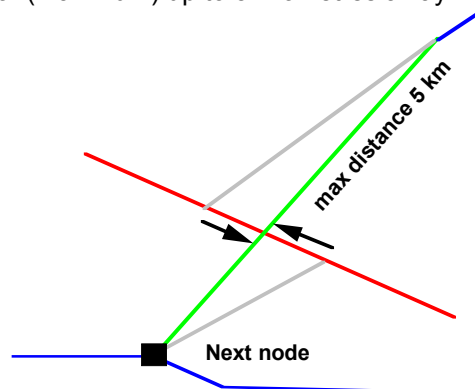
The stretching also raises the problem of geometrical deformations. Theoretically the geometrical anamorphous can be applied on both side or on one side only (see following figure). Rules will be required, e.g. applying the anamorphous on less accurate data.

Initial state	changing the “blue data”	changing the “red data”

**Figure 27 – Stretching the data along a boundary (from Lamine and Mustière 2005)**

Example EGM (accuracy around 1000 m):

Modifying lines to facilitate a smooth edge match line: Lines composing the line feature will be modified to the next node, or (maximum) up to 5 kilometres away from the boundary.

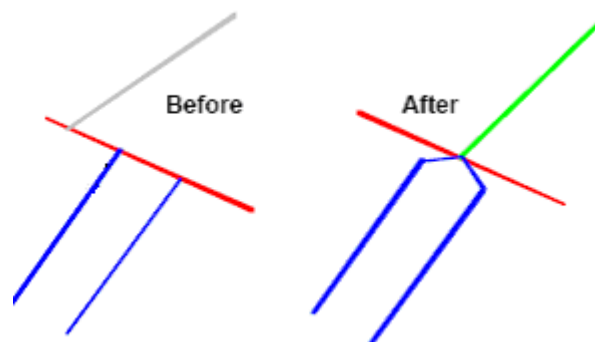


**Figure 28**

For some themes, it may be useful to consider more complex cases:

Example ERM (accuracy around 125 m):

When one spatial object on one side of the boundary corresponds to two spatial objects of the same type on the other side of the boundary, and if the gap is no greater than approximately 125 meters, the spatial objects will be moved equal distance to form a fork.



**Figure 29**

In ERM, this situation may happen for parallel powerlines. The situation might also happen if two watercourses or roads meet near the national border and continue as one beyond the national border. At large scale, it may happen for dual carriageway roads.

NOTE: for some INSPIRE themes, perfect edge-matching at international boundaries won't be always possible (and even may be, won't be required)

Example (Sea Regions)

Another example which may be informative is the rather esoteric task of defining Sea Regions – which INSPIRE has chosen as a distinct theme. The responsibility belongs to IHO in Monaco, but the documentation is only in paper form. The difficulties arise because in the normal case there is little requirement for high precision. Sea regions are often locally agreed between nations rather than internationally, but imprecisions arise because the points are defined usually between land promontories and islands. Promontories erode, and the sea region border may go through islands or skirt the coasts without any consistency.

### B.3.2 Creation of connecting spatial objects:

The use of connecting points (or lines) will have to be decided by each “Thematic Working Group”, according to the characteristics of the spatial objects (e.g. it is of no use for administrative units or parcels (as they do not cross the boundary) and according to the users requirements.

The main issue will be to decide how to manage these connecting nodes:

- should they be in the initial databases? or only in the INSPIRE data set?
- when matching two spatial objects, should we have:
  - 2 connecting points or only one connecting point?
  - if 2 connecting points, should they have the same location or are different locations allowed?

If it is decided that connecting nodes should be on the same location, this location should be on the agreed national boundary.

However, the technical implementation of this principle seems to have raised problems, e.g. the management of coordinates and topology is different depending on different GIS.

Connecting nodes must ensure the link between the two spatial objects to be connected, either by the same location, or by a relationship between the two connecting nodes.

#### Example 1: EuroRoadS

If a road continues in reality after the end of the data set border, it has to be registered as an attribute to the node. If the corresponding node identification number is known it shall be stored.

