LIFE+10 ENV/IT/000389

INTEGREEN

Action 4: Implementation & Integration

P.4.1.1

Data management unit prototype

Project Coordinating Beneficiary	Municipality of Bolzano
Project Associated Beneficiary n.2	TIS innovation park (TIS)
Project Associated Beneficiary n.3	Austrian Institute of Technology (AIT)

Document history

Date	Document Author(s)	Document Contribution
31/03/14	Roberto Cavaliere, Paolo Valleri, Stefano Seppi (TIS), Reinhard Kloibhofer, Wolfgang Ponweiser (AIT)	First document version submitted to the EC
31/05/15	Roberto Cavaliere, Paolo Valleri, Patrick Bertolla (TIS), Reinhard Kloibhofer, (AIT)	Second and final document version submitted to the EC. Contributions to the document have been given by the external assistance company CISMA responsible for the implementation of the emission and dispersion models.

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1 Introduction

1.1 Purpose of the document

The purpose of this document is to present the final version of the prototype of the “core” of the INTEGREEN system, i.e. its Supervisor Centre, as designed in Action n.3 (Figure 1).

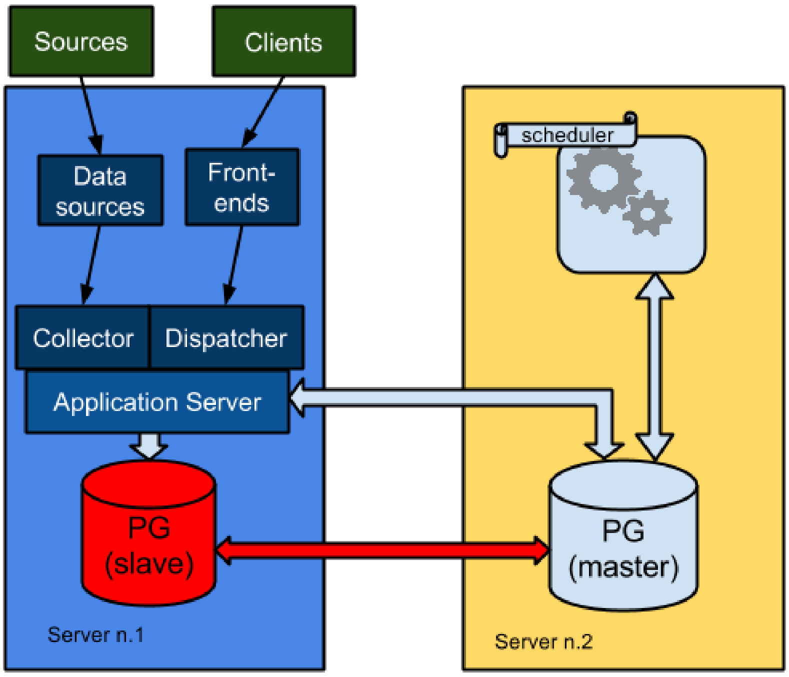

Figure 1: The design of the core of the Supervisor Centre of the INTEGREEN system [1].

The Supervisor Centre is a complex software entity, which is at present developed and executed in a protected network under the control of Associate Beneficiary TIS.

The part of the system that is going to be covered in this prototype deliverable are the ones whose design has been presented in Chapter 5 of deliverable D.3.1.1 [1], namely:

- **data center collector;**
- **data center elaboration tasks.**
- **database structure.**

1.2 Document structure

The document is structured in one single chapter presenting the prototype of the above system components. The source code and additional technical documentation, specifically destined to third parties IT specialists, are to be intended as a natural annex of this prototype deliverable and should be jointly consulted.

2 Prototype description

As specified in the design phase of the project, the architecture of the data center layer of the INTEGREEN Supervisor Centre is simply structured in four software components (apart from the Database Management System):

- **Data sources**: these are components which collect data from different sources, do simple elaborations and adjustments, and finally send the data to the "data collector";
- **Collector**: the main task of the data collector is to take the data, provided from the data sources and write it into the database. It also has the functionality to retrieve data from the database that can only be requested from a "data source";
- **Dispatcher**: This component with access to the "read only" database, has the task to distribute data in a specific way (which will be covered in a later part) to different "front-ends".
- **Front ends**: This part of the architecture takes care of delivering the elaborated data to external clients, e.g. service providers.

The communication between these internal components is carried out through a simple and well-known protocol, i.e. **XML-RPC**. Being all the architecture written in Java language, the implementation has actively used the functions and libraries provided by the **Apache XML-RPC project**.

2.1 Data Center Collector

The collector is the unique component which handles the connection with the database in a write mode, which has the privilege to contain the **DAL** (*Data Access Layer*). In computer science, a DAL is the piece of a software agent which provides simplified access to data stored in persistent storage of some kind, in our case an entity-relational database. It's a very common method to interact with a DBMS in object-oriented programming languages [2].

The mapping between the DAL and the database is handled by a **ORM** (*object/relational mapping*) called **HIBERNATE**. Hibernate is simply a Java library that provides a framework for this kind of interactions. The connection with the database was configured in a file called persistence.xml. In there, a persistence unit is defined which is used to make transactions and queries to the database.

Furthermore the collector serves as an XML-RPC server which serves and receives data from/to different data-sources. The collector has the ability to recognize the data source which is sending the data, and associate it to the specific source which has delivered it. An **XML-RPC servlet** was defined, which handles all the incoming requests. The servlet was configured for simple and complex data types, as specified in **Apache XML-RPC library**. For more information on this please refer to http://ws.apache.org/xmlrpc/types.html.

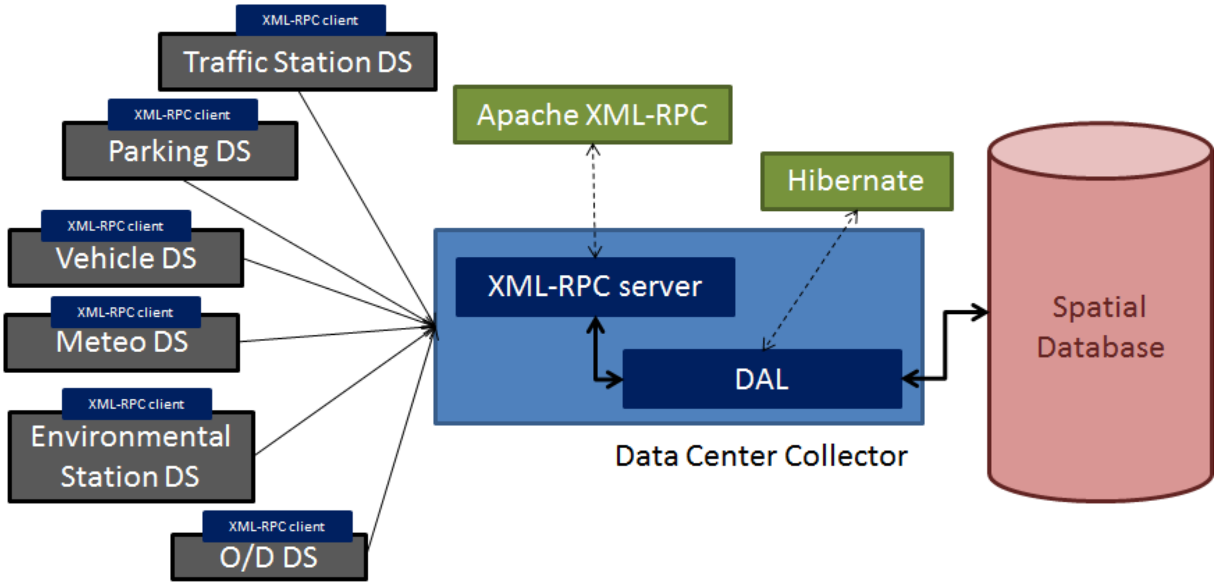

Figure 2: A schematic representation of the Data Center Collector.

2.1.1 Data Center "library"

The core of the INTEGREEN Supervisor Centre contains software code parts that are used in several components of its infrastructure. For this reason, all these common parts are managed through a reference software project managed through the well-known **Apache Maven** tool (rif.: http://maven.apache.org). In this way, each component can include the central functionalities included in this internal "library", and the dependency and building phase are easily maintained through the use of Maven. The dependency is satisfied by adding the following few lines to the **POM** (*Project Object Model*) file:

```
<dependency>
        <groupId>it.bz.tis.integreen</groupId>
        <artifactId>integreen-base</artifactId>
        <version>0.0.1-SNAPSHOT</version>
</dependency>
```

As long as the different software projects (one for each central components) are located in the same workspace, the jar-File of this internal repository will be automatically added to the project which declares the dependency. If not, the jar-File has to be added to the local maven repository by issuing the command "*mvn install*" in the root folder. For the future it is planned to upload the project to the maven central repository to have even easier dependency management.

The shared code through different projects can be split into 3 parts:

- **DTO** (*Data Transfer Objects*): is the part which covers the data transfer between components;
- **XMLRPC-CLIENT**: covers the part which handles connection with the data center collector or dispatcher;
- **MEMCACHED**: covers the parts which handles the connection with the caching system.

In the source code, these three parts are divided in three packages:

- ***it.bz.tis.integreen.dto***: contains **POJOs** (*Plain old Java objects*) which are mostly used in the connection from the Dispatcher to the front-ends. They all have the common interface "serializable" which allows them to be serialized;
- ***it.bz.tis.integreen.xmlrpc***: This package contains two classes:
    - *XMLRPCPusher* handles the connection from data source to collector;
    - *DataRetriever* handles the connection from frontend to dispatcher.
- ***it.bz.tis.integreen.caching***

2.2 Elaboration tasks

Elaboration tasks are automatic routines which are automatically executed on top of the real-time measured data that is automatically stored in the database, and have the common goal to provide an overview of the current traffic and environmental conditions in the city. Each elaboration which is presented in the following paragraphs is characterized by the fact have the common ability to access all the data stored in the database tables, without any interaction with the other software entities of the architecture. At present elaboration tasks are triggered periodically and under the supervision of a completely automatic and configurable "**scheduler**", which is responsible to launch the execution of all elaborations. On-demand analysis have been at present not implemented but could be easily introduced in a short-term future, for example through a specific request from the operators interface "BZAnalytics".

The outputs of the elaboration outputs have all a geographic reference, so that they can be easily displayed on a map.

