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Participatory engineering for recovery in post-earthquake Haiti

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Participatory engineering has been called for after major catastrophes, yet is often bypassed due to countervailing implementation of 'quick fixes'. While immediate expert-driven solutions may be attractive, in the long-term they may be ineffective and inconsistent with the goals and capacities of local stakeholders. This article discusses the findings of National Science Foundation research by a team of three engineers and one social scientist who visited Haiti twice, four and seven months after the January 2010 earthquake, to investigate community participation in water and sanitation engineering processes in Léogâne. Methods included interviews with local inhabitants, water-sector actors, and government agencies; inspections of the engineering of the existing water and sanitation system; surveys of the affected population; and a participatory workshop to which numerous community-based organizations were invited. The research tests the potential for engineers to develop stakeholder-based participatory processes in a post-disaster context, which is hypothesized to produce better outcomes than traditional top-down authoritative planning processes. Focusing on the sanitation sector within a multi-stakeholder arena, the article analyzes the potential for various kinds of interactions amongst actors during unfolding decision-making processes at multiple scales, and assesses how each might contribute to better post-disaster engineering and ultimately more sustainable water and sanitation systems.

Keywords: participatory engineering; deliberation; post-disaster; sanitation; Haiti

Introduction

During the 12 January 2010 Haitian earthquake, it is estimated that 160,000+ people perished in collapsing buildings, 300,000 people received injuries to various degrees and 1.5 million were made homeless.[1] The country's water and sanitation infrastructure was inadequate prior to the earthquake, and afterwards was in need of urgent rehabilitation, along with other infrastructure systems. Engineering investigations and analyses were thus crucial to earthquake recovery efforts in Haiti, and teams of international engineers were amongst those sent immediately to assist. About US$2 billion was raised from individual donors immediately after the quake and about $9.9 billion was pledged by nations

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[1]The actual number of fatalities and injuries is not known exactly, with estimates ranging from 160,000 in Port-au-Prince in the most reliable academic study (Kolbe et al., "Mortality, Crime and Access") up to 316,000 total fatalities claimed by Haitian Prime Minister Jean-Max Bellerive one year after the earthquake.

at the Donors' Conference in New York City in late March of 2010 to aid in the emergency recovery and reconstruction effort. Because of the path-dependency of infrastructure investments, decisions about how the international community would invest these critical resources was therefore intimately linked to how millions of Haitians might eventually acquire water, remove wastes, power homes and businesses, and communicate for decades. In this kind of context, engineers are embedded in crucial decisions about technology selection, siting, design, and system placement; their decision-making process is thus key in determining whether, under the pressures of an emergency situation, engineering projects are able to produce ecologically, socially, and economically sustainable outcomes.

In actuality, the funds for reconstruction were slow to be disbursed because of title disputes over land, lack of coordination amongst a plethora of organizations, and the delayed formation of a new government due to elections. With poor progress already visible 6 months after the earthquake, more than half a million people remained without adequate shelter, potable water, and sanitation 2 years after the disaster, and up to 300,000 people three years after.[2] The slow speed of post-earthquake re-building in Haiti gives us pause to consider how participatory processes might have been implemented, and could have contributed to better outcomes even amidst the pressing demands of a post-disaster situation. We aim to show how our own testing of a process for local stakeholder involvement in decisions concerning water and sanitation systems offers insights that might make a difference in how engineering is practiced in post-disaster transition and recovery processes.[3] We want to suggest that the practice of 'participatory engineering' can not only improve the meeting of immediate needs by distributing infrastructure services more equitably among the population, but also might influence how sustainable the entire coupled human physical system will ultimately be.

