Accountability Technologies

Tools for Asking Hard Questions

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Bejing Air Tracks: Tracking Data for Good

Sarah Williams

One of the biggest barriers to sustainable development in many rapidly developing countries is the lack of data which would allow us to make informed decisions about the places we live. If data exists, it is rarely obtainable or used by those who are charged with development decisions and it often does not land in the hands of the citizens themselves. The ubiquitous nature of mobile devices world-wide has made us all data collectors. While there is much concern about how this data is used by governments and private corporations, and there should be, these ubiquitous data recorders can just as easily be leveraged by citizens for a public good.

An example of this public good can be seen in a project my research lab developed with the Associated Press (AP) to create mobile air quality sensors during the 2008 Beijing Olympics. *Beijing Air Tracks*, as the project was known by the AP, started with a simple question: "Can the Olympics be a way to expose air quality issues in China?" By using our sensors, the Associated Press, not the Chinese Government, became the only organization to report on particulate matter, the fine dust pollutants in the air that could have had the largest effects on athletes during the Olympics. The Chinese government did release what it called an "air quality index;" however, the index was un-interpretable because little information was provided on how the numbers were developed.[1] The Associated Press sensors provided the only real-time, geo-registered measurements for particulate matter and carbon monoxide, and did so at the events the reporters were covering. *Beijing Air Tracks* showed how new technologies could be used to advocate for environmental change and illustrated how anyone can take control of data and inform the public at large. The lessons learned from this experiment go beyond exposing air quality conditions in China, as the devices developed showed that ubiquitous computing, such as mobile phones, can allow us to take control of information and use it to advocate for change.

When the project was conceived in 2007, there was much conversation in the press about whether the Beijing City Government would be able to clean up its act for the Olympics. The *Washington Post*'s Maureen Fan reported that many visitors to Beijing were struck by the grey skies and wondered "how this city can possibly be ready to host them in less than 10 months" (Fan, 2007). London's *Guardian* questioned how Beijing would be able to improve air quality after "more than a million cars were taken off the roads for the four-day test period, but there was no improvement in the air quality" (Watts, 2007). The *New York Times* perhaps summed up the situation best when Jim Yardley said: "Beijing is like an athlete trying to get into shape by walking on a treadmill yet eating double cheeseburgers at the same time" (Yardley, 2007). Factories in and around Beijing were polluting more than ever, while the country claimed to be making a reduction. The reports coming in from Beijing made the task to improve air quality seem impossible.

The Chinese government assured the international community that air quality would be significantly improved by the time of the Olympics. In order to do so, they would put certain policies in place. There were to be widespread shutdowns of factories. Just months before the Olympics, the Chinese government ordered business to suspend operations in Tangshan, one of China's busiest steel centers, about 90 miles from Beijing. The Chinese government also wanted to address air quality on the congested roadways and removed over 3.3 million cars from the streets by mandating alternative day traffic regulations for vehicles with even and odd license plate numbers. The *Washington Post* reported that as the Olympics approached, an additional 220 factory closures were made in Tianjin City and Hebei province, as air quality did not seem to be improving just days before the Olympics. Beijing also extended measures

A montage of photos taken of Associated Press reporters while they were measuring particulate matter and carbon monoxide during the Olympics in Beijing 2008. Photos credited to Sarah Williams and Cressica Brazier

to include a ban on construction during the Olympics (Fan, 2008). Many eyes, including the International Olympic Committee, were anxious to see if Beijing's policies would decrease their problematic air pollution during the Olympics.