2.2.1 Bluetooth-based travel times estimator

A real prototype system for the detection of vehicles based on Bluetooth technology has been developed and already widely tested on the field. The roadside part of this system implementation is presented in P.4.1.3 [3]; the focus here is mainly destined to the central "engine", called **scheduler**, which on a real-time basis provides reliable vehicular travel times on specific road links.

The basic logic presented in D.3.1.1 has been already implemented. Two classes of elaborations are available:

- elaborations which are directly related to the **Bluetooth stations**;
- elaborations which are related to a logical **link connecting two different Bluetooth stations**.

In the first case, the elaborations implemented are:

1. **number of Bluetooth detections**;
2. **number of estimated heavy and light vehicles detections.**

All these elaborations are calculated for different monitoring intervals, i.e. 15 [minutes], 30 [minutes] and 6 [hours]), so that it is possible to use this elaborated information both on a real-time basis as well as for offline analysis. These elaborations are quite simple, since they are just a sum over a moving time interval of the vehicle detections associated to a Bluetooth station. The estimation of heavy and light vehicle detections is simply done based on an average of historical traffic data collected in measurement points not reasonable near to the positions in which the Bluetooth stations are positioned.

For the elaborations related to the links, the following output are computed on a real-time basis:

3. the **"matches" between the couple of Bluetooth stations** associated to the link;
4. the **number of "matches"**, calculated in the aforementioned time intervals;
5. the estimated **travel time** and **speed** on the link, calculated only in the time interval of 15 [minutes].

The **matches** create an association between vehicles detections with the same car identified (MAC address of the Bluetooth device) of two different Bluetooth stations, in which one is considered to be the "**origin**" (O) and one the "**destination**" (D). According to the logic introduced in the project, which is widely illustrated in [4], a match is considered "valid" if and only if:

- *the record at station O is detected in time before station D;*
- *in the time interval identified by its two timestamps there is no other record detected by at least one of the two monitoring stations having the same car identifier*.

The estimated travel time is evaluated on the base of a more complex logic. Once the matches have been identified, an elapsed time value can be associated to each of them, simply calculated as the difference of the timestamps of the associated vehicle detections. In order to determine an accurate estimation of a representative value of travel time referred to a specific monitoring period, a proper indicator must be considered. The most reliable one has revealed to be the "mode", i.e. the elapsed time which is more representative among all elapsed times calculates. However, this computation suffers of the problem associated to the fact that if the majority of vehicles detected have made a stop between O and D, the estimated travel time will not be representative of the real traffic conditions. For this reason, a post-processing algorithm has been introduced, expressed by the following equation:

$$t + m_t < (t + 1) + m_{t+1}$$

where t is the instant associated to the monitoring interval, and m_t is the estimated travel time.

In this way, by considering the previous travel time estimation, one can properly correct this value through an iterative process which identifies and does not take in consideration the matches which are considered not valid.

At present, no **four-class classification of the traffic conditions** (i.e. low", "medium", "high", "congested") as well as a **short-term prediction of the traffic conditions** based on average historical data is computed and stored. During the implementation process, it has been decided to put this intelligence directly in the end-user application, as better explained in [5].

The full list of links which are present used for this first implementation of this system component is presented in Table 1. As it is possible to see, due to the small availability of data travel times computations are possible on link which have an extension of about 1 [km].

Link ID	Bluetooth Station O	Bluetooth Station D	Length [km]
71 Resia Street (Resia Bridge → Druso Street)	48 Resia Bridge	373 Druso Street	1.6
72 Resia Street (Druso Street → Resia Bridge)	373 Druso Street	48 Resia Bridge	1.6
73 Claudia Augusta (Roma Bridge → Claudia Augusta Street)	50 Roma Bridge	374 Claudia Augusta Street	0.9
74 Claudia Augusta (Claudia Augusta Street → Roma Bridge)	374 Claudia Augusta Street	50 Roma Bridge	0.9
75 Volta Street (Claudia Augusta Street → Galvani Street)	374 Claudia Augusta Street	64 Galvani Street	1.5
76 Volta Street (Galvani Street →	64 Galvani Street	374 Claudia Augusta	1.5

Claudia Augusta Street)		Street	
46 Vittorio Veneto Access (Castel Firmiano → city centre)	19 Castel Firmiano	15 Vittorio Veneto Street	3.0
375 Vittorio Veneto Access (city centre → Castel Firmiano)	15 Vittorio Veneto Street	19 Castel Firmiano	3.0
77 Galvani Street → Einstein Street	64 Galvani Street	49 Einstein Street	0.7
78 Einstein Street → Galvani Street	49 Einstein Street	64 Galvani Street	0.7
53 Einstein Street (direction city centre)	49 Einstein Street	52 Einstein Street (fuel station)	1.0
57 Einstein Street (direction Laives)	52 Einstein Street (fuel station)	49 Einstein Street	1.0
62 Roma Street (Adriano Square → Roma Bridge)	41 Adriano Square	50 Roma Bridge	0.5
63 Roma Street (Roma Bridge → Adriano Square)	50 Roma Bridge	41 Adriano Square	0.5
54 Torricelli Street	52 Einstein Street (fuel station)	13 TIS	1.7
69 Druso Street (Resia Street → Adriano Square)	373 Druso Street	41 Adriano Square	2.0
70 Druso Street (Adriano Square → Resia Street)	41 Adriano Square	373 Druso Street	2.0
56 Arginale	50 Roma Bridge	48 Resia Bridge	2.0
58 Arginale (Galilei Street → Resia Street)	13 TIS	48 Resia Bridge	0.9
59 Galilei Street	13 TIS	50 Roma Bridge	1.5

Table 1: Full list of "links" associated to Bluetooth detectors.

2.2.2 Emission model

Two computational models have been developed in order to estimate emissions from road-transport and air pollution concentrations as a result of the dispersion process at the urban scale in the Municipality of Bolzano. These programs have been integrated as elaboration tasks in the complex traffic planning and management system of the Supervisor Centre.

The **traffic emissions model** (**TEM**) is a software tool that has been designed to be a part of the more complex traffic planning and management system. It has been developed to assess the environmental impact from road traffic. The vehicular traffic flowing on the road network produces air pollutants depending on the number of transits and the average speed of the vehicles. It estimates emissions of all major air pollutants produced by vehicle combustion, including:

- **ozone precursors** (CO, NO_x, VOC_s);
- **greenhouse gases** (CO_2, CH_4);
- **acidifying substances** (NH_3, SO_2);
- **particulate matter** (PM_{10}, TSP);

It also provides:

- **FC** (fuel consumption)
- **HC** (hydrocarbons).

The reference design choices for this software are explained in [1]. The purpose of this document is to present how it is implemented in the system. It is important to underline that the TEM program is not only available as an elaboration task automatically executed within the INTEGREEN Supervisor Centre, but also as a standalone software (even as an Excel file).

According to the simplified COPERT algorithm defined in the design phase, the necessary information for the evaluation of the road-traffic emissions are:

the **vehicle speed**. In order to evaluate road-traffic emissions, a distributed estimation over the whole network of the average vehicle speed is necessary. Nevertheless at present only punctual estimations of this parameter at the fixed traffic count stations are available; the information of the estimated speeds on the Bluetooth links have however a spatial accuracy which is insufficient for the model. Therefore, a simplified approach has been proposed: for every street a reference speed value has been assigned, on the basis of previous studies conducted by the Municipality of Bolzano for the air quality plan in 2010 [6]. Where no measured value is available, this reference vehicles speed is used. This association is contained in a particular table of the database structure, called *streetbasicdata*, organized as graphically presented in Table 2.

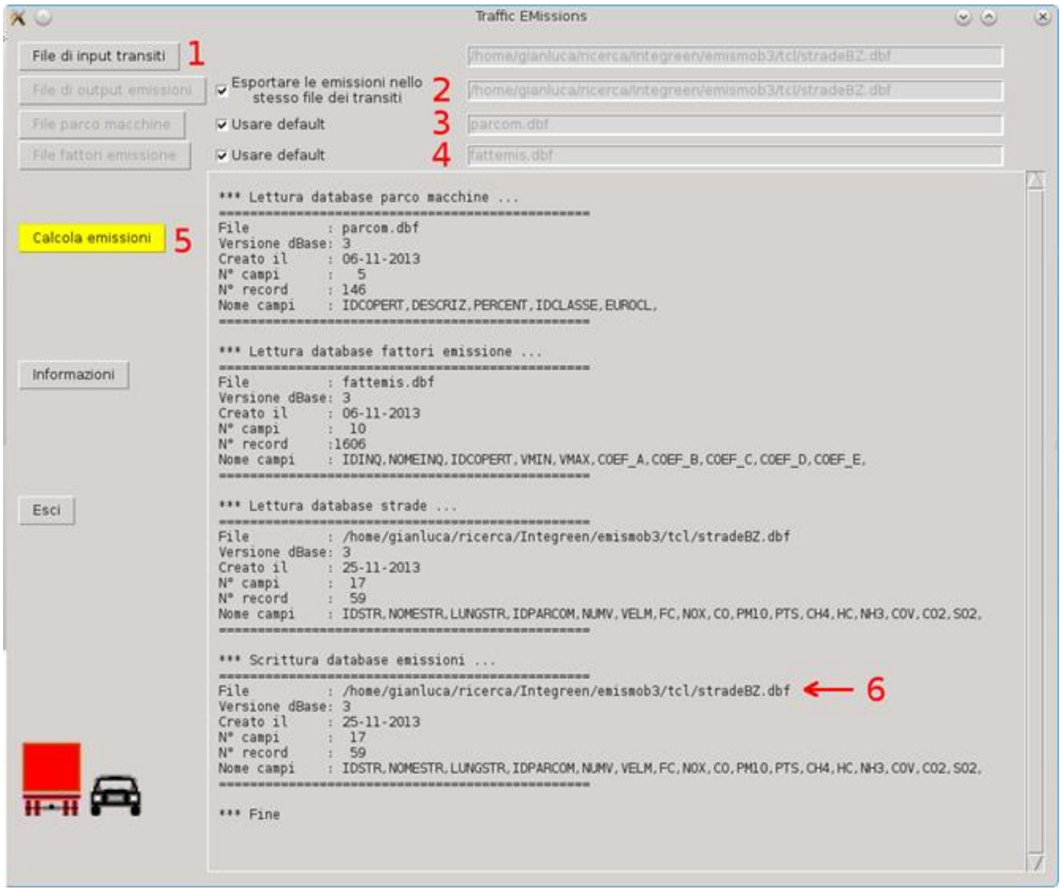

Figure 3: The stand-alone emission model TEM.

