Citizen-sensor-networks to confront government decision-makers: Two lessons from the Netherlands.

Linda Carton*, Peter Ache
Institute for Management Research (IMR), Radboud University, Department Geography, Planning and Environment (Spatial Planning Group), Thomas van Aquinostraat 3, 6525 GD, Nijmegen, The Netherlands
* Corresponding author: l.carton@fm.ru.nl

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- Citizen-sensor-networks;
- Participatory Sensing;
- Voluntary Environmental monitoring;
- Airport noise;
- Human induced earthquakes;
- Citizen Empowerment;
- Participatory GIS.

Highlights:

1. Citizen groups increasingly embrace low-cost sensor networks, open data and social media for environmental monitoring.

2. Case studies in monitoring provide insight in how social-technical innovations of *'citizen-sensor-networks'* come about and form *'networked geo-information tools'* in a process of co-construction.

3. Analyzed citizen-sensor-networks, which monitor airport noise and gas-extraction-induced earthquakes, publicly falsified the hypotheses held by governing regimes.

4. Through processes of collective sense-making and meaning construction, citizen-sensor-networks form a powerful tool for informed planning. There is a shift in power balance involved between government and affected communities, as the government no longer has information monopoly on environmental measurements.

Abstract:
This paper presents one emerging social-technical innovation: The evolution of citizen-sensor-networks where citizens organize themselves from the 'bottom up', for the sake of confronting governance officials with measured information about environmental qualities. We have observed how citizen-sensor-networks have been initiated in the Netherlands in cases where official government monitoring and business organizations leave gaps. The formed citizen-sensor-networks collect information about issues that affect the local community in their quality-of-living. In particular, two community initiatives are described where the sensed environmental information, on noise pollution and gas-extraction induced earthquakes respectively, is published through networked geographic information methods. Both community initiatives pioneered in developing an approach that comprises the combined setting-up of sensor data flows, real-time map portals and community organization. Two particular cases are analyzed to trace the emergence and network operation of such *'networked geo-information tools'* in practice: (1) The Groningen earthquake monitor, and (2)

The Airplane Monitor Schiphol. In both cases, environmental 'externalities' of spatial-economic activities play an important role, having economic dimensions of national importance (e.g. gas extraction and national airport development) while simultaneously affecting the regional community with environmental consequences.

The monitoring systems analyzed in this paper are established bottom-up, by citizens for citizens, to serve as 'information power' in dialogue with government institutions. The goal of this paper is to gain insight in how these citizen-sensor-networks come about: how the idea for establishing a sensor network originated, how their value gets recognized and adopted in the overall 'system of governance'; to what extent they bring countervailing power against vested interests and established discourses to the table and influence power-laden conflicts over environmental pressures; and whether or not they achieve (some form of) institutionalization and, ultimately, policy change.

We find that the studied-citizen-sensor networks gain strength by uniting efforts and activities in crowdsourcing data, providing factual, 'objectivized data' or 'evidence' of the situation 'on the ground' on a matter of local community-wide concern. By filling an information need of the local community, a process of 'collective sense-making' combined with citizen empowerment could grow, which influenced societal discourse and challenged prevailing truth-claims of public institutions. In both cases similar, 'competing' web-portals were developed in response, both by the gas-extraction company and the airport. But with the citizen-sensor-networks alongside, we conclude there is a shift in power balance involved between government and affected communities, as the government no longer has information monopoly on environmental measurements.

Selected Classifications:
180: CO-MANAGEMENT/COLLABORATIVE/COOPERATIVE MANAGEMENT
190: COMMUNITY-BASED MANAGEMENT
210: CONFLICT ANALYSIS/RESOLUTION
450: ENVIRONMENTAL PLANNING
460: ENVIRONMENTAL POLICY
640: GEOGRAPHIC INFORMATION SYSTEMS (GIS)

Authors:

Linda Carton
Institute for Management Research, Spatial planning group, Radboud University, Th. Van Aquinostraat 3, 6525 GD, Nijmegen, the Netherland.

Peter Ache
Institute for Management Research, Spatial planning group, Radboud University, Th. Van Aquinostraat 3, 6525 GD, Nijmegen, the Netherlands.
e-mail: p.ache@fm.ru.nl

Contact information:
e-mail: l.carton@fm.ru.nl
tel: +31 24 3612724
address: Faculty of Management, Department GPE, Thomas van Aquinostraat 3, 6525 GD, Nijmegen.

MANUSCRIPT

1. INTRODUCTION

Using new digital technologies and media for self-organization, more and more citizen networks organize themselves voluntarily, especially around sustainability themes like renewable energy, sustainable resource use and preservation of neighborhood quality. In doing so, citizens create information networks for the purpose of sharing knowledge and monitoring environmental phenomena like air pollution, noise, or other non-visible but yet human-experienced social-environmental pressures, which are usually not accounted for in current institutionalized governance system, being considered mostly as 'environmental externalities'. It is this last form of bottom-up social network creation that we address in this paper: The use of geo-information about sustainability issues and the publication of 'live' or near-real-time map-based apps through open web-portals and social media networks. Through world wide web and social media, citizen groups increasingly have access to advanced technical know-how and low-cost sensing devices and software applications, allowing them to undertake complex activities previously undertaken only with highly expensive instruments and large information systems. The latter systems are typically built by governments, large public research institutes, or private industry.

Nowadays, low-cost sensors in the hands of many participants form similar (networked) approaches that can monitor and potentially manage environmental problems. Our objective with this study was to understand the origination and impact of two very early examples of 'networked geo-information tools' and the actor-network or human organization surrounding it. The main question addressed in this paper, is: How do the social-technical innovations that we call *citizen-sensor-networks* come about, and can these networks become a powerful agent in environmental planning and governance? The main question is studied by tracing two case studies in particular, and from those case studies reflecting, in the concluding section, upon the following research questions: How do citizen-sensor-networks come about and what effects do they have? How does the process of knowledge construction and collective sense-making work within citizen-sensor-networks? How can we understand this innovation of citizen-sensor-networks in terms of transformative potential in planning? Can citizen-sensor-networks become a powerful agent in environmental planning and governance, confronting government decision-makers more often?

A first version of this paper has been presented to the Association of European Planning Schools (AESOP) conference in Utrecht (Carton and Ache, 2014).

Article structure
After an overview of recent examples of citizen-sensor-networks and brief discussion of theoretical background stemming from Participatory GIS literature, this paper presents two cases from the Netherlands. Lending from ethnography, a narrative approach was followed, reconstructing the storyline in each case of how the particular *citizen-sensor-network* came about in its social environment, structured along the main interview topics that were central in our interview questionnaire. After the two case descriptions, we interpret our findings on the research questions, reflecting on aspects of social and technical networking like the interconnectedness of people, places, things and information, processes of empowerment, alterations of boundaries and knowledge politics. We conclude with a diagnosis to what extent the presented examples of 'networked GIS use' by local communities and their social-

technical organizations that we call citizen-sensor-networks, are expected to become influential agents in bringing about policy change in environmental planning.

Voluntary environmental monitoring

Recently, Stepenuck and Green (2015) have studied when and how instances of *volunteer environmental monitoring* leads to impacts on individual and community level. Their article gives a state of the art overview of research on this topic, with an extensive literature analysis and evaluation of advancements in this field. They note a lack of research dedicated to understanding to what extent, and how, attitudes and behavioral changes occur as a result of the participatory set-up of the analyzed environmental monitoring programs. They conclude that most research articles seem to focus on the *technical* rather than the *participatory* aspect of monitoring. For instance, Adams and Kanaroglou (2016) have studied how one can process and analyze real-time measurements in monitoring air pollution, but they do not study social or behavioral aspects among participants, or implications for planning or governance. An exception from this tendency to look at the technical side is the work of Lawrence (2006). She calls for research on questions around the experience and changing values of participants in voluntary (biological) monitoring and the conditions required for empowerment in relation to participatory environmental governance. In our research, coming from a background in participatory planning and GIS, we have not studied the literature on environmental monitoring in-depth as Stepenuck and Green (2015) have, but rather, we have looked at cases in planning practice where we have seen citizens taking initiatives to gather information. We have analyzed to what extent, and how, those citizen-initiated practices have influenced decision-making processes on the level of governance and collective action.

Empowerment of citizens accelerated by web 2.0 and social media developments
The empowering impact of the web infrastructure and social networking practices have been noticed in government discourses for some time. For example, the E-Government survey of the United Nations in 2010 formulates how the increasing use of 'Web 2.0' by citizens is bringing change to government decision-makers. They signal that Web 2.0 and social networking tools have empowered citizens to become more active in expressing their views on many issues, especially on issues concerning environment and health (and other areas of government policy). In words of the UN E-Government survey 2010 (section 5.1.1. p.84, italics added):

> "*Citizens use Web 2.0 and social networking tools to galvanize other like-minded citizens to share ideas and to develop collaborative approaches in tackling the issues that are important to them.* Politicians and other decision-makers need to tap into this wealth of information and knowledge in order to be more responsive to their constituents."

The UN E-Government survey in 2016 mentions the use of GIS data explicitly as one of the *potential transformers* in today's development (Executive Summary, p. 5-6, italics added):

> "Technological progress continues to drive innovative development interventions. The use of *Geographic Information System data* and Internet of Things (IoT) hold the potential to transform the way public policy is formulated, implemented and monitored."

Recent examples of citizen-sensor-networks in practice

We do not pretend to study all actual projects currently being undertaken in this direction, but we do see a number of projects that may fit in the category termed by the UN E-Government survey (2016) as holding transformative potential: We provide an overview of recent projects in the next section. These projects have in common their focus on monitoring urban environmental pressures, in particular air quality, together with citizens and ICT technology. Since these projects are very recent, academic literature on these projects is yet limited. These projects, in our view, signal a growing trend of experimenting with combinations of technology, citizens and collaboration for sensing urban qualities. In Appendix 1, Table A1, we have added an overview of these projects including links to websites where more information on each project can be found.

International examples:

In **Tokyo** (Japan) the web-based platform *Savecast* was established in 2011 as a 'volunteer-centred organization devoted to open citizen science for the environment,' after a severe earthquake and tsunami had struck Japan and had let to the meltdown of the Fukushima Nuclear Power Plant. Citizens formed Savecast in response to the unavailability of accurate and trustworthy information of the side of government, and quickly began monitoring, collecting, and openly sharing information on environmental radiation, with privately bought Geiger counters. The three founders, Sean Bonner, Pieter Franken and Joi Ito, went to the *Tokyo Hacker Space* for help and together they developed a working system within weeks, collaborating within a network of 20-25 people.

In **Barcelona** (Spain) the *Barcelona Fablab* has created the Smart Citizen Kit based on open source technology (Arduino board). The Smart Citizen Kit (SCK) is equipped with low-cost sensors measuring air quality, temperature, sound, humidity and light quantity. Follow-up research is currently being undertaken by the Fab Lab, directed by Tomas Diez, and connected to the Institute for advanced architecture of Catalonia, Barcelona.

