White Paper Report

CITI-SENSE in numbers

June 2016

Summary:

The main concept behind the CITI-SENSE project is to empower citizens through Citizens' Observatories, enabling them to contribute to and participate in environmental governance. Citizens will be able to support and influence community and societal priorities as well as other related decision making processes.

In order to ensure the success of CITI-SENSE, the project had to:

- Raise environmental awareness amongst citizens.
- Increase user participation in community environmental decisions
- Provide feedback on the impact of citizens within decision-making processes.

CITI-SENSE started in October 2012 and runs for a period of four years, completing at the end of September 2016. Snowflake Software is excited to have been involved right from the start, bringing our years of experience with data exchange and open standards in to the consortium team's skill mix. Our contribution within CITI-SENSE was to explore through the project, how best to design and implement a solution to host both sensor and questionnaire information, allowing end users to access that same information over the internet in a secure method, and ensure the SEDS platform was performant under heavy loads, in a maintained environment.

This whitepaper aims to walk the reader through what's involved in hosting large volumes of data, and as an interest piece, see how the CITI-SENSE measurements compare to those collected during the 2016 Rio Olympic games.

Empowerment Initiatives

The CITI-SENSE project focused primarily on three main empowerment initiatives:

- Outdoor Air Quality
- Indoor Air Quality in Schools
- Personal comfort in public spaces

Citizens from 9 cities participated in the project forming around 20 citizen observatories in Barcelona, Belgrade, Edinburgh, Haifa, Ljubljana, Oslo, Ostrava, Vienna and Vitoria. Static sensors (fixed sensors) were deployed in these cities to monitor various environmental components of air quality. Mobile sensors (personal sensors) were distributed and allowed citizens to monitor air quality as they moved around the city.

Data Models

Data collection can be a complicated process, and it is important before doing any data collection to consider what it is you want to collect and why – what data analysis might be undertaken. Snowflake Software often use UML modelling to construct a logical model of the real world information being collected and how pieces interact with one another. This certainly helps to understand what you do and don't need to collect, saving time by ensuring data that will be useful is recorded.

SEDS Platform

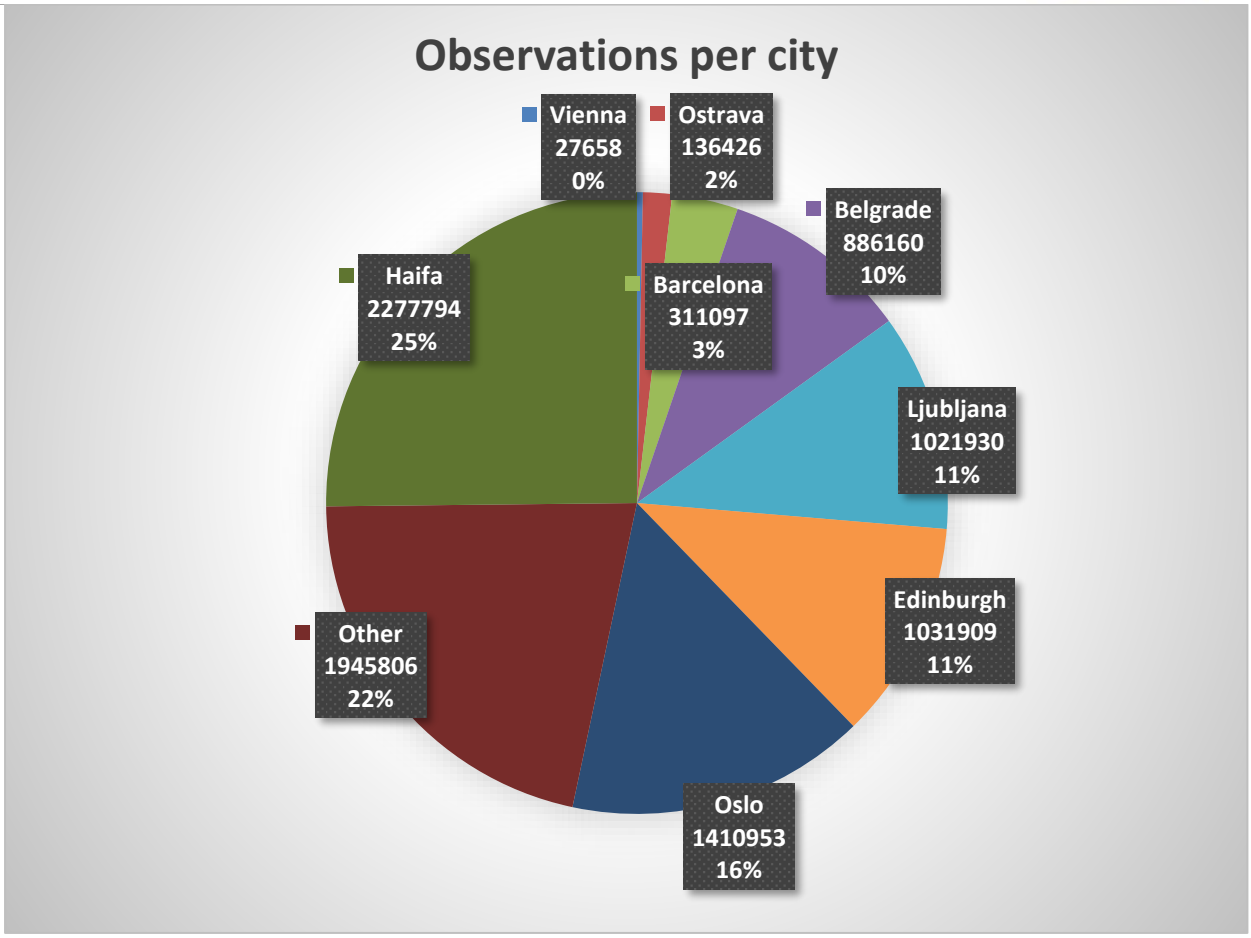
Once you know what you need to collect, you need somewhere to store it. The Spatial and Environmental Data Services (SEDS) Platform provides the core interface between data providers (those static sensors or personal sensors providing data or people completing questionnaires) and data consumers (e.g. applications developed against the platform using the raw data for analysis). The SEDS platform allows data providers to upload data collected from all sensors into a centralised data store. It also allows data consumers to access this data using open standards (WFS and REST) web interfaces.