This article is based on a National Science Foundation (NSF) Haiti-RAPID grant (ENG 1032184) designed to investigate various kinds of local participation in the transitional phase of infrastructure planning and rebuilding in Léogâne, Haiti, in the first four to eight months after the earthquake. The research team consisted of three engineers and one social scientist, along with Haitian consultants, translators, survey-takers and facilitators. We were not engaged as part of any discreet engineering project, nor were we tasked with providing any direct assistance. Rather, our first goal was to assess whether local stakeholders were being engaged in decisions regarding meeting post-earthquake water and sanitation needs, and if so, by whom. Secondly, we sought to demonstrate how social science perspectives on deliberative processes could be applied through stakeholder-based participatory methods (including surveys, interviews, and community-based workshops) informing engineering decision-making, even in this challenging post-disaster context. We hypothesized that through such methods community participation could inform water and sanitation infrastructure decisions, producing more sustainable outcomes than traditional top-down, expert-driven engineering work.

In developing a participatory model of engineering, we hope to show how more robust social interactions between various stakeholders (including engineers and foreign aid agencies as well as local citizens and government agencies) can improve outcomes in the

[2]IFRC, "Haiti"; Schuller, "Cholera and the Camps"; Katz, *The Big Truck That Went By*.

[3]In this paper we focus on issues related to sanitation systems only. Elsewhere we report findings from Léogâne on stakeholder preferences for centralized versus decentralized water systems (Galada et al., "Assessing Preferences, Haiti"); on issues of management and payment in the water and sanitation sector (Galada et al., "Attitudes Toward Post-earthquake Water and Sanitation Management, Haiti"); and on gender issues and women's water and sanitation needs (Sheller et al., "Gender, Disaster and Resilience").

dynamic environmental, political, and socio-economic constraints and opportunities of a post-disaster transition from emergency response to rebuilding. Participatory engineering can help to shape a social learning process that influences how effective, equitable and sustainable a particular socio-technical assemblage of sanitation will be. In the second section, we give an overview of the research context and the literature informing our approach to participatory engineering. In the third section, we present what we call the Haitian sanitation regime, and how it functioned in Léogâne, including centralized versus decentralized approaches to sanitation. The fourth section describes the multiple methods of the study, including survey, interviews and a stakeholder workshop. In the fifth section, we present our findings and discuss them more fully in the sixth section using both quantitative methods such as contingency tables and qualitative methods such as discursive analysis of interviews to create mental maps. The conclusion summarizes our findings and their implications for future participatory engineering.

Participatory engineering in the Haitian context

In this article we seek to identify some of the actors, practices, opportunities, and challenges faced in the processes for local stakeholder involvement in the (re)building of sanitation infrastructure in Léogâne. The city of Léogâne, situated about 30 kilometers west of Port-au-Prince, was at the epicenter of the 2010 earthquake and suffered a devastating loss of human life and extensive physical damage. The commune of Léogâne is distributed across a $\sim$114 square kilometers coastal plain bordered by mountains. It is divided into 13 administrative units known as sections. Approximately one-third of the commune's 300,000 people live in the three sections including and adjacent to its urban center, which is also the seat of local government. The coastal plain is underlain by a productive shallow unconfined aquifer that typically can be accessed at depths of 5–10 meters below the surface. At greater depths (25–30 meters) a confining layer separates the unconfined aquifer from a deeper confined one. Two rivers bisect the commune accompanied by a multitude of smaller tributaries, irrigation canals, and drainage ditches.

Stakeholder participation and citizen involvement have been widely embraced as ideal policies for a range of situations including water management, sustainable development, and green infrastructure.[4] We draw on that literature but focus especially on the role of citizen participation in engineering work associated with post-disaster recovery and rebuilding. The analysis presented here of participatory approaches to sanitation is just one aspect of post-earthquake engineering challenges, however it can contribute to better modeling and understanding of the complex dynamics involved in post-disaster situations. In particular, we explore how engineering is embedded in social processes and we illustrate how participatory processes can be mobilized to assist in making more sustainable connections not just between technical elements, but also between various stakeholders within a society including engineers, builders, managers, policy-makers, government officeholders, community-based organizations (CBOs) and citizens.