Governmental regulatory agencies, including the EPA and the World Health Organization, are largely concerned with chemicals found in the air that contribute to smog. Smog is comprised of particulate matter (PM10), ground level ozone, nitrogen oxide, sulfur dioxide, and carbon monoxide.[2] Fine particulate matter is a broad name given to particles of liquids and solids that pollute the air. PM 10 can be breathed deeply into your lungs and will stay there, causing health problems. Fine particles, defined as PM 10, can stay in the air longer and travel farther than larger particles sizes (WHO, 2006). It should be noted that the United States uses a smaller fine particulate size, PM2.5, as its standard, creating stricter regulations for reductions of these pollutants that can cause adverse health conditions. Ground-level ozone (O3) is not emitted directly into the air, but forms when nitrogen oxide and volatile organic compounds (VOCs) from vehicle exhaust, factory emissions and other sources react with sunlight. It is called the "bad ozone" because if you breathe it in, it can cause various health problems. Nitrogen oxide (NO) is a reddish-brown gas that smells foul; it contributes to acid rain and has adverse effects on water quality. Sulfur dioxide (SO2) combines with volatile organic compounds (VOCs) and sunlight, creating ground-level ozone (WHO, 2006). According to the US Environmental Protection Agency, "carbon monoxide is an odorless, tasteless, colorless gas. At high levels, it can be life threatening."[3] In urban areas, carbon monoxide is a temporary atmospheric pollutant largely resulting from vehicular traffic. In developing countries, carbon monoxide pollution in urban areas can also come from coal-burning stoves that might be used for roadside cooking. Carbon monoxide is often measured along with particulate matter to understand urban air quality microclimates, because carbon monoxide does not travel far and usually expresses highly localized conditions (Kaur et al., 2007; Flachsbart, 1999).

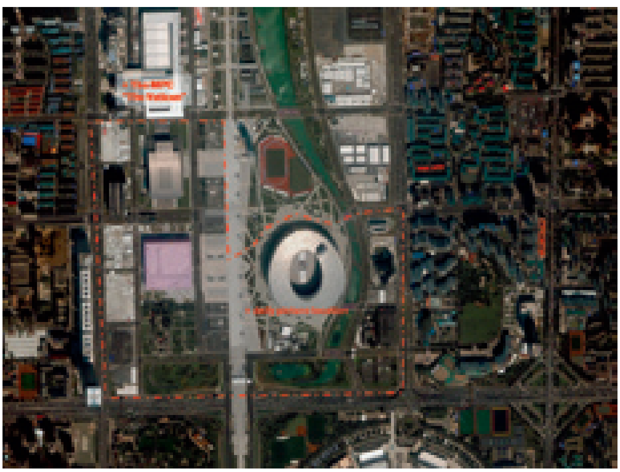
The local air pollution sensors needed to be highly mobile and portable, so we had to limit the amount of pollutants we could measure. We chose to measure pollutants that would tell us the most about the environmental conditions that would impact the athletes, while also testing Chinese government policies that were meant to improve those conditions. We focused on collecting fine particulate matter and carbon monoxide measurements. Fine particulate matter was critical for telling the story of air quality in Beijing, as it is the pollutant that would have the largest effect on athlete performance and related most directly to the Chinese mandate to have widespread factory shutdowns (Harrison and Yin, 2000). Largely powered by coal, Chinese factories are arguably the largest contributors to particulate matter pollution (Hao and Wang, 2005). The regional factory shutdowns were mandated because particulate matter can travel long distances in the air and the Chinese government was unsure how the regional pollution would affect Beijing. It should be noted that particulate matter can be detected in MODIS satellite data and, therefore, the interpretation of MODIS images can provide general measurements of the regional levels of this air pollutant. While this data was helpful for gauging regional air quality levels, it was not used for this study because air quality conditions can be highly localized, and we wanted to know the on-the-ground conditions the athletes were experiencing. While there are several pollutants associated with traffic conditions, we chose carbon monoxide, as we felt that it was the pollutant most understandable to the public. Real-time carbon monoxide sensors have been available longer than many air pollutants. As a result, the sensors had been developed to be more compact and a bit more cost-effective.

