ETC HE Report 2023/12

Methodology to assess vulnerable groups exposed to environmental noise

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Summary

This report aims to develop a methodology to analyse the potential impact of environmental noise at schools. This objective aligns with the Environmental Noise Directive (END) and the Zero Pollution Action Plan, which call for stronger action to reduce noise pollution.

This methodology is based on available data on schools from Eurostat and strategic noise maps reported under the END. The combination of these two datasets intends to provide knowledge on the potential impact of exposure to environmental noise in schools. The methodology will help in evaluating learning impairment (or other outcomes) due to environmental noise in school children."

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The expected outputs from the methodology are 1) the noise value (the dB range) at the school and 2) the areas of different noise values (in dB ranges) in the surface nearby the school. Considering the variability in the school's location, i.e., sometimes it is georeferenced in the façade, and other times the school is georeferenced at a midpoint inside the building, it has been defined a buffer of 100 m around the point representing the school as the surface nearby the school to be considered for the analysis. We assume that 100 m is a reasonable distance for most schools since we want to focus on the most immediate area.

The methodology was tested with road traffic noise data and schools from Czechia. The results of the test area cover the road noise sources reported by the END, both inside agglomerations (including major sources) and outside agglomerations (major sources). The analysis undertaken can be extrapolated to other noise sources i.e. rail noise, aircraft noise and industrial noise.

1 Introduction

The quality of the local environment influences people's health by determining their exposure to environmental health hazards. The individual's tolerance of hazard levels and ability to recover from the impacts modulate the impacts of such hazards on people's health. Consequently, the health effects associated with environmental stressors, such as noise, arise from the interplay of environmental conditions, the degree of exposure, and an individual's susceptibility to harm.

Children and the elderly are considered two of the most vulnerable groups because of their inability to withstand the adverse impacts of environmental health hazards. Children and elderly may demonstrate increased sensitivity to environmental stressors and, therefore, experience more acute impacts than a healthy adult subject to the same level of exposure (EEA, 2019).

The current report is driven by the availability of data on schools from Eurostat, which, combined with strategic noise maps reported under the Environmental Noise Directive, provides a ground for increasing the knowledge of the potential impact of exposure to environmental noise in schools. There is already some literature on children's learning and cognition focused on the school environment and either used measured or modelled noise levels at schools (e.g. Clark et al., 2012; Haines et al., 2001; Stansfeld et al., 2009), or both the exposure at schools and at homes (e.g. Clark et al. 2018; Belojevic et al., 2012; Zijlema et al., 2021; Tangermann et al. 2022).

This report aims to develop a methodology to help evaluating learning impairment (or other outcomes) due to environmental noise in school children. This objective aligns with the END and the Zero Pollution Action Plan, which call for stronger action to reduce noise pollution.

2 Input data

The following principles will guide the methodology presented in this document:

- Wide geographic coverage.
- Data updated regularly.
- Dataset documentation.

Therefore, the methodology is data-driven, based on the data set on European education services from GISCO (see section 2.2.) and END data reported by MS (see section 2.1).

2.1 Noise

The methodology and test results that are presented in this report are based on noise contour maps reported under strategic noise maps (dataflow DF4_8) as requested by the Environmental Noise Directive (END) (EC, 2002/49).

This information is delivered in a 5 years reporting cycle since 2007, with the latest reporting cycle due by 31st of December 2022.

A new datamodel and a new reporting system have been implemented by the European Environment Agency to report strategic noise maps from 2022 onwards, which establish some changes on the specifications to provide noise contour maps compared with previous reporting cycles.

The noise contour maps that will be used for developing the methodology and the test cases are the ones reported officially by EEA Member Countries for the 2022 reporting cycle.

Noise contour maps are reported individually and address individual noise sources :

- Noise contour maps for major roads above 3 million vehicles/year (including agglomerations)
- Noise contour maps for major railways above 30.000 train passages/year (including agglomerations)
- Noise contour maps for major airports with more than 50.000 movements/year (including agglomerations
- Noise contour maps for agglomerations with more than 100.000 inhabitants for road noise, rail noise, aircraft noise and industrial noise (sources inside agglomerations reported, if applicable, i.e. if an agglomeration do not have the aircraft source, then the noise contour map for aircraft noise inside the agglomeration will not be provided)

To be noted that the noise contour maps inside agglomerations are not mandatory to be reported under the END. However, it is highly recommended that noise contour maps inside agglomerations are reported because they need to be made available and disseminated to the public in accordance with relevant Union legislative acts, in particular Directives 2003/4/EC and 2007/2/EC of the European Parliament and of the Council.

Noise contour maps information is reported in polygons (or multipolygons) or lines (or multilines), with a specific attribute indicating the noise level and noise indicator that the polygon or the line represents.

See Table 2.1 for details.

The methodology is based on L_{den} noise contour maps of road, railway and aircraft traffic noise inside and outside urban areas as well as industry noise inside urban areas. A pre-processing will be needed in order to combine :

- Noise contour maps for major roads and noise contour maps for road noise inside agglomerations
- Noise contour maps for major railways and noise contour maps for rail noise inside agglomerations
- Noise contour maps for major airports and noise contour maps for aircraft noise inside agglomerations

In the case of industrial noise, the information is only reported inside agglomerations, so there is no need to establish any pre-process in this case.

Finally, if data is reported in lines (or multiline format), an extra process will be needed in order to convert the information into polygons : this methodological report is based on areas where noise can be evaluated, so the line information need to be converted into polygons.

Both of the pre-processing requirements mentioned above will need to be undertaken before applying the analysis to assess vulnerable groups exposed to environmental noise presented in this document.

Table 2.1. Detail of the noise contour map information reported in the different dataflows (per noise indicator and noise band)

Dataflow	Spatial layer	Noise bands that will be considered in the analysis	
		Polygons (multipolygons)	**Lines (multilines)**
Strategic noise maps for major airport (DF4_8)	NoiseContours_majorAirportsIncludingAgglomeration_Lden	**Lden5559** Lden6064 **Lden6569** Lden7074 LdenGreaterThan75	**Lden55** Lden60 **Lden65** Lden70 LdenGreaterThan75
	NoiseContours_majorAirportsIncludingAgglomeration_Lnight	Lnight5054 Lnight5559 Lnight6064 Lnight6569 LnightGreaterThan70	Lnight50 Lnight55 Lnight60 Lnight65 LnightGreaterThan70
Strategic noise maps for major railway (DF4_8)	NoiseContours_majorRailwaysIncludingAgglomeration_Lden	**Lden5559** Lden6064 **Lden6569** Lden7074 LdenGreaterThan75	**Lden55** Lden60 **Lden65** Lden70 LdenGreaterThan75
	NoiseContours_majorRailwaysIncludingAgglomeration_Lnight	Lnight5054 Lnight5559 Lnight6064 Lnight6569 LnightGreaterThan70	Lnight50 Lnight55 Lnight60 Lnight65 LnightGreaterThan70
Strategic noise maps for major road (DF4_8)	NoiseContours_majorRoadsIncludingAgglomeration_Lden	**Lden5559** Lden6064 **Lden6569** Lden7074 LdenGreaterThan75	**Lden55** Lden60 **Lden65** Lden70 LdenGreaterThan75
	NoiseContours_majorRoadsIncludingAgglomeration_Lnight	Lnight5054 Lnight5559 Lnight6064 Lnight6569 LnightGreaterThan70	Lnight50 Lnight55 Lnight60 Lnight65 LnightGreaterThan70

Dataflow	Spatial layer	Noise bands that will be considered in the analysis	
		Polygons (multipolygons)	**Lines (multilines)**
Strategic noise maps for agglomeration (DF4_8)	NoiseContours_airportsInAgglomeration_Lden; NoiseContours_industryInAgglomeration_Lden; NoiseContours_railwaysInAgglomeration_Lden; NoiseContours_roadsInAgglomeration_Lden	Lden5559 *Lden6064* *Lden6569* *Lden7074* *LdenGreaterThan75*	Lden55 *Lden60* *Lden65* *Lden70* *LdenGreaterThan75*
	NoiseContours_airportsInAgglomeration_Lnight; NoiseContours_industryInAgglomeration_Lnight; NoiseContours_railwaysInAgglomeration_Lnight; NoiseContours_roadsInAgglomeration_Lnight	Lnight5054 Lnight5559 Lnight6064 Lnight6569 LnightGreaterThan70	Lnight50 Lnight55 Lnight60 Lnight65 LnightGreaterThan70

Note: Noise bands in bold are mandatory for major sources. Noise bands in italics are requested for agglomerations, if information is provided.

2.1.1 *Criteria for noise data completeness*

It is important to evaluate the completeness of the noise data in order to distinguish where noise noise contour maps are not available (i.e. late delivery of expected information), where noise contour maps are only voluntarily delivered (i.e. noise contour maps inside agglomerations) or where noise contour maps are not applicable (i.e. noise source not existing -inside agglomerations or outside agglomerations-; noise source below the threshold specified in the END, etc.).

Depending on this analysis, the methodology will conclude in different resulting outputs that distinguishes the cases described above, as can be seen in Figure 3.4.

As explained in section 2.1., the noise contour maps proposed to be used for evaluating vulnerable people exposed to environmental noise need to take into consideration the noise contour maps of the same noise source inside and outside agglomerations (i.e. road noise in Europe containing noise contour maps for major roads and for road noise inside agglomerations, etc.), with a pre-processing of the data delivered by Member Countries.

Once the new combined layer is calculated, and after correcting any potential overlays that can occur with the delivered data, the following criteria is applied to define if a country or an agglomeration is considered complete or not per each noise source (see Table 2.2).