Participatory engineering is a crucial aspect of the imperative to 'build back better' after major catastrophes. Increasingly it is argued that the 'conventional top-down approach, by governments and large relief agencies coming in with large projects' is being rejected in

[4]Barreteau et al., "A Framework for Clarifying 'Participation'"; Creighton, *The Public Participation Handbook*; Daniell, *Co-Engineering and Participatory Water Management*.

favor of 'more involvement of local people' and community-driven projects.[5] The participation of local stakeholders in the conceptualization and design of infrastructure projects acknowledges the 'stake' that the intended beneficiaries have in the project's outcome, and increases the likelihood that these investments will directly address local needs and capacities.[6] Historically, and especially in developing world settings, infrastructure designed and implemented from the top-down has often failed and/or led to the marginalization and demoralization of the intended beneficiaries.[7] Recent studies of cases such as post-tsunami Aceh, Indonesia and Sri Lanka, or floods, landslides, and earthquakes in other Small Island Developing States (SIDS) have emphasized the importance of integration of local and indigenous knowledge with scientific knowledge as a crucial basis for disaster risk reduction, especially in the face of increased place-based vulnerability due to climate change and historical processes of marginalization.[8]

More democratic and participatory tools can enable 'co-construction of meaning and the sharing of information and understanding regarding a particular context that is to be managed', generating a deliberative process of 'social learning'.[9] Public deliberations encourage reflexivity about preferences and opinions, and clearer articulation of implicit values, beliefs, interests and concerns, which can inform engineering decisions.[10] Recent studies demonstrate that stakeholder-based participatory processes produce better outcomes than classical top-down authoritative planning processes.[11] In particular, a participatory process known in French as 'accompagnement' [accompanying] can help to support experiential learning about the issue at hand, about solutions to technical problems, and about other stakeholders, and can thus support the kind of collective learning or organizational learning that is necessary to participatory engineering.[12] It is especially crucial in the period of transition from emergency relief into post-disaster reconstruction that local community knowledge, skills, and capacity are incorporated into rebuilding processes, in order to support long-term sustainability goals that include social equity, the reduction of social vulnerability and hence future risk reduction.[13]

Emergency relief often entails quick fixes developed in a top-down or expert-driven process, which are seen as easier to implement in the immediate aftermath of a disaster.

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[5]Fountain, "Managing Disasters with Small Steps," D1.

[6]Daniell, *Co-Engineering and Participatory Water Management*.

[7]For example, the failure of soil and water conservation planning in the Chemoga watershed in rural Ethiopia was found to be due in large part to unwilling and disinterested participation of local farmers in an externally designed plan to construct structures widely perceived as ineffective on the ground (Bewket and Sterk, "Farmers' Participation in Soil and Water Conservation Activities"). See also Scott, *Seeing Like a State*; World Bank, "Analytical and Advisory Services."

[8]Mercer et al., "Reflections on Use of Participatory Research"; Mercer et al., "Integrating Indigenous and Scientific Knowledge Bases"; Leon et al., "Capacity Building Lessons"; Kelman et al., "Combining Different Knowledges."

[9]Alexander et al., "Water Needs Assessment"; Etienne et al., "ARDI"; Greenwood and Levin, *Introduction to Action Research*; Pahl-Wostl, "Towards Sustainability in the Water Sector"; Pahl-Wostl, "Participative and Stakeholder Based Policy Design Evaluation"; Pahl-Wostl, "A Conceptual Framework."

[10]Travaline et al., "Deliberative Methods of Public Participation," under review; Parkinson, *Deliberating in the Real World*; Wagenaar, *Meaning in Action*.

[11]Lynam et al., "A Review of Tools"; Reed, "Stakeholder Participation for Environmental Management"; Voinov and Brown, "Lessons for Successful Participatory Watershed Modeling"; Voinov and Bousquet, "Modeling with Stakeholders."

[12]Daré et al., *Repères méthodologiques pour la mise en oeuvre d'une démarche de modélisation d'accompagnement*; Etienne, "La modélisation d'accompagnement."