The fast-paced news of the Olympics meant we needed air quality sensors that could measure data in real-time. Real-time sensors have different levels of accuracy when compared with static sensors, which are usually left on rooftops and designed to better handle sensing anomalies caused by wind and climate conditions. The team realized our mobile sensors might have some differences in measurement levels from other static devices. However, we believed that exposing the conditions with a full disclosure of possible errors was better than not exposing the air quality conditions at all. The team also knew that we might find pollution levels to be so high that if we under-counted the data, the recordings would still show air levels dangerously above World Health Organization standards.[4] More importantly, the air quality sensors were not compared against the measurements of the statics sensors, but to each other, which created similar accuracy levels. When using any measurement device, accuracy levels will come into question, but given that the team was trying to get a rough estimate of what was happening in real time, and that we fully disclosed the possible errors, we knew the sensors we used were the best fit to allow us to tell the story of air pollution in Beijing.

Real-time particulate matter sensors use optical technology, which measure the shadows of the fine particles as air passes through a light component. We purchased an optical sensor developed by MICRODUST which, at the time of the 2008 Olympics, was considered one of the best optical sensors in the field. There is some discussion in the scientific community about the accuracy of optical sensors versus mass-based sensors, with arguments for both. We believe that, when calibrated, these real-time sensors are the only way to obtain the best estimate of the amount of particulate matter in Beijing's air (Baltrenas and Kvasauskas, 2005; Giugliano et al, 2005).[5] Mass-based devices pump air into filter bags; once the particles are trapped, the bags they are sent to a lab, where they can be measured and analyzed for composition and size.[6] While there are benefits to using filter bags, including a particle composition analysis, they would not have provided real-time reporting.

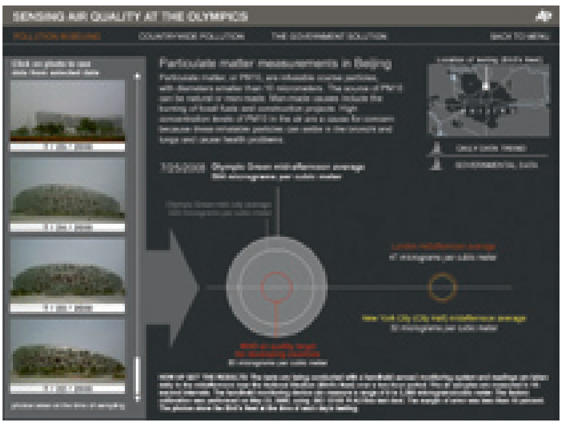
The carbon monoxide sensor measured CO levels using chemical reactions. Chemical-based sensors have decreased levels of accuracy the longer they are used, because the chemical agent in the sensor degrades. We purchased new carbon monoxide sensors and calibrated these sensors before leaving for Beijing. The particulate matter sensors were much more expensive than the carbon monoxide sensors, because the optical technology needed for these types of sensors is more complex than the chemical detectors for carbon monoxide. It should be noted that just in the last year there have been developments in optical sensors which have made them smaller and cheaper (Mead, 2013).[7] Both devices were connected to GPS receivers and the sensor data was given a geographic location based on the time records associated with the GPS and sensor data points. Once each sensor measurement was given a latitude and longitude, the data was sent back to the main press center via phone.

Weeks before the Olympics started we gave the sensor devices to several reporters and set out to collect recordings in diverse but well-known locations throughout Beijing. The team focused on performing daily recordings in the Olympic Park, Tiananmen Square, and the Temple of Heaven. Just days before the beginning of the Olympics, our ambitious data plans had to change. Several of the Associated Press photographers, who had been given the devices, were questioned by the Chinese government for photographs they had taken. Surveillance of the reporters was cause for concern, and the Associated Press took many reporters off the project because they were worried the Chinese government might detain them. The Associated Press therefore limited the data sensing team to a few reporters. The team focused their work in two areas: 1) Developing a data visualization showing the particulate matter levels in the Olympic Park; 2) Measuring carbon monoxide on the marathon routes before and after the removal of half the cars on the roadways.