Based in Barcelona as well, Mark Nieuwenhuijsen, of the Center for Research in Environmental Epidemiology, uses wearable sensors to measure and map air pollution with citizens while they travel through the city, using new wearable sensing devices (like a small sensor called TZO), in combination with people's smartphones.

The city of Barcelona is one of the European cities involved in the European *Citi-sense* project consortium (EU FP7 R&D project, 2012 – 2016) with 8 European cities: Besides Barcelona, Belgrade, Oslo, Ljubljana, Vienna, Edinburgh, Ostrava, Vitoria Gasteiz and Haifa join in this consortium. This consortium, led by Alena Bartonova at the Norwegian Institute for Air Research, has developed an overview of sensor platforms and has published a 'citizen's observatories toolbox' in 2016. In the toolbox are sensors, systems, platforms, apps and methods/guiding protocols for doing participatory air measurement campaigns.

In **London** (UK) the *Mapping for Change laboratory* of Muki Haklay has supported the citizen science project 'London Citizen Science 2014 - Network for Clean Air'. This project uses analogue NO_2 tubes to measure air quality. The process involves replacing tubes and lab analysis per tube on a monthly basis, and putting the results on a map. The tubes are known to give an accurate monthly average NO2 level. Citizen communities could sign up for being funded with 1000 UK pounds to undertake Air Quality Mapping projects, covering costs for purchasing the diffusion tubes, laboratory analysis to read the measurement from each tube, and map creation.

In **Chicago** (US) the *'Array of Things'* network started in September 2015 with dedicated sensor hardware and software developed by Argonne Lab scientists Charlie Catlett, Pete

Beckman and Rajesh Sankaran. The first sensor has been installed in August 2016. An original plan to use a Bluetooth modem (that would be installed in electrical BigBelly bins, which are present on nearly every street corner in the city center) was scrapped as citizens had raised concerns about their privacy. This Bluetooth signal would have helped to collect foot traffic data by detecting the number of smartphones moving through an area. Instead, a series of community meetings is held as 'Array of Things Civic Engagement' project since summer 2016, to discuss how the Internet of Things can benefit communities.

Recent examples in the Netherlands, focusing on air quality:
In **Eindhoven**, specially designed 'Air Boxes' are used to measure different types of fine dust, ultra- fine particles and ozone in the community project *Aireas*, an initiative started by Jean-Paul Close en Marco van Lochem. The boxes used in this project are in a higher-priced category than the 'small, low cost sensors for consumers' of the other Dutch projects, with professional air-measurement equipment produced especially for this project.
In **Amsterdam**, a similar project with the Barcelona Smart Citizen Kit has been carried out in 2014, with partners *Waag Society* and Amsterdam Smart City, funded by the Amsterdam Economic Board. One of the findings was, that the accuracy of the sensor, particularly the NO_2 indicator that was used in the pilot, would need improvement in measurement range and accuracy. But the citizens were very enthusiastic to measure themselves, on their own location. Currently, a follow-up project is in preparation for 2017.
In **Amersfoort**, a *Fablab* like Barcelona's Fablab, smaller in size, has been established by Harmen Zijp. Zijp has initiated a citizen science project since 2015 with a small subsidy from the city government to 'measure (effects of climate change) in the city'. Having experience in connecting technologies, art and making equipment on a self-help basis, they put together and placed Arduino-based sensors themselves, connected through a Long Range Low Power (Lora) network between the installed nodes across the city.
In **Nijmegen**, a consortium called *Smart Emission,* existing of the local Radboud University, city government, Geonovum (national knowledge institute on Geo-information), RIVM (national institute of health and environment), and small-medium-companies Intemo and CityGIS, have installed a low-cost sensor network in the city, together with citizens. The sensor Jose was designed and assembled for this purpose by Intemo. CityGIS and Geonovum developed a data infrastructure for harvesting, processing and calibrating the sensor dataflow in a manner that presents the resulting flow of Open Data in a standardized format. This technical development of sensor and data infrastructure was combined with a collaboration process with citizen-expert meetings and online forum.

The above initiatives have been including (a number of) citizens as core-feature of the project, or with conducting citizen science as core objective. The projects have in common their presentation of measured air quality data over the web, on Apps and Maps.

Empowering citizen-sensor-networks and Participatory GIS

The above is not an exhausting list, and developments are evolving rapidly with the current action in the emerging field of "Big Data". Kamel Boulo et all (2011) note the revolutionary dynamics surrounding citizen engagement and geolocated apps and maps:

> "Geolocation-aware mobile crowdsourcing apps [..] are leveraging the power of the Social Web ('Web 2.0') and smartphones to provide unprecedented levels of citizen engagement and participation in their local and wider communities. [..] These apps

and maps, freely available to the public online, are excellent examples of how crowd-enabled systems are revolutionising the way we tackle problems and allowing us to monitor and act upon almost anything, anywhere, in real-time."

Theory development about participatory sensing, geo-sensor networks or citizen-sensor-networks, is rooted in multiple disciplines, with Participatory GIS (PGIS) or Critical GIS as an important cornerstone. This field has been brought forward by multiple researchers publishing about these concepts, from an empirical point and from a theoretical point. Sheppard (2005) provides an overview of the evolution of this field, perceiving the emergence of critical GIS as an evolving research program, and as example of knowledge production in geography. Reviewing literature, Sheppard examined how technology, the geography of GIS research, and politics are shaping the research trajectory of critical GIS. 'Critical' here refers to the influence of social theory within (Anglo-American) geography, arguing that positivist or classic geography has put too much emphasis on economic and political rationality that bring forward a dominance of instrumental rationality over other forms of rational behavior, leading to an extreme commodification of society. Habermas' 'communicative rationality' is referred to as counter-perspective, arguing that an alternative form of rationality exists, characterized by how people communicate on an everyday basis as they seek to achieve *mutual understanding*.
The growing use of maps by marginalized groups to stand up for their rights, has also been recognized and notified (amongst others Pickles, 2004). In his groundbreaking 'Ground Truth', John Pickles (1995) criticized the taken-for-granted assumptions embedded in what he called the cartographic gaze and the Cartesian grid, and the social implications attached to them. In his update book (2004) Pickles critically examines the ongoing social implications of GIS technologies, and warns for the development of a governmental and economical complex of earth observation technology, paired with surveillance and government control, and a growing information industry, leading towards a 'surveillance society.' A growing countermovement coming from grassroots levels doing counter-mapping, with focus on information access and participation, empowerment and ethics, would become more needed in such a society. (Pickles seems to have grasped in 2004 how technology, government, economy and society would unfold, reflecting 12 years after he wrote this). Francis Harvey (2001) has extended the research into the social construction of GIS. He has studied the relationships in GIS socio-technical networks, using concepts from actor network theories. Harvey's research results show the importance of network relationships in the formation of GIS actor networks. Harvey recommends to jointly consider GIS technology with those who develop it, a feature that is being taken into account in this study. For descriptions of the emergence of PGIS as a social practice, see Craig et al., 2002; Corbett et al., 2006; Carton, 2007; amongst others.

Multiple researchers have discussed the emergence of Voluntary Geographic Information (VGI) (Goodchild, 2007; Elwood, 2010; Haklay, 2013, amongst others.) Elwood (2010) summarizes how the research of Participation GIS, 'Voluntary Geo-Information' or 'wikification of GIS' (or similar terms) is unfolding, drawing from a large body of geographical scholarship that is based on examining ways in which information technologies are embedded in changing social, political, and economic geographies. Before the term VGI was coined, Elwood studied the empowerment potential of GIS use with grassroots communities. In one case study in particular, she studied GIS use by a grassroots neighborhood association in south central Minneapolis (Elwood, 2002). Based on this case

study, she has proposed a framework for conceptualizing 'empowerment' in three distinct ways:
1. Distributive types of empowerment, about allocating material resources with redistribution being granted by the dominant to the less powerful actor;
2. Procedural empowerment, with the remark that once procedures have changed so that wishes and opinions of community groups are considered legitimate parts in urban policymaking, it is not so easy to undo and difficult for the state to revoke this legitimacy;
3. Capacity-building empowerment, framed as 'an expansion in the ability of citizens or communities to take action on their own behalf', refers to acquiring new skills and knowledge, but also to developing a certain politicized consciousness, an understanding of structural power inequities and how these inequities effect the citizens or communities.

We will use Sarah Elwood's distinction as a reference in diagnosing the type of empowerment we have found in the case studies that are described in this article. Furthermore, geographically referenced sensors, also called geo-sensor networks (Kooistra, Thessler and Bregt 2009) can offer a shared, bottom-up or grassroots-based image of environmental quality when placed in a network of information infrastructures. This image can be compared with the bodily experiences of local inhabitants. The knowledge process in planning can be opened-up for –sensed and bodily experienced– information, which offers citizens an opportunity to *'informationally' confront governing officials, based on their own intimate involvement in the information creation process.* As Gouveia et all (2004) have noted, the use of ICT enables public involvement and empowerment in monitoring activities, since it facilitates communication among stakeholders. This way, democratization of the knowledge process in monitoring becomes the next step for—improving legitimacy in—participatory planning. Participatory sensing or 'grassroots' sensing (Burke et all. 2006) is oriented at the *democratization of knowledge processes in planning*. Participation means more than just data collection; it can also impact professional research and planning. According to Burke et al:

> "Democratizing practice in both fields [urban planning and health] demands that professional knowledge not be compartmentalized from practical experience, that lay knowledge be considered alongside expert judgments, and that the incomplete models of the technically literate not be mistaken for the sum total of reality."
> Corburn (2004: 543)

2. METHODS

For this study, we have analyzed two case studies in the Netherlands. In the case studies the emergence and network operation of a particular geo-information instrument is analyzed in its social context; the Groningen earthquake monitor and the Airplane Noise Monitor Schiphol respectively. These cases were not selected at random, but picked for their innovative use of ICT and GIS maps, in combination with sensor-data and community initiative. As these two cases are older than the projects referred to in the previous section, it is possible to trace the impacts that the projects had 'later on'. In both cases, the narratives of how the particular monitoring network has evolved is traced and reconstructed, with special attention for the origination and institutionalization process of the tool in its social context. For each case study, four thematic categories of questions were being addressed to trace the origination,

'coming to live' and impact on the policy dialogue and governance issue being addressed (see full questionnaire in Appendix 2): How did the citizen sensor network come about? What was the strategy with the sensor network in the community and wider actor network? How was the sensor network presented to the public, how was it received, and what effects did it have later on? Reflection in hindsight: How do the respondents perceive the social/network 'value' of this instrument, what lessons can be drawn?