ID_road-arch	Length [km]	linegeometry	Speed [km/h]
a code identifying the specific arch of the road network	the length of the road arch	the polyline of the road arch	the reference vehicle speed associated

Table 2: The basic association road archs and vehicular transits.

- the **number of vehicles for each class**. The traffic flows, measured in number of vehicles in the unit time, are available at the fixed traffic count stations and the Bluetooth gates. The number of vehicles data must be provided as a traffic flux: if the number of vehicles per hour [veh/h] is used, the corresponding emissions refer to the same time interval. In order to evaluate road-traffic emissions, a distributed estimation over the whole network of the average traffic flows is a necessary. Also in this case a simplified approach has been proposed: for every street a reference fixed station has been assigned, along with a scale factor to correct the flow value. This scale factor has been estimated on the basis of the same studies conducted for the air quality plan of the Municipality of Bolzano in 2010. This association is contained in a particular table of the database structure, called *trafficstreetfactor*, organized as graphically presented in Table 3, which contains even a reference of the percentage of the heavy vehicles population.

- the **length of the street**, an association which is indicated in both aforementioned tables.

The full set of traffic data considered at present in input to the TEM model is presented in Figure 4. It is important to underline that the more the automatic traffic stations providing real-time data will be available, the less the approximations will be, since vehicular transits could be associated 1:1 to each road arch.

ID_road-arch	ID_traffic-station	Scale factor	Length [km]	heavy vehicles population [%]
a code identifying the specific arch of the road network	a code identifying the specific traffic station	an adimensional value between 0…1, which identifies the amount of traffic flows which can be associated to the road arch	the length of the road arch	the percentage of heavy vehicles according to the traffic station data

Table 3: The basic association road archs and vehicular transits.

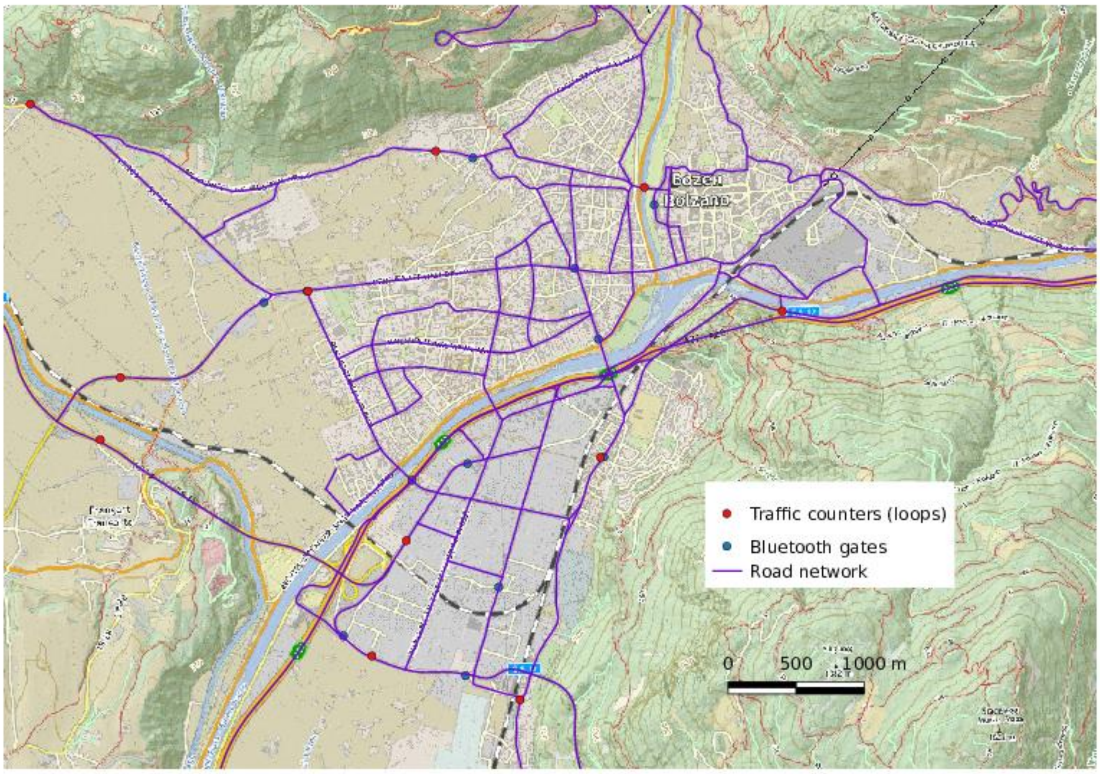

Figure 4: The road network archs and the set of traffic detection points at the basis of TEM.

To get an estimate of the **composition of the vehicle fleet**, reference is made to the data provided annually by **ACI**, which are essentially a reworking of vehicles registered at the PRA

(*Pubblico Registro Automobilistico*) divided by the Province. At present the most recent data are for the year 2012. Because the fleet is constantly updated and emission factors can vary significantly between different types of vehicles, it is important that the statistical composition of the fleet is always up to date as possible.

It is obviously necessary to refer to a statistical distribution, because the transit data typically measured (or simulated through traffic models) provide information much more aggregated, namely total transits or transit split in macro category (e.g. light vehicle, heavy vehicles, motorcycles).

The ACI data provided are mainly corresponding to the COPERT, but the coincidence is not complete on the entire fleet. In particular, there are two differences that have been compensated in the mapping phase of the ACI data on the categories COPERT:

- ACI data do not include mopeds because they are not registered with the PRA. As already done for the provincial emissions inventory, in the same way a number of mopeds divided into classes "EURO" with the same percentages of motorcycles has been assumed;
- in ACI data there are two classes for the "road tractor", namely the TIR trucks, and heavy duty vehicles classified by weight, however in the COPERT classification it is not important the registration class but how they travel. Hence they can be aggregate assuming that the tractor almost never travels without a trailer.

The fleet classification adopted is the methodology COPERT, as mentioned above, which also responds to the requirements of the European guidelines on emissions. Table 4 shows the classification that is used and that includes: 146 unique id, vehicle class description, the EURO class (from 0 to 6) and the relative percentage with respect to the total value.

COPERT code	Vehicle description	EURO class	% fleet
001	Passenger Cars - Gasoline <1.4 l - PRE ECE	0	0.43%
002	Passenger Cars - Gasoline <1.4 l - ECE 15/00-01	0	0.43%
003	Passenger Cars - Gasoline <1.4 l - ECE 15/02	0	0.43%
004	Passenger Cars - Gasoline <1.4 l - ECE 15/03	0	0.43%
005	Passenger Cars - Gasoline <1.4 l - ECE 15/04	0	0.43%
006	Passenger Cars - Gasoline <1.4 l - Euro I - 91/441/EEC	1	0.99%
007	Passenger Cars - Gasoline <1.4 l - Euro II - 94/12/EC	2	4.45%
008	Passenger Cars - Gasoline <1.4 l - Euro III - 98/69/EC Stage 2000	3	2.74%
009	Passenger Cars - Gasoline <1.4 l - Euro IV - 98/69/EC Stage 2005	4	8.48%
010	Passenger Cars - Gasoline <1.4 l - Euro V - future	5	5.67%
011	Passenger Cars - Gasoline 1.4 - 2.0l - PRE ECE	0	0.23%
012	Passenger Cars - Gasoline 1.4 - 2.0l - ECE 15/00-01	0	0.23%
013	Passenger Cars - Gasoline 1.4 - 2.0l - ECE 15/02	0	0.23%
014	Passenger Cars - Gasoline 1.4 - 2.0l - ECE 15/03	0	0.23%
015	Passenger Cars - Gasoline 1.4 - 2.0l - ECE 15/04	0	0.23%

016	Passenger Cars - Gasoline 1.4 - 2.0l - Euro I - 91/441/EEC	1	0.88%
017	Passenger Cars - Gasoline 1.4 - 2.0l - Euro II - 94/12/EC	2	2.70%
018	Passenger Cars - Gasoline 1.4 - 2.0l - Euro III - 98/69/EC Stage 2000	3	1.24%
019	Passenger Cars - Gasoline 1.4 - 2.0l - Euro IV - 98/69/EC Stage 2005	4	3.67%
020	Passenger Cars - Gasoline 1.4 - 2.0l - Euro V - future	5	0.68%
021	Passenger Cars - Gasoline >2.0l - PRE ECE	0	0.05%
022	Passenger Cars - Gasoline >2.0l - ECE 15/00-01	0	0.05%
023	Passenger Cars - Gasoline >2.0l - ECE 15/02	0	0.05%
024	Passenger Cars - Gasoline >2.0l - ECE 15/03	0	0.05%
025	Passenger Cars - Gasoline >2.0l - ECE 15/04	0	0.05%
026	Passenger Cars - Gasoline >2.0l - Euro I - 91/441/EEC	1	0.07%
027	Passenger Cars - Gasoline >2.0l - Euro II - 94/12/EC	2	0.20%
028	Passenger Cars - Gasoline >2.0l - Euro III - 98/69/EC Stage 2000	3	0.19%
029	Passenger Cars - Gasoline >2.0l - Euro IV - 98/69/EC Stage 2005	4	0.53%
030	Passenger Cars - Gasoline >2.0l - Euro V - future	5	0.11%
031	Passenger Cars - Diesel <2.0l - Conventional	0	0.25%
032	Passenger Cars - Diesel <2.0l - Euro I - 91/441/EEC	1	0.17%
033	Passenger Cars - Diesel <2.0l - Euro II - 94/12/EC	2	2.43%
034	Passenger Cars - Diesel <2.0l - Euro III - 98/69/EC Stage 2000	3	6.10%
035	Passenger Cars - Diesel <2.0l - Euro IV - 98/69/EC Stage 2005	4	9.39%
036	Passenger Cars - Diesel <2.0l - Euro V - future	5	11.93%
037	Passenger Cars - Diesel >2.0l - Conventional	0	0.18%
038	Passenger Cars - Diesel >2.0l - Euro I - 91/441/EEC	1	0.17%
039	Passenger Cars - Diesel >2.0l - Euro II - 94/12/EC	2	0.90%
040	Passenger Cars - Diesel >2.0l - Euro III - 98/69/EC Stage 2000	3	2.16%
041	Passenger Cars - Diesel >2.0l - Euro IV - 98/69/EC Stage 2005	4	2.63%
042	Passenger Cars - Diesel >2.0l - Euro V - future	5	1.33%
043	Passenger Cars - GPL (converted) - Conventional	0	0.11%
044	Passenger Cars - GPL (converted) - Euro I - 91/441/EEC	1	0.09%
045	Passenger Cars - GPL (converted) - Euro II - 94/12/EC	2	0.21%
046	Passenger Cars - GPL (converted) - Euro III - 98/69/EC Stage 2000	3	0.06%
047	Passenger Cars - GPL (converted) - Euro IV - 98/69/EC Stage 2005	4	0.50%
048	Passenger Cars - GPL (converted) - Euro V - future	5	0.10%
049	Passenger Cars - GPL - di fabbrica - Euro III - 98/69/EC Stage 2000	3	0.06%
050	Passenger Cars - GPL - di fabbrica - Euro IV - 98/69/EC Stage 2005	4	0.50%
051	Passenger Cars - GPL - di fabbrica - Euro V - future	5	0.10%
052	Passenger Cars - CNG (converted) - Conventional	0	0.01%
053	Passenger Cars - CNG (converted) - Euro I - 91/441/EEC	1	0.00%
054	Passenger Cars - CNG (converted) - Euro II - 94/12/EC	2	0.02%
055	Passenger Cars - CNG (converted) - Euro III - 98/69/EC Stage 2000	3	0.01%
056	Passenger Cars - CNG (converted) - Euro IV - 98/69/EC Stage 2005	4	0.09%
057	Passenger Cars - CNG (converted) - Euro V - future	5	0.05%
058	Passenger Cars - CNG - di fabbrica - Euro III - 98/69/EC	3	0.01%