The SEDS platform went live on the 1st September 2015 and since then a significant amount of data has been collected and added to the data store. To date, the SEDS platform stores just under 10 million observations collected by the different sensors across the 8 cities.

Total Observations*	Total Measurements*
9486947	**88672046**

** - Numbers correct at the time of writing this whitepaper.*

The pie chart below shows the distribution of the data collected across the pilot cities.


Observations per city
Vienna 27658 0%
Ostrava 136426 2%
Belgrade 886160 10%
Haifa 2277794 25%
Barcelona 311097 3%
Ljubljana 1021930 11%
Edinburgh 1031909 11%
Other 1945806 22%
Oslo 1410953 16%

Busiest Sensors

Both static and mobile sensors were placed in each city, and were used to capture observations. Static sensors captured observations at fixed locations whereas mobile sensors captured observations as the user moved around the city.

The following few tables show the top 5 busiest sensors for each sensor provider and the city these sensors were located in.

LEO sensors

Sensor ID	Observations Captured	City
LEO-666B9D4F	145899	Barcelona
LEO-666BA0D9	140408	Barcelona
LEO-666B9893	57165	Ostrava
LEO-666BA0CE	45926	Ostrava
LEO-666BA0BC	43702	Oslo

AQMesh sensors

Sensor ID	Observations Captured	City
AQ_739150	132470	Haifa
AQ_703150	132377	Haifa
AQ_842150	132308	Haifa
AQ_822150	131945	Haifa
AQ_780150	131904	Haifa

Atmospheric Sensors

Sensor ID	Observations Captured	City
AT_2	98236	
AT_13	95951	Oslo
AT_23	95934	Edinburgh
AT_21	95456	Edinburgh
AT_4	92031	Oslo

CITISENSE OBEO Sensors

Sensor ID	Observations Captured	City
CITISENSE-OBEO-NORBGO28339	2295	Bergen
CITISENSE-OBEO-SVNLJU28305	2272	Ljubljana
CITISENSE-OBEO-NOROSL28545	605	Oslo
CITISENSE-OBEO-NOROSL56021	554	Oslo
CITISENSE-OBEO-NOROSL28537	521	Oslo

CITISENSE JSI Sensors

Sensor ID	Observations Captured	City
CITISENSE-JSI-AQ_000SI114513	23	Ljubljana
CITISENSE-JSI-AQ_000compound12	20	Ljubljana
CITISENSE-JSI-AQ_000200543620	17	Ljubljana
CITISENSE-JSI-AQ_000200543621	17	Ljubljana
CITISENSE-JSI-AQ_000AS393511	14	Ljubljana

Average Common Air Quality Index (CAQI) values

Each sensor is used to take measurements for various aspects relating to the environment such as Relative Humidity, Temperature, Pressure and Activity Index. These sensors also measure the levels for various gases and particle matter floating in the air. These gases and particle matter are also sometimes referred to as pollutants.