With these interview questions, we looked at the social and policy context involved in each citizen sensor network, and we looked at the web-tools ourselves. The research is limited in nature, based on document analysis and a limited set of interviews. The documents studied comprise of media articles, reports, internet websites, portals and online information about the web applications and the respective grassroots organizations. Eight interviews were held in spring 2014, with in each case the founder, a second co-worker in the early initiative, and two community members involved. Next to these interviews a handful conversations with civil servants were held, amongst others in a meeting on developments in (GIS) visualization on 24 April 2014 at the Ministry of Infrastructure and Environment, where intermediate results of case studies were presented. On the basis of these materials and dialogue with civil servants, the two narratives were constructed along the lines of the interview questionnaire. These were presented to an audience of planning researchers in July 2014 in Utrecht, at the AESOP conference (Carton and Ache, 2014). Updates of policy documents were studied and two additional interviews were held in 2015 to study the aftermath of the narrated cases.
We did not reconstruct how the tools were built technically, or how the man-machine interaction or graphic user-interface was perceived by users. Instead, we aimed at understanding the social dimension, describing its process of origination, of inventing the idea, forming a social network with citizens, combining information from sensors in an online mapping application, and relating this 'story of origination' to the impact these initiatives had on influencing national governmental policy. To clarify, we did not evaluate the quality of the project as such, but rather sought to trace and reconstruct the emerging network, trying to understand the actions and reactions of stakeholders and the process dynamics between them. The study is looking back at these initiatives in hindsight.

In the next sections, these narrated storylines are presented. They reflect the 'coming about' of the citizen-sensor-networks from an ethnographic perspective, focusing on the human relationships and the network relationships between people, tools and government. Next, the cases are compared and analyzed. Our analysis focuses on dimensions raised in the previous section, amongst others of how citizens confront governing officials with their generated information, what type of empowerment takes place, and what (counter-) forces and powers are at work in influencing the policy discourse, and ultimately, public policy.

3. CASE 1: MAPPING GAS EXTRACTION-INDUCED EARTHQUACKES

In 2009, the citizen initiative "Groninger Bodem Beweging" was founded. A reason for its foundation was the breakdown of trust in the national government (2014, personal quote, interview 1): "Trust is simply not there any longer. Until now, that is also justified." Earthquakes were causing more and more cracks and other damage to houses in the region around Loppersum, a village east of the city Groningen. A part of the local community was worried about the earthquakes in relation to their homes, house values, quality and safety of living, and in relation to the ongoing fossil fuel exploitation of the 'Slochteren gasbel',

officially known as the 'Groningen field'. The extraction of gas from this large gas field is operated by the company NAM, though the field is controlled by a separate partnership, the Groningen Maatschap. This partnership is owned 40% by the state (EBN) and 60% by NAM (owned 50:50 by Shell and ExxonMobil, two globally operating oil and gas extraction-and-distribution companies). The gas extraction and distribution of this Dutch gas field is a highly capital-intensive activity, with significant importance to the Dutch state treasury. Many households in the Netherlands are connected to the national gas infrastructure network for distributing the gas for purposes of heating, cooking and provision of hot water. Besides international contracts with foreign customers, and income for the state's treasury, this makes the exploitation of the field, a matter of national importance for the Dutch government.

How the tool came about
For a long time, NAM doubted openly whether the earthquakes had any relation with the gas exploitation. When the interdependency between gas extraction, soil subsidence and earthquakes became inevitably clear, the occurrence of earthquakes and especially its impact (meaning damage to houses and other constructions like churches, pipes, dikes), was said to be little, minor to other causes or marginal. If damage to houses was detected, citizens could file a complaint to the NAM and an expert would come and locally inspect if any financial compensation should be warranted. Often the conclusion of NAM-experts was that the NAM was not proven to be responsible, and thus did not need to take any compensating action. Local people felt as if they were not taken seriously by the NAM or by any governmental body, regarding this issue. Some people in the area were of the opinion that all the fuzz about 'earth vibrations' was exaggerated, others did not want to speak about it loudly, or wanted to prevent others to do so because it could cause housing values to decrease if the severity of the phenomenon of recurring earthquakes would become widely known.

Because the earthquakes (or 'earth vibrations') became more frequent and more severe, damage to houses became more serious. In 2009, the Groninger Soil Movement (in Dutch: Groninger Bodem Beweging, GBB) was founded as citizen initiative[1]. Part of its community activities was to make a clear and transparent overview of the earthquake activities. The maker of the Groninger Earthquake monitor is mr. Blanken, geo-information advisor of profession working mostly for governance bodies. Mr. Blanken envisaged that the citizen association would become much stronger if the GBB could provide oversight information and imagined a real-time web-based GIS map that showed all earthquakes and (reported or verified) damage. Blanken: "You would have an instant overview of the situation." In those days in 2009, there was no oversight of the situation, and when the press or researchers asked for data, the new citizen initiative could not provide this.

Building the public monitoring tool 'Groningen Bevingskaart'
As geo-information professional in programming with open source software Quantum GIS, Blanken built the tool, in Dutch called "Bevingskaart", in about two to three weeks. Because Blanken could do most work himself, in his available 'free time', the tool was inexpensive[2]. While the cracks and damage to houses are being recorded and photographed by the inhabitants themselves, the earthquakes are not traced by citizens with seismic data. For this,

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[1] Source: Werkgroep PR, Groninger Bodem Beweging, Factsheet Gaswinning, 2014.
[2] The hosting of the sites costs about 20 Euro a month, and the maintenance of the applications takes one or two days a month, in total.

Blanken used the seismologic information of the KNMI, the Royal Netherlands Meteorological Institute of the Dutch Ministry of Infrastructure and the Environment. KNMI is a national reference point and research institute focused on weather, climate, and seismology. The KNMI has a network of seismometers to measure seismic activity in and around the Netherlands. Its network consists of geophones in boreholes (up to 300m depth), accelerometers and 'broadband' seismometers (source: KNMI). Blanken noted that the KNMI did not provide a complete overview of all earthquakes and vibrations in the territory on its website, but just showed the last 30 earthquakes. It did have a report with older earthquakes, but this was a report in PDF, not in any suitable GIS-format. In order to build a complete dataset with all recorded earthquakes, Blanken wrote a semi-automated script to import the earthquake data from the annexes in the old PDF report into his own database, and published them on a web map, the "Bevingskaart". Furthermore, he programmed the automatic insertion of new earthquakes on the Bevingskaart[3]. Now, the monitoring tool made all data openly available, and interactively updated, creating a real-time public monitoring portal where both new and historic earthquakes, including "earth vibrations" with smaller values on the Richter scale, could be seen at one glance. The map provided a 'big picture', showing all heavy and light earthquakes registered over time.

Effect when the tool was launched and network formation practices
In hindsight, Blanken had not expected that the launch of the Bevingskaart would have the huge impact that it did. After he tweeted that the Bevingskaart was online on the internet in 2013, many people visited the website. And after two heavy earthquakes in February 2013, around the same time when this instrument became 'alive', the number of new citizens applying for membership of the GBB exploded. The province and the Safety region (Veiligheidsregio) came to visit GBB. Emergency services requested if the real-time data could be served as Open Data[4] as it was the only service that provided a complete dataset about earthquakes.
The association GBB, mostly run by volunteers, was growing and professionalizing further. On February 28th of 2013, a new board was installed. The municipality of Loppersum made an empty building available, offering office space to the GBB.

During 2013, the Groningen Earthquake Monitor instrument has got a network function in the region. Currently, the GBB has produced successor of the "Bevingskaart" in the more extensive, Open Data based "Gasbevingen portal" (gas vibration portal, available at http://opengis.eu/gasbevingen/, see Figure 1 and 2).

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[3] Technical detail: Blanken did so by importing a real-time geo-RSS feed from the KNMI website into his database, which is being updated every 15 minutes.
[4] In technical terms: the Open Data with a geographic reference that is referred to, is disclosed in the Netherlands through "Public Service on the Map" (in Dutch: PDOK) a public webservice. This webservice provides for real-time digital maps and geo-information sets that are being disclosed by Dutch governments as Open Data since 2011, in various geo-information formats.
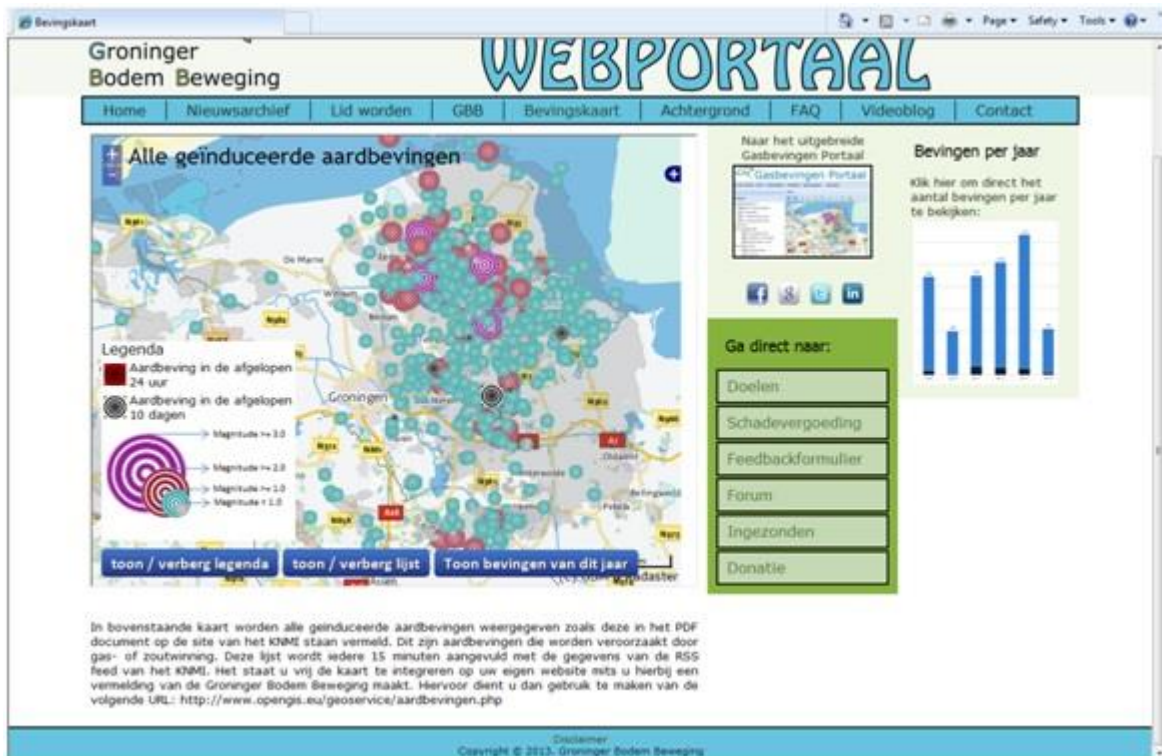
[Figure 1]

