Mobile embedded system for monitoring air quality

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Abstract *-* This paper talks about a case study that used a mobile app to track air quality. The case study was done in Sibiu, Romania. It includes a review of past work on air quality, a poll, an explanation of the mobile air quality tracking tool, and the outcomes of tests that were done in February 2017. So that more research can be done on how to use small, cheap tools that are easy to carry to check the air quality, this case study was made.

INTRODUCTION

This article talks about a case study that used a mobile tool to check the quality of the air as part of a research project that the "Lucian Blaga" University of Sibiu, Romania, and the University College of Southeast Norway worked on together. The case study took place in Sibiu, Romania. The air quality in Sibiu is bad because of all the traffic. A paper [1] already talks about how the platform was designed and built, so I will only quickly talk about it here. This study aims to compare the site with other ones and show how it is used. A poll of college students and workers was used in the case study to find out what they thought about the air quality. A. Background

Europe and the rest of the world have big problems with their societies, mostly with how much energy they use, the environment, and safety. In most cities and developed places, air quality has become a big problem. Fuels used in cars, ships, and energy production, heavy traffic and poor forms of transportation, burning trash, and industry activities are all things that make the air less clean [2, 3]. About 2% of the world's CO2 emissions and about 8% of the power used in the EU come from information and communication technologies [4]. Air pollution is a problem all over the world and in my own neighborhood. On a world scale health problems like asthma, allergies, and coughing are caused by air pollution from smoke, ash, dust, spores, pollen, and mildew. A study from the World Health Organization (WHO) in September 2016 says that 3 million deaths a year are linked to breathing in dirty air outside [5]. Polluted air may also make homes in open places less valuable.

A lot of places, like London, Madrid, and Paris, have very bad air quality issues, especially in the winter. On cold days, air pollution affects a lot of people and pushes them to quickly decide whether to stay inside or take a different route to avoid being exposed. The weather makes even Norwegian cities like Oslo and Bergen worse because the dirty air doesn't get warm enough to leave because the cities are ringed by hills and mountains. When there is a lot of smog, Bergen and Paris limit the use of cars based on the last number on their license plates. Oslo was closed to diesel cars for a short time in January 2017. The city government is thinking about making it more expensive to drive on days when smog is high. People from all over the world, especially those who live in megacities, are very worried about air pollution [6]. Besides that, every trip between Paris and New York melts 3 cube meters of icecap. The Arctic ice cap will be gone in 30 years if things keep going the way they are [7].

According to information presented by Dr. L. Roman from Autohaus Huber SRL (Sibiu), in a workshop1 organized as part of the project, the pollution levels caused by automobiles change (to the worse) depending on several factors such as: • Road traffic contributing to particle pollution both because of car tires wearing down the asphalt surface, and due to incomplete combustion. • Quality of the fuels and lubricants. • State of wear of the mechanical components of the engine and its auxiliary installations.

• The level of wear on electrical and computer parts.
• The distance that the car is driven every day.
• How well the car is taken care of.
• The quality of driving of the people who use the vehicles.
• The political choice to lower taxes on bringing in used cars.

Most of the time, there is no quick fix for air pollution. It usually takes a long time to shut down power plants or other businesses that pollute the air. If filters and catalysts are used, the pollution may go down. But small projects might help cut down on smog in the area. Giving people ways to cross over or under busy roads is one example [8], as is making viaducts over trains. This can help

more cars get through and cut down on the smog that comes from cars that are just sitting there.

To fight air pollution, we need precise ways to measure the quality of the air. There are only a few expensive fixed machines that do most of the tracking of air quality these days. Granularity is messed up because of this. A fixed machine only gets information from one place, so the information might not be accurate for a bigger area.

One way to improve air quality is to cut down on traffic and make the traffic that is still there more efficient. There are many ways to do this, such as raising tolls on traffic, making public transportation better, installing smart parking systems that show drivers where to park, and not letting certain types of cars use the roads. In Oslo, cars with winter tires that have spikes have to pay an extra tax. This is done to encourage owners to choose tires that are better for the earth. (The spikes leave behind dust and wear down the road.)