	Stage 2000		
059	Passenger Cars - CNG - di fabbrica - Euro IV - 98/69/EC Stage 2005	4	0.09%
060	Passenger Cars - CNG - di fabbrica - Euro V - future	5	0.05%
061	Passenger Cars - Ibrida (elettrica. ecc) - Euro IV	4	0.00%
062	Passenger Cars - Ibrida (elettrica. ecc) - Euro V - future	5	0.00%
063	Passenger Cars - 2-Stroke - Conventional	0	0.00%
064	Light Duty Vehicles - Gasoline <3.5t - Conventional	0	0.11%
065	Light Duty Vehicles - Gasoline <3.5t - Euro I - 93/59/EEC	1	0.04%
066	Light Duty Vehicles - Gasoline <3.5t - Euro II - 96/69/EC	2	0.10%
067	Light Duty Vehicles - Gasoline <3.5t - Euro III - 98/69/EC Stage 2000	3	0.12%
068	Light Duty Vehicles - Gasoline <3.5t - Euro IV - 98/69/EC Stage 2005	4	0.22%
069	Light Duty Vehicles - Gasoline <3.5t - Euro V - future	5	0.09%
070	Light Duty Vehicles - Diesel <3.5t - Conventional	0	0.44%
071	Light Duty Vehicles - Diesel <3.5t - Euro I - 93/59/EEC	1	0.30%
072	Light Duty Vehicles - Diesel <3.5t - Euro II - 96/69/EC	2	1.09%
073	Light Duty Vehicles - Diesel <3.5t - Euro III - 98/69/EC Stage 2000	3	2.17%
074	Light Duty Vehicles - Diesel <3.5t - Euro IV - 98/69/EC Stage 2005	4	2.33%
075	Light Duty Vehicles - Diesel <3.5t - Euro V - future	5	1.33%
076	Light Duty Vehicles - Gasoline >3.5t - Conventional	0	0.00%
077	Heavy Duty Vehicles - Diesel <7.5t - Conventional	0	0.06%
078	Heavy Duty Vehicles - Diesel <7.5t - Euro I - 91/542/EEC Stage I	1	0.02%
079	Heavy Duty Vehicles - Diesel <7.5t - Euro II - 91/542/EEC Stage II	2	0.05%
080	Heavy Duty Vehicles - Diesel <7.5t - Euro III - 1999/96/EC	3	0.09%
081	Heavy Duty Vehicles - Diesel <7.5t - Euro IV - COM(1998) 776	4	0.04%
082	Heavy Duty Vehicles - Diesel <7.5t - Euro V - COM(1998) 776	5	0.05%
083	Heavy Duty Vehicles - Diesel <7.5t - Euro VI - future	6	0.00%
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086	Heavy Duty Vehicles - Diesel 7.5 - 16t - Euro II - 91/542/EEC Stage II	2	0.06%
087	Heavy Duty Vehicles - Diesel 7.5 - 16t - Euro III - 1999/96/EC	3	0.06%
088	Heavy Duty Vehicles - Diesel 7.5 - 16t - Euro IV - COM(1998) 776	4	0.01%
089	Heavy Duty Vehicles - Diesel 7.5 - 16t - Euro V - COM(1998) 776	5	0.06%
090	Heavy Duty Vehicles - Diesel 7.5 - 16t - Euro VI - future	6	0.00%
091	Heavy Duty Vehicles - Diesel 16-32t - Conventional	0	0.06%
092	Heavy Duty Vehicles - Diesel 16-32t - Euro I - 91/542/EEC Stage I	1	0.03%
093	Heavy Duty Vehicles - Diesel 16-32t - Euro II - 91/542/EEC Stage II	2	0.15%
094	Heavy Duty Vehicles - Diesel 16-32t - Euro III - 1999/96/EC	3	0.34%
095	Heavy Duty Vehicles - Diesel 16-32t - Euro IV - COM(1998) 776	4	0.06%
096	Heavy Duty Vehicles - Diesel 16-32t - Euro V - COM(1998) 776	5	0.42%
097	Heavy Duty Vehicles - Diesel 16-32t - Euro VI - future	6	0.00%

098	Heavy Duty Vehicles - Diesel >32t - Conventional	0	0.00%
099	Heavy Duty Vehicles - Diesel >32t - Euro I - 91/542/EEC Stage I	1	0.00%
100	Heavy Duty Vehicles - Diesel >32t - Euro II - 91/542/EEC Stage II	2	0.00%
101	Heavy Duty Vehicles - Diesel >32t - Euro III - 1999/96/EC	3	0.00%
102	Heavy Duty Vehicles - Diesel >32t - Euro IV - COM(1998) 776	4	0.00%
103	Heavy Duty Vehicles - Diesel >32t - Euro V - COM(1998) 776	5	0.00%
104	Heavy Duty Vehicles - Diesel >32t - Euro VI - future	6	0.00%
105	Heavy Duty Vehicles - Urban buses - Conventional	0	0.01%
106	Heavy Duty Vehicles - Urban buses - Euro I - 91/542/EEC Stage I	1	0.01%
107	Heavy Duty Vehicles - Urban buses - Euro II - 91/542/EEC Stage II	2	0.05%
108	Heavy Duty Vehicles - Urban buses - Euro III - 1999/96/EC	3	0.02%
109	Heavy Duty Vehicles - Urban buses - Euro IV - COM(1998) 776	4	0.00%
110	Heavy Duty Vehicles - Urban buses - Euro V - COM(1998) 776	5	0.02%
111	Heavy Duty Vehicles - Urban buses - Euro VI - future	6	0.00%
112	Heavy Duty Vehicles - Urban buses (CNG) - Euro IV - COM(1998) 776	4	0.00%
113	Heavy Duty Vehicles - Urban buses (CNG) - Euro V - COM(1998) 776	5	0.02%
114	Heavy Duty Vehicles - Urban buses (CNG) - Euro VI - future	6	0.00%
115	Heavy Duty Vehicles - Pullman - Conventional	0	0.01%
116	Heavy Duty Vehicles - Pullman - Euro I - 91/542/EEC Stage I	1	0.00%
117	Heavy Duty Vehicles - Pullman - Euro II - 91/542/EEC Stage II	2	0.02%
118	Heavy Duty Vehicles - Pullman - Euro III - 1999/96/EC	3	0.02%
119	Heavy Duty Vehicles - Pullman - Euro IV - COM(1998) 776	4	0.01%
120	Heavy Duty Vehicles - Pullman - Euro V - COM(1998) 776	5	0.02%
121	Heavy Duty Vehicles - Pullman - Euro VI - future	6	0.00%
122	Mopeds - <50cc - Conventional	0	1.28%
123	Mopeds - <50cc - Euro I - 97/24/EC Stage I	1	0.36%
124	Mopeds - <50cc - Euro II - 97/24/EC Stage II	2	0.30%
125	Mopeds - <50cc - Euro III	3	1.03%
126	Mopeds - <50cc - Euro IV - future	4	0.00%
127	Motorcycles - 2 Tempi >50cc - Conventional	0	1.17%
128	Motorcycles - 2 Tempi >50cc - Euro I - 97/24/EC	1	0.41%
129	Motorcycles - 2 Tempi >50cc - Euro II	2	0.37%
130	Motorcycles - 2 Tempi >50cc - Euro III	3	0.84%
131	Motorcycles - 2 Tempi >50cc - Euro IV - future	4	0.00%
132	Motorcycles - 4 Tempi 50 - 250cc - Conventional	0	1.17%
133	Motorcycles - 4 Tempi 50 - 250cc - Euro I - 97/24/EC	1	0.41%
134	Motorcycles - 4 Tempi 50 - 250cc - Euro II	2	0.37%
135	Motorcycles - 4 Tempi 50 - 250cc - Euro III	3	0.84%
136	Motorcycles - 4 Tempi 50 - 250cc - Euro IV - future	4	0.00%
137	Motorcycles - 4 Tempi 250 - 750cc - Conventional	0	1.34%
138	Motorcycles - 4 Tempi 250 - 750cc - Euro I - 97/24/EC	1	0.33%
139	Motorcycles - 4 Tempi 250 - 750cc - Euro II	2	0.53%
140	Motorcycles - 4 Tempi 250 - 750cc - Euro III	3	1.09%
141	Motorcycles - 4 Tempi 250 - 750cc - Euro IV - future	4	0.00%
142	Motorcycles - 4 Tempi >750cc - Conventional	0	0.69%
143	Motorcycles - 4 Tempi >750cc - Euro I - 97/24/EC	1	0.40%
144	Motorcycles - 4 Tempi >750cc - Euro II	2	0.33%

145	Motorcycles - 4 Tempi >750cc - Euro III	3	0.64%
146	Motorcycles - 4 Tempi >750cc - Euro IV - future	4	0.00%

Table 4: COPERT classification of motor vehicles and fleet composition of the Province of Bolzano (ACI data 2012).