Figure 1. First tool called "Bevingskaart" at the website of GBB, with all earthquakes since 1986, data of the Groninger Bodem Beweging and the KNMI. Source: Vereniging Groninger Bodem Beweging (GBB).
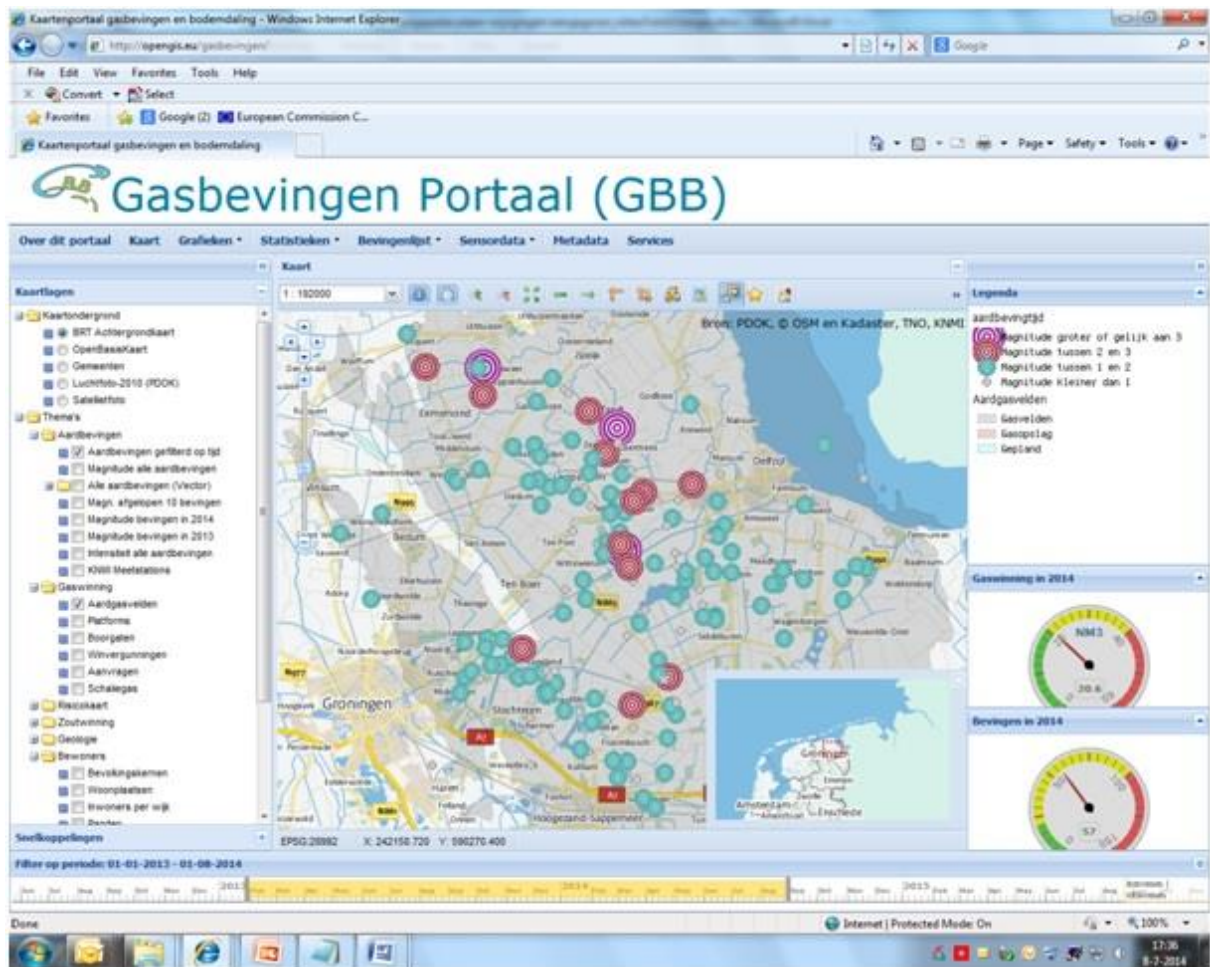
[Figure 2]

Figure 2. "Gasbevingen portaal" website with data of the Groninger Bodem Beweging, the KNMI and other sources. Source: Vereniging Groninger Bodem Beweging (GBB).

Developments after January 2014

In 2013, the conflict between North-East Groningen citizen movements and the Dutch state reached its peak so far. Interviewed citizens recall to journalists that they had never thought the national government would allow for earthquakes as high as 3.6 on the Richter Scale. In recent studies, earthquakes of 4.1 and 4.3 on the Richter Scale have been projected for the future. According to GBB, the gas extraction should be scaled back to half the current rate. GBB: "The current policy is "pappen en nathouden" (a Dutch expression for "muddling through". There is hardly any reduction in gas extraction, only some minor changes in drilling locations. This has to stop. We citizens are all in the same mess. And we cannot leave, because no one is going to buy our houses. So we are here to stay."

Meanwhile, the national government has done research in autumn of 2013, and has decided in January 2014 to change the gas extraction scheme and extract less gas in extraction sites in

Loppersum, but to increase gas extraction rates in other places. According to the Minister of Economic Affairs, international agreements and related national interests are of such an economic importance for the state, that slowing down gas extraction rates any further is not in the interest of the Netherlands as a whole (although implicitly admitting this would be beneficial for the region of North-East Groningen). Research in the effects of gas extraction will be intensified, and the process of damage reclamation will be further object of study and decision-making. For the region, the national government wants the damage caused by gas extraction limited as much as possible and reimbursement of remaining damage. The reimbursement process should be improved. Aside from that, the NAM needs to help building owners to strengthen houses against earthquake damage, for example by placing additional support beams.

In March 2014, TNO, a government institution for technical building research, has been commissioned by the NAM to place 200 sensors in buildings in North-East Groningen. The building sensors are part of a new *measuring and monitoring network* of the NAM. The objective of the NAM with the measurement results is to learn more about the strength of houses and buildings, and how (and what) buildings above the Groningen gas field could be made earthquake-proof. The sensors measure and record each earthquake and the effect it has on the building. During the interviews and analysis carried out as part of this research, in May 2014, the mayors of 15 Groningen municipalities have requested to place a sensor in their town hall and over 300 inhabitants of Northeast Groningen have signed up for placing a sensor at their home. The NAM has started to make its own earthquake map on its website. Recently, also the national institution KNMI has disclosed its seismic information in a kml-file that is accessible in Google Earth, so the Bevingskaart is not unique anymore. The Bevingskaart thus now has two similar 'sister websites'5, one of the government seismologic research institute KNMI and one of the gas exploitation firm NAM.

Ongoing controversy and critical report
Since the earthquakes are appearing more and more often, and increase in spatial scope in 20146, the controversy over the amount and rate of gas volumes extracted and the damaging effect on housing constructions and safety, is increasing more and more. The responsible minister of Economic Affairs has promised to commission several studies.

One study, executed by the independent Dutch Safety Board on February 18th, 2015, has investigated the treatment of issues related to safety of citizens during the decision-making process on gas extraction (1959-2014). One of its conclusions was that there is an inadequate level of accountability to, and communication with, the Groningen population.

> From the report (Dutch Safety Board 2015. English summary, p.7):
> "Until 2013, the national gas exploration company (NAM), the Ministry of Economic Affairs and the supervisory authority provided citizens with inadequate insight into the uncertainties relating to the earthquake issue. Communication focused primarily on the expected maximum earthquake intensity and the lighter material damage that could be caused by earthquakes. On account of this technocratic approach, insufficient consideration was given to the anxiety and safety concerns of the citizens of

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5 or 'competing websites', depending on someone's perspective on what may be called information-power-struggles.
6 on 30 September 2014 an earthquake reached the city-center of the town Groningen.

Groningen. This moreover precluded citizens and their MPs from acting as countervailing power."

Aftermath
In 2015, after consultation between various levels of governance, acknowledging the lack of trust of citizens in the national government and the lack of accountability identified by the Dutch Safety Board on state level or with the NAM, government plans have been made to establish a central 'information house' on earthquakes on the regional level, at the province of Groningen. This should ensure better information and communication flows in both bottom-up and top-down directions, and keep the information process closer to the place and community where the gas-extraction is taking place. Yet, still most important information flows seem to be managed or operated by the NAM, the most distrusted organization in the eyes of a large part of Groningen citizens.
Anno 2016 NAM continues to have clear opposite interests in relation to an organization like GBB with regard to balancing financial revenues of gas exploitation against unsafety of inhabitants and damage to houses and landscapes in the region. As the state government benefits as large shareholder from the financial revenues of gas exploitation next to multinational corporations Shell and ExxonMobil, the emotional feeling of being treated as 'neocolonial profit region' (in Dutch: neokoloniaal wingewest) remains a commonplace sentiment in the region of Groningen, according to interview respondents. The results of the political provincial elections in 2015 seem to support this view[7]. Citizen organization GBB keeps playing a role as grassroots movement that organizes countervailing power against the information hegemony of NAM and state institutions, regarding gas extraction and related human-induced earthquakes.

In hindsight: provisional conclusion in the case of gas-induced earthquakes
To conclude, we see a blend here of citizen information and use of government sensor data. We find it remarkable that lists of earthquakes had been produced previously by the seismic government authority KNMI, but this information had not been mapped. Citizen organization GBB was the first organization that structurally published earthquake information and related aspects like borehole locations on a publically available geographic map. When draft findings of this study were presented on a "visualization seminar" on April 24th 2014, the secretary-general of the ministry of Infrastructure and Environment, the primary government body ruling over public works and water management in the Netherlands, mr. Riedstra, reacted: "This is a nice item. We have to do something about this, the public government has to map the situation and have the information, otherwise citizens are going to do it themselves. Pictures are powerful messages, if you do not refute image information, than the picture becomes the truth." The response reveals a defensive attitude and perspective of the institution as ruling party. The response could also have been otherwise, with a tone-of-voice emphasizing the freedom of citizens to map their environment, and the beneficial aspects of having people engaged with the environmental quality of their immediate surroundings and daily habitat. Governments could facilitate, support and embrace the self-monitoring initiatives of citizens, as the enabling of citizens as 'citizen scientists' could be considered a virtue and voluntary monitoring networks an innovative, efficient and value-adding partner to

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[7] A remarkably large transformation in number of seats for political parties has taken place in 2015 in the province Groningen. Results of the 2015 political elections can be retrieved at
http://www.provinciegroningen.nl/actueel/dossiers/verkiezingen/uitslagen/ and
https://www.kiesraad.nl/nieuws/definitieve-uitslagen-provinciale-statenverkiezingen

government, in a society where education and democratization of knowledge are considered important public values.