[13]Leon et al., "Capacity Building Lessons."

However, in the long term, these solutions are often ineffective and inconsistent with the goals and capacities of local stakeholders.[14] There remains a gap between recognizing the importance of stakeholder participation and how to actually implement it within engineering work contexts influenced by the countervailing post-disaster desire for implementation of quick fixes. Even though it is well known that a multi-stakeholder participatory process may yield better and more sustainable results, international aid for implementation of engineered reconstruction often fails to adhere to these principles with undesired side effects (dysfunctional systems, limited acceptability, unsustainability, falling into disrepair, etc.). Both governmental and non-governmental organizations (NGOs) may be overwhelmed by the scale of immediate needs after a disaster, and may lack the capacity to act in a coordinated fashion. Even when participatory processes are desired, it is not always self-evident what the most effective forms of participation will be. Efforts to involve local stakeholders often run into complex challenges which were apparent in post-earthquake Haiti, including difficulties in the co-ordination of dozens of NGOs with differing goals, processes and funding mechanisms; incapacitation of local and national government agencies also affected by the earthquake; worries about the undue influence of economic elites, political power-holders, and corrupt officials; and sometimes inappropriate actions being taken by foreign actors lacking cultural awareness (each of these factors was identified as a key problem by various actors in Léogâne).

Participatory initiatives are already recognized as a crucial part of existing plans for advancement of the water and sanitation sector in Haiti, including the current plans of DINEPA (*Direction Nationale de l'Eau Potable et de l'Assainissement*, the national authority in charge of water and sanitation). Formed in 2009, their action plan calls for a process described as 'social engineering' (not to be confused with the meaning of this term in English, which often has negative connotations):

> Social engineering [*l'ingénierie sociale*] . . . rests on community participation but goes even further in the degree to which it pushes the community to take ownership of the projects in their phases of conception, realization, and implementation. Significant results have already been obtained in Haiti by the application of the philosophy and methods encompassed by Social Engineering. The application of social engineering is equally a gauge in matters of sustainability and the realization of sustainable development.[15]

Yet in the immediacy of the post-earthquake situation, we observed few efforts being made (by DINEPA, by the local government, or by international NGOs) to engage local people in Léogâne with the rebuilding process. It was not until October 2011 that a new director of sanitation was appointed by DINEPA and two years after the earthquake a national sanitation plan was still under development. However, the announced principles of the plan will include equity; flexibility; information, education and communication; participation; subsidiarity; and incentives. The director, Edwige Petit, summarized the approach as 'encouraging the beneficiaries to construct their own infrastructure' and to manage it themselves with the collaboration of technical experts.[16] While in some respects this represents a consumer model for public services of water provision based on a neoliberal

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[14]Kennedy et al., "The Meaning of 'Build Back Better'"; Lawther, "Community Involvement in Post-disaster Reconstruction"; Leon et al., "Capacity Building Lessons."

[15]DINEPA, *Rapport Annuel 2009-2010*, 33.

[16]Petit, "Présentation Stratégie Assainissement de la Direction de l'Assainissement, DINEPA." DINEPA has also hired a consulting firm "to make technical guides and establish national standards with the collaboration of all actors on the spot."

approach to market allocation and management, it also combines elements of a citizen model of 'regulated solidarity and differential responsibility in the achievement of collective goals'.[17]