Different kinds of rules may be put in place by the towns to cut down on pollution. Some mayors, like those of Paris, Madrid, Athens, and Mexico City, have said that cars will not be allowed in the middle of their cities after 2025. City governments are also thinking about raising tolls on days when smog is bad [9]. Diesel cars will also be banned. People will be given benefits to use electric or hybrid cars [10], and walking and riding will be promoted.

The goal of this paper is to describe a project that will use a mobile tool to measure the quality of the air. This tool can give you more correct information about problems with air quality. This kind of tracking can help people learn more about air quality problems, including what causes them and how they affect people, which can help them make better decisions.

• Give people a real picture of the air quality in towns by having the mobile tracking app gather data from devices and send it to a computer so it can be analyzed and shown in a more visual way.

• Make environmental tracking better by creating and building a cheap "proof of concept" version that can be used in cars.

• The mobile tool for tracking the world is in cars. The station will start to watch the area around itself as soon as the car is stopped.

Send this data to the computer. You can use the deck even when the car is moving.

• The platform might do some work on the data before it is sent so that there is less data flow. The tool can send alerts when things change instead of sending info at set times. The system may be able to handle more users if this is done.

The remaining part of the paper is divided into four parts. Part II quickly goes over some recent papers that are similar to this study. In Section III, the Sibiu case study is shown. It includes the poll, some studies that have already been done by the Romanian National Network for Air Quality Monitoring, and data from the traffic and roads office. Section IV talks about the study design, which is the mobile tool for watching the environment, from both the hardware and software points of view. It also shows some of the results that were found. Finally, we talk about effects and findings in Section V.

I. WORK RELATED TO

tracking air quality has been around for a long time, but it has mostly been done by government agencies that are in charge of tracking the environment. Most of the time, tracking is done by expensive tools that stay in one place. The project's goal was to look into different ways to get measurement data in order to make measures more accurate.

A. Hand-held devices that are linked to smartphones

People could carry hand-held units around with them as one solution. Most of the time, these kinds of devices connect to a smartphone and use that phone to connect to the internet.

Leonardi, Cappellotto, Caraviello, Lepri, and Antonelli [11] made a device that people could carry around to check the quality of the air. "Official authorities use to monitor and publish air quality data collected by networks of static measurement stations." This was a big reason for making the mobile unit. But this method is often pricey, hard to keep up, and can't be expanded in the long run. As well, they say that set stations give "a lack of accuracy in the intra-urban air pollution maps." Eighty people in Trento, Italy, were asked to give the writers information. The "SecondNose" machine checks for carbon monoxide (CO) and nitrogen dioxide (NO2) in the air, as well as temperature, light, humidity, altitude, pressure, and light. A Bluetooth connection lets the unit talk to an app on an Android phone. The unit is very light (only 28 grams) and has a power life of five days.

"AirSense" was created by Dutta, Chowdhury, Roy, Middya, and Gazi [12]. It is a tracking tool built on Arduino Nano that has two sensors: one for carbon monoxide (MQ7) and one for air quality (MQ135). The platform weighs about 60 grams and can connect to an Android phone via Bluetooth. The writers of "AirSense" said that they made it because there weren't enough set tracking sites.

CITI-SENSE, an EU-funded project, developed a hand-held sensory unit to be carried around [13]. The "*Little Environmental Observatory*" (LEO) is a portable sensor pack. It measures NO, NO_2 and O_3 using electrochemical sensors. It also provides information about the current temperature and relative humidity. LEO connects to an Android smartphone through Bluetooth. CITI-SENSE also developed an app to let citizens report their own perception of air quality. CITI-SENSE ran from 2012 to 2016.

AIRALERT [14] is a service recently launched by the Romanian NGO CivicAlert. The service obtains data from a handheld sensor platform "*AirBeam*" with Bluetooth connection to an Android smartphone. Their idea is to collect data by issuing units to volunteer bicyclists. AIRALERT is using an existing visualization package to display results.