A calculation procedure has been implemented, in order to obtain the automatic evaluations of the road-traffic emissions. The input of TEM are automatically stored in the spatialized relational database of INTEGREEN. The extraction of input data, the emissions evaluation and the outputs storage have been performed by means of a python script. It is important to notice that some tables contain information about variables and parameters which remain fixed and depend on the geometry and on the methodology of the COPERT model. Tables that contain gathered data are populated whenever a new information is available. Tables that contains evaluated data are populated whenever a new calculation id performed. Together with the previously presented "support tables" *trafficstreetfactor* and *streetbasicfactor*, the following ones have been introduced:

- **copert_emisfact**: this table contains the coefficient for the simplified COPERT formulation (A, B, C, D and F) and the maximum and minimum velocity for each vehicle class to calculate the emission factor of each pollutant and of each vehicle, classified according to COPERT methodology;
- **copert_parcom**: each vehicle class COPERT has a percentage of the presence in the fleet according to the ACI data;

More information about the other main tables of INTEGREEN where measurement data are stored and output elaborations are saved is going to be illustrated in the paragraph related to the database. A logical scheme of the connections between all tables needed to execute TEM is presented in Figure 5.

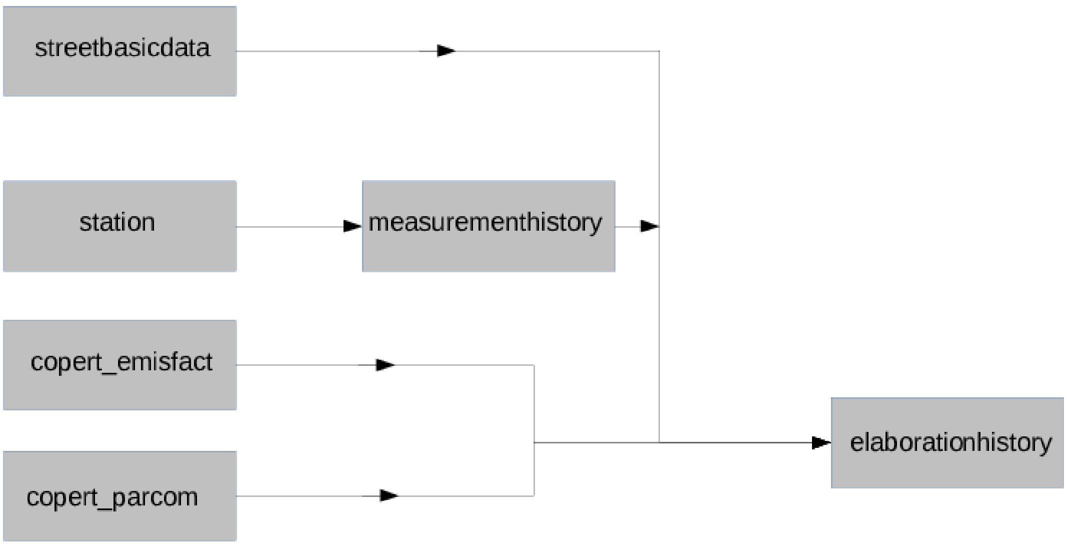

Figure 5: The full set of tables included in the execution of TEM.

Acalculation of the traffic induced emissions is performed every 3600 [s], i.e. every hour. During night-time (from 22 p.m. to 5 a.m.) the traffic flows are set to zero, and emissions are set equal to 6.5% of the average emissions of the last 24 hours.

In order to add, modify or delete streets a GIS tool can be used, which natively supports the geographic information SHP+DBF (eg. Arcview, QGis, GRASS, SagaGIS, etc...). Thereby it is possible to modify geometry elements, adding or deleting road network arcs, and it is also possible to change traffic volume per each arc.

The output of the emissions model is the evaluation of the total emissions, on the basis of the traffic flow data, for each road arch. An example of a possible emissions map is reported in Figure 6. The model is able to evaluate emissions in real-time, since the calculation is fast instantaneous.

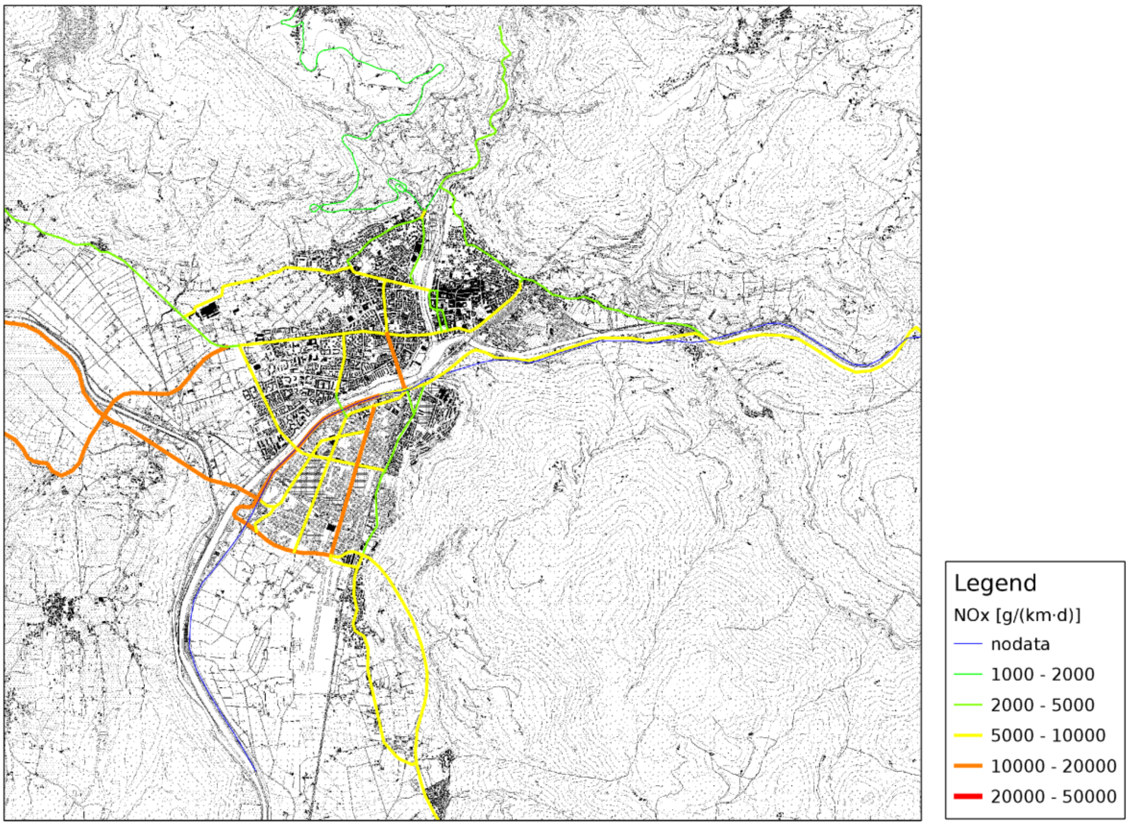

Figure 6: An example of the output of TEM, visualized through a GIS software.

2.2.1 Dispersion model

The emissions from road traffic are still one of the main sources of air pollution relevant for human exposure, especially in urban areas. Exceedances of NO_2 and PM_{10} limit values are wide spread over Europe, occurring most frequently at traffic (roadside) stations.

The increasing number of diesel cars has led to an increase in the fraction of direct NO_2 emissions in NO_X, partly counteracting the effects of generally reduced NO_X emissions from road traffic. Diesel vehicles are known to be significant emitters of both NO_X and PM_{10} and the share of diesel in the overall fuel consumption has increased. These developments have led to an increase in air pollution levels in some European cities, as registered for NO_2 by some traffic stations, or slowed down improvements brought about by mitigation measures [7]. The fraction of direct NO_2 emissions from diesel vehicles tends to be higher and so the difference between the emission standards and real world driving emissions, especially for diesel vehicles with particulate filters for controlling CO, HC and PM. Thus, diesel vehicles meeting more recent Euro standards tend to have higher NO_2 values.

NO_2 can have significant effects on human health. Epidemiological studies provide some evidence that long- NO_2 NO2 exposure may cause an increased likelihood of respiratory problems. It can inflames the lining of the lungs, and it can reduce immunity to lung infections. This can cause problems such as wheezing, coughing, colds, flu and bronchitis decrease lung function and increase the risk of respiratory symptoms. Moreover nitrogen dioxide contributes to the formation of photochemical smog, which can have significant impacts on human health.

At the same time, traffic is one of the major source of the PM fractions responsible for adverse health effects, which also come from non-exhaust PM emissions, for example, brake and tyre wear or re-suspended particles from pavement materials. PM_{10} and $PM_{2.5}$ are very small particles which can penetrate deep into the respiratory tract. Inhalation of these particles can increase the risk, frequency and severity of respiratory and cardiopulmonary disorders.

To evaluate the impact of these traffic emissions on human health, it is very important to determine air pollutants concentration at the ground level. So the traffic emissions model has been coupled with a dispersion model in order to deliver quasi-real time maps of pollutants concentration at a urban scale. The attention has been focused on NO_X and PM_{10}.

This document presents the implementation of the CALINE model applied to INTEGREEN requirements, according to design choices presented in [1]. Some improvements have been in fact needed in order to adapt it to the global computational structure of INTEGREEN. **Input** and **output** have been completely rewritten. Moreover the original version of the model permits the specification of up to 20 links, that is defined as a straight segment of road having a constant width, height, traffic volume, and vehicle emission factor. This **restriction** in the maximum number of links results particularly severe because the aim of the model is to evaluate the dispersion of the traffic induced emissions on the main road network of the entire urban area. Also the restrictions on the maximum number of computational grid cells have been removed, in order to obtain an output map on a regular grid with **spatial resolution of about 50 [m]**. To <u>reduce the total computational time</u>, a **mask** has been defined, outside of which no dispersion calculation is performed. In this way it is possible to avoid computation far away from emission sources (Figure 7).