Many Haitian CBOs, such as INURED, GRET, and the Lambi Fund, also called for greater 'solidarity' with 'civil society', participation by local stakeholders in the rebuilding and planning process, and self-management of community assets via committees.[18] This study therefore sought to examine what actual practices were in terms of engineering post-earthquake sanitation systems in Léogâne, and what the potential might be for developing such participatory processes in the water/sanitation sector, even in the face of drastic post-earthquake needs. We set out to discover some of the baseline parameters for engaging in a stakeholder participatory process in the earthquake-affected region within and around the city of Léogâne. Our first goal was to characterize the differing perspectives, involved actors, and visions regarding water and sanitation infrastructure engineering in the region. Our second goal was to demonstrate and test a process by which the perspectives of a wide range of stakeholders could be elicited rapidly and not only incorporated into post-disaster decision-making processes, but also potentially built into longer-term 'solidarity' and 'accompanying' amongst the groups tasked with sanitation engineering. In doing so we hoped to explore the benefits and challenges of participatory engineering and to consider how it might support a social learning process that could inform post-disaster rebuilding planning and decision-making processes in the water and sanitation sector.

The Haitian sanitation regime

One of the major infrastructure challenges in post-earthquake Haiti was the immediate need for sanitation systems in a context where there were no existing sewage treatment facilities, no centralized collection systems, and a displaced population congregating in large camps throughout the urban and peri-urban area. As McFarlane, Desai and Graham observe, "There is a small but growing literature on urban informal sanitation, but we

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[17]Furlong, "The Dialectics of Equity," 1176; Swyngedouw, *Social Power and the Urbanization of Water*; Bakker et al., "Governance Failure."

[18]The Lambi Fund calls for a "Policy Advocacy program to express voice of the Haitian people in rebuilding Haiti. As foreign corporations and governments jockey for rebuilding contracts, the Haitian voice has been neglected. Haitians must be involved in all facets of rebuilding" (Lambi Fund, *6 Months Later*). INURED concludes that international efforts to "save" Haiti,

> have largely failed because of the fundamental lack of people's voices, resiliency, and solidarity into development plans. [. . .] Failure to connect with and capitalize on people's solidarity and ability to organize will result in the failure to connect the nation to the larger rebuilding process; a process not simply of rebuilding infrastructure but of rebuilding Haitian society. (INURED, *Voices from the Shanties*, 20)

GRET, a French NGO with a long-term Haitian staff working specifically in the water sector, also concludes that

> Civil society must be in a position to be involved in the reconstruction of the country. In each neighborhood, there should be support for legitimate grassroots organizations and for the water committees [komite dlo] so that they can have a say in the matter both around current debates and future actions; and there should be assistance for this local civil society to think and act through [their involvement in] local development projects. (GRET et al., *Rapport de diagnostic*, 11)

See also Schuller, *Unstable Foundations*, 2010.

lack an understanding of how residents get access to, maintain, experience, and politicize sanitation on a day-to-day basis.[19] Haiti is the only country in which access to improved sanitation has significantly decreased over the past decade as indicated by the sanitation report by the World Health Organization/UNICEF Joint Monitoring Programme for Water Supply and Sanitation. The percentage of the urban population with access to sanitation fell from 44% in 1990 to only 24% in 2008, and in rural areas from 19% to only 10%.[20] Until 2009 there was no governmental organization with the responsibility to improve sanitation.[21]

> The country's existing water regulatory agencies do not account for sanitation, resulting in the absence of any sewage systems as well as isolated and inadequate wastewater systems, no control of hospital waste and according to the Pan-American Health Organization, bad excreta disposal practices, which are polluting almost all 18 water sources supplying Port-au-Prince. (PAHO, WHO)[22]

The immediate post-earthquake response, led especially by foreign NGOs, involved the building of thousands of shallow latrines across many camps.[23] While this addressed the most pressing hygiene needs, it was not implemented with an eye toward any long-term or even medium-term solution to the sanitation crisis. On the ground, even well-meaning efforts appeared to be uncoordinated, often failing, and sometimes chaotic.[24] We identified numerous foreign NGOs working in the area, some with a presence pre-dating the earthquake (e.g. Save the Children, Oxfam, and Care) and others who arrived after the earthquake (e.g. Hands on Disaster Response [later re-named All Hands Disaster Response], Samaritan's Purse, and the Spanish Red Cross). These were organized into the UN's 'cluster system' to coordinate relief and rebuilding activities.[25] Meetings of the local water, sanitation and hygiene (WASH) cluster were held at the local encampment of the United Nations Stabilization Mission in Haiti (MINUSTAH), where, we noted, armed

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[19] McFarlane, C., Desai, R. and Graham. S. "Informal Urban Sanitation: Everyday Life, Poverty, and Comparison", Annals of the Association of American Geographers, 104: 5 (2014), p. 989.