Z. Pan, H. Yu, C. Miao and C. Leung [15] used a somewhat different approach, by using smartphone cameras to detect air pollution through artificial intelligence techniques to determine particle pollution. This solution requires humans to actively do measurements.

A. *Units equiped with GSM communication*

Another approach is to equip the monitoring platform with built-in Global System for Mobile Communications (GSM) communication capabilities.

B. Migliore [16] developed a platform mounted on a bike, "*SwarmBike*", to measure air pollution. The unit has a Global Positioning System (GPS) receiver, a GSM module to handle communication, and sensors for barometric pressure, temperature, humidity and a CO sensor. His thesis describes other types of sensors for measuring air quality.

The projects OpenSense and OpenSense II [17] installed air quality measurement units on trams in Zurich and buses in Lausanne, Switzerland. The sensor platform measures ozone (O_3), nitrogen-dioxide (NO_2), carbon-monoxide (CO) and ultra-fine particles (UFP). The platform has a GPS-receiver, and transmits data to a server using GSM. A sensor was also installed in a Citroen C-Zero.

C. *Related work compared to our platform*

The problem with hand-held units is that someone must carry them around. Several solutions require Android smartphones. This excludes the large number of Apple iPhone users. Users may also be reluctant to provide access through their own phones. It seems that most of the projects described above lasted for a limited period.

Leonardi, Cappellotto, Caraviello, Lepri and Antonelli [11] reported that usage of "*SecondNose*" declined over time. Users said they were curious in the beginning, but soon learnt the characteristics of the places they measured. This may partially explain the non-sustainability of the projects using hand-held sensors.

Our unit is autonomous. No human is needed to carry it or turn it on or off. It uses a GSM module, and does not need smart phone for communication. It also has a built-in GPS. Insert a SIM-card and connect to car battery, and it is operating (plug-and-play).

The hand-held units described above seem to be more expensive. The sensor used by Leonardi, Cappellotto,

Caraviello, Lepri and Antonelli [11] (SensorDrone) costs around USD 200. It only contains sensors and Bluetooth. The components for our unit cost around 130 Euro, including sensors and GSM/GPS-module.

The OpenSense platform [17] closely resembles our platform, but collects data from trams and buses on the move. This brings some uncertainty caused by trucks being close to the measurement platform.

Our novel approach is to use parked cars. Parked cars provide the possibility to measure from one location over time. It is not dependent on human intervention to make the measurements. A city always owns cars used to provide services. But it is also possible to call on volunteers to host the platform in their cars.

D. Shared characteristics of monitoring platforms

Environmental monitoring platforms might be used by the municipality to create another layer in the city map (transparent for citizens), like layers showing networks of water, gas and electric cables, the sewer network, telephone and cable TV networks etc. Such layers may easily be implemented in a GIS system and can be used for increased transparency, sustainable regional development and innovative applications visualizing the pollution levels.

By collecting data from city and surroundings areas, platforms can identify the city's pollution hotspots (from air quality viewpoint), suggesting alternative positions for fixed stations or the need to introduce new ones. Such data will be valuable for the authorities responsible for air quality monitoring (National Environmental Protection Agency).

Platforms, like the ones described above, may provide real-time monitoring to preserve citizens' health and warn them when permissible level of pollution are exceeded. Platforms equipped with particle detectors may warn citizens about increasing levels of pollen or dust (producing allergies). In such situations, it may advise people to avoid areas that could be dangerous for health conditions and choose another detour and locate the closest pharmacies where antihistamine pills can be bought.

I.   SIBIU CASE STUDY

This section presents the case study done as part of a research project conducted jointly by the "Lucian Blaga" University of Sibiu and University College of Southeast Norway and financed by European Economic Area (EEA) grants [18]. The focus is on a specific case for air quality monitoring: the city of Sibiu, Romania. The city is in Transylvania, and has a permanent population of approximately 155.000, and up to 25.000 students and temporary inhabitants. The traffic is high since two national roads, one south-north and one west-east, are meeting in the city. According to technical data obtained from Romanian National Company of Road Infrastructure Management, more than 70,000 cars are crossing Sibiu city every day.