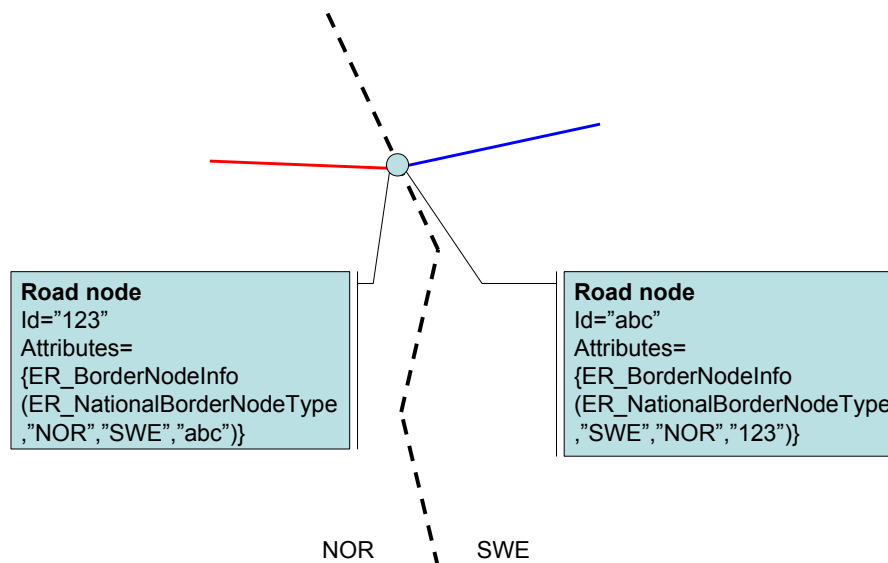


Figure 30

## B.4 How to match attributes?

There are two cases:

- When a spatial object lies on the national boundary and is part of the two countries. This occurs mainly with line and point features
- When a spatial object over crosses the national boundary. This occurs mainly with line and area features

### B.4.1 Matching rule for duplicated spatial objects located on the national boundary

The general rule is that all the matched attributes must have the same value.

- The unknown and unpopulated values must be replaced by a populated one if available.
- When no real information is provided at both sides, then we can give a priority in the null values

However, there may be exceptions for geographical names (according to the model chosen for multilingual texts) and for some national codes:

- in France, "Rhin" will be the national name and "Rhein" may be included as "exonym"
- in Germany, "Rhein" will be the national name and "Rhin" may be included as "exonym"

### B.4.2 Matching rule for spatial objects crossing the national boundary

Some attribute values need to be consistent at both side of the boundary. This is mainly applied to line and area features.

For each theme, define which attributes must have the same value (or corresponding values) and which attributes may have independent values.

Example (ERM):

The attributes, which need to be logically matched, are highlighted in bold. Matched value:

- Y means that the spatial object should be logically matched at both side of the boundary
- N means that inconsistency in attribute values is allowed.

Table 1: Extract of matching attribution for cross-border spatial objects

HYDRO	Area/ Line	BH5 02	Watercourse	
	<b>Area/ Line</b>	<b>EXS</b>	<b>Existence Category</b>	<b>Y</b>
	<b>Area/ Line</b>	<b>HO C</b>	<b>Hydrographical Category</b>	<b>Y</b>
	<b>Area/ Line</b>	<b>HYC</b>	<b>Hydrological Category</b>	<b>Y</b>
	Line	LOC	Location Category	N
	Area/ Line	NHI	National Hydrological Identification Code	N
	Area/ Line	NA MN1	Name in first national language	N
	Area/ Line	NA MN2	Name in second national language	N

## B.5 Which national boundaries?

Another issue of edge-matching at national boundaries is to know where the national boundary is, i.e. to agree on a common representation of the boundary to be used.

The national boundaries are generally defined in bilateral treaties between the neighbouring countries, but it does not mean that an agreed geographical representation of the boundary is available.

### Recommendation 34

In order to avoid manifold work, it is recommended to use already agreed national boundaries, when and where they exist. Generally, for one level of detail, there should be only one representation of the national boundary; this common representation for a special scale can be created by the mapping authorities of two neighbour countries.