[20] WHO and UNICEF, "Joint Monitoring Programme," 15.

[21] Varma et al., "Woch nan Soley."

[22] McLeod, *Haiti*, 11. Following the earthquake and the construction of thousands of latrines by NGOs (11,500 in the first six months), an open pit landfill at a site near Port-au-Prince known as Truitier was used to empty 24,000 gallons of untreated sewage each day (Troutman, "Sanitation Efforts"). This was eventually closed, and a site known as Morne à Cabrit was used until it too was temporarily closed in August 2011. Finally, in late October 2011 this site was re-opened with UNICEF funding for 3 months to utilize 16 trucks and 54 staff to "desludge" latrines in the Port-au-Prince area (DINEPA, "Notes de la Reunion du Sous-Cluster de l'Assainissement"). As is evident, these are on-the-fly plans, developed month to month, and inadequate to the population size.

[23] Initial estimates six months after the earthquake show, for example, 2,671 latrines constructed by Red Cross Red Crescent; 1,373 build by Oxfam; 1,072 built by HAVEN; and around 900 each built by Save the Children, ACTED and ACF (IFRC, "Haiti").

[24] A telling example is the introduction of cholera into Haiti via the failed sanitation system of a United Nations base housing soldiers from Nepal. To date more than 704,000 people have been infected with cholera and more than 8,563 have died, according to the Centers for Disease Control and Prevention.

[25] The cluster system was created by a 2005 UN review following the 2004 Indian Ocean earthquake and tsunami, when it was realized that better coordination was needed amongst the "second tsunami" of disaster responders from around the world. First officially practiced in 2009, the cluster system is facilitated by the United Nations Office of Coordination and Humanitarian Affairs, and includes 12 clusters active in Haiti, such as Early Response, Shelter, and WASH.

guards and passport checks made it quite difficult for Haitians to participate.[26] In addition to international NGOs, we also discovered a sector of CBOs throughout Léogâne, part of the wave of popular organizations that emerged in the aftermath of Haiti's democratic election mobilization in 1996 representing what are sometimes called 'communité de base', meaning the social base and grassroots sector. There was also a significant presence of Haitian diaspora or transnationals in Léogâne, who in some cases owned property in the area and participated in recovery activities

A crucial aspect that we will explore here is how these various actors thought about, engaged in, and took ad hoc or improvised engineering actions that influenced the post-disaster implementation of sanitation systems. Throughout most of the industrial and post-industrial world a transition took place from decentralized to centralized sanitation systems in the late nineteenth to early twentieth centuries. A classic example of such a transition pathway is provided by Geels in his description of the gradual transition from cesspools to sewers in the Netherlands. He identifies the involvement of a range of actors (e.g. private households, city councils, hygienist doctors, waste disposal companies); a complex interaction between technology, markets, expert knowledge, public regulation, public opinion, and electoral politics; and adjustments in rules (e.g. knowledge about disease, perceptions about waste, perceptions about the role of public authorities, ideologies of cleanliness). Overall changes in the 'regime' were influenced by contestation and struggle between social groups, but also by broader developments such as democratization, urbanization, political ideology and macro-economic growth.[27] Geels' analysis suggests the complexity of transformations in sanitation engineering practices, a reminder that engineering new sanitation infrastructure is not a simple matter of expert knowledge or technological advancement on its own.