TABLE I.   SURVEY QUESTIONS AND RESULTS

Q1: A1:	How interested are you in air quality in general? The citizens of Sibiu have high interest (>85%) in air quality and pollution level
Q2: A21: A22: A23:	How would you describe the air quality in Sibiu in general? The air quality in Sibiu is rather good (70%) The air quality in Sibiu is poor (21%). Uncertain: 9%. Arguments of respondents for "good air quality" consist in: • The air is clean and fresh due to relatively small distance to Carpathians mountains (Păltiniș). • There are enough green spaces in and outside the city ("Sub Arini" large park and "Dumbrava" forest – as known as "the city lung"). • The industrial areas are placed outside, rather to isolate the city by generated pollution. • Sibiu is a small town with relatively small number of inhabitants. • The Sibiu ring road reduced the traffic and contributed to diminish the noxious cars' emissions, even on highly travelled boulevards. Arguments for "poor air quality" are the followings: • The transformation of green spaces in residential districts. • The inefficient modes of transport and traffic. • There are many cars that pollute the air. • 31% of persons over 18 from Sibiu County have own cars (117.663 of 378.382), according to the Public Community Service for Driving License and Vehicle Registration Sibiu. • The number of cars increased in recent years: 6.14% from 2015 to 2016.
Q3: A3:	To what extent do you think that the air quality in Sibiu affects your health? Most subjects (76%) believe that air quality in Sibiu might be an important factor that can influence their health.
Q4: A4:	Do you consider air quality when moving around in Sibiu (e.g. avoid cycling in busy roads or exercising outdoors if air quality is bad)? About one third (35%) think they should avoid activities when pollution levels are high.
Q5: A5:	What do you think about accessibility to air quality information in Sibiu? Or "How often do you consciously look at air quality information (e.g. via television, newspapers, Internet)"? Consciously, people are rarely seeking information on air quality (About once a month 18%). Although interest in environmental quality exists and usefulness of such information is obvious, the biggest problem lies in finding it.
Q6: A6:	Who can improve air quality in Sibiu? And How? The top three groups which can contribute to air quality improvement are: The municipality (e.g., city council): • By not allowing deforestation in the whole county, except dry/sick wood, which should be replaced by other freshly planted trees. • Protecting parks and forests, and developing new green spaces. • Introduction of electric public transport. • Optimize traffic in order to avoid congestion and useless fuel consumption. Industry and commerce: • Industry and commerce can find ways to pollute less by controlling their activities (dematerialization of economy). • Proper management of waste. People who spend most of their time in the city (e.g., residents, workers, students): • Students could participate as volunteers to plant trees in

	deforested areas. • Large scale use of public transportation or other alternatives (e.g. bicycle) Other groups were regional agencies or research scientists: • Regional and central government agencies must take responsibility to respect the law regarding the maximum level of air pollution, and if this level is overrun by any industrial company take appropriate measures. • Proposing legislation to reduce urban pollution. • Research scientists can contribute by finding new ways to stop air pollution.
Q7:	What steps do you think you would personally take to help improve air quality in Sibiu?
A7:	The large majority of the respondents are willing to: • use more environmentally-friendly means of transportation (electric bus, bicycle, etc). • involvement in public policy making, of social polls and participating to citizen advisory committees. • use greener systems at home such as renewables energy and electric heating to the detriment of burning wood.
Q8:	In which format would you prefer to receive air quality information?
A8:	Subjects suggested that an application for mobile phone would be most appropriate since they live in the "Internet of Things" and, nowadays over half of them use such easy accessible technology. Smartphones have excellent processing and storage capabilities and people carry them in their daily lives. Alternatively, information might be exhibited on panels in main public places, in public transport but also using social networks where information dissemination can be done very easily. Websites, TV and radio were also mentioned as alternatives.
Q9:	If you could have an application mobile phone app to inform you about air quality, how important would it be to have the following features?
A9:	See table II.
Q10:	In relation with the previous question, are there any other features you would like to have in a mobile app to be informed about air quality?
A10:	In addition to the numerical information about concentrations of air pollutants it would be useful that each pollutant to be accompanied by immediate and long-term effects on health. Possibility to select decongested routes to move in the city