4. CASE 2: MAPPING AIRPORT NOISE

The idea for a tool that would monitor airplane noise originated in 2003, in the city of Leiden. In that year, airport Schiphol, the main airport of the Netherlands near Amsterdam, opened the so-called "fifth runway," the 'Polderbaan'. Many reports had been published to analyze and deliberate the pros and cons of the planned airport expansion: The new runway would cause airplanes to make turns, take-off or land over densely populated areas, flying low over many towns and villages in the vicinity of the airport. The official hypothesis of the state government was, that the airport would increase economic activity and simultaneously reduce environmental and noise impacts. From the moment the fifth runway of Schiphol was taken in use, it rained complaints in the region. Many people experienced sleep disturbance during night times because of loud landings and take-offs during the night. The people felt betrayed by the government and Schiphol about the positive predictions of the noise impact of the fifth runway in official policy reports. There was a common feeling of *injustice*, and frustration about the lack of transparency of public information about noise burden for citizens.
As response to this societal unrest, the Dutch government installed the committee Eversdijk in 2003. This committee's assignment was to formulate recommendations about the measurement of airport noise, norm setting and noise regulations.

How the tool came about
The Schiphol airplane noise monitor was an idea of mr. Post, an ICT/internet pioneer and civil entrepreneur living in the city of Leiden. In 2003, Post owned an ICT firm that serves information on internet speed. One day he saw the Dutch minister responsible for Schiphol airport and the extension with the fifth runway speaking on television: "Noise is unmeasurable, so we have to calculate the noise." Post thought: "This must be complete nonsense. The state and Schiphol do not *want* to measure." He acquired information from noise experts, who answered that this statement was, from a technical or science perspective, nonsense. According to the same noise experts it is possible to measure noise although it is a very complex phenomenon.

Mr. Post considered it a challenge to proof that the minister talked nonsense, and that airplane noise can be measured. In his eyes, the public should get an open, insightful picture of the substantive noise load in the affected towns and villages. Somebody should debunk the *mystified* and on some points *false information* that was being spread around, in this controversial planning process. An 'independent picture of noise', measured on the ground, should shed some light on the real noise loads experienced by large amounts of people in North and South Holland.

Post managed to arrange for a small subsidy and, after an intensive search, bought 25 microphones in Germany for less than 200 Euro a piece. In his company, he had people who could build a matching ICT infrastructure to create a network with the microphones. Then he asked citizens to join his pilot project and allow for a microphone on their rooftop, connected to their own personal computer. This was a cost-effective part of the idea; the pilot project would make use of the existing ICT infrastructure and internet providers which the participants used at home. It was not difficult to find 25 volunteers who wanted to join the pilot project and place the microphones on their rooftops, cable-connected to their computer.

Since societal outrage about Schiphol and the airplane noise was at its peak, many people wanted to assist.

Tool design
As entrepreneur Post envisaged the desired result: a simple website, with a map and locations of microphones. Relatively low-cost microphones should be found somewhere, which could record and measure the noise, and local personal computers would communicate this data over the Internet to a central server. There, the overall data could be visualized on graphics related to each microphone spot on the map. The instrument would be public, on the Internet, and the noise would be measured. The tool would be made on the basis of want-to-know the measured level of airplane noise, but without an opinion about it. Just plain outcomes of measurements would be shown. The main objective for the tool was to provide independent, factual noise loads, measured on various locations in populated areas.

Post was convicted the monitor had to represent in *real-time* that people could check in the field themselves; there should be face validity. Another conviction was that the Instrument should be openly accessible through Internet, and the processing of data should be as transparent as possible. Post: *"Openness is in the genes of the internet."* In about *five mouse-clicks,* it should be possible to trace graphics and monthly report data back to its original measurement by individual sensors, in a language that lay-people can understand. This last principle was important, and distinguished the tool from the lengthy reports of the national government, where information in annexes usually was lengthy and not understandable for others than professional noise experts.

Architecture of monitoring system
One of the arguments why airplane noise could not be measured, stated by experts of Schiphol airport, was that other sources of noise could pollute the data. This argument, however, was circumvented by placing multiple sensors in triangles in the field. This way, triangulation calculations could be performed to calculate the speed of the incoming sound. This idea is very much like the old 'classical idea of triangulating in geodesy', e.g. calculating coordinates from field observations using a network of triangles. If the calculated speed of sound between measurement points would be high, say over 200 km/hour, then it would be clear that this noise would not come from other objects pertaining noise, like cars or scooters. Noise that travels at speeds higher than say 200 km/hour, usually is coming from an airplane. Later, this hypothesis turned out to work well and provided for validly represented airplane passages (see Figure 3).

With the network of microphones, the noise profile during the passage and the duration of noise per passage of an aircraft was measured. The passage's peak noise level [LAmax dB(A)], as well as the total amount of noise energy [SEL dB(A)] per passage, was derived from these measured noise profiles (see Table 1, further in the text). Also, for each monitoring point the number of airplane passages in 24 hours were counted, time-stamped and archived (see Figure 4).

During the construction of the microphones, it turned out to be difficult but not impossible to measure noise. Although noise turned out to be a complex phenomenon, and there were issues with accuracy of measurement, the overall pattern that was visualized by the tool, was remarkable. The many airplanes and the high level of accompanying noise loads at the 25 observation points was now visible, and was being recorded continuously. The objective of

open, independent, observed-and-measured, factual information about airplane noise was achieved.
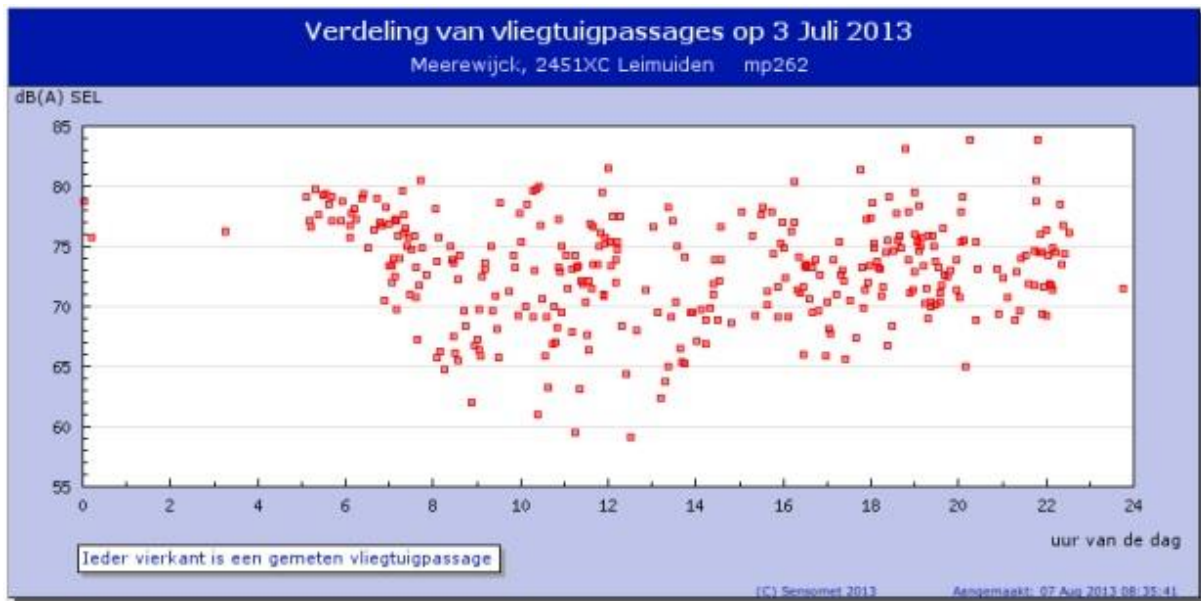

[Figure 3]

Figure 3. Noise measurements presented "live" through Internet. (source: Sensornet, 2014). www.sensornet.nl (Note: a picture of the original version of 2004 was not available)

Effect when the tool was launched
The first pilot only took half a year (2003 – 2004). The pilot was rounded off with a conference at the Waag Society in Amsterdam. For this conference, a wide set of invitations were sent to all stakeholders including the national government, citizen groups, and the committee Eversdijk. The outcome, a simple map on the internet with the sensors and their measurements represented on the map was presented. In the back of the room, one national delegate, a member of the committee Eversdijk expressed his criticism and doubts about the pilot study. He discredited the project members as "not being noise experts." After the conference, it appeared an advantage that the national's official committee member had been so critical so loudly. A local environmental group now said to mr. Post: "If he is so angry with you, then we believe in you."

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[Figure 4]

Figure 4. Graphics of Geluidsnet Schiphol for the place of Leimuiden on one day (24 hours). Every point is a measured airplane passage over de village, with the locally measured total noise energy in dB(A) SEL levels (left). Source: Werkgroep "Geluidshinder Kaag en Braassem Noord" (2013)

The environmental group wanted the project to continue. Other members stepped in that also wanted to 'keep this instrument in the air,' in what now had evolved into a polarized conflict between local groups and municipalities on one side, and the state government and Schiphol at the other side. Ten municipalities wanted to have an own information base about measured noise in their deliberation with the national level of government, in order to stand stronger. These municipalities didn't believe the minister anymore, and too, felt fouled by the succeeding committees, which had been putting them asleep with reassuring scenarios and reports. They sponsored a number of measurement points in their municipalities. In 2004-2005, agreements were signed and the pilot-study succeeded under the name of "Geluidsnet", a foundation funded by municipalities, citizen platforms and the professional 'Milieudienst West-Holland', an inspection institute. In the meantime, the Dutch Minister of Infrastructure and Environment gives the committee Eversdijk an explicit request to accelerate the formulation of an advice on the measurement of noise (Trouw, 2004). In parliament reference is made to the noise measurements. The earlier claim of the minister that airplane noise around Schiphol cannot be measured, is unmasked, and is no longer the line of argument.

Process of institutionalization of the instrument
In 2005, the Geluidsnet professionalized and registered as foundation. Contracts with ten municipalities were signed and the technical setup and architecture of the pilot project was improved. One of the improvements was the use of transponder information sent by the airplanes themselves. Now, also the plane itself was visualized on the map. In 2006, the re-launch in new format was widely received in the media, and covered by the national news on television on prime time. Since then, citizens can find the actual data on the Internet. The participating municipalities get monthly reports.

In the meantime, the social movement 'Platform Vlieghinder Regio Castricum' (PVRC) had a similar idea. One of its members had made an app8 that showed flight number information on a map using Google Earth. But they did not have noise measurements. Geluidsnet and PVRC made an agreement of the use of noise measurements from the Geluidsnet network and providing this continuous data flow to the platforms website application. Now the air flight information and the sensed noise measurements were both made visible in real-time in Google Earth, in a "live" 3D airplane monitor (see Figure 5 and 6).