More specifically, engineers today are well aware that centralized and decentralized approaches apply different spatial strategies, but also differ in terms of their associated costs, operation and management, latent vulnerability to hazards, and expandability potential. Although the benefits of centralized sanitation systems are well known (e.g. improved public health, environmental protection, streamlined operations, economy of scale, reliability), they are not always feasible or appropriate in developing world settings, where financing or other capital funds may not be readily available so the start-up costs to build a centralized sanitation system can be prohibitively high. In addition, if an economically stable user base is not present, the revenues needed to pay for recurring operation and maintenance costs cannot be guaranteed, a situation that can lead to gradually deteriorating system performance. Since damage to critical nodes or segments can compromise the functionality of the entire system, centralized infrastructure can also be vulnerable to environmental hazards such as earthquakes or hurricanes. In such contexts, there has been growing interest by infrastructure experts, engineers, and international lending institutions in decentralized sanitation approaches.[28]

Compared to centralized sanitation systems, decentralized systems can have lower maintenance costs, require fewer upgrades, and can be installed in a phased and incremental

[26]We continued to monitor meeting notes through the WASH cluster website for more than a year. Other international actors in the area included USAID, the World Bank, International Monetary Fund, Inter-American Development Bank and other government organizations sent by individual countries such as Japan, Spain, Brazil, and Venezuela. All of these organizations were trying to coordinate their activities either via the Interim Haiti Recovery Commission, or working directly with the Haitian national government and local government bodies.

[27]Geels, "The Hygiene Transition."

[28]Wilderer and Schreff, "Decentralized and Centralized Wastewater Management."

fashion that allows them to be built in response to actual demand. Decentralized sanitation is accomplished formally using latrines, septic tanks, and disposal fields, along with other dry systems. Decentralized systems have independent components, making the system less vulnerable to systemic failures, hazards, and extreme environmental events.[29] However, at a very rudimentary level, decentralized sanitation also includes a series of informal disposal options (e.g. open air defecation) that are problematic from a public health perspective. Additionally, expansion of a decentralized system can be easier because it is not contingent upon availability of treatment plant capacity, as is necessary in expansions to centralized systems. A high level of service, however, is contingent upon the consistent availability of human capital to operate and manage the entire decentralized network.[30] As DINEPA's new sanitation director noted, she has 'reservations about composting at the individual or family level; [you] could not ask for people to be their own 'bayakou', this practice is too risky. Collective composting . . . will preferably be encouraged'.[31]

It remains an open research question whether a centralized or decentralized sanitation system (as well as potable water system), or perhaps some combination thereof, would be the most sustainable solution for 'building back better' in post-earthquake Haiti. It was not obvious to the research team whether, in this post-disaster situation, that simply importing a centralized sanitation infrastructure model represented the most appropriate local solution. At the same time, the extent to which decentralized, 'green' approaches would be publically accepted was unknown. As one American aid worker noted on her blog:

> Do not go to a place thinking you have all the answers and that you know how to fix their problems. It is important that we learn how to work with what is there and with what Haitian people are willing to accept. They have a set of values that need to be respected.
>
> For example, considering the lack of sanitation infrastructure, composting toilets in our building make a great deal more sense than Western-style flushing toilets do. However, without a reliable system that will provide service to these toilets – a factor that is far beyond our control – they would be rendered practically useless as owners will not want to maintain them, on top of their other responsibilities. Would you want to maintain the septic system in your house? Also, composting or biodigesting toilets need to be designed to have the visual appearance of being progressive and modern. They may not currently have it, but Haitians know what is out there in the world. Why should they be satisfied with a virtual hole in the ground when they know there is something much better?[32]

With this backdrop, sustainable water and sanitation decisions need to incorporate both technical expertise *and* local stakeholder perspectives. The question, though, is how best to practice participatory engineering in a post-disaster context, with all of its complexities, contingencies, and competing pressures. What methods should be used for citizen deliberation? Over what time frame? In relation to what scale of planning? As McFarlane, Desai and Graham argue, "sanitation is sociopolitically differentiated within community, neighborhood, or city and the ways in which articulations of technology, landscape, and politics can lead to different sanitation experiences.[33] We argue that participatory processes

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[29] Venhuizen, "Decentralized Wastewater Management."