A. Survey about air quality perception of people

Before starting our project implementation, we developed a survey regarding air quality perception by people, to see the relevance of air quality monitoring in Sibiu and its surroundings. We requested feedback from people working / studying / living in Sibiu (66% being in their twenties, 10% being between 30 and 45, and 24% being older than 45), most of them being students at the Faculty of Engineering.

200 participants were surveyed, 54% men, 46% women. 81% of respondents have secondary level education, 19% have higher education (Bachelor, Master, PhD). In the following we present the most important questions and the answers we received.

Table II lists the possible features of a mobile app to inform about air quality. The most important feature sought was information on how to protect own health. The second important feature sought was information about current air quality, followed by an air quality index to show how air quality improves or degrades.

TABLE II.   SURVEY RESULTS (Q9)

No.	Feature	Priority			
		High	Med.	Low	Not a priority
1.	Air quality in your immediate vicinity	58.5	29.3	11	1.2
2.	Numeric information on pollutant	40.2	41.5	14.6	3.7
3.	An *air quality index* indicating if the air quality is poor or good	72	23.2	3.7	1.2
4.	Ability to report what you think the air quality is like	28	45.1	22	4.9
5.	Ability to see what other users have reported	18.3	42.7	26.8	12.2
6.	Information on past air quality	36.6	34.1	22	7.3
7.	Information on *current* air *quality*	75.6	20.7	3.7	0
8.	Information on *forecasted* air quality	43.9	42.7	11	2.4
9.	Information on what to do to protect your health	84	14.8	1.2	0
10.	Notifications in case of increased air pollution	65.9	29.3	4.9	0
11.	Possibility to see the air quality levels in the routes you move around the city	59.8	26.8	12.2	1.2
12.	Possibility to select cleaner routes to move in the city	59.8	25.6	11	3.7

B. Earlier Studies

In Romania, air quality from ambient environment is legislated in accordance with European laws by the Air Act

(no. 104/2011) [19], which establishes that the responsibility for air quality monitoring is undertaken by the National Environmental Protection Agency, through the National Network for Monitoring Air Quality [3]. Unfortunately, the number of air quality monitoring stations in Romania is rather small (142 fixed & 17 mobile units). This network includes four fixed stations in Sibiu County, which continuously monitor the air quality (Two are located in Sibiu, one in Mediaş and one in Copşa Mică).

The results presented in Figure 1 and Figure 2 were obtained from the two stationary units located in Sibiu city: SB1 – urban residential station and SB2 – industrial-type station.

The figures show CO and NO_2 concentration levels, for 2016. The agency has also on occasions used mobile units. The monitored parameters are: Sulphur dioxide (SO_2), nitrogen oxides (NO_X), carbon monoxide (CO), ozone (O_3), particles (PM 10 and PM 2.5), benzene (C_6H_6) and lead (Pb).

Figure 1.   CO concentration levels in 2016

The evolution of values for CO concentration between 1st of January to 31st of December 2016 show that there were no exceedances of the daily limit value for health, taking into account that the daily maximum of averages at each 8 hours is 10 mg/m^3, according to the Air Act 104/2011.
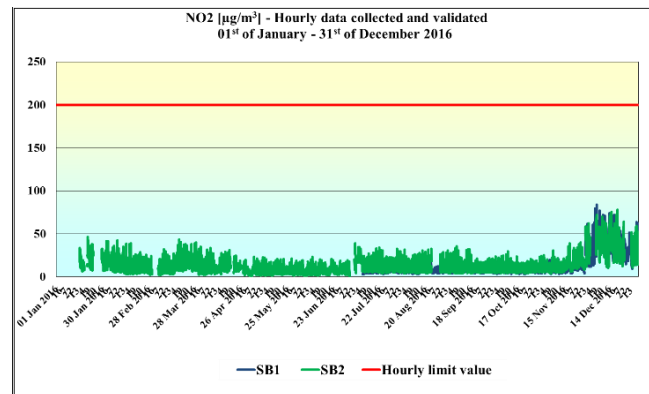