On social media and in digital communities, particularly the kml-layer in Google Earth was well-shared and liked. Here, we see that the tool became an *information hub*, a "*social boundary object*" that collects noise produced by airplanes and translates it into standardized norms and values, and then serves as mediator in interactions among the citizens and between the citizen network and the government. Stakeholders adopted the tool because the actors *recognized their own perspective and noise perception* visualized on the internet through this monitoring instrument. The tool served different purposes, from checking and counting airplane passages to confronting national government with monthly reports of the manifested, recorded, noise patterns of airplanes.

More and more citizen initiatives start using the monitors, the Geluidsnet information and the Google Earth airplane noise monitor; for instance, platform "Oegstgeest ziet ze vliegen" and working group "Geluidshinder Kaag en Braassem Noord". Especially in the wider area, citizen movements emerge. The tool gives them *information power*. With this asset, the local interest groups gain respect with official institutions. For instance, the village Leimuiden has shown with the Geluidsnet overviews how much noise its citizens have to bear at night in 2013 (see Table 1). Geluidsnet itself became an 'established' airplane noise monitoring system. The microphone network was extended to 200 measurement points. The organization professionalized and started to measure noise in other projects as well.
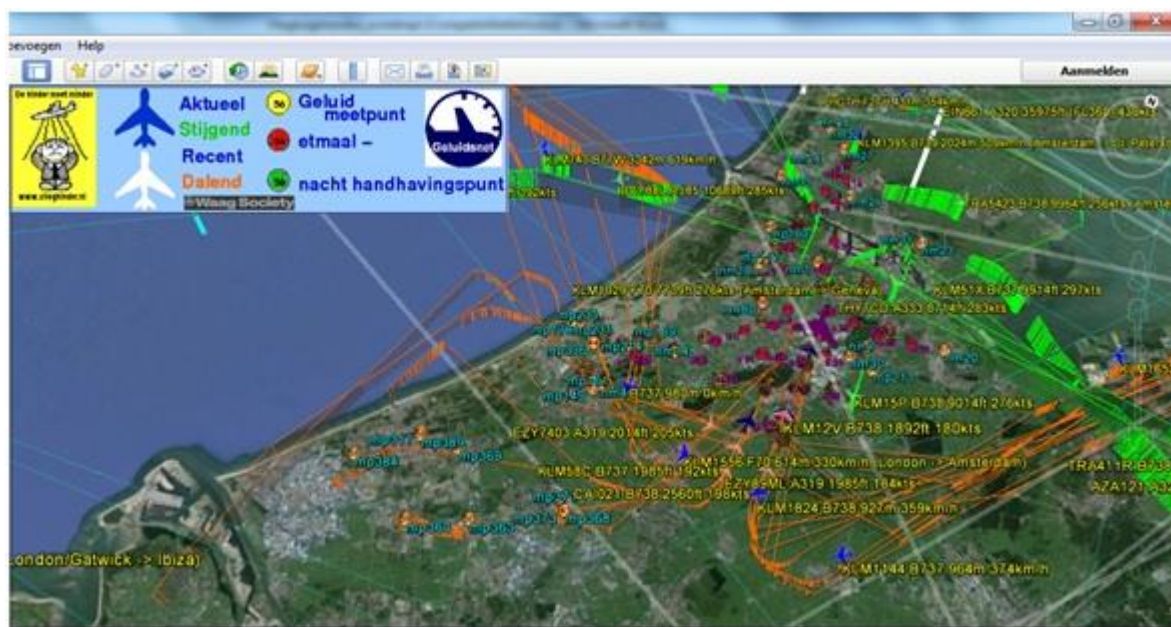
[Figure 5]

8 This app is publically available as kml layer

Figure 5. Real-time airplane monitor, including flight information per incoming and outgoing airplane.
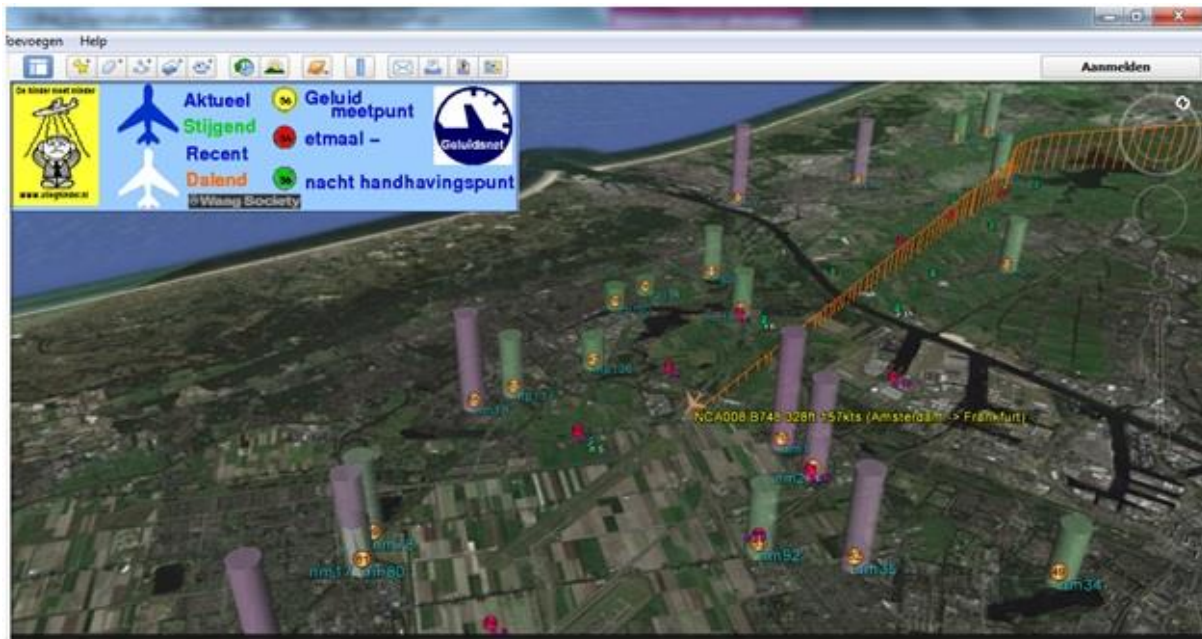
[Figure 6]

Figure 6. Combination of real-time noise measurements of Geluidsnet with real-time aircraft tracing in 3D in Google Earth. The vertically visualized sensor values are growing and shrinking according to measured noise level. Source: Platform Vlieghinder Regio Castricum (PVRC) and Geluidsnet (nowadays called Sensornet).

Table 1: Example of the reporting on the Internet by Geluidsnet about Schiphol aircraft noise

[table 1 here]

Tijdstip [time] 2013-07-01	Duur sec.	SEL dB(A)	LAmax dB(A)	[height] in m	Toestel [aircraft]
00:35:23	79	74.1	65.3	1112	Boeing 737-82R (B738) Pegasus Airlines
01:09:44	124	83.6	74.4	716	Boeing 747-4EVF (B744) Southern Air
01:48:07	127	76.4	64.4	1242	Boeing 737-8K2 (B738) Transavia Airlines C.V.
01:54:37	82	71.1	61.5	1127	Airbus A319-111 (A319)
02:34:02	111	79.8	68.6	949	Boeing 747-406F (B744) Martinair Holland N.V.
03:18:57	98	78.5	67.0	1318	Tie-up extracted from Country Sequence
03:28:40	96	75.6	65.1	1165	Boeing 737-8S3 (B738) Corendon Airlines
04:21:14	127	77.8	69.1	1193	Boeing 737-8K2 (B738) Transavia Airlines C.V.
04:25:19	93	72.1	59.5	2363	Boeing 767-38EER (B763) JetAirFly
04:29:05	111	75.8	64.5	1043	Boeing 737-8KN (B738) Corendon Dutch Airlines B.V.
05:07:25	99	77.0	65.9	1383	Boeing 737-8K2 (B738) Transavia Airlines C.V.
05:09:19	110	78.8	69.1	1264	Boeing 737-46J (B734) AirExplore
05:11:18	96	77.5	67.5	1191	Boeing 737-86N (B738) TUI Airlines Nederland B.V.
05:12:48	78	78.7	67.2	1351	Boeing 737-8K2 (B738) Transavia Airlines C.V.
05:14:07	83	77.1	66.4	1150	Boeing 737-8K5 (B738) TUI Airlines Nederland B.V.
05:15:40	91	78.7	68.2	1283	Boeing 737-8K2 (B738) Transavia Airlines C.V.
05:17:32	111	77.2	67.8	1257	Boeing 737-8EH (B738) Transavia Airlines C.V.
05:19:44	101	77.9	68.0	1198	Boeing 737-8EH (B738) Transavia Airlines C.V.
05:24:32	81	74.5	63.2	1275	Boeing 737-7K2 (B737) Transavia Airlines C.V.

Tijdstip [time] 2013-07-01	Duur sec.	SEL dB(A)	LAmax dB(A)	[height] in m	Toestel [aircraft]
05:27:47	109	77.0	65.4	1232	Boeing 737-8K2 (B738) Transavia Airlines C.V.
05:31:03	117	76.4	67.1	1259	Boeing 737-8K2 (B738) KLM Royal Dutch Airlines
05:34:02	123	78.1	67.3	1112	Boeing 737-8K5 (B738) TUI Airlines Nederland B.V.
05:43:00	71	78.7	69.2	1158	Boeing 737-86N (B738) TUI Airlines Nederland B.V.
05:50:14	106	76.3	64.7	1135	Boeing 737-85P (B738) Corendon Airlines

The committee Eversdijk was installed to advice on a new noise regulation in 2005. In December 2006, a new state committee is installed to deal with the Schiphol noise affairs, called the Alders Table. This committee gave advice about the balance between the development of Schiphol and the region, first on short term, then on middle-long term (2020). The Alders Table used a roundtable approach with representatives of stakeholder groups, in the Netherlands also called 'polder deliberation.' This Alders Table functioned for 9 years. In 2015, the committee is succeeded by the Omgevingsraad Schiphol, whose structure altered the communications and organization of the representatives, reducing the amount of deliberation structures. One thing that has changed with the Alders Table, is that the "omwonenden" (people living in the affected areas) are now considered a separate category. The platforms of citizens representing the people who complain about the noise levels and effects on sleep disturbance are being regarded as a relevant constituency in its own right.

Meanwhile, Schiphol copied the idea of the airplane noise monitor of mr. Post and started its own online version of their noise measurement system in 2005, NOMOS Online. This sensor network is owned and operated by Schiphol. The setup and graphic outlook is remarkably similar to the monitor of PVRC (see Figure 7). The Alderstafel had commissioned a study in order to make a technical description, characterization and comparison between the technological set-up, equipment, protocols and tools of Geluidsnet (renamed Sensornet), Nomos Online, and a third system, Luistervink, in 2012 in order to learn about the pros and cons of each system and to learn about and explain differences between them (Schiphol Alderstafel, 2012).