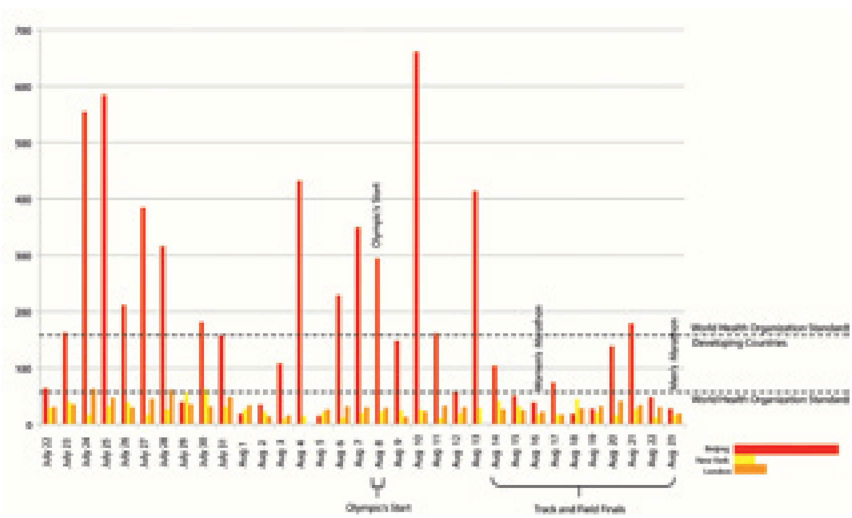


This image shows the location of daily air quality measurements taken by Associated Press reporters on the Olympic Green. Images created by Sarah Williams

The Olympic Park data visualization focused on presenting particulate matter data recordings that were contextualized by international standards and compared to air quality levels in New York and London during the same time. The visualization also used photographs to capture the atmospheric conditions, which often looked like a hazy soup on poor air quality days. It should be noted that the Beijing government officially referred to good air quality levels as "Blue Sky Days" (Fan, 2007). "Blue Skies" could be seen in many of the Bird's Nest pictures. The data for the interactive graphic was collected by an Associated Press reporter who walked the Olympic Green the same time every day. He took a picture of the Bird's Nest from the same vantage point, while also collecting air quality data through the sensor. Pictures of the Bird's Nest Stadium on every day during the Olympics were used to navigate the interactive data visualizations which showed the average mid-afternoon air quality around the Olympic Green, and compared those numbers with average readings in London and New York for the same day. The data visualization revealed that the air quality in Beijing was often at a level 10–20 times higher than what was seen in New York City, and often did not meet the World Health Organization standards (World Health Organization, 2006). New data was added to the visualization daily and Associated Press member newspapers picked up the visualization and posted it on their various web sites.



Interactive graphic of particulate matter on the Olympic Green made available to Associated Press member institutions. Image created by Sarah Williams and Siemond Chan from the Associated Press, 2008



Graph of raw data for the particulate matter sensor used on the Olympic Green by the Associated Press during the Olympics. The graph shows Beijing in comparison to New York and London for the same days. Beijing has levels often 10 times higher than New York City and way above the World Health Organization standards. Image by Sarah Williams

The interactive graphic was just as important for communicating the air quality experience in Beijing as the raw data collected by the sensors. Data measurement reports from the Associated Press about the air quality were picked up by Associated Press subscribers and incorporated in stories across the globe. Observations of the particulate matter results show that air quality was over the World Health Organization standards for much of the Beijing Olympics, except for the last week when it rained. Rain molecules latch onto the fine particles, bringing them to the ground and clearing the sky. The Chinese government was certainly lucky to have rain during the track and field events, where particulate matter would have had the most effect on the participants.