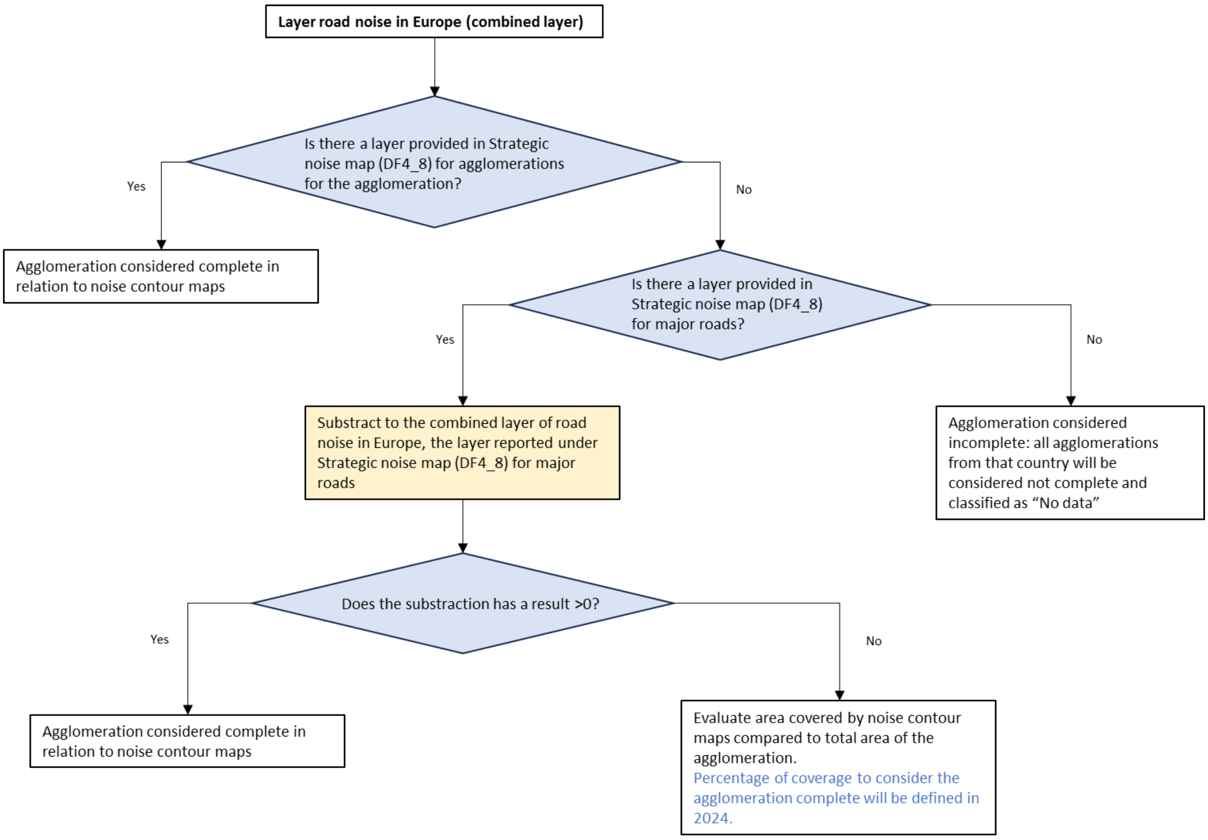
Table 2.2. Criteria to define noise contour maps completeness per each noise source

Noise source	Assumption	Decision criteria	Completeness calculation
Road noise inside agglomeration	Road traffic noise is the most widespread noise source, so it is assumed that should cover the majority of the streets of the agglomeration, and not only major roads	If an agglomeration has contour maps only for major roads, this city will be considered not complete	See Figure 2.1.
Rail noise inside agglomeration	It is possible that an agglomeration only has major railways in the context of railway noise source inside the agglomeration	Any data reported is considered complete.	No analysis of completeness of data provided will be performed. It will be checked if railways data has been provided in the Strategic Noise maps (DF4_8) for major railways or in the Strategic Noise maps (DF4_8) for agglomerations. If no data reported in any dataflow, the country will be considered not complete, and all agglomerations will be classified as no data.
Aircraft noise inside agglomeration	Is it possible that an agglomeration only have major airports in the context of aircraft noise source inside the agglomeration	Any data reported is considered complete.	No analysis of completeness of data provided will be performed. It will be checked if aircraft data has been provided in the Strategic Noise maps (DF4_8) for major airports or in the Strategic Noise maps (DF4_8) for agglomerations. If no data reported in any dataflow, the country will be considered not complete, and all agglomerations will be classified as No data.

Noise source	Assumption	Decision criteria	Completeness calculation
Industrial noise inside agglomeration	Not applicable	Any data reported is considered complete.	No analysis of completeness of data provided will be performed. It will be checked if industrial data has been provided in the Strategic Noise maps (DF4_8) for agglomerations. If no data reported, the country will be considered not complete, and all agglomerations will be classified as No data.
Major road noise outside agglomeration	Road noise segments provided in DF1_5 need to be covered by noise contour maps provided in DF4_8 Major roads dataflow	A threshold value is established to define complete and not complete data at country level (*)	Percentage of completeness calculated after data accepted in quality control process
Major railway noise outside agglomeration	Rail noise segments provided in DF1_5 need to be covered by noise contour maps provided in DF4_8 Major railways dataflow	A threshold value is to be established to define complete and not complete data at country level (*)	Percentage of completeness calculated after data accepted in quality control process
Major aircraft noise outside agglomeration	Major airports provided in DF1_5 need to be covered by noise contour maps provided in DF4_8 Major airports dataflow	Any data reported is considered relevant and complete.	No analysis of completeness of data provided will be performed. It will be checked if data has been provided in the Strategic Noise maps (DF4_8) for major airports. If no data reported, the country will be considered not complete and classified as No data.

(*)A 100 % value will not be achieved in the majority of the cases due to the existence of tunnels and bridges that are not mapped, so the threshold need to be established based on the country specific situations observed.

Figure 2.1. Criteria to define completeness in the case of road noise inside agglomerations



Finally, the completeness analysis explained in this section need to be undertaken before starting the analysis presented in this report. The results of this completeness analysis are summarized in tables per country and per agglomeration, which are integrated in the FME process implemented, as explained in Section 4.2.

2.2 Education Services in Europe

To evaluate the schools that are affected by noise in the EU, the data set Education Services in Europe provided by GISCO (Eurostat) is used. This dataset integrates Member States official data on the location of education services. Additional information on these services is included when available. A variety of data sources are available at MS level with different quality criteria: level of detail, timeliness and update frequency, etc. The Eurostat approach aims to progressively build pan-European datasets from MS official data and maintain them in a sustainable manner. Different data sources could be selected depending on the needs and the cases but priority is given to data sourced from governmental sources such as Education Ministries or other official outlets indicated by Ministries. Data is semantically harmonised with a common (simple) schema. Production relies on automated processes: MS data are retrieved, harmonised combined and updated automatically, as far as possible.

The dataset is updated regularly as data coverage improves. Once considered complete, it is updated annually.

Annex 1 provides a complete overview of the metadata. A selection of the relevant fields for this study is presented below:

- **Coordinates of the school**. The position of an education service is provided by the MS or, sometimes, computed automatically from its postal address, using geocoding.
- **Levels**. Education levels. For the current report, we have selected levels 0 to 4. One school may have multiple levels:
    - 0 – Early childhood education
    - 1 – Primary education
    - 2 – Lower secondary education
    - 3 – Upper secondary education
    - 4 – Post-secondary non-tertiary education
    - 5 – Short-cycle tertiary education
    - 6 – Bachelor's or equivalent level
    - 7 – Master's or equivalent level
    - 8 – Doctoral or equivalent level
- **Maximum number of students**. Capacity of the maximum number of students. This information is largely missing. Only available ins some schools from Bulgaria, Czechia, Croatia and Norway.
- **Enrolment**. Measure of capacity by number of enrolled students. This information is only available in Austria, Finland, France (partially), Ireland, Luxembourg and Latvia (partly).
- **Geo-qual**. A quality indicator for the geolocation. As can be seen, the quality is relatively high:
    - 1: Good, 70 % of the schools
    - 2: Medium, 13 %
    - 3: Low, 6 %
    - 4: From source, 12 %
    - -1: Unknown (7 cases)

Table 2.3 provides an overview of the school coverage by country and level.

Table 2.3. Overview of the country coverage as number of schools per country. Level refers to education level (see description in the text)

Country code	Levels 0-4	Other levels or NoData	Total
Austria	4702	1076	5778
Belgium	7991		7991
Bulgaria	3843		3843
Cyprus	933		933
Czech Republic	11420		11420
Denmark	3209	1313	4522
Estonia	600		600
Greece	10158	2001	12159
Spain	21500	12519	34019
Finland	2610		2610
France	62987		62987
Croatia	1402		1402
Hungary	11680	1412	13092
Ireland	3829		3829
Italy	61607	754	62361
Lithuania	2139	7213	9352
Luxembourg	208	12	220

Country code	Levels 0-4	Other levels or NoData	Total
Latvia	2617	99	2716
Netherlands	7917		7917
Norway		3830	3830
Poland	25027	20902	45929
Portugal	8070	366	8436
Romania	9945	3	9948
Sweden	4516	2365	6881
Slovenia	1830	336	2166
Slovakia	7988		7988
Total	**278728**	**54201**	**332929**

The main limitations of the data can be highlighted as follows:

- Low availability of the number of students enrolled (the same for the maximum capacity that could be used as a proxy). Therefore, the analysis will focus on the number of schools instead of students. However, where this information is available, it could be used for a test case to show the potential of the database.
- Geographic coverage. The data set focuses on EU27 and Norway. Moreover, Eurostat does not directly provide data for Germany since no national data source currently exists -information is available at a regional level. It could be downloaded from the links provided in the metadata.

3 Methodology

3.1 Rationale

Most of the assessments of noise impact on children focus on learning impairment (Clark and Paunovic, 2018). Many of these studies used noise exposure at school, either modelled for the most exposed façade or measured in the classroom. However, the information of the END has been analysed in residential environments. Therefore, our approach focuses on the noise environment around the school and related access areas. Distribution of transportation noise for schools in Europe may be different than for home address as schools. Such a systematic difference would affect any impact assessment and result in an inaccurate estimation of the health impact.

Figure 3.1 illustrates an example from Brno (Czechia) where two schools are located in contrasting situations: one school is below 55 dB (all the areas not covered by noise bands are below 55 dB L_{den}), and another school is located in a range of 70-75 dB.

Considering the variability in the school's location, i.e., sometimes it is georeferenced in the façade, and other times the school is georeferenced at a midpoint inside the building, a buffer of 100 m around the point representing the school will be considered for the analysis. Ideally, the street around the school could be considered the area of interest. However, this is out of the scope of the present analysis. We assume that 100 m is a reasonable distance for most schools since we want to focus on the most immediate area. Extending to more considerable distances would increase the uncertainty of the results.