Each observation published from the SEDS platform contains a CAQI value for the different pollutants. The CAQI value is calculated for the following pollutants:

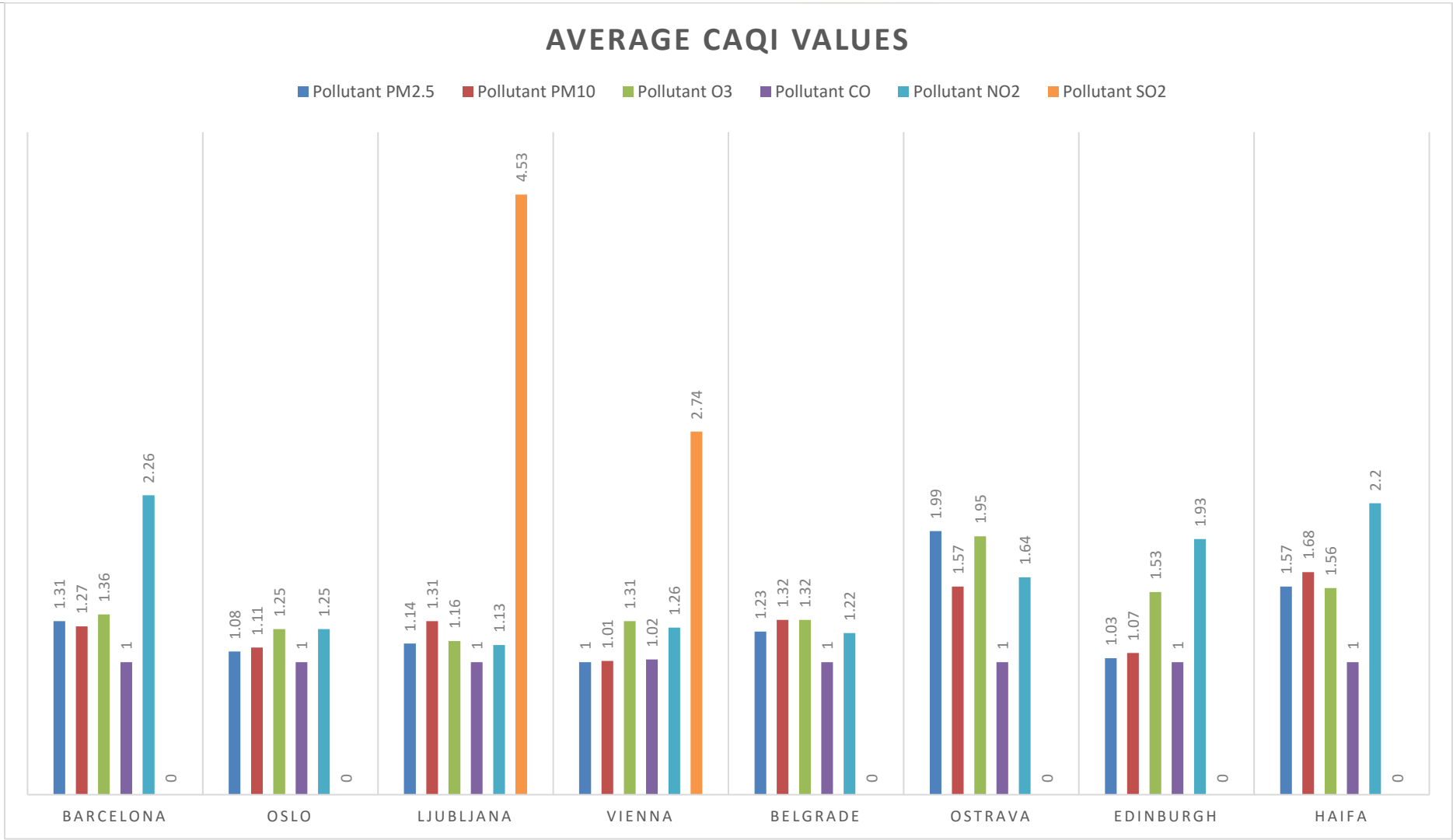
- NO – Nitrogen Monoxide
- NO2 – Nitrogen Dioxide
- O3 – Ozone
- SO2 – Sulphur Dioxide
- PM2.5 – Particle Matter (<2.5 microns) and
- PM10 – Particle Matter (between 2.5 and 10 microns)

The CAQI values are expressed in five levels:

Very low = 1, Low = 2, Medium = 3, High = 4, Very High = 5

Individual pollutant CAQI values are used to calculate the Global CAQI value.