It is useful to notice that COPERT provides NO_X emissions and not directly NO_2. Since CALINE is fed with NO_X traffic emissions, it produces NO_X concentration maps. Nitrogen oxides (NO_X) are emitted in the form of nitric oxide (NO) and nitrogen dioxide NO_2. The

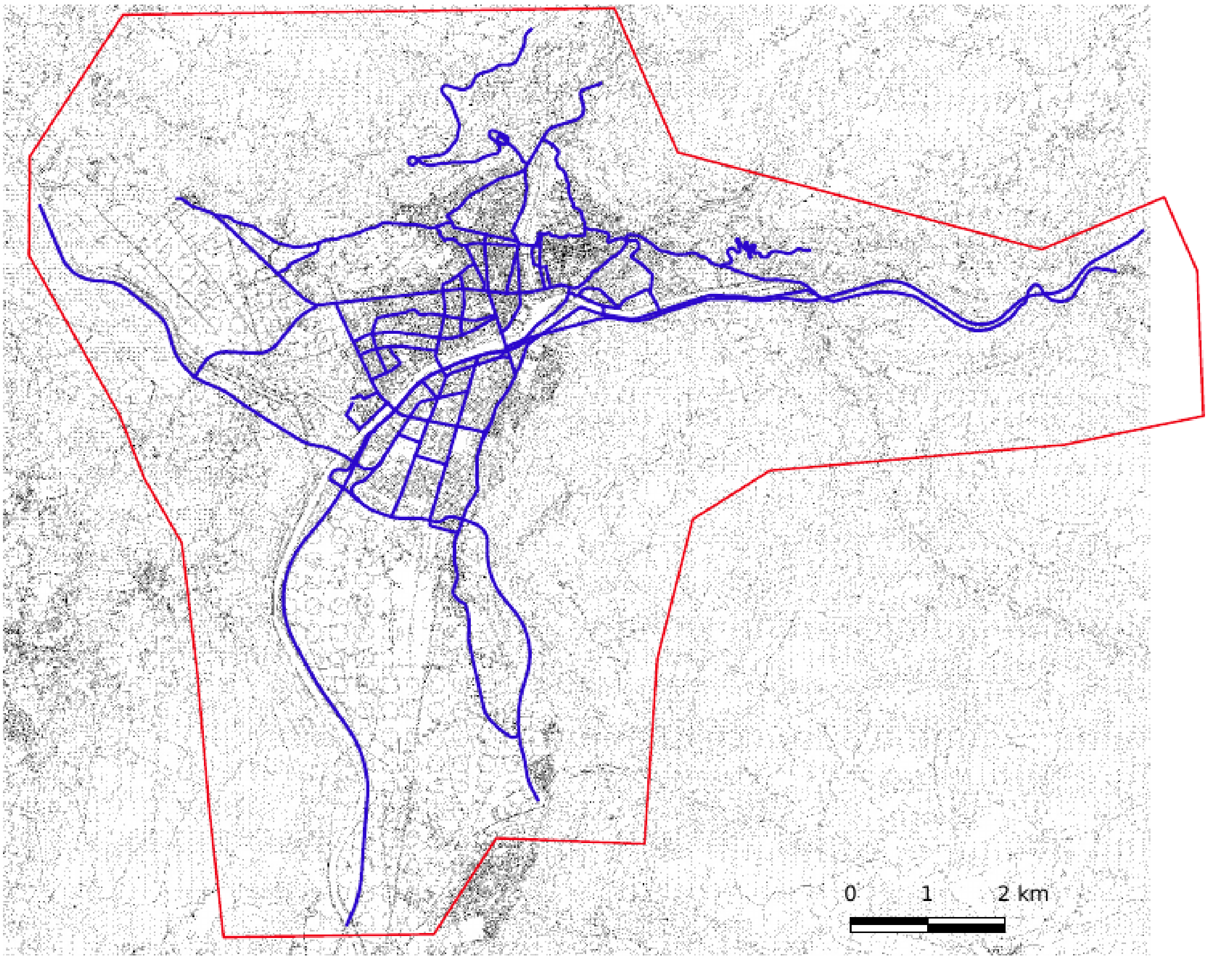

Figure 7: The mask introduced for the spatial limitation of the computation of the dispersion model.

fraction emitted directly as NO_2 is of particular interest for air quality modelling. The NO_2 concentrations depend non only on the compositions of emissions emitted by motor vehicles but also on the chemical environmental conditions (mainly ground level ozone) because of the chemical conversion of NO to NO_2. A widely applied conversion model, the so-called **Romberg approach** [8] has been used to obtain NO_2 concentration maps.

For the evaluation of the pollutants concentrations at the ground level the emission values, the geographic coordinates of the nodes of each road and the meteorological values are needed.

Meteorological parameters as the wind speed and direction, the stability class and the mixing height should be provided in order to evaluate air pollution dispersion. Wind speed and direction and solar radiation flux are measured in the weather station of the Hydrographic Office of Bolzano, located in via Mendola. The atmospheric stability class is evaluated by means of the **Pasquill algorithm**, that is one of the most commonly used method of categorizing the amount of atmospheric turbulence [9]. Six stability classes named A, B, C, D, E and F are defined:

- A = very unstable

- B = moderately unstable
- C = slightly unstable
- D = neutral
- E = slightly stable
- F = stable

In the original formulation of the Gaussian dispersion model, the dispersion parameters were read from graphs. Several studies have derived empirical formulations to describe these graphs. One of the most successful is proposed by Briggs [10]. According to this formulation, the meteorological parameters that define each stability class are provided in Table 5.

Wind speed [m/s]	Global solar radiation [W/m2]					
	>700	700-540	540-400	400-270	270-140	<140
<2	A	A	B	B	C	D
2-3	A	B	B	B	C	D
3-4	B	B	B	C	C	D
4-5	B	B	C	C	D	D
5-6	C	C	C	C	D	D
>6	C	C	D	D	D	D

Table 5: Meteorological conditions defining Pasquill stability classes during daytime, according to Briggs formulation.

During night-time, the stability classes are usually specified in terms of wind speed and net solar radiation or cloudiness. Since none of these two parameters are available, an algorithm derived during field campaigns in the **Alpnap** project has been used (www.alpnap.org). The algorithm, suited for our latitudes, is reported in Table 6.

Wind speed [m/s]	Month	
	Jan-Feb-Mar-Sep-Oct-Nov-Dec	Apr-May-Jun-Jul-Aug
<1	F	E
1-3	E	D
>3	D	D

Table 6: Meteorological conditions defining Pasquill stability classes during nighttime, according to Alpnap project results.

Another important parameter, required by CALINE, is the mixing height, that can be evaluated starting from stability class values, according to the simplified algorithm presented in Table 7. The stability class and the mixing height are evaluated by means of a python script, before executing CALINE model.

Stability class	Mixing height [m]
A	2000
B	1500
C	1000
D	500
E	300
F	200

Table 7: Mixing height as a function of the Pasquill-Gifford stability class.

Each road can be described as a linear source. It can be identified as a sequence of linear segments, whose coordinates should be provided in the CALINE input file. Moreover the input file must contain the information regarding the width of the road and the emission height.

In INTEGREEN, the extraction of input data, the dispersion evaluation and the outputs storage have been performed automatically by means of a python script. In this case, the execution is simpler since all input are the measurements of the traffic and meteorological stations and the emissions calculated (Figure 8).

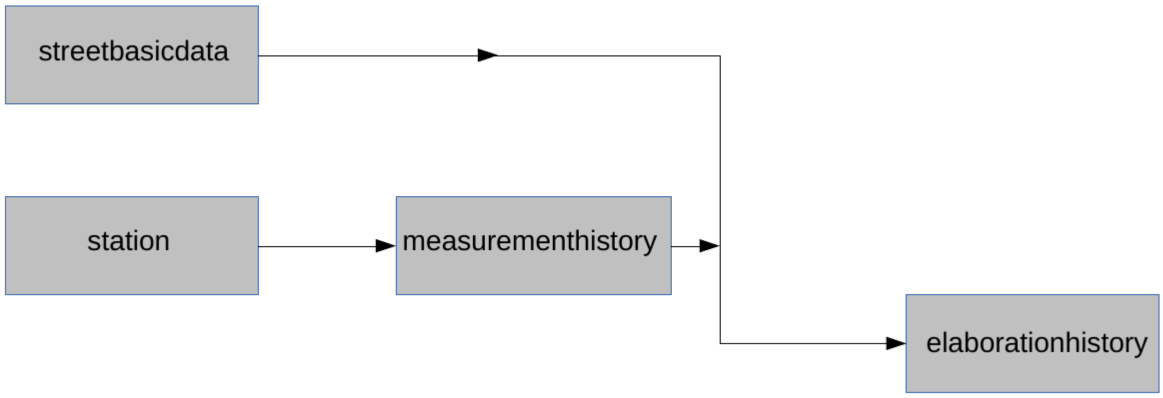

Figure 8: The full set of tables included in the execution of the dispersion model.

The output of the dispersion model, available a GIF/TIFF file which is managed separately from the database tables, is the spatial evaluation of how emitted pollutants are distributed over the city of Bolzano, on the basis of the traffic flow data, for each road arc. Only most recent dispersion model outputs are maintained, since these files can occupy a lot of memory on the servers and such routines can be executed again on an offline basis, if needed, since all input data are not cancelled. The actual choice is to maintain the maps of the last month. An example of a possible dispersion map is reported in Figure 9 and Figure 10. The execution of CALINE takes for both PM10 and NOX approximately 10 [minutes] if a resolution of 50 [m] is adopted. The calculation process can be therefore considered quasi real-time.