The 100 m buffer delimitates an area that usually includes several noise levels (Figure 3.2). We need to integrate this information to understand the significant patterns at the European level. Two complementary options are considered, and pros and cons are provided:

- Integrate the data within the 100m buffer, calculating the average dB based on the area covered by each dB band within the buffer.
  - Pros: it integrates the prominence of noise levels.
  - Cons: Noise data is modelled. Moreover, the area covered by 100m buffer may introduce some bias if it integrates a large part of the school. Finally, the weighted average could not reflect the perception and higher annoyance due to existing dB levels above the average.
- Consider the maximum noise level within the 100 m buffer.
  - Pros: persistence of perception of higher noise levels.
  - Cons: the maximum noise level is only found in a small area within the 100 m buffer, resulting in overestimation.

Figure 3.1. Location of schools (grey dots) and noise contour bands for traffic noise (L_{den}) reported by the END in Brno (left). The right map shows a zoom with two schools in contrasting situations: the school on the top left is located below 55 dB; a second school on the bottom right is in an area of 70-75 dB. The background represents buildings (dark grey) and streets (white lines). Source: EEA Environment and Health Atlas

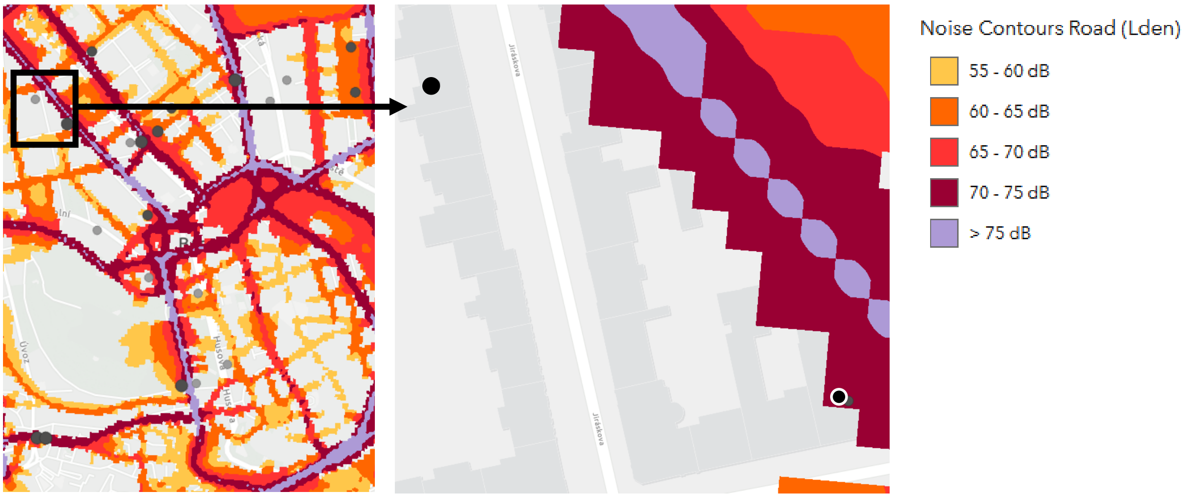


Figure 3.2 Noise levels from traffic road inside 100 m buffer of a school in Prague. The 50-54 dB L_{den} value has been assigned to an area that does not intersect with any dB band (dark blue on the top left). All the dB bands ≥55 dB have been reported under the END. The value of the dB at school (the point at the centre of the figure) is 55-59 dB L_{den}

3.2 Detailed description

The methodology is intended to provide the following outputs:

- dB at the school address
- area of the noise contour bands within 100 m buffer from the school address point

From the geographic perspective, the END provides information on noise sources inside agglomerations (including major sources) and outside agglomerations (major sources). An overview is provided in Table 3.1. Four combinations are possible, and each combination indicates the availability of only a major source or all sources. This is relevant for the assessment since the END provides full coverage inside agglomerations (if data reported), while outside only covers the major sources.

The major complexity is found in those cases where the buffer is only partially inside an agglomeration. Figure 3.3 exemplifies this situation in a school in Ostrava. In the processing, we have done all calculations differentiating if the buffer is inside or outside an agglomeration to keep the higher granularity of the information.

Table 3.1 Data available by the combination of the location of the school and the intersection of the 100m buffer with the agglomerations

		Intersection of the buffer with an agglomeration		
		Completely inside *an agglomeration*	***Partially inside*** *an agglomeration*	*Completely* ***outside*** *an agglomeration*
Location of the school	***Inside*** *an agglomeration*	All sources, including major sources	All sources, including major sources	Not applicable
	Outside *an agglomeration*	Not applicable	All sources, including major sources	Only major sources

Figure 3.3. Illustration of a school inside Ostrava (point at the centre of the map) and associated buffer extending outside the agglomeration (right side part of the map). Noise levels inside the buffer are indicated by different colours

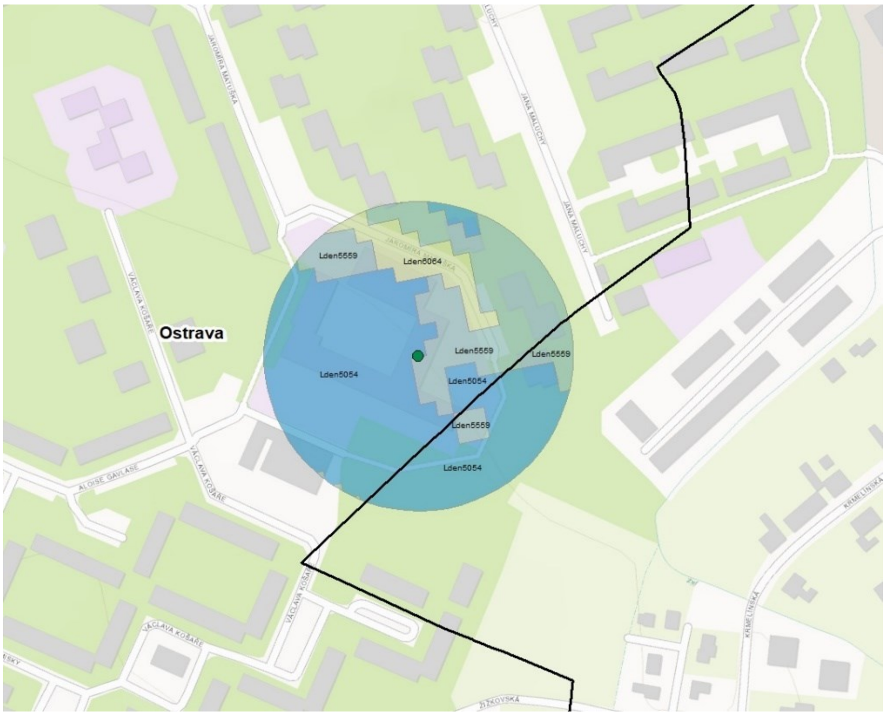
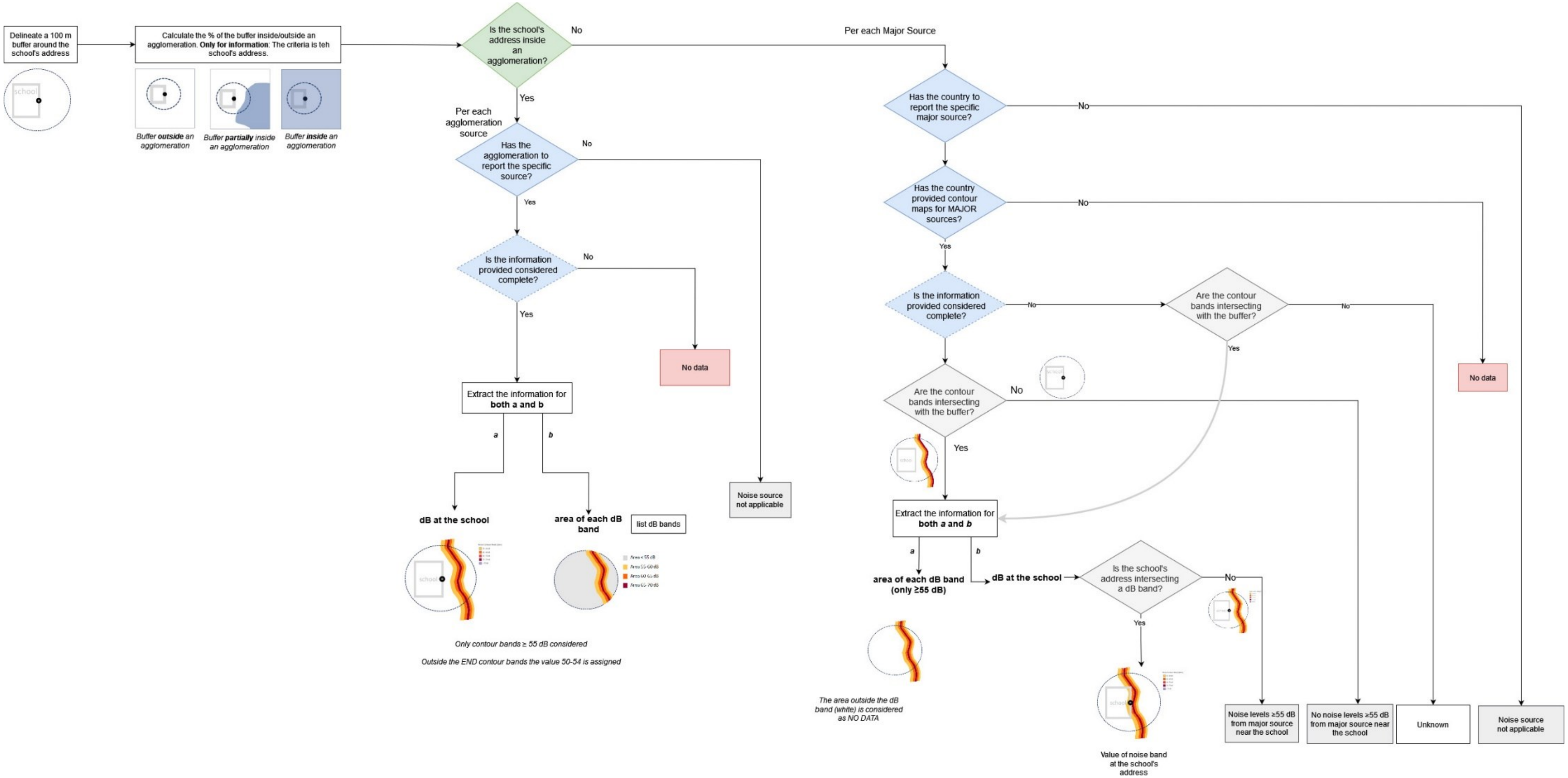