[figure 7 here]

Figure 7. Schiphol starts its own noise measurement network,
NOMOS Online (source picture: Schiphol Nederland BV., 2011).

Aftermath

Today, 2016, there are still two alternative sensor networks in operation around Schiphol airport. The two sensor networks, Geluidsnet and NOMOS Online, will both rely on regulation and resources in their continuation and maintenance. At the moment of writing this paper, it is not clear how this information-power-struggle will evolve. Reading from the mapping viewers, it seems that Geluidsnet, now called Sensornet, concentrates in and around the city of Leiden south of Schiphol airport, and explores new projects elsewhere like the airports Lelystad and Eindhoven and NATO air base Geilenkirchen in Germany, while Schiphol expands its NOMOS network in amount of sensor points and quantity of publicly disclosed, on-line information.

As for the communicative process between various actors with different interests united in what was called the 'Alders Table' since 2006, in 2015 renamed as Omgevingsraad Schiphol: With "Omwonenden," e.g. people living in the affected areas considered a separate category and constituency in its own right, citizen movements organized around airport noise have

gained status in 2016 in relation to 2003, the start of this case study. In 2016, in February the largest political party has proposed an amendment in the new aviation Law to limit the power of this roundtable institute9.

What the role, place and power of this roundtable institute will become in the future, remains to be seen. Speculating on possible future developments, with a decreased status of the governmentally institutionalized deliberation process, the citizen sensor network may regain its reputation and social status as non-governmental network with potential countervailing power. On the other hand, with a potentially weaker position (in number of sensors, quality of equipment, level of maintenance, 'newness') the citizen sensor network might also be marginalized in relation to the Schiphol sensor network NOMOS. Backed by capital inflow of the airport, NOMOS can become better, more extensive and more attractive. As the measurements in near locations seem to differ not much between the two systems, one could question why it would be necessary to uphold a second sensor network with its own maintenance costs, brought up by local governments and grassroots organizations. The ongoing lack of trust in the national government and Schiphol is currently the most important argument. On the positive side, a balance between the two competing sensor networks can keep parties 'sharp'; claims regarding the use or increase of the 'noise space' for Schiphol airport based on 'noise evidence' can remain to be cross-checked, both by the state and by the grassroots level.

Looking back in hindsight on the case of sensing Schiphol's airport noise
According to interview respondents, it was to be expected that Schiphol would 'take all the noise-space it would get', and that it would argue and lobby for freedom and borderless-ness of its noise space. In addition, the professional noise experts of Schiphol and the inspection service formed a "small world where people know each other well". They used to have a world of their own, where their statements were authoritative. Now, they were confronted by 'novices' who approached the complex phenomenon of noise in a 'lay-person with common sense' manner way.

The tool could spread fast with help of media attention, because it was well-timed. The pilot happened in a time when citizen protest groups that had lost trust in their national (and local) government. Multiple statements were made, in newspapers, on websites and in municipalities' communications, arguing that the 'national parties' had bluntly lied to its citizens, had been delaying decision-making by parking critical thought in 'committees', and by subtle sabotage of the existing way of calculating the noise.

Because many people in the region felt lied to and misled, there was huge support for such a protest activity/project, designed by a creative individual that courageously said "let's go measure the noise ourselves". The tool did provide the "objectivized measurements" that people missed. People now had an impartial piece of technology, that would put the noise phenomenon along a standardized rod and classify the levels as high or not. The values became less and less debated. The debate shifted towards how to solve the high noise levels and divide the noise burden evenly. Initiator Post, in hindsight: "You are transferring the discussion, coming out of the 'trenches'. That is beneficial." After the citizen-sensor-network demonstrated its success, Schiphol airport started a similar project of its own – but it has lost the information monopoly on aircraft noise information.

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9 Source: http://fd.nl/economie-politiek/1139117/vvd-eist-meer-politieke-zeggenschap-over-toekomst-schiphol

5. COMPARATIVE ANALYSIS AND CONCLUSIONS

Comparing the two case studies and the social dynamics around the Schiphol airplane monitor and the Groningen Earthquake Monitor, we can summarize the following observations to answer our research questions:

1. How do citizen-sensor-networks come about and what effects do they have?

We highlight here the most remarkable overlapping elements in both narrated case studies:
(1) In both cases, there is a remarkably strong *lack of trust* in the information provision by the national government, and public opposition against the attack on people's local quality of life. There is a manifest information interest regarding phenomena that affect the 'quality of life in the region' of larger groups of inhabitants in both cases. *How bad is it?"* is the core question that local people ask, they want to get an idea of proportionality. Local people want an 'objectivized' type of monitoring. Many inhabitants find each other in experiencing the same burden from the developments that become intrusive and affect the private livelihood.
(2) In both cases, *ICT professionals take the initiative* and develop the idea and build the tool. Both professionals have experience with Internet technologies in their work. In both cases, the pioneers have a "can do" mentality. They developed the tool with relatively low costs and unpaid work. Part of the success of the tools is that they have been developed by an unsuspected party in the eyes of community members, by someone from 'within' the region, being affected with the same 'externality burden'. The State government and the large companies Schiphol and NAM are conceived as the 'other'.
(3) Both tools are founded on principles of *openness of data,* on cumulating measurements and data over time, and on providing all information with others through a *publicly accessible website.* In both cases, the designers of the tools put effort in an *understandable format* to present the information on a dynamic map interface. Both designers criticize the national government for not providing understandable information in an easily accessible fashion, nor providing the source data.
(4) Because the tool is "live", with *near-real-time measuring and visualizing* the phenomena under observation, people can 'validate' by looking out of their window. What they find relevant and experience in daily live, 'on the ground', what touches people by hearing and feeling (noise intrusion, earth vibrations and earthquakes) in their homes, is now being represented in a monitoring tool 24/7. While citizens feel they are not taken seriously if they express what they experience directly ('human senses'), now they have a tool that shows factual evidence in units of analysis that are '*objectivized'*, like SEL dB(A), and that shows a *complete picture* of data.
(5) Both instruments had a *big media effect*: the airplane monitor came on the 20:00 hour news (prime-time in the Netherlands), the Bevingskaart came in the newspaper and was retweeted on Twitter, leading to new membership applications. Both instruments became institutionalized to some degree, because the sensor networks were embraced by the municipalities and resources were made available. In the case of Schiphol municipalities co-funded the foundation, 'buying-in' and formalizing the organization structure. In the case of Groningen, an office building was given free of charge.
(6) In both cases, the 'social boundary function' of the tool contributed considerably to its success. Many people could pick their own pieces of interest from the vast amount of information; the instrument became a kind of *information hub* in a network. As the hub

function grew, the importance of this node in the actor network also grew, as did ultimately the actor network itself.

The overlapping contextual circumstances of societal concern about specific environmental issues, lack of trust in the state government, the availability of ICT expertise, low-cost infrastructure to produce 'objectivized' data, and the media attention when the tools were launched, formed a fruitful social environment where the citizen-sensor-networks could come about and grow.

2. How does the process of knowledge construction and collective sense-making work within citizen-sensor-networks?

How does this process work in interactions between people, the citizen network, and the environmental phenomenon that is being monitored? An explanation of how and why the two citizen-sensor-networks worked in a social-relational sense and had an impact, relates to communication, subjectivity, social relations, and *digital selves*. While acknowledging the deep influence and meaning of language in our thinking and decision-making (Lakoff and Johnson 1980, 1999, Lakoff and Núñez 2000), we emphasize that the natural world has its own 'embodiment' and can be felt, sensed with other means besides the intermediary of spoken, written, graphic or 'digital' language. The worlds out there, communicate or interact their signals in forms like rhythms, smells, temperatures, light and darkness, and in "wholes" like landscapes, ecosystems and emotions. We make sense of these signals not only in terms of language, but also by directly sensing smells, tastes, feelings, and sounds ('human sensors'). In all their diversity, humans may interpret these signals differently. Sensors can bring a certain level of *inter-subjectively agreed standardization* in measuring parts of these phenomena. The technical process of calibrating and validating sensor instruments is designed to bring uniformity and rigor in the process of identifying and classifying the strength of signals. Combining sensors with citizens brings this measured, standardized information back to the community. A *networked feedback loop*[10] is constructed between multiple people: from sensing a phenomenon, identifying this as a burden to the people's health (for instance sleep disturbance caused by noise), through monitoring with technical sensor instruments at many places and interpreting the collected measurement data alongside multiple people their 'bodily' experiences, towards discussing among the people how they diagnose the situation individually and as a community, or as actor-coalitions within this community. In this process, where feedback loops are established among a network of people, a process we call *'collective sense-making'* emerges. The interpretation of intangible phenomena in this process is not a purely technical matter, nor a purely individualistic and subjective endeavor, but a combination of measuring, comparing with people's experiences, discussing and adapting while going through a *collaborative learning process*.

In this process the interpretation of measured values could be debated and negotiated among experts, citizens and government officials. Government can no longer say "it is not that bad", or deny the severity of the environmental burden, framing the affected community as "notorious complainers", implicitly stating that these voices do not need to be taken seriously. In the Groningen case one cannot say that the number of earthquakes is not that much. And in the Schiphol case public authorities have to acknowledge that there are (many) landings or take-offs that take place during the deep night hours, as can be seen in Table 1 (with 23 airplane passages between 1:00 and 6:00 at night). These numbers are now on the table of

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10 In Senge's (1990) interpretation of feedback loops.

governments, which gives them responsibility to have a viewpoint on whether this monitored situation is acceptable.

In our view, the *socio-technical construction of meaning in this way,* contributes to the persuasive value of a citizen sensor network[11]: by agreeing on classification systems and units of measurements, combined with validating outcomes of measurements by a multiplicity of citizens in terms of 'checking direct personal ('bodily') experience with the visualized information on the web portal,' and consequently interacting and discussing outcomes in a social network, leads to making a collective diagnosis of proportionality, scope and impacts regarding the monitored issue. However, it is also a critical dimension, related to subjectivities and social relations (Elwood, 2010, 353). In line with Elwood (2010, who refers to Schuurman, 2004 and Dodge & Kitchen, 2007), we could argue on the basis of the two cases, that not only the individual but the entire group of individuals increasingly 'know' their environment through the data – that is, replacing their direct bodily experiences and trusting in an extended 'digital' self. Certainly a point of (self-) critical reflection, as we continue working with citizen sensors in neighborhoods.

3. **How can we understand this innovation of citizen-sensor-networks in terms of transformative potential in planning?**

Looking back at these observations, it is now possible to draw some conclusions regarding the connection between web based mapping and information technology, participation and planning practices. To begin with, we see a *co-evolution between technological 'revolutions' on one hand and transformation of planning practices* on the other hand. However, while in the previous days the state was receptive and can be seen as an early adopter, nowadays the embracing actor and pioneer is found in other spheres in society. Very much in line with Elwood (2010, 351, emphasis deleted) arguing that a 'multivocal model' has become possible, in which 'citizens, states, and private entities are all involved in producing patchwork data'. Up to the point, that government actually was asking for the data managed by citizens and their sensor networks.