Figure 2.   NO2 concentration levels in 2016

The NO_2 pollution indicator has not revealed breaches of the hourly limit of 200 $\mu g/m^3$ (the maximum number of

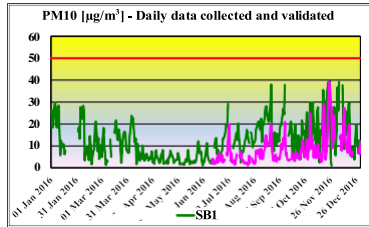exceeding's allowed by Air Act 104/2011 is 18 times yearly / station).

Figure 3.   Particle concentration levels (PM10) in 2016

Particles are measured by size. PM 10 is the unit used to measure particles with a diameter between 2.5 and 10 µm. The particles (PM 10) pollution indicator is measured at SB1 station both automatically and manually. Figure 3 shows the daily limit values from SB1 and SB2 obtained in 2016. In 2016, the SB1 station reported 8 overruns of daily limit (50 µg/m^3) but which is still acceptable considering that the limit set by Air Act is 35 times yearly / station. (Single overruns cannot be seen in Figure 3, due to low resolution in the X- axis). Measurement results indicate that particle pollution is mainly caused by heavy traffic. The maximum (60.28 µg/m^3) was recorded in a heavily transited location at the entrance to the city where several hypermarkets are in the same area, while in Sub Arini Park (the largest park in the city) the recorded value of 13.93 µg/m3 was far below the daily limit value.

Explanations for this situation are: Apparently, in Sibiu the air quality is rather good, but the results might be pseudo true. The two fixed stations are situated as follows: SB1 is placed in an area where the traffic is relatively low and, SB2 is placed in an area which, on its deployment, in 2007, was heavily industrialized. Today, most industry has relocated (outside the city). Air pollution contributes to climate changes and to the emergence of *urban heat islands* (higher temperatures concentrated in urban areas densely populated and built), which cause temperature increases by up to 5 degrees compared with unaffected areas.

II.   PROJECT DESCRIPTION

The main objectives of the mobile air quality monitoring platform project were to:
- Develop a low-cost mobile platform for air quality monitoring where data are collected through crowdsensing.
- Test the platform in the City of Sibiu, Romania (and other locations) and compare collected data with already existing data, to verify results and extend the number of measurements being made.

- Make the necessary groundwork for establishing a larger project on air quality monitoring, this time with focus on analysis, prediction and visualization.

A. The Platform

The platform has been described in an earlier paper [1]. Shortly summarized the platform consists of a processor unit (LinkedIt Smart Duo 7688 - an open development board with two processors, one running Linux, the other compatible with Arduino), a combined GPS/GSM unit for location and communication, a gas sensor for measuring CO_2 and NO_X (SainSmart MQ135 Sensor Air Quality Sensor and Hazardous Gas Detection Module), a particle sensor measuring PM 10 (Grove Dust Particle Concentration Detection Sensor), and sensors for temperature (DS18B20 Temperature Sensor) and barometric pressure (BMP085 Digital Barometric Pressure Measurement Sensor). The technologies used are: Eagle (for printing the PCB) and Custom Electronic Shields, ASP.NET and Microsoft Azure (for database and cloud), C/C++ (for LinkedIt 8266 programming). 16 prototypes were built for experiments.