Figure 3.4. Overview of the workflow for the calculation of dB at school and area within the buffer covered by noise contour bands



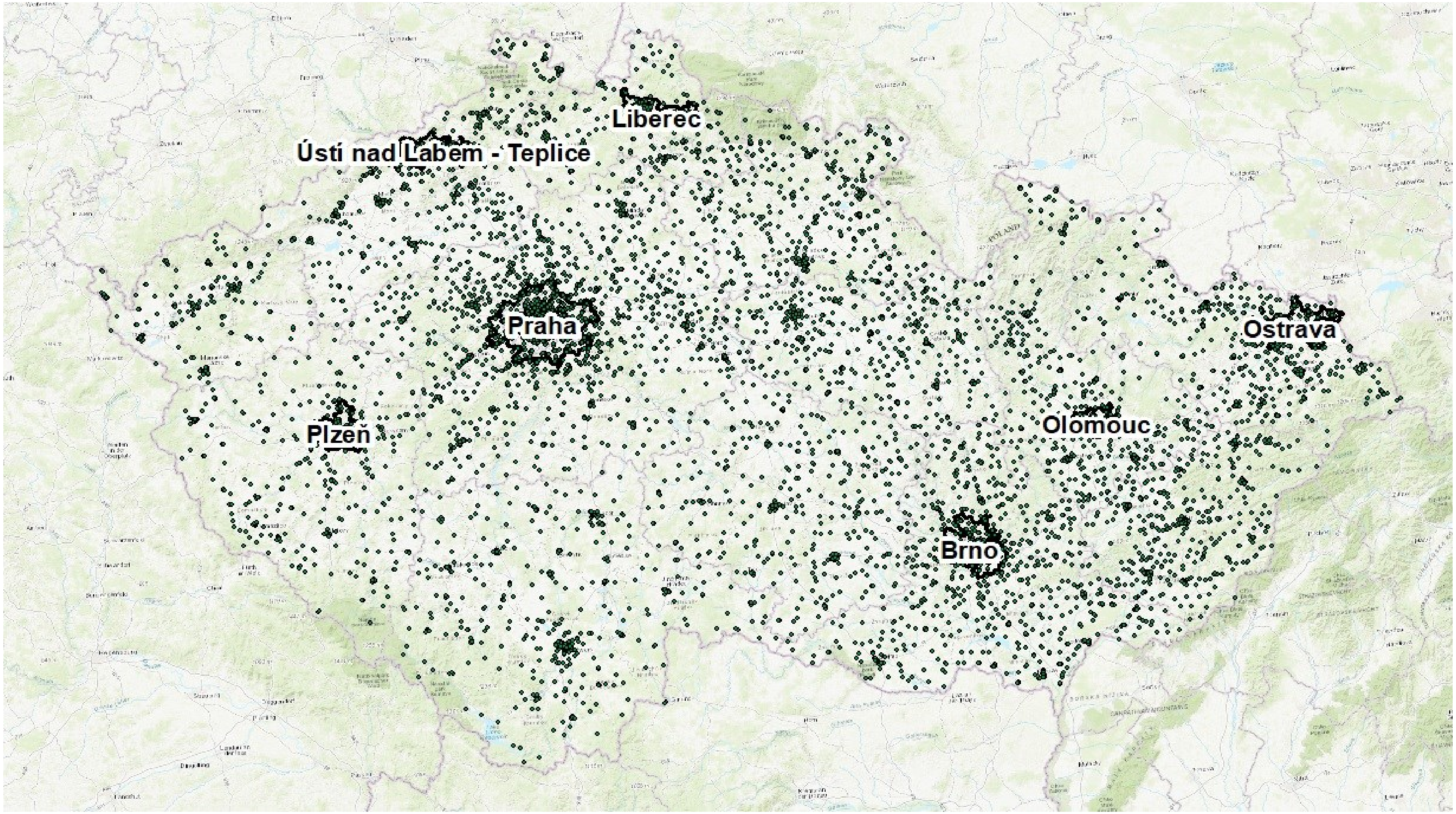
An overview of the workflow is presented in Figure 3.4. It can be outlined as follows:

1. Create a 100 m buffer around the schools, ensuring that possible overlaps between buffers are kept separated and the school ID is retained in each buffer.
2. Identify schools inside agglomerations and outside agglomerations.
3. Processing will depend on whether the school is inside an agglomeration and the data is provided
   3.1. Schools inside agglomerations
      i. Identify if the noise source applies to that particular agglomeration. If not, then the output is that the noise source does not apply to the school.
      ii. If the information is incomplete, the output is “No data”. Section 2.1.1 provides the criteria for data completeness by noise source.
      iii. Extract the following information
         - dB at the school georeferenced point. A 50-54 dB L_{den} value is assigned if the school does not intersect any dB band.
         - Calculate the area covered by each dB band in the 100 m buffer. A 50-54 dB L_{den} value is assigned to the portion of the 100m buffer that is not intersecting any dB band.
   3.2. Schools outside agglomerations
      i. Identify if the noise source applies to the country of the school. If not, then the output is that the noise source does not apply to the school.
      ii. If the country has to report and has not provided any noise contour band, “No data” will be assigned to the school.
      iii. If the information provided by the country is incomplete and there is no noise contour band intersecting the buffer, “Unknown” will be assigned to the school.
      iv. When all data has been reported OR partial data reported, AND at least one noise contour band intersecting the buffer, extract the following information
         - dB at the school georeferenced point. If the school does not have an intersection with any noise contour band, the value assigned will depend on whether there is at least one band intersecting the buffer: “Noise levels ≥ 55 dB nearby” if it is positive, or “No noise levels ≥ 55 dB nearby” in the other cases.
         - Calculate the area covered by each dB band in the 100 m buffer. The same rule described above for the dB at school applies to the buffer area not intersecting any noise band.

4 Test case implementation

The methodology was evaluated using a test case study to get an overview of the possible implications of the proposed methodology. For this test case we selected Czech Republic, as it was one of the countries with best available data to deal with as an example (see Figure 4.1). In what concerns to the technology used to perform the test case, the Feature Manipulation Engine (FME) software was selected as it is the standard tool provided by the EEA to deal with data integration and transformation. Before going into the FME project, it follows a description of the spatial analysis involved in the process of assigning decibel data into schools.

Figure 4.1. The 11420 Czech Schools from GISCO database



4.1 Spatial analysis workflow

In order to calculate the noise indicators at schools described in section 3.2., there is the need to implement a variety of spatial analysis in order to calculate the noise values defined for each specific school point.
The test case only contemplates road noise data, both inside agglomerations and outside agglomerations (see section 2.1), where it is explained which data is to be used for the analysis.

Below you will see the spatial analysis workflow that is applied (consecutive phases):

1) Preparation phase
   a) For Schools
      i) Download GeoPackage format files from GISCO services website
         (1) https://gisco-services.ec.europa.eu/pub/education/
      ii) Reproject from EPSG:4326 into EPSG:3035
   b) For Noise Contour Maps (inside agglomeration and majors)
      i) No prior data cleaning needed
   c) For Agglomeration delineations
      i) No prior data cleaning needed
      ii) Clip the contour maps using the delineations
2) Processing phase (using FME)
   a) Separate Schools inside and outside agglomeration
      i) Create buffer of 100 metres for both loops (polygon layer)
   b) For Schools inside agglomeration
      i) Calculate percentage of the buffer inside and outside the agglomeration
      ii) Overlay School buffer with the Noise Contour maps (pre-processed layer outside the task, as explained in section 2.1) and merge both datasets to get the area in square meters per dB range.
      iii) In the areas where no overlap is found set the buffer value to dB "50-54".
   c) For Schools outside agglomeration
      i) If the buffer cross the boundary of the agglomeration calculate the percentage of the buffer that is inside the agglomeration.
      ii) Overlay School buffer with the Noise Contour maps (pre-processed layer outside the task, as explained in section 2.1) and merge both datasets to get the area in square meters per dB range.
      iii) In the areas where no overlap is found set the buffer value to "no data". Except if the buffer area part is inside the agglomeration, where the value should be set to dB "50-54"
   d) Dissolve both loops in order to get as less areas as possible per School id row.
   e) Calculate dB at School intersecting the School point layer with the temporary buffer output including inside and outside agglomerations data.
3) Cleaning phase (using FME)
   a) Correct field names to ensure readability
   b) Delete useless information (fields)

4.2 Feature manipulation engine (FME)

The FME software was selected to process all the spatial analysis flow described in the last section 4.1, as the best solution available that can be replicated in the future for all the noise sources and all the EU members states where both Schools and Noise contour maps data are available.

As a first step all the input data was added to the FME project as readers as follows:

- Type of readers (format)

Microsoft SQL Server Spatial (JDBC)

- DF1_5 Agglomeration Sources (Agglomeration delineations)
- DF4_8 Noise Contour Maps Major Roads Including Agglomerations
- DF4_8 Noise Contour Maps Roads Inside Agglomerations
    - This implementation is planned to be done by means of a test case and this is the reason why two different types of noise contour maps (major roads including agglomerations and road inside agglomeration) were included in the analysis. The methodology and its implementation is based on the creation of a new layer (e.g. road noise in Europe) that combines both datasets into a single one, as a pre-processed layer needed for this analysis to deal with potential overlays between both datasets.