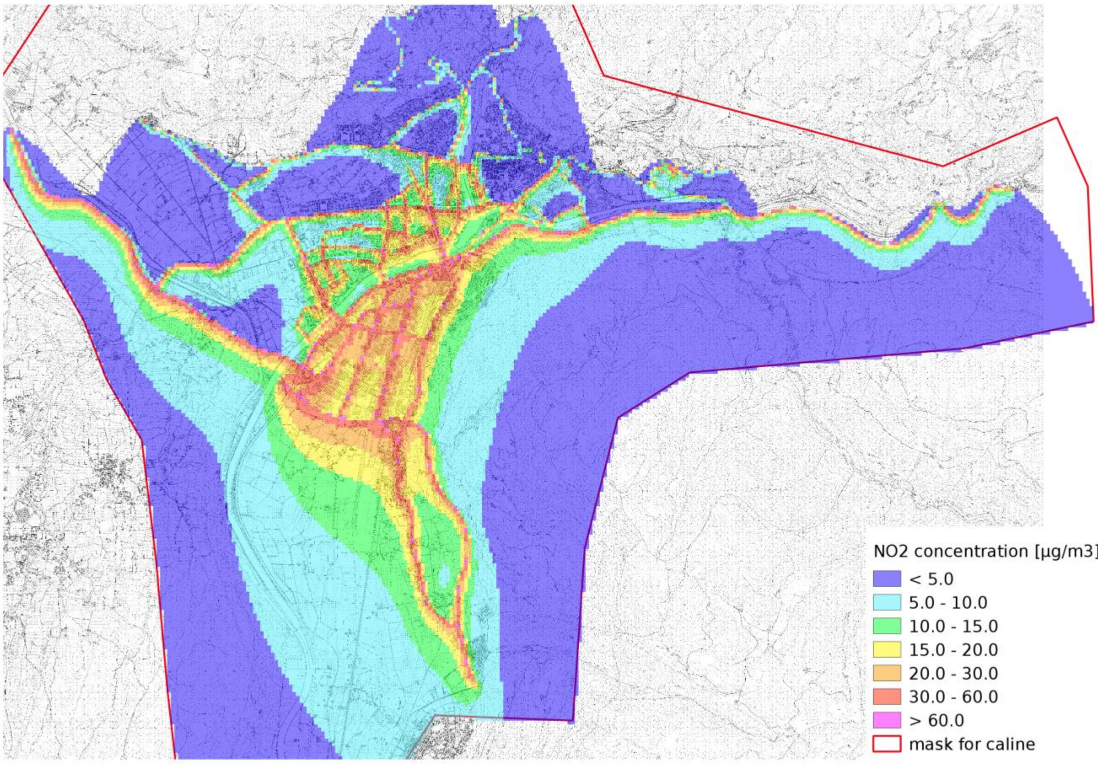

Figure 9: An example of output of the dispersion model.

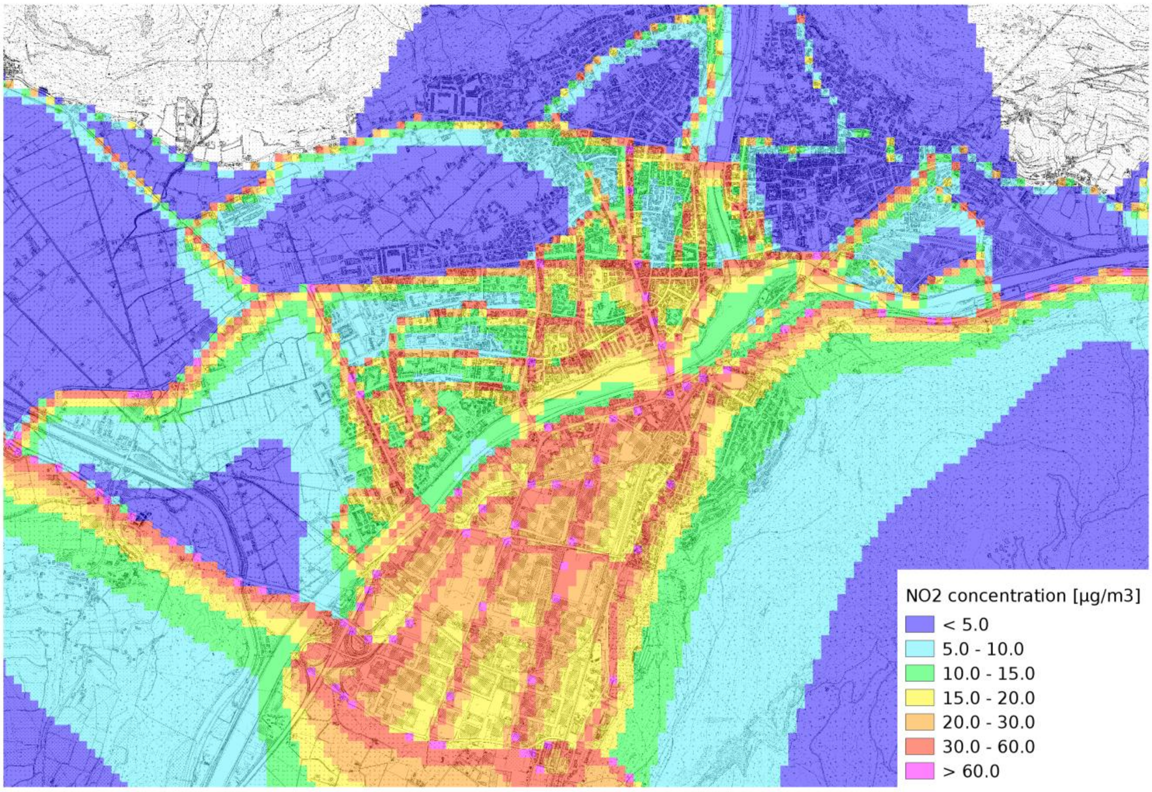

Figure 10: An example of output of the dispersion mode (higher zoom).

2.2.2 *XFCD data analyzer*

The XFCD data analyzer is the automatic elaboration process which is applied to the mobile system data, and in particular of mobile air pollution measurements. The computation procedure has been consolidated during one of the initial component test sessions in which the mobile system was tested on the road of Bolzano.

The refinement of the mobile air pollution data is carried out according to the following procedure:

1. **pre-validation of the data**, with cancellation of the data with no GPS position or clear GPS fake data;

2. **conversion from [ppb] to [μg/m^3]**, with constant conversion factors specific for each detected air pollutant (e.g. 2,052 for NO_2 and 2,142 for O_3);

3. **calibration of air pollution measurement**, according to a linear regression formula, e.g. for NO_2:

$$NO2_{\mu g_c} = NO2_{\mu g} * scale_{NO2} + offset_{NO2}$$

   where $NO2_{\mu g}$ and $NO2_{\mu g_c}$ are respectively the corrected and the non corrected values, respectively, and $scale_{NO2}$ and $offset_{NO2}$ are the proper calibration factors, pollutant-dependent, empirically estimated during specific calibration sessions between the mobile system and the official air quality measurement stations;

4. **temporal alignment**, in which the delay caused by the tube through which the air is pumped inside the mobile system and which is directly proportional to its lengths is properly recovered;

5. **furthering filtering process**, in which the quality of the data is further improved by applying a proper filtering technique to the data. In the project four different filters have been studied:

   - **moving average filter;**

   - **negative exponential filter;**

   - **Kalman filter;**

   - **OPTIMOS filter**, according to what has been suggested in [11]

   Filters have different pros and contra. The latter are built in order to reduce the overall amount of root-mean-square error (RMSE), i.e. to optimize the overall level of measurement accuracy. First filters, have on the other side more the propriety of giving emphasis to sudden variations in the measured levels. Since the latter one is the main purpose of INTEGREEN-as-a-system, at present only the first two filters are implemented and automatically executed on the data collected by the mobile system.

The moving average filter simply takes the average value of the air pollutant measurements with reference a moving temporal window, which has been set at a value of 6 [s]. The negative exponential filter is similar to the moving average filter but uses coefficients that are automatically updated as a function of the vehicle speed, according to a negative exponential formula.

It is important to underline that part of these tasks have been transferred directly to the on-board telematic unit of the mobile system, in particular 1.,2. and 3. Therefore, at the Supervisor Centre only task 4. and 5. are automatically executed. The mobile air pollution measurements can be automatically visualized on a map, as illustrated in Figure 11. This is the typical visualization given to traffic operators.

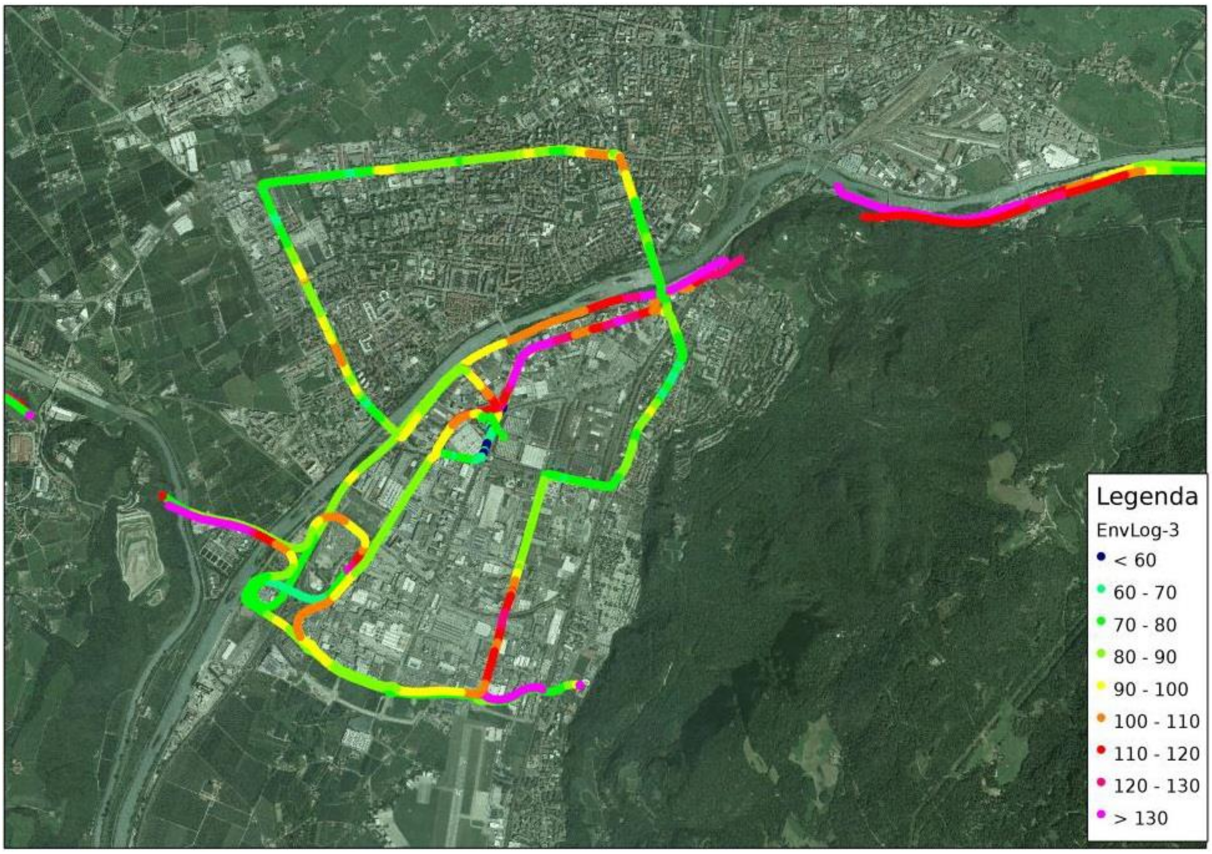

Figure 11: Empirical output of the XFCD data analyser obtained during the first joint component test session in Bolzano, February 2014.