B. Hardware and Software Architecture

On the client side, the software will detect when the car is parked, and then start data collection from the sensors at regular intervals. The data are stamped with time and location (both retrieved from the GPS receiver) and sent to a server using a GSM data connection. Figures 4 and 5 show the hardware design of printed circuit board holding the sensors (except the particle sensor which is connected by a wire).
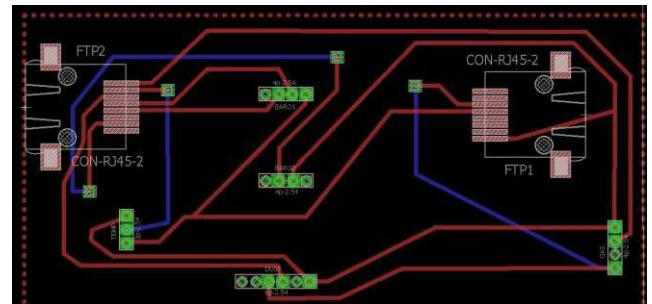

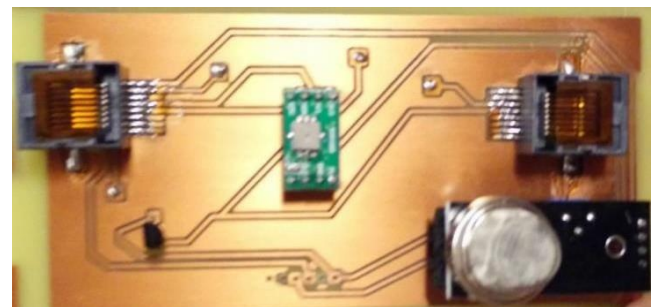Figure 4.   The hardware design of prototype

Figure 5.   Sensor printed circuit board

On the server side, the data are stored in a database for further analysis. The location of active cars is shown on a map (Google maps) with the possibility to click on one specific car to see the latest data.

C. *Visualizing data*

By clicking on each point from the map, information from each sensor is disclosed. The map is shown in Figure 6.
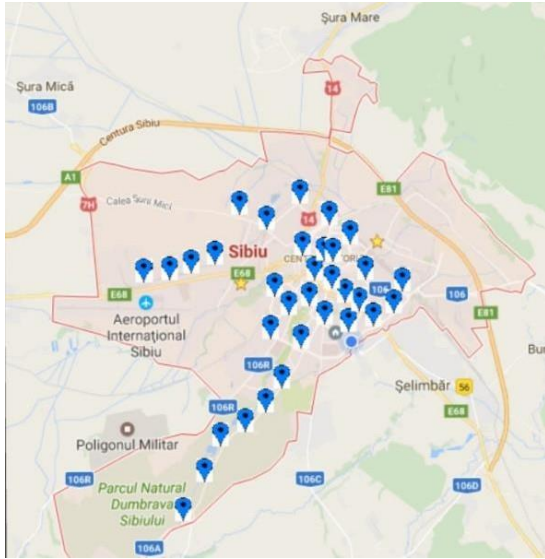

Figure 6.   Clickable Google Maps

D. *The Test*

The platform was used for air-quality monitoring in Sibiu first weeks of February 2017. Data were collected from four units, each installed within a car. The data collected generally corresponds to earlier data collected by the National Environmental Protection Agency. At the same time, we showed that granularity has been improved since we could measure from many more locations. Some data were collected from cars driving the same route at different times.

Figure 7.   Data collection in Sibiu (moving cars).

Figure 7 illustrates a Google Maps snapshot with the route on which the data were collected at 5 pm when many people return from work. The red color shows heavy traffic because this road is connecting the airport with the city center and represents the single entrance in the city from the west side. In Figure 8, we present the chart with CO_2 variation during the route that takes around 16 minutes. The