OGC GeoPackage

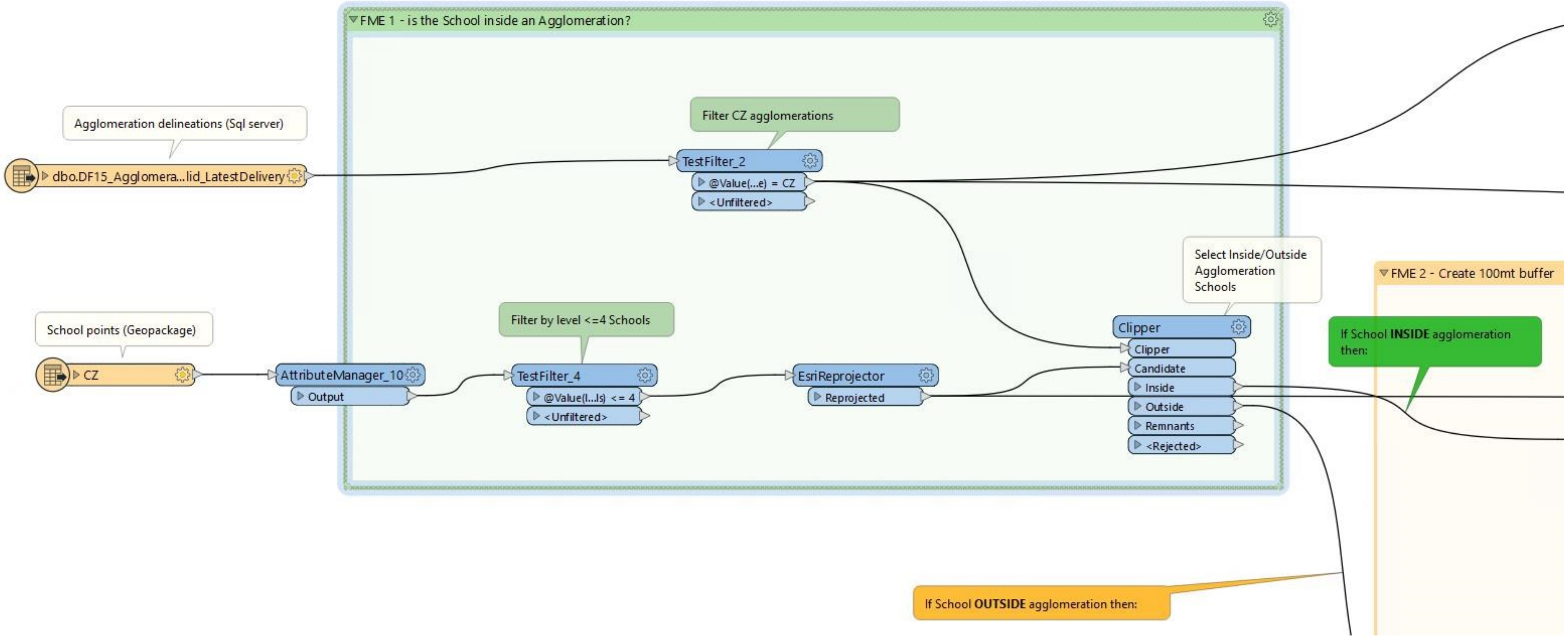
- Czech Republic GISCO Schools gpkg

For all the subsequent steps FME bookmarks were used in order to document what is being done in each part of the workspace.

In the first bookmark (FME 1) it is calculated which point School features are located inside or outside each agglomeration, so we can clearly distinguish two different flows and ways to deal with the data. Inside this bookmark Czech Republic delineations are selected using a “TestFilter” transformer, Schools dataset is reprojected into the LAEA EPSG:3035 coordinate system using the “EsriReprojector” transformer and School levels from 0-4 are selected also using a “TestFilter” transformer.

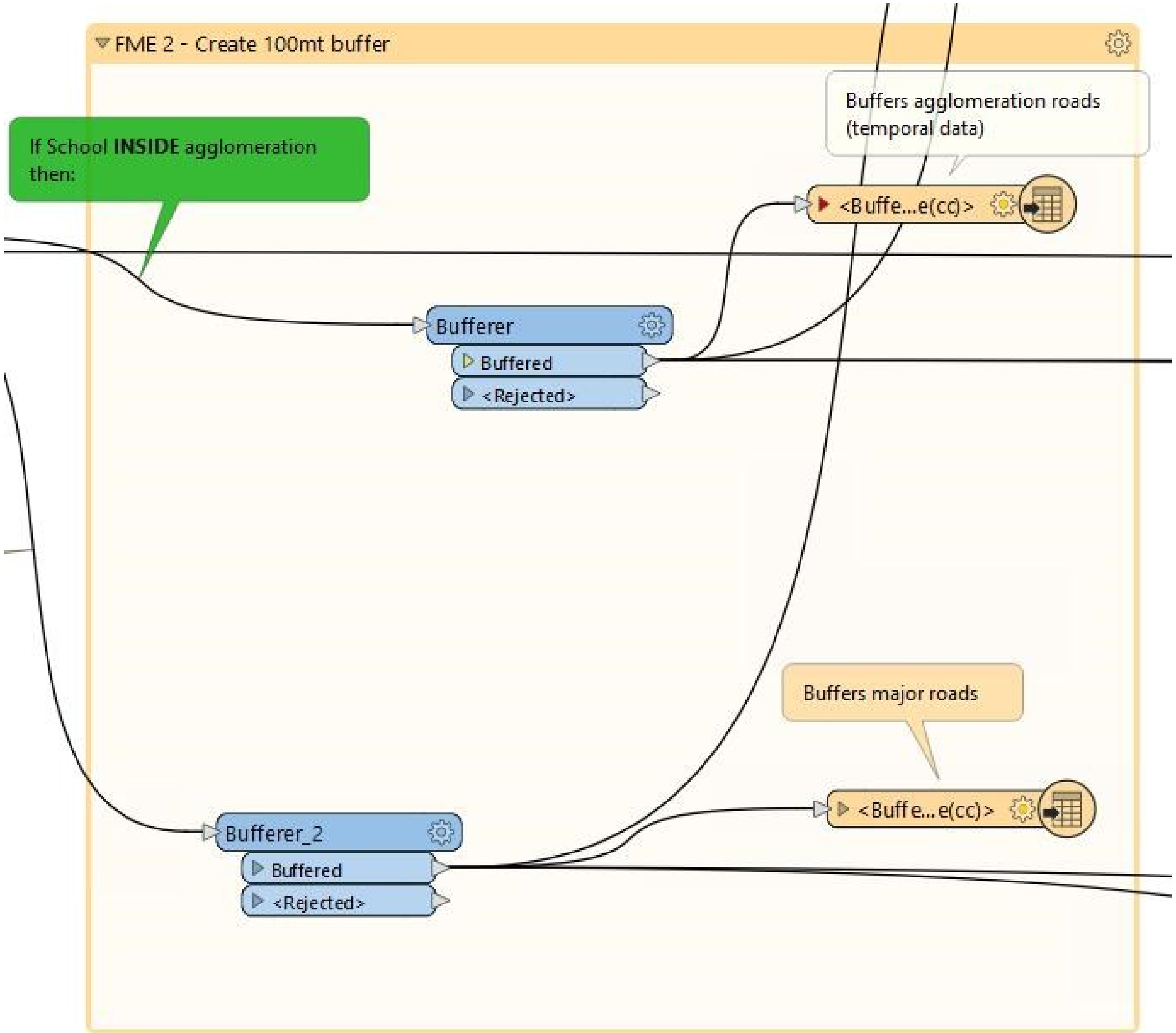
The last step within this bookmark is to distinguish between School point features, inside and outside agglomerations, using the “Clipper” transformer, delineations as clipper and School points as “candidates”.

Figure 4.2. First bookmark (FME 1) used to separate Schools inside and outside agglomerations



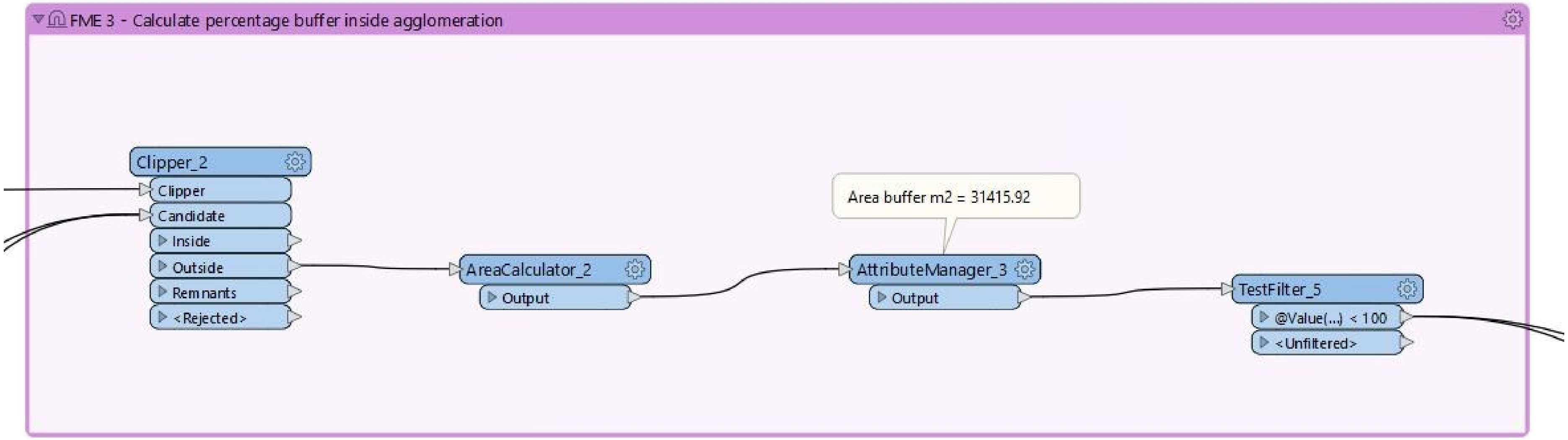
The bookmark (FME 2) is where both buffers of 100 meters are created using the "Bufferer" transformer as seen below (Figure 4.3). Both are outputed as "SHAPEFILE" writers in order to quality check the data and for visualization purposes.

Figure 4.3. Bookmark (FME 2) where the 100 meter buffers are created



The next Bookmark (FME 3) deals with the calculation of area percentages inside the agglomerations for both buffers.