2.2.3 Extended traffic simulation model

During the design process, a preliminary technical investigation about the possibility to couple the INTEGREEN system with an online traffic simulation model has been carried out and a specific procedure identified [1]. At present, however, due the limitations in time and budget of the project, such an integration with the traffic simulation model used by the Municipality of Bolzano (PTV VISUM) has not been performed. A simple traffic model has been therefore considered for estimating the traffic flows on the single road archs needed in order to execute the emission model TEM, as already illustrated in the paragraph before.

2.3 Database structure

A Data-model (DM) defines how the high-level information of different applications are structured and stored in a database. Without delving into the general details of a DM the attention of this report is to present one of the key point of the approach followed during the development of the INTEGREEN platform, which has been how to group the different data that are the system needs to manage. At the database level, data are treated and stored accordingly to their natural data type, which can assume different formats (an integer, a float number, a string, etc.).

In the development of the INTEGREEN DM the decision has been to try to generalize it as much as possible, in order to guarantee the following requirements:

- **extendibility**: ability to manage additional data types without the need of changing the DM;
- **scalability**: maintain the same performance with any amount of historical data;
- **audit**: maintain a persistent storage of both raw and elaborated data.

In other words, the purpose is to build a DM that can be able to store any kind of real-time data and elaborations. The approach followed is based on the simple consideration that each **data record** is characterized by only three features:

- **reference station**: it has been collected by a specific monitoring station;
- **type of data**: it is associated to a very specific data type (and a measurement unit);
- **time window**: the data refers to a certain type of measurement process, associated to a temporal interval in which it is executed.

The definition of the main tables of the database have been therefore the following, as already specified in the design phase:

- **station;**
- **type;**
- **measurement / measurementhistory;**
- **measurementstring / measurementstringhistory;**
- **elaboration / elaborationhistory;**
- **measurementmobile / measurementmobilehistory;**

- **carparkdynamic / carparkdynamichistory.**

2.3.1 The table "station"

The table **station** contains the list of all monitoring stations managed by the INTEGREEN system. The most relevant columns of this table are:

- **ID**
- **name**
- **stationtype**, which identified the type of station. At present in the database following stationtypes are contained:
    - **Parkingstation**
    - **Bluetoothstation**
    - **Meteostation**
    - **Environmentstation**
    - **Trafficstation**
    - **Mobilestation**
    - **Linkstation** (reference "logical" station associated to a couple of Bluetooth stations, as already discussed)
    - **Streetstation** (reference "logical" station associated to the archs of the road network)
- **pointprojection**, which contains the spatial coordinates of the position of each station;
- **active**, which indicates if the station is active or not because for example is dismissed.
- **available**, which indicates if the station is momentarily active or not. This is an indication for the uppers layers, which in this way are told to not publish the data associated to this station.

In some cases more metadata are available for each station. In order to store this additional information, some more tables have been created, namely:

- **carparkingbasicdata**, which contains some additional information related to the parking areas, in particular its nominal capacity;

- **linkbasicdata,** which contains some important information:
  - the association with the origin / destination Bluetoothstation IDs;
  - the linegeometry, since this station is not a point but a line;
  - the length of the link;
- **meteostationbasicdata**;
- **streetbasicdata** (already presented)**.**

2.3.2 The table "type"

The table **type** contains the list of all types managed by the stations of the INTEGREEN system, including the elaboration types. At present 37 data types are managed, which demonstrate the variety of data managed within the INTEGREEN project. The most relevant columns of this table are:

- **ID**
- **name**
- **measurement unit**
- **rtype**, which indicates the type of measurement associated to this type. Possible values are:
  - **instantaneous**, e.g. the vehicle detection of the Bluetooth system;
  - **mean**, e.g. the average NO_2 pollution concentration given by a fixed monitoring station;
  - **count,** e.g. the number of Bluetooth detections;
  - **forecast**, e.g. the forecast of the parking occupancy.

2.3.3 The tables "measurement" and "measurementhistory"

The tables **measurement** and **measurementhistory** are the tables in which the raw measurements are stored as soon as they are received by the Data Center Collector. The difference between the two tables is that the writing operation overwrites the existing value, while in the measurementhistory a new data record is created. In this way, in the table measurement only the most recent records are stored; in measurementhistory all historical values are contained. Thanks to the structure created with the tables station and type, these tables, which are identical in terms of columns, look very simple, as illustrated in Table 8.

created_on	timestamp	value	station_id	type_id	period
the timestamp of when the data record has been inserted	the timestamp associated to the measured vale	the measured value	the ID of the station which has provided this measurement	the ID of the data type associated to this measurement	the reference measurement period

Table 8: The columns of the table “measurement” of the INTEGREEN database.

2.3.4 The tables “measurementstring” and “measurementstringhistory”

The main limitation of this approach is that the tables measurement and measurementhistory can contain one single value, which has been defined to be a number (an integer or a float). Unfortunately, in INTEGREEN there are measurements that can also look like a string, which can not be saved in these cells. This in particular true for the Bluetooth detections, which have as data the MAC address of the Bluetooth devices. Instead of creating multiple columns in the above tables, with the negative consequences that for every record one or more cells could be empty, the decision has been to create another couple of tables, completely identical to the previous ones, but with the capability to store integer values.

2.3.5 The tables “elaboration” and “elaborationhistory”

These tables are exactly the same as measurement and measurementhistory, but with the only difference that values are stored by an elaboration task, and not by the Data Center Collector. This means that certain data types will be available in the measurement tables, and other ones in the elaboration tables only.

2.3.6 The tables “measurementmobile” and “measurementmobilehistory”

The management of mobile system data must consider a completely different approach, since the amount of data to be stored is much more richer. Putting all this data together with the ones delivered by the fixed station would have significantly decreased the performance of the data center layer of the INTEGREEN Supervisor Centre.

For this reason, all raw measurements and elaborated outputs associated to the mobile system are stored in a couple of ad-hoc tables. The number of columns are much higher since each record contains all the data associated to the on-board traffic or environmental unit. The table measurementmobile contains the most recent values only, which can a precious information for the uppers layers which may want to have this information very quickly (a query on the other table gives much less performance).

2.3.7 The tables “carparkdynamic” and “carparkdynamic history”

These tables, which contain the real-time parking data, have been historically developed first, and for this reason they have left grow independently from the other values contained in the tables measurement and measurementhistory. With these tables, a first attempt to fully respect the In-Time model [1] was carried out – a mapping which is however possible even with the data model considered for the other values of INTEGREEN.

Conclusions

The report has presented the final version of the prototype of the “core” of the INTEGREEN system, that was called in the proposal “data management unit”.

The following components characterize this central layer of the Supervisor Centre:

- the **data center collector**, which is the unique entity in charge of writing data in the INTEGREEN database. A common data library has been introduced, which is shared together with the data center dispatcher, the data source and the front-ends;
- the **data center elaboration tasks**, which are specifically:
  - the **Bluetooth-based travel times estimator**, which automatically estimates average vehicular travel times (and speeds) on a specific set of “links”, i.e. logical association of two different Bluetooth detectors that are representative of the test route covered in the INTEGREEN project;
  - the **emission model**, which automatically estimates, among the other values, the air pollutants and the greenhouse gases emissions as well as the fuel consumption associated to road traffic. The model is run on an entire model of the road network of the city;
  - the **dispersion model**, which automatically models the distribution of traffic-emitted pollutants over the urban area. The model is computed only on a certain area of influence in order to allow real-time computations, and at present is limited in scalability to a broader regional range;
  - the **XFCD data analyzer**, which improves the accuracy of the mobile air pollution measurements through a certain number of calibration and filtering processes, which in part have been transferred directly to the on-board telematics unit;
- the **database**, which has been structured through an innovative approach which ensures a high degree of extendibility and scalability to similar “big data” applications.

At present, traffic data have been simple distributed over the road network on top of which the emissions are calculated through simple static assignment rules. This is a temporary and approximate solution which will be further enhanced in the future when the actual offline **traffic simulator** in use at the Municipality of Bolzano will be elevated to an online mode according to the design indications given in D.3.1.1.

It is important to notice that the proposed elaborations require a large amount of data in order to be sufficiently accurate and useful for real-life applications. This is a necessary condition for the applicability of the entire system to another town. It is certainly possible to apply this approach at a larger scale, but with some limitations. The most relevant challenge is in particular to find the best compromise between computational time and spatial resolution.

Bibliography

[1] INTEGREEN consortium, "D.3.1.1 "Data management unit and environmental stations front-end"," 2014.

[2] M. Reza, "Adaptation of the Data Access Layer to Enable Cloud Data Access," Institute of Architecture of Application Systems (University of Stuttgart), 2012.

[3] INTEGREEN consortium, "P.4.1.3 "Environmental stations front-end prototype"," 2014.

[4] R. Cavaliere, P. Valleri and R. Kloibhofer, "The INTEGREEN approach for assessment of environmental traffic management policies," in 9th ITS European Congress , Dublin, 2013.

[5] INTEGREEN consortium, "P.4.1.5 "Public web interface prototype"," 2014.

[6] CISMA srl, "Valutazione dell'impatto sulla qualità dell'aria nella città di Bolzano," 2010.

[7] I. Sundvor, C. Balaguer, N. Viana, X. Querol, C. Reche, F. Amato, G. Mellios and C. Guerriero, "Road traffic's contribution to air quality in European Cities," Europan Topic Centre on Air Pollution and Climate Change Mitigation (ETC/ACM), 2012.

[8] E. Romberg, R. Boesinger, A. Lohmeyer and R. Ruhnke, "NO-NO2 Umwandlungsmodell fuer die Anwendung bei Immissionsprognosen fuer KFZ-Abgase. Geharstoffe-Reinhaltung der Luft.," 1996.

[9] F. Pasquill, "The estimation of the dispersion of windbom material," The Meteorological Magazine, vol. 90, no. 1063, pp. 33-49, 1961.

[10] G. A. Briggs, "Diffusion estimation for small emissions," ERL ARL USAEC Report ATDL-106, 1974.

[11] Z. Yan, J. Eberle and K. Aberer, "OptiMoS: Optimal Sensing for Mobile Sensors," Nokia Research Center, Lausanne, 2012.