More specifically, internet and digital media technology has enabled new ways of information processing, with standardized schemes for directing and transforming continuous data flows, from diverse networked sources and towards diverse target groups and mass media. The interconnectedness of people, things and places by sensors, smartphones, social media and a working, decentralized and networked information and communication infrastructure binds pieces of information together and connects individuals with the crowd or cloud. This enables individuals to reach their audience, and empowers them to voluntarily gather and upload for them relevant pieces of information. The creative ideas and practices in the described cases were developed bottom-up from pro-active individuals, being receptive of the enabling power these technologies provide. Building monitoring and information infrastructures that produce data flows which are feeding back live information to the crowd, they ultimately formed communities around these networks of information. These communities have *gained independence* of (state) governments for their information base. This means a breakthrough

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[11] The persuasiveness of a citizen sensor network lies in the combined social and technical approach, with the potential of producing what is nowadays called 'citizen science,' combining science and citizenship (Irwin, 1995: 131) .

regarding the monopoly position of the state government in producing environmental information.

In order to assess 'transformative potential' in terms of empowerment of participants, we use Elwood's (2002) distinction between types of empowerment in Participatory GIS. We find that both cases show signs of *distributive empowerment*, because resources of local governments were shifted towards the citizen-sensor-networks, in terms of providing office space (Groningen) and financing the continuation (Schiphol). In the Schiphol case, there was also a *procedural empowerment*, as people living in the affected areas have been regarded as a relevant constituency in its own right since 2006. In the Groningen case we have not seen such a procedural empowerment. The last dimension, *capacity-building empowerment*, is less straightforward to assess. It refers to acquiring new skills and knowledge, developing a certain politicized consciousness, and expansion in the ability of citizens or communities to take action on their own behalf. The ability to take action in terms of interacting with state government seems to have increased, as the formed local working groups "Oegstgeest ziet ze vliegen" and "Geluidshinder Kaag en Braassem Noord" show in the Schiphol case. But this does not change the decision-making structure having control over the causes of the environmental pressures. In that sense, the decision-making structure has not changed. In the Groningen case, during the last political elections for the Province, the gas extractions and earthquakes were an important discussion item, and local political parties won considerable in comparison to the 'classic' parties with a representation in the national government. Thus, these local parties have gained strength in terms of council seats, political power, governing representatives, and voters base. As they have considered gas extraction a major elective item, these parties will probably support further capacity building in this field.

We note another type of capacity-building empowerment, which is the acquired skills and knowledge that enables people to develop more citizen-sensor-networks, elsewhere and on different issues. As presented in the background section, currently four initiatives have started in the Netherlands to measure air quality in cities with a type of citizen-sensor-network. As the Netherlands is a small country and the ICT and GIS community are tightly connected, knowledge and experience is exchanged easily. This may bring a significant increase in capacity-building empowerment for those people in these fields (ICT and GIS) who are involved in constructing citizen-sensor-networks. If the number of citizen-sensor-networks continues to grow, then more influence and transformative potential for planning and environmental governance could be expected.

4. **Can citizen-sensor-networks become a powerful agent in environmental planning and governance, confronting government decision-makers more often?**

The latter point can be linked to another aspect, related to alterations of boundaries (inside, outside groups) and knowledge politics (Elwood, 2010, 352). In the two case studies of this paper, the state government was first an inhibitory factor, which did not acknowledge local concerns. Eventually, this attitude of the state government *empowered its own countervailing forces*. Because of its passive attitude on the quality of living for many local citizens, and because of repeatedly announcing on television there is no real problem, the national government in fact evoked more worries 'on the ground'. People got angry by seeing and hearing politicians making public statements saying, in summary: "You do not need to worry, and you can sleep peacefully. I am certain that the company [Schiphol or NAM respectively] that is working for our general interests has it all under control." As a reaction to the denial of

problems and the downplaying of the severity of external effects like noise and earthquakes, individuals started the formation of a networked community raising objections to truth-claims made by the state government.

In our view, these Open Data web map applications ('vliegtuigmonitor Schiphol' and the 'Bevingskaart'), functioned as so-called *social boundary objects* (Star and Griesemer, 1989), which were first embraced by local communities and later also by municipalities and other local government bodies. This is a sign of reinforced 'bottom up planning'. The early adopters find in the tool a powerful information instrument that legitimates their position and point of view in dialogue with the national government, strengthening their negotiation power. The networked structure of getting data from many places and the open way of communicating these data in understandable and transparent format, providing feedback to the affected citizens, provides legitimacy. This legitimacy is an important factor in dealing with and reducing conflict over the environmental issues at stake. As Bodansky (1999, referred to by Van Vossole, 2012) has researched, legitimacy as the 'right to govern' always rests on the acceptance of rules and rule by affected communities. If hypotheses under policy regimes are proved untenable, responsible decision-makers have to take action and change the policy regime accordingly towards more legitimate planning strategies, in order to remain legitimized. In both case studies of this paper, the responsible Dutch minister eventually, after a period of delay or stagnation and intense political deliberations, took action. We conclude that both sensor projects seem to have contributed eventually to a process of gradual policy change. This result confirms the statement of Burke et all (2006) that participation can mean more than just data collection, that participatory processes potentially can impact professional planning and research. Therefore, we conclude that *citizen-sensor-networks, in the hands of many, form a powerful tool for informing planning processes and confronting government officials.*

With this conclusion, it can be expected that more citizen-sensor-networks may be initiated. The UN E-Government surveys mentioned earlier (2010, 2016) support this view, and the summarized overview of recent citizen-sensor-network projects (see background section and appendix 1) confirms this trend.

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APPENDIX 1. REFERENCES TO EXAMPLES OF CITIZEN-SENSOR-NETWORKS

City	Project and url project website	Lab and project leader	Project duration
	International		
Tokyo, Japan	1. **'Savecast'** volunteer organization and web platform http://fukushima-diary.com/2011/09/breaking-news-japanese-govs-trying-to-stop-citizen-measuring-radiation/ http://blog.safecast.org/about/ http://blog.safecast.org/videos/	Savecast office in Shibuya, Tokyo. Annual global Savecast conference	2011 – current
Barcelona (Spain)	2. '**Smart Citizen Kit**' (SCK) Fablab: http://spain-lab.net/project/smart-citizen-fab-lab-barcelonaiaachangar/ Smart Citizen Kit (SCK): https://smartcitizen.me/pages/sck	Fablab Barcelona (SCK)	2012 (crowdfunding) – current
Barcelona (Spain) and 7 other cities, a.o. Belgrade	3. '**Citi-Sense**' project consortium (EU FP7) http://www.citi-sense.eu/ http://co.citi-sense.eu/TheProject/Deliverables.aspx http://co.citi-sense.eu/CitizensObservatoriesToolbox/SensorsandSensorPlatforms/SensorPlatforms.aspx	Barcelona Citizens' Observatory (Citi-Sense)	2012 – 2016
London (UK)	4. '**London Citizen Science 2014 – Network for Clean Air**' http://mappingforchange.org.uk/projects/citizen-science-used-to-map-community-air-quality/ https://communitymaps.org.uk/	Mapping for Change laboratory	2014 – current
Chicago (USA)	5. '**Array of Things**' network https://arrayofthings.github.io/	Argonne National Lab and University of Chicago	2014 – current
	Netherlands		
Eindhoven (NL)	6. '**Aireas**' network organization http://www.aireas.com/	Aireas cooperative union	2013 – current
Amsterdam (NL)	7. '**Smart Citizen Kit**' project in Amsterdam (follow-up in 2016 by project 'Urban AirQ')	Amsterdam FabLab/ Smart	2014

	https://waag.org/en/project/smart-citizen-kit	Citizens Lab, Waag Society	
Amersfoort (NL)	8. '**Meet je stad**' (Measure your city) http://meetjestad.net/	Fablab Amersfoort	2015 – current
Nijmegen (NL)	9. '**Smart Emission'** http://www.smartemission.ruhosting.nl	Consortium, a.o. Radboud University and Municipality Nijmegen	2015 – current

Table A1, Appendix 1. Overview of recent projects in cities to measure urban air quality with citizens, using new sensor and web technology for monitoring and/or presenting monitoring information.

APPENDIX 2. INTERVIEW QUESTIONNAIRE

Interview questionnaire: Interview Guide used for conducting interviews in the case studies

Introduction:
- Context of this research.
- Encounter with the <u>community</u> and the <u>instrument</u> (geo-tool) through document/Internet analysis)

(In this questionnaire, the networked geo-tools 'Groninger Bevingskaart' and 'Vliegtuigmonitor' respectively will be referred to as *'the instrument'*)

Part 1. About the origination of the instrument

1. Why was the tool developed? What goals and intentions did you (or them, the developers) have?
2. What led to its initiation? Why did people start this project, as it is time-consuming, costs efforts, 'pioneering'
3. What roles should the instrument play in the social network: in the community –in the union, platform, regional community, political and media arenas? Did you have an idea about this on beforehand?
4. How did you think of building it; what methods and approaches did you envisage? -- did you have previous experience with those kinds of methods/approaches?

Part 2. Role of respondent and part in the community and view on wider actor network where the instrument originated

5. Can you tell me your part; how did you get involved in the community/company and what was your role in the development or adoption of the idea to develop/adopt the instrument?
6. Question about the actor-network constellation (community; network and spheres of interaction)
7. (extra question about mission and concrete practical problems if this was not already obvious from the desk study)

Part 3. As researchers we are particularly interested in how the tool came about and what effects it had (when it was launched, and later on)

8. Can you describe different stages in the process of developing/implementing the instrument?
9. Can you summarize the most important elements: What is the essential methodological engine/kernel (in an analytic/technical sense) on which the instrument is built, and did it work as expected?
10. How was the social response in your view, when the instrument was ready, in the wider community after launch? How did the launch take place? What was its effect?
11. Is it used, or taken notice of, of the 'target audience', or by key-players in the spatial planning debate?

12. Has the instrument been used in spatial planning and decision-making? Was there a new dynamic in the wider debate or planning process? Or what happened simultaneously?
13. Has it led to spin-off activities later on? What kind of?

Part 4. Reflection in hindsight.
14. How do you perceive the social/network 'value' of this instrument ?
15. Can you describe the difference between the networked-approach (through Internet) that was taken in developing and implementing this instrument, and older 'classical methods' like GIS, which did not have a network approach or network-focus?
16. What lessons did you draw? What lessons could you give us, as spatial researchers and educators in spatial planning?
17. Can you also give a stimulating advice and a warning or critical advice if these methods are explored more, by more people and (future) planners and communities and businesses?