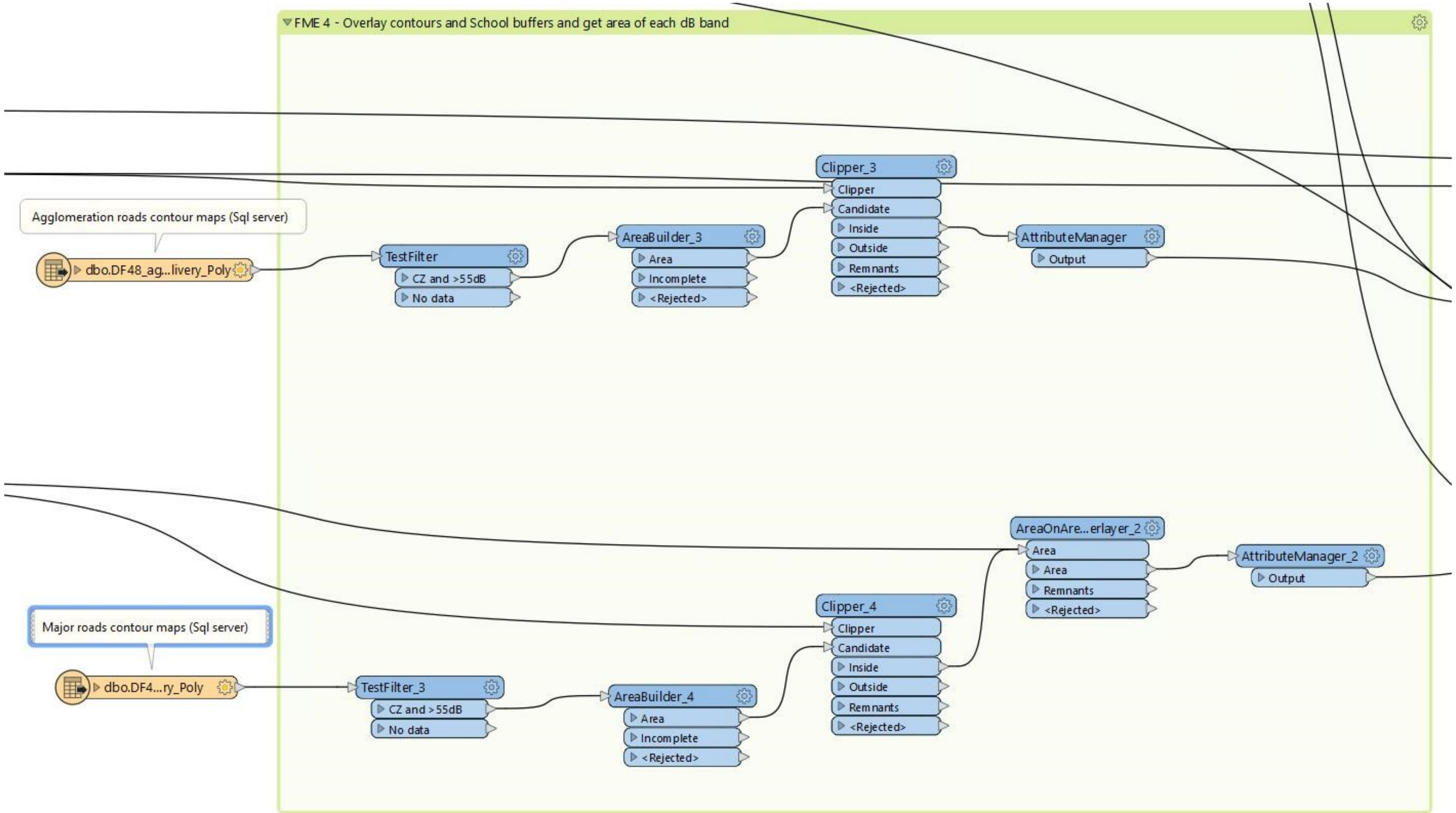
Figure 4.4. Bookmark (FME 3) used to calculate percentage of the buffers inside the agglomerations



Using the "Clipper" transformer and the delineations as clipper input, both buffers, inside and outside agglomerations are used as candidate inputs. All the buffers have the same square meter area of 31415,92 m2, and with the "Clipper" function we can distinguish which area of the buffer is inside the agglomeration and which area of the buffer is outside agglomeration.

The next Bookmark (FME 4) is where the decibel data is overlapped with the buffers so every contour map inside the buffers is located and the noise values are assigned and intersected with the buffers, creating new polygon areas. In the figure below (Figure 4.5) both Road contour maps inside and outside (major) agglomerations are feeded as readers from the SQL Server last delivery database.

Figure 4.5. Bookmark (FME 4) where decibel data is assigned into the 100 meter buffers. When the new pro-processed layer will be available, this Bookmark will only feed as reader this layer

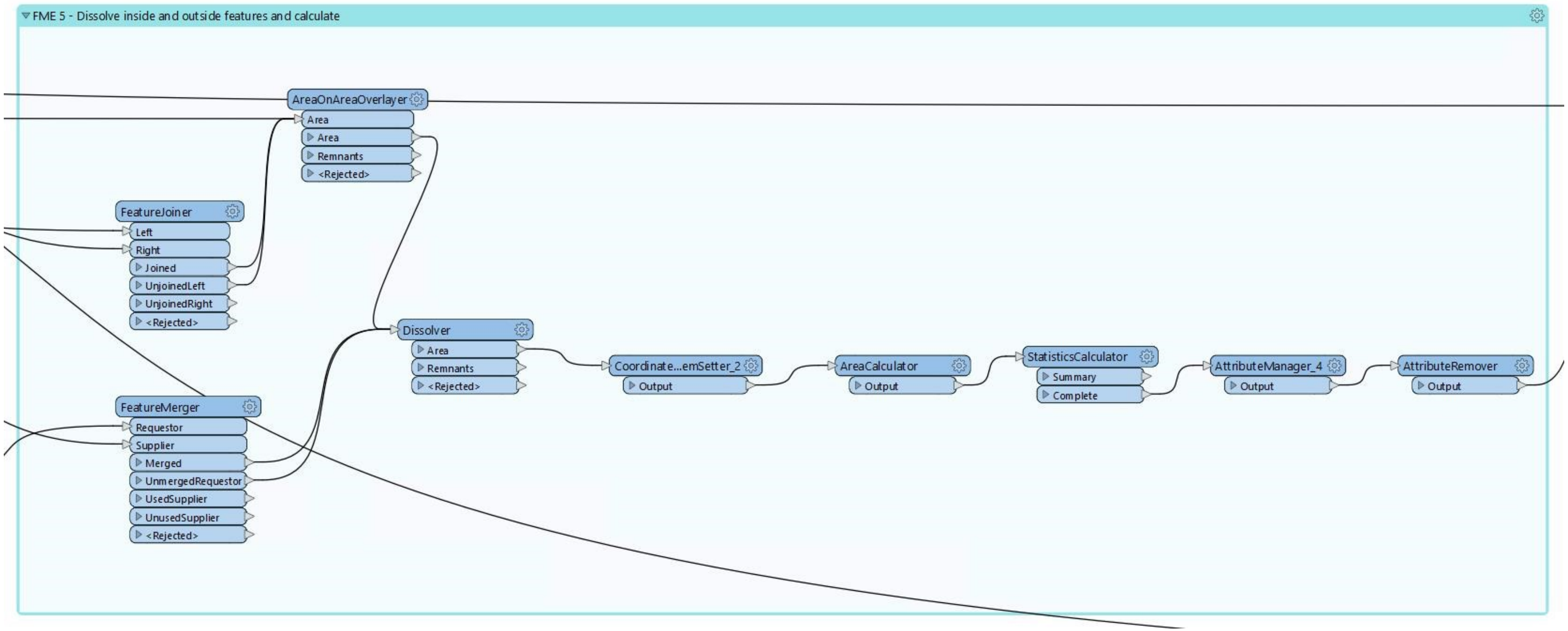


Afterwards, noise contour maps from Czech Republic higher than 55 decibels are filtered and the polygon geometries are created using the “AreaBuilder” transformer. Datasets coming from EEA SQL server databases needs to be recreated in FME as geometries in order to be used in spatial analysis processes. As mentioned before two clippers are used to intersect both information. From the inside port we get the intersected features so further on we also need to use the “AreaOnAreaOverlayer” transformer to include in the analysis the “lost” buffers where no intersection was detected.

When all the information is collected, every polygon needs to be aggregated and dissolved into single features that share the same values. The bookmark below (FME 5, Figure 4.6) is then where features get aggregated by using the "FeatureMerger" transformer, which merges outside agglomeration features with the area percentage inside agglomeration features, the "FeatureJoiner", which joins ids to get the same area percentages but only for the features inside agglomerations, and finally the dissolver, which dissolves both inside and outside features into one single flow.

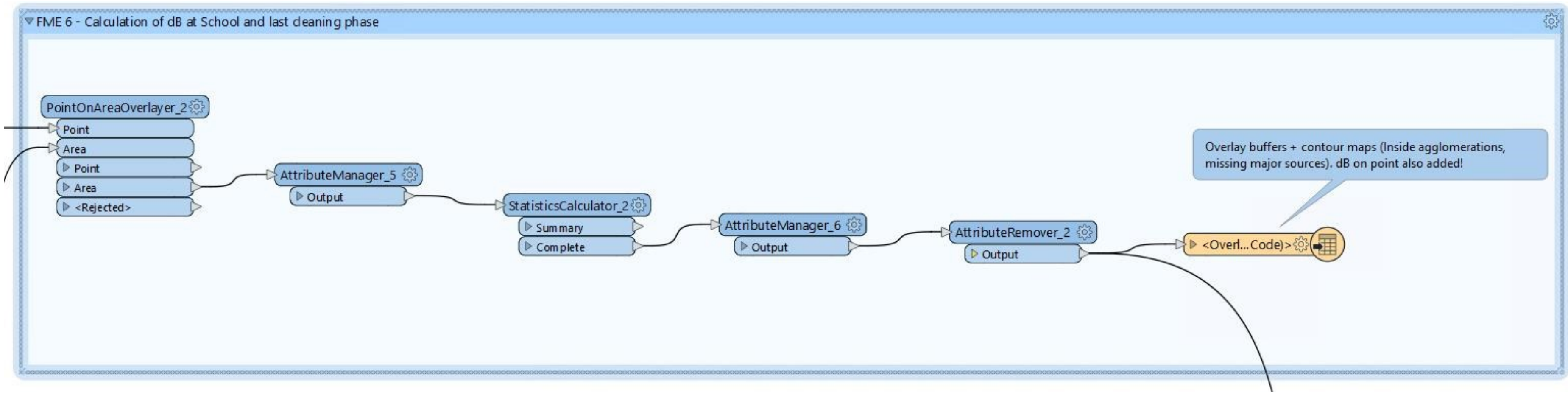
Also within this bookmark, some support transformers are used to clean the data and provide a better input for the next and last transformation phase.

Figure 4.6. Bookmark FME 5 used to aggregate features and first clean data



In the last bookmark (FME 6) we find the calculation of the dB at the School for every single polygon area and also some last attribute cleaning transformers. The output is a shapefile and also a CSV format file that feeds the last processing phase explained in the following chapter.