The visualization of the Olympic Green was complimented by a data visualization that took advantage of the highly mobile nature of the sensors. This info graphic showed geo-registered air quality measurements taken along the Olympic marathon route before and after the Chinese government ordered 3.3 million cars removed from the roadway. Developed in coordination with the *New York Times*, the info graphic focused on carbon monoxide levels because they were more closely associated with vehicle exhaust. We compared the figures in Beijing to measurements obtained on New York City's Marathon route for the same day. An analysis of the data conveyed through the visualizations showed that in many areas along the Olympic route, air quality was reduced by almost half, and levels overall were comparable to what would be found in New York City on the same days. The marathon route was a great way to tell the story of air quality. It was an event readers could connect with and contextualize. It should be noted that particulate matter measurements along the route were also captured, but remained fairly close to the numbers at the Olympic Green. The marathon route became a more compelling story using the CO measurements, which showed that car traffic restrictions did help CO emission in some parts of Beijing.

Overall, air quality conditions during much of the Olympics were at a level higher than World Health Organization standards. Exposing the air quality allowed the press to discuss the topic with real numbers, while the government was largely talking about the poor air quality conditions simply as fog, not smog. Having the measurements allowed us to discuss this statement in more specific terms and provide a fact-based counter opinion to the smog argument. The government's air quality index, which ranged from 1–500, was hard to interpret and Beijing government had to essentially tell reporters what the index meant (Fan, 2008). Often the government simply interpreted the results as "Blue Sky Days," meaning the air quality was good, not bad. Having real measurements during the Olympics allowed a real conversation to happen in the press about air quality conditions for the athletes and, more largely, for Beijing residents who would be affected by the air quality after the Olympics were over. Yet measuring the data alone did not change the conversation. By creating compelling graphics for a large, captivated Olympic audience, we were able to bring the story of air quality in Beijing to people all over the world.

Fast-paced development seen in many of the BRIC (Brazil, Russia, India, China) countries, and especially in China, is often associated with high costs to the environment. In China, one of the biggest concerns over the last 10-15 years has been the deterioration of the air quality. Yet with much environmental sensing equipment being controlled by the government and released as indexes, it has been almost impossible to know the true level of air pollution that exists in China, among other countries. Using new, portable environmental sensing devices like the ones developed for the

Carbon monoxide measurements along the Olympic marathon route, before and after the Beijing City Government restricted 3.3 million cars from the roadways during the Olympics. The results shows air quality conditions similar to what would be seen along New York City's marathon route. Image by Archie Tse and Sarah Williams

Beijing Olympics allows anyone to test and release air quality measurements in areas where no other data exists. Armed with information, citizens everywhere are empowered to start a conversation with their government about air quality conditions. These types of citizen sensing projects rarely occur in places such as China, where government control of data is tight, and air quality conditions are at levels way above what is recommended by the World Health Organization. We hope our model for data collection shows how the power of mobile phones and new sensor technology can be harnessed to tell a story about the places where we live, giving citizens the possibility to change the places where they live.

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1 And, therefore, the numbers were only interpretable by the Chinese government themselves.

2 The 2005 *WHO Air quality guidelines* (AQGs) set acceptable levels of these various substances in the air for countries worldwide.

3 Cf. http://www.epa.gov/iaq/co.html.

4 The sensors were calibrated for air quality conditions in Beijing.

5 Baltrenas and Kvasauskas (2005) tested optical and mass particulate matter sensing tools and found the optical sensors were usually above the mass sensors. This goes against previous claims that mass-based particulate matter sensors are usually better quality.

6 One benefit of using mass devices is that the analysis of bag contents provides information about the types of particles which can help determine the likely source of the pollutants.

7 According to the Seeed Wiki (http://www.seeedstudio.com/wiki/Grove_-_Dust_Sensor), the Grove Dust Sensor "measures the particulate matter level in air by counting the Lo Pulse Occupancy time (LPO time) in given time unit. LPO time is in proportion to PM concentration. This sensor can provide you pretty reliable data for your PM2.5 project or air purifier system because it's still responsive to particulates whose diameter is 1μm." It is roughly a little bigger than a quarter.