The graph on the next page shows the average CAQI values for the various pollutants mentioned above for 8 of the 9 cities involved in the project.


AVERAGE CAQI VALUES
Pollutant PM2.5
Pollutant PM10
Pollutant O3
Pollutant CO
Pollutant NO2
Pollutant SO2
1.31
1.27
1.36
1
2.26
0
1.08
1.11
1.25
1
1.25
0
1.14
1.31
1.16
1
1.13
4.53
1
1.01
1.31
1.02
1.26
2.74
1.23
1.32
1.32
1
1.22
0
1.99
1.57
1.95
1
1.64
0
1.03
1.07
1.53
1
1.93
0
1.57
1.68
1.56
1
2.2
0
BARCELONA
OSLO
LJUBLJANA
VIENNA
BELGRADE
OSTRAVA
EDINBURGH
HAIFA

Putting numbers in perspective:

The 2016 Rio de Janeiro Olympics has been dominated with news about the poor quality of air in Rio de Janeiro. Rio's average reading for PM10 values between 2010 and 2014 was 52 ug/m3 (micrograms per cubic metre). The World Health Organisation's (WHO) limit for annual average is 20 ug/m3. In comparison to Rio some of the previous Olympic host cities had a lot lower PM10 reading, except Beijing which recorded a PM10 level of 82 ug/m3 during the 2008 Olympics. The table below shows a brief overview of the PM10 values from the various Olympic host cities.

Olympic City	Olympic Year	Pollutant	Value*
Rio de Janeiro (figure from 2010 – 2014)	2016	PM10	52.00
London	2012	PM10	23.00
Beijing	2008	PM10	82.00
Athens	2004	PM10	44.00
Sydney	2000	PM10	24.00
Atlanta	1996	PM10	28.00

Comparing these numbers with the cities involved in CITI-SENSE we find that a lot of the cities record fairly low values for PM10 on an average.

City	Pollutant	Value**
Vienna	PM10	4.72
Edinburgh	PM10	6.85
Oslo	PM10	7.28
Barcelona	PM10	12.42
Cambridge	PM10	12.88
Ljubljana	PM10	17.31
Belgrade	PM10	23.36
Ostrava	PM10	31.14
Haifa	PM10	41.14

With regard to the PM2.5 values the table below shows the average values for the various pilot cities in the CITI-SENSE project.

City	Pollutant	Value**
Edinburgh	PM2.5	2.78
Vienna	PM2.5	3.00
Oslo	PM2.5	3.76
Ljubljana	PM2.5	5.27
Cambridge	PM2.5	7.05

Barcelona	PM2.5	8.23
Belgrade	PM2.5	8.26
Ostrava	PM2.5	29.65
Haifa	PM2.5	87.68

The PM2.5 values in Rio de Janeiro recorded on June 30th 2016 were very high as compared to the above average values. The following table shows the PM2.5 values recorded at various places within Rio de Janeiro.

City	Place	Pollutant	Value***
Rio de Janeiro	Olympic Village	PM2.5	32
Rio de Janeiro	Copacabana Beach	PM2.5	57
Rio de Janeiro	Olympic Stadium	PM2.5	65

** - Source: http://uk.reuters.com/article/uk-olympics-rio-air-insight-idUKKCN10C255*
*** - Some of the values in the database had suspiciously high readings which have been ignored whilst calculating the averages.*
**** - Source: http://uk.reuters.com/article/uk-olympics-rio-air-insight-idUKKCN10C255 These are not annual averages but one-hour long test values and may be representative of an annual average.*

Summary

The AQMesh sensors in Haifa have been the busiest and the Leo sensors in Barcelona collected the most amount of observations. Haifa also has the highest values for the average CAQI values for the various pollutants, understandably so as Haifa also happens to have the biggest share of the observations that have been captured.

The CITI-SENSE project focussed on empowering citizens through Citizen Observatories and the capture and storage of information from both static and mobile sensors, to record a range of air quality sources. The information gathered was hosted and utilised by applications that focused on visualising this air quality information in a variety of formats, giving citizens first hand access to the data recorded. In reflection, this paper presents metadata about the sensors used in the project and takes a look at data recorded at 2016 Rio Olympic Games, as a point of interest. The amount of data collected is large, spanning over a year. Future consideration surrounds how to move with technological advances, in sensor technology, hosting large volumes of data and providing data access as a service to cope with demand.