Figure 4.7. Bookmark FME 6 where the dB at School indicator is calculated and the output is created



The FME workspace is located under: S:\Common workspace\Noise\2023\3252_Schools\data\test_case\fme

The last version of the file is: 2_dB_in_Schools_Roads_v3.fmw

4.3 Output

The output of the spatial analysis has been further processed with R for quality checks (completeness, total computed area, possible duplicates amongst others) and to provide the final results in an Excel file. The results are provided in 2 tables:

- One table with one row per school. In those cases where the buffer is only partially intersecting an agglomeration, the areas for each dB band from both inside and outside agglomeration have summed up, resulting in one row per school.
- One table with the schools where the buffer partially intersects an agglomeration. The information has been kept separately for the buffer part crossing the agglomeration and the outside part.

Figure 4.8 provides a description of the information included in the final output.

Figure 4.8. Overview of the output of the analysis of schools and noise

Type of info	*Name*	*Description*	**Format/values**	*Source*
School	**id**	The education service identifier. This identifier is based on national identification codes, if it exists.	xxxxxxxx_x	Eurostat
	country	Country code	two letters	Eurostat
	city	City name (Sometimes refers to a region or municipality)	text	Eurostat
	levels	Education levels represented by a single integer or range. See ISCED 2011 guidelines for definitions.	0 – Early childhood education 1 – Primary education 2 – Lower secondary education 3 – Upper secondary education 4 – Post-secondary non-tertiary education	Eurostat
	max_students	Measure of capacity by maximum number of students.	Integer. Blank cells are no data.	Eurostat
	enrollment	Measure of capacity by number of enrolled students.	Integer. Blank cells are no data.	Eurostat
Noise info at school address	**school_inout**	Location of the school address inside or outside an agglomeration	school inside agglomeration school outside agglomeration	Eurostat - school location END -agglomeration delineation
	agg_at_school	Agglomeration at school address if the school is inside an agglomeration	Name of the agglomeration in English	Eurostat - school location END -agglomeration delineation

Type of info	*Name*	*Description*	**Format/values**	*Source*
	dB_at_school	dB at the school address	**Lden5054** - Value assigned to schools inside agglomerations not intersecting with any noise contour band **Lden5559** - Value at the school address **Lden6064** - Value at the school address **Lden6569** - Value at the school address **Lden7074** - Value at the school address **LdenGreaterThan75** - Value at the school address **No noise levels Mroads nearby** - Value assigned when the school address is outside an agglomeration, is not intersecting with any noise contour band and there is not any noise contour band inside the buffer **Noise levels Mroad nearby** - Value assigned when the school address is outside an agglomeration, is not intersecting with any noise contour band and there are noise contour bands inside the buffer	Eurostat - school location END -agglomeration delineation END - noise contour bands (roads & Mroads)
Buffer area	**buffer_inout**	Intersection of the 100 m buffer around the school address with the delineation of the agglomeration.	Buffer completely inside an agglomeration Buffer completely outside an agglomeration Buffer partly intersecting an agglomeration	Eurostat - school location END -agglomeration delineation
	agg_at_buffer	Name of the agglomeration that is intersecting, completely or partially, the buffer	Name of the agglomeration in English	Eurostat - school location END - agglomeration delineation END -agglomeration name
	area_in_pcnt	Percentage of the buffer inside an agglomeration	Double	Eurostat - school location END - agglomeration delineation

Type of info	Name	Description	Format/values	Source
Area covered by noise contour bands in buffer	**nd_bo_type**	Categorisation of the portion of the buffer outside agglomeration that is not intersecting with a noise contour band (no data in a section of a buffer outside agglomerations).	**No noise levels Mroad nearby** - No noise levels higher than 55 dB L_{den} from major roads inside the buffer. **Noise levels Mroad nearby** - Noise levels higher than 55 dB Lden from major roads inside the buffer. **Not applicable** - Schools with a buffer completely inside an agglomeration.	Eurostat - school location END -agglomeration delineation END - noise contour bands (roads & Mroads)
	no_data	Area of the buffer not intersecting with a noise contour band. See nd_bo_type for an explanation.	Percentage of the buffer	Eurostat - school location END -agglomeration delineation END - noise contour bands (roads & Mroads)
	Lden5054	Percentage of the buffer within L_{den} 50-54 dB noise contour band	Percentage of the buffer	Eurostat - school location END -agglomeration delineation END - noise contour bands (roads & Mroads)
	Lden5559	Percentage of the buffer within L_{den} 55-59 dB noise band	Percentage of the buffer	Eurostat - school location END -agglomeration delineation END - noise contour bands (roads & Mroads)
	Lden6064	Percentage of the buffer within L_{den} 60-64 dB noise band	Percentage of the buffer	Eurostat - school location END -agglomeration delineation END - noise contour bands (roads & Mroads)
	Lden6569	Percentage of the buffer within L_{den} 65-69 dB noise band	Percentage of the buffer	Eurostat - school location END -agglomeration delineation END - noise contour bands (roads & Mroads)
	Lden7074	Percentage of the buffer within L_{den} 70-74 dB noise band	Percentage of the buffer	Eurostat - school location END -agglomeration delineation

Type of info	*Name*	*Description*	**Format/values**	*Source*
				END - noise contour bands (roads & Mroads)
	Lden75	Percentage of the buffer within L_{den} >=75 dB noise band	Percentage of the buffer	Eurostat - school location END -agglomeration delineation END - noise contour bands (roads & Mroads)
Reference info on schools and quality	**ref_date**	The reference date (DD/MM/YYYY) the data refers to. The dataset represents the reality as it was at this date.	DD/MM/YYYY	Eurostat
	pub_date	The publication date of the dataset by Eurostat (DD/MM/YYYY). This should be used to track when this Eurostat dataset has changed.		Eurostat
	geo_qual	A quality indicator for the geolocation.	1: Good, 2: Medium, 3: Low, 4: From source, -1: Unknown	Eurostat

5 Results of the test case

The methodology was tested with road traffic noise data and schools from Czechia.

The database on schools provides 11,420 schools in Czechia covering grades 0 to 4 corresponding to primary and secondary school (see section 2.2 for description).

The test and school-level results have only been processed for road noise, but the same methodology can be applied to obtain outputs for rail and aircraft noise exposure. In the case of industrial noise exposure, strategic noise maps are only provided inside agglomerations, so the analysis can only be done with schools located inside agglomerations.

Most of the schools are located outside agglomerations (Table 5.1), and the number of schools inside agglomeration is closely related to the size of the population, as one would expect (Figure 5.1).

The information from the analysis described in this report allows us to identify the dB at the school and characterize the neighbouring area (100 m buffer) in terms of noise levels. The combination of both may be relevant to assessing the potential health impact of noise on children, as explained in the next section.

Table 5.1 Overview of the distribution of Czech schools inside and outside agglomerations

	completely inside an agglomeration	**partially inside an agglomeration**	**completely outside an agglomeration**	TOTAL
school inside agglomeration	2367	16		2383
school outside agglomerations		13	9024	9037
Total	2367	29	9024	11420

Figure 5.1 Number of schools per number of inhabitants inside the Czech agglomerations

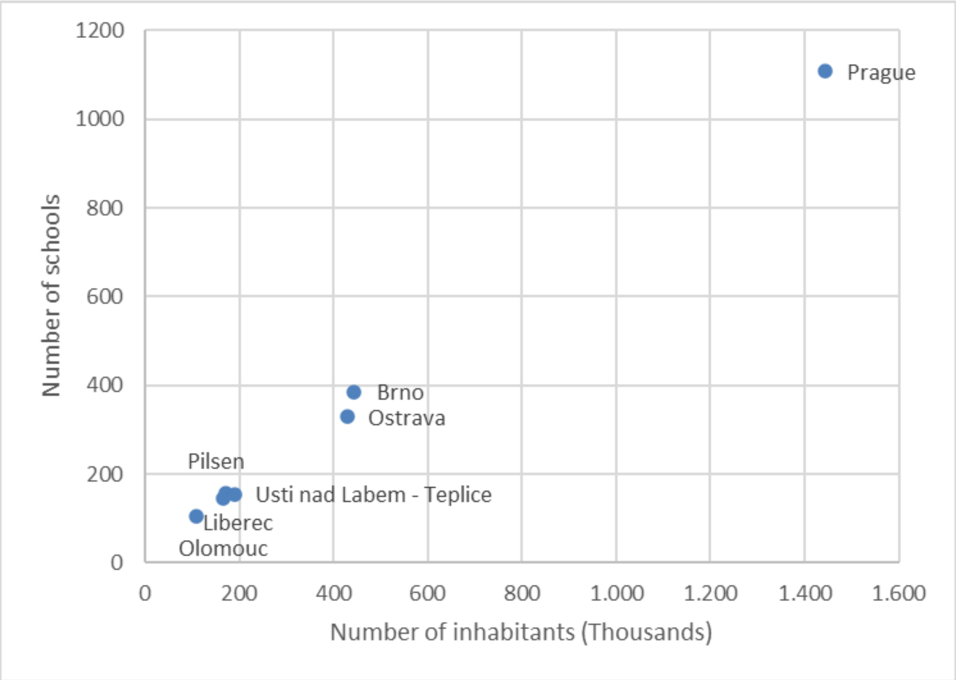
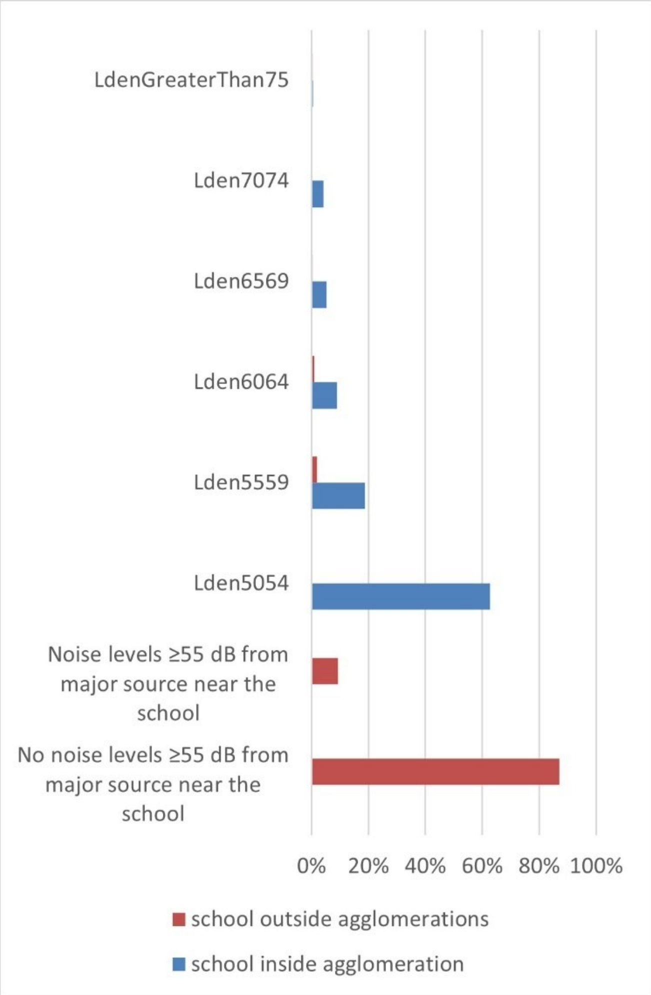


Figure 5.2. Distribution of schools by the corresponding dB at the school's address. In blue are schools inside agglomerations. In orange, schools outside agglomerations. It should be noted that Lden5054 only applies to schools inside agglomerations



Considering the dB at the school's address, it can be seen that schools inside agglomerations have higher noise levels than schools outside. These results should be taken with caution given the limitations explained in the methodology.