Some work on this topic has been already done by EuroGeographics and a set of agreed boundaries is more or less available:

- the EuroBoundaries project aims to provide legally agreed national boundaries at the highest available accuracy; however, as it involves legal procedure, the collection and preparation of these boundaries of the whole Europe will be quite long (about 10 years) and until its full achievement, the EuroBoundaries data set is planned to contain :
  - one common representation based on the legally agreed national boundaries at high accuracy for some parts of the boundaries
  - two different national representations of some other parts if there are such
  - one provisional line in cases the two others are not available on the basis of best possible information as temporary limited representation.
- EuroRegionalMap is a topographic pan-European database at scale 1 : 250 000 ; it includes 30 countries (including all countries of the European Community, except Bulgaria). The administrative theme contains agreed representations of national boundaries; however, the agreement is not a legal one but just an agreement between NMCAs. In disputed areas, the two national representations are represented by ERM. Consistency between national boundary and topographic objects included in ERM (roads, rivers, ...) is ensured.
- EuroGlobalMap is a topographic pan-European database at scale 1:1 000 000 ; it includes 36 countries (incl. all countries in the European Community). As for ERM, the administrative theme contains agreed representations of national boundaries; however, the agreement is not a legal one but just an agreement between NMCAs. In disputed areas, the two national representations are represented by EGM. Consistency between national boundary and topographic objects (roads, rivers, ...) included in EGM is ensured.
- EuroBoundaryMap is an administrative pan-european database; data is represented at two resolutions 30 m and 200 m.; it includes 36 countries (incl. all countries of the European Community). The representations of national boundaries in EuroBoundaryMap are not legally agreed but proposed by the data set coordinator and approved by NMCAs.

### Recommendation 35

Boundaries in dispute for geopolitical reason can be maintained separately. Boundaries in dispute owing to technical or administrative reasons cannot be considered as such and should be solved.

In case, there is not yet an agreed boundary, at the required Level of Detail [LoD] between two neighbouring countries, criteria for a suitable fixed boundary may be the following:

- The first criterion to resolve a boundary is to agree on the geometric resolution accuracy and a degree of generalisation suitable for the different scales or LoDs involved.

The degree of generalisation focuses on the density of vertices. Geometric data resolution in the density of vertices on an edge should be as low as possible keeping a realistic size and shape of the spatial object.

When two boundaries are presented having similar resolution, the preference should be given to a given boundary with the best positional accuracy and degree of generalisation.

- The second criterion is to keep the full consistency of the national boundary with the topography or at least the relative topological relation of the national boundary with the topographic objects, even to the detriment of its absolute positional accuracy. For medium and small scale data, this means that the relative position of the boundary with the topographic situation should prevail on its absolute position .
- When the national boundary is determined by real-world topographical objects (like a mountain range or a river), the geometry of the boundary should exactly fit the geometry of the topographical object. When practicable, neighbouring countries should agree on common representation of those topographical objects coincident or coterminous with the national border line. Consistency of the national boundary with the water network has the highest priority.
- The referring coordinate system of the agreed geometrical location of the boundary vertices should be the European reference system (ETRS 89)
- All decisions concerning the representation of national boundaries should be based on traceable arguments (like boundary treaties and supporting documents as orthoimages, maps).

Furthermore, the EuroBoundaries project may offer the contact person responsible for the country's national boundary.

#### **Recommendation 36**

As soon as fixed, those agreed international boundaries should be stored and structured in a common data schema. This international boundaries data set would serve as reference data for sustainable maintenance at national level and could be stored at European level.

## **B.6 Organisational point of view**

Member States must agree on shared edge-matching responsibilities. Generally, it does not mean that they must agree individually for each pair of corresponding spatial objects; they may agree on some automatic method (based on the above recommendations) at least to detect which spatial objects may be matched and to match spatial objects when the distance between these spatial objects is considered as "small". Nevertheless, some discussion may be required in more complicated cases. Edge-matching in INSPIRE should be done, using as much as possible automatic procedures but there might be cases that require manual interventions. In which case the economics of "resolve once – use many times" will be more important from a cost benefit perspective.

NOTE: the mutual agreement for each pair of corresponding spatial objects has to be done for EuroBoundaries, as this project is expected to supply reference international boundaries for INSPIRE.

It is likely that during the matching phase, some inconsistencies will be shown. Data providers should be encouraged to correct these inconsistencies in the source/original data sets as soon as possible.

The edge-matching has to be considered not only once but also at each update of one of the neighbour databases. If updates are frequent, use of automatic methods to detect and correct inconsistencies seems the only solution.