measurements were done with MQ135 gas sensor set up for CO_2 and the results are exhibited in parts per million (PPM). Regarding the MQ135 sensor and its detection capability, the researchers consider that the general sensitivity is roughly the same for all the gases sensed [14]. Since CO_2 is the fourth most abundant trace gas in the earth's atmosphere they recommend that it is safe to assume that in a normal atmosphere the MQ 135 sensor mostly detects CO_2. The values from Figure 8 somewhat faithfully follows the route from Figure 7, namely, where there is heavy traffic, CO_2 values are higher than 230 PPM. However, the maximum value obtained (277 PPM) is under the highest-ever daily average[2] at planet level (409.44 PPM) reached in 9 of April 2016.
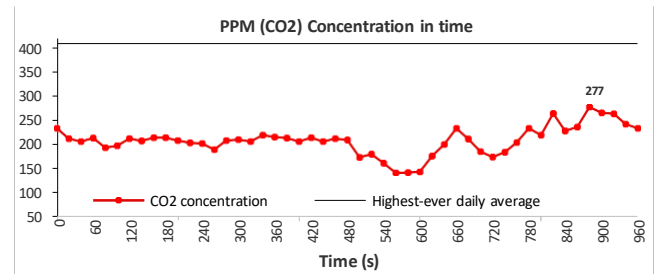

Figure 8. CO_2 values [PPM] collected with MQ 135 gas sensor from a heavy traffic boulevard from Sibiu

Table III presents the range where are situated the measured parameters (gas, temperature, dust and humidity). From a temperature point of view is observed how the heavy traffic produces higher temperature by approximately 2 degrees compared with unaffected areas (urban heat islands effect).

TABLE III.   PARAMETERS VARIATION

	CO_2 [PPM]	Temperature [Celsius degree]	Dust [mg/m³]	Humidity [%]
Maximum	277	2	0.35	87
Average	207.92	1	0.33	87
Minimum	141	0	0.32	87

Measurements were also made from parked cars in an densely populated area close to a major road, and here CO_2 values varied between 200 to 500, depending on the time of the day.

E. Making Groundwork for a New Project

EU Research & Innovation program H2020 [3] has allocated 80 billion Euros funding for initiatives related to environmental sustainability and energy efficiency. In a follow-up project, we intend to focus on further developing analytics, prediction algorithms and visualization. By collecting data over a longer period, we will be able to predict when pollution levels reach certain levels. Such information will be useful for decision-making.

III. CONCLUSIONS

As mentioned earlier, several cities around the world are restricting car use when air pollution levels are too high. The use of stationary units provides low granularity of measurements, and are expensive. This project has shown that data can be collected by means of crowdsensing, either by using cars of the municipality or calling upon volunteers to accommodate units in their cars.

Largely, the obtained results are consistent with measurements from fixed stations. However, our solution provides much higher granularity of the measurements.

In a longer perspective, our aim is to further develop our platform as part of a system for smart-cities with the purpose of providing insights about people and environmental conditions, and disseminate such information to the public through multiple channels. Such a system will be important for decision making related to environmental issues, and be a measure to increase the transparency of the cities.

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[2]Air Pollution: Current and Future Challenges is a report from the US Environmental Protection Agency. You can find it online at https://www.epa.gov/clean-air-act-overview/air-pollution-current-and-future-challenges

[3]The Romanian National Network for Monitoring Air Quality. You can read it online at http://www.calitateaer.ro/structura.php

[4]Ericsson: Ericsson study on energy and carbon. About how the connected world has changed things. You can read the report online at http://www.ericsson.com/res/docs/2013/ericsson-energy-and-carbon-report.pdf.

[5] WHO: The WHO calculates how much air pollution people are exposed to and how it affects their health. You can find it online at http://www.who.int/mediacentre/news/releases/2016/air-pollution-estimates/en/.

"Independent" says that London's air pollution is worse than Beijing's because of all the smog in the UK city. The article can be found online at http://www.independent.co.uk/news/science/london-air-pollution-rates-worse-beijing-smog-china-vehicles-weather-a7545446.html.

It's possible that the Arctic Ocean will melt in 30 years. You can read it online at http://www.foxcrawl.com/2016/11/07/arctic-ocean-thawing-ice-cap-melting-30-years/.

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