Considering the area surrounding the school address point (100m buffer), Table 5.2 shows the predominance of the different noise bands within the buffer of schools completely inside agglomerations. About 70 % of the schools (1665), 65 % of the buffer is below END thresholds. As one would expect, as the dB range increases, the number of schools and the average area decreases. However, it's worth to note the case of 70-75 dB. There are 72 schools where this noise band is the predominant and it covers 59 % of the buffer.

The same results have been analysed in the schools with the buffer completely outside agglomerations (Table 5.3). In that case, in 98 % of the schools, about 97 % of the buffer is not crossed by any major road.

Table 5.2. Number of schools with buffer completely inside the agglomerations and average area of the predominant dB band

Predominant dB band (L_{den})	Number of schools	Average area (%)
50-55 dB	1665	65,4
55-60 dB	357	53,8
60-65 dB	193	46,1
65-70 dB	76	39,0
70-75 dB	72	59,4
>75 dB	4	24,5

Table 5.3. Number of schools with buffer completely outside the agglomerations and average area of the predominant dB band

Predominant dB band (L_{den})	Number of schools	Average area (%)
no dB band	8886	97,0
50-55 dB	74	52,4
55-60 dB	32	35,6
60-65 dB	25	31,4
65-70 dB	2	26,8
>70	5	39,0

6 Discussion and further work

The methodology proposed in this report aims at determining noise exposure at the school address and surrounding areas. This methodology can be used to determine the number of school children affected by noise and estimate subsequent health effects. Noise exposure in children at the residential environment and at schools may differ. An assessment of the noise levels surrounding schools in addition to the noise levels in their residence, is important in the context of protection of buildings with vulnerable populations.

As this study has shown, it can be challenging to evaluate exposure at school for a few reasons. First, the size and orientation of the buildings paired with the geometries of the transportation networks means that indoor noise levels can differ widely within schools. A single noise level for the “front door” address point, thus may not reflect classroom exposure. This is likely better captured in health studies by measuring noise levels inside/outside the specific classroom. This mode of exposure assessment would probably be most applicable or useful to the younger children, in early and primary education, that spend most of their time in a single classroom. As children grow up and progress through the school system, however, they typically have more mobility around the school and take lessons in different rooms. This adds complexity for a measurement-based exposure assessment because it is often not feasible in health studies to measure in multiple classrooms to determine time weighted exposures for individual children. From this vantage point, an average across the whole school – as would be captured by the 100 m buffer – could be reasonable. Further, measurements inside the classroom capture all sounds including those from the children themselves; and depending on the activities this classroom noise could be the predominant noise source rather than traffic. This argues for the validity of using modelled noise exposure – the foundation of the methods described above – as a proxy for exposure in the classroom.

There are several options for how exposure may be parametrised using the methodology presented in this report , for example:

- Noise level at the school address point,
- Maximum noise level within the 100 m buffer, and
- Weighted mean of noise levels within the 100 m buffer.

For future health risk assessment (HRA), a key consideration is to align the exposure assessment with that used in deriving the exposure-response relationships as far as possible. Thus, exactly how the database is used to calculate exposure depends on the epidemiological evidence. Several previous studies on children’s learning and cognition focused on noise in the school environment and either used measured or modelled noise levels at schools (e.g. Clark et al., 2012; Haines et al., 2001; Stansfeld et al., 2009), whilst other studies have focused on both noise exposures, at schools and at homes (e.g. Clark et al. 2018; Belojevic et al., 2012; Zijlema et al., 2021; Tangermann et al. 2022). As examples, Haines et al. (2001) used aircraft noise contours to determine exposure at school. Likewise, Clark et al. (2012) and Stansfeld et al., (2009) used aircraft noise contours in addition to a simplified model for road traffic noise based on proximity to roads and traffic flow data confirmed against measurements at the school front façade. Belojevic et al. (2012) undertook noise measurements as part of their study in front of the schools. Tangermann et al. (2022) and Zijlema et al., (2021), the newest of these studies, used noise modelled at the loudest façade of the school. Given the few studies, the evidence pattern is still ambiguous to what extent school and/or residential noise exposure matters for children. A meta-analysis from three studies found that reading comprehension scores in quiet classrooms were 0.80 (95 %-CI: 0.40-1.20) points higher than children in noisier classrooms (Leq: 59-69.9 dB vs. 54.4-57 dB) but these studies did not address residential noise (Thompson et al. 2022). A few other studies addressed residential exposure from aircraft or road traffic noise exposure and some associations were observed. Most studies on behavioural problems addressed residential exposure and data from school is still scarce (Engelmann, N., Blanes Guàrdia, N., Fons Esteve, J., Vienneau, D., Röösli M. (2023).

Thus, a closer review of the epidemiological literature, which is planned for 2024 in the frame of the ETC/HE, is needed to take informed decisions about the main exposure vs. secondary exposure measures (e.g. for sensitivity analyses) that should be used in an HRA. To focus on the address point noise or maximum noise level within the 100 m buffer would align well with the use of maximum façade as in studies like Tangermann et al. (2022) and Zijlema et al., (2021). The risk is it could potentially overestimate exposure for some schools. However, this overestimate will likely be offset by underestimation due to known data gaps in both the schools and the noise exposure data in other areas. On the other hand, the weighted mean, which would be lower than the maximum, may be more appropriate given that the outdoor noise levels are attenuated inside the classroom due to damping by windows.

For HRA, another aspect is the combination of effects from noise at home and at school. It is conceivable that these two exposure sources are not well correlated. This implies that noise effects at school and at home can be regarded as independent and future health risk assessment should consider both for children, exposure at school and exposure at home. It is thus recommended to derive exposure-response associations for relevant outcomes separately for exposure at school and exposure at home and assume additive impact of different pathways. Noise effects at home may be mostly caused by noise induce restoration and disturbance of learning for school. Noise at school may have an impact on the motivation of teacher and students and directly disturb teaching activities resulting in reduced learning activities. , Thus health impacts of these two types of pathways are then added by assessing exposure distribution at home and at school.

To the best of our knowledge, most studies addressing residential exposure use modelled noise exposure at the most exposed façade. This is in line with the END data collection. However, studies in schools that used measured noise exposure inside the building add an additional layer of complexity for health risk assessment as this does not align with END. Damping by the wall results in deduction of the noise exposure. Typical values for the outdoor–indoor sound level differences are of 10 dB(A) for open, 16 dB(A) for tilted, and 28 dB(A) for closed windows based on a measurement campaign in residential buildings. This implies that any linear exposure-response analysis (e.g. changes in outcome per 10 dB in noise) is not affected, although the threshold for absence of effects would be lower. As a consequence it would be possible to pool studies using indoor and outdoor noise assessment for derivation of linear exposure-response associations. However, the effect threshold should be aligned with the END exposure assessment methods. For instance, if a study reports an effect threshold of 30 dB for noise measurements in the empty class room, one would expect that this translates in an effect threshold, which is 10 to 30 dB higher for outdoor noise.

In addition to children, people with chronic diseases and patients may be particularly vulnerable to transportation noise. Thus, the approach presented for schools could also be applied to characterise noise at hospitals, elderly homes or similar buildings for other vulnerable populations.

This methodology could also be used to improve the current representation of noise around schools in the Environment and Health Atlas.

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Annex 1. Metadata of the Education Services in Europe (Eurostat)

Attribute	Datatype	Description
id	text	The education service identifier. This identifier is based on national identification codes, if it exists.
name	text	The name of the education institution.
site_name	text	The name of the specific site or branch of an education institution.
lat	double	Latitude (WGS 84).
lon	double	Longitude (WGS 84).
street	text	Street name.
house_number	text	House number.
postcode	text	Postcode.
city	text	City name (Sometimes refers to a region or municipality).
cc	text	Country code (2 letters, ISO 3166-1 alpha-2).
country	text	Country name.
levels	text '-' delim	Education levels represented by a single integer or range. See ISCED 2011 guidelines for definitions. 0 - Early childhood education 1 - Primary education 2 - Lower secondary education 3 - Upper secondary education 4 - Post-secondary non-tertiary education 5 - Short-cycle tertiary education 6 - Bachelor's or equivalent level 7 - Master's or equivalent level 8 - Doctoral or equivalent level
max_students	int	Measure of capacity by maximum number of students.
enrollment	int	Measure of capacity by number of enrolled students.
fields	text '-' delim	Academic disciplines that the institution specializes in, according to ISCED Fields of Education and Training 2013 (ISCED-F 2013) (mainly applies to tertiary institutions).
facility_type	text	Type of institution in reference to ownership and operation e.g. Catholic, International, etc.
public_private	text	The public or private status of the education service.
tel	text	Telephone number.
email	text	Email address.
url	text	URL link to the institution's website.

Attribute	Datatype	Description
ref_date	date	The reference date (DD/MM/YYYY) the data refers to. The dataset represents the reality as it was at this date.
pub_date	date	The publication date of the dataset by Eurostat (DD/MM/YYYY). This should be used to track when this Eurostat dataset has changed.
geo_qual	int	A quality indicator for the geolocation. 1: Good, 2: Medium, 3: Low, 4: From source, -1: Unknown
comments	text	Some additional information on the education service.

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