[30] Mintz et al., "Not Just a Drop in the Bucket"; Wolff and Gleick, "The Soft Path for Water."

[31] Petit, "Présentation Stratégie Assainissement de la Direction de l'Assainissement, DINEPA". The Haitian *Kreyól* term 'bayakou' refers to men who empty pit latrines and cesspools by entering into them and digging them out by hand; it is a highly stigmatized occupation.

[32] Weissman, "Bienvenue a Haiti!"

[33] McFarlane, C., Desai, R. and Graham. S. "Informal Urban Sanitation: Everyday Life, Poverty, and Comparison", Annals of the Association of American Geographers, 104: 5 (2014), p. 993.

can be implemented wherever and whenever engineers work, and that through a participatory model of engineering, more robust social interactions can emerge between the kinds of stakeholders we found in Léogâne (including CBOs and earthquake-affected people; foreign aid agencies, engineers, and researchers; local government representatives and national government agencies). While always improvisational, uncertain, and evolving, we argue that broad stakeholder participation in sanitation (and water) engineering will ultimately shape a social learning process that determines whether a particular socio-technical assemblage will be ecologically, socially and economically sustainable or not.

Research methods

The overall methodology involved a number of different research activities intended to survey, rapidly and comprehensively, the perspectives of a wide range of stakeholders using different types of methods. The full research team included four professors (three engineers and one social scientist), three community planners from Léogâne, six trained Haitian enumerators, and five trained Haitian workshop facilitators. All field work was performed over a four month period, during two, one-week trips by the research team to Léogâne (May–June and July–August of 2010), plus additional phone interviews during this period. This included (1) a paper survey implemented on the streets of Léogâne by *Kreyól*-speaking enumerators ($n = 171$); (2) a series of interviews conducted by an engineer and a sociologist (semi-structured, $n = 19$, and in-depth open-ended, $n = 6$) as well as more general participant observations made at two different WASH cluster meetings; and (3) a full-day participatory workshop attended by 76 local community leaders during the second trip. Details on only those aspects of the full methodology that are relevant to the research presented in this paper are further elaborated below.

Our team of engineers also first assessed the state of sanitation in Léogâne, finding no sewage collection system nor any centralized treatment system. Rather, current sanitation practices were grouped into three general categories: septic and flush toilet systems, pit latrines, and open field disposal. All three practices are completely decentralized approaches. It was also observed that sanitation infrastructure reflected the socio-economic structure; those who can afford to live in Léogâne's downtown tend to have reasonably adequate set ups with flush toilets and attached septic systems, while those at the opposite end of the socio-economic ladder utilize makeshift latrines or open field disposal. We examine these social patterns in more detail in the results section below.

During the first trip, the researchers trained six Haitian university students who administered a paper survey in *Kreyól* throughout the Léogâne region. The survey consisted of 42 questions about pre- and post-earthquake water and sanitation conditions, practices, and problems. The survey included the 'core questions' used by UNICEF and WHO for quantifying the percentage of a population that has reasonable access to water and sanitation, and those at risk to flooding. A purposive sample of 171 respondents was obtained from the city, urban peripheral and outlying areas of Léogâne. We were seeking earthquake-affected populations, both male and female, distributed across these differing geographic zones. Table 1 lists the age, gender, employment status, and location of the participant's home before the earthquake for all survey respondents. Approximately 60% of participants were between the ages of 19 and 50, and approximately 25% were over 50 years old. Males and females were about equally represented (49.7% and 44.8%, respectively). While 65.2% of participants considered themselves to be 'unemployed', some were self-employed and/or worked in agriculture. A majority of participants (52.5%) were from outlying areas of the city. About one-third (31.6%) of the respondents were living at the same location and in

Table 1. Demographics of survey participants.

	Number of respondents	Percentage of respondents
Age group		
18 years and under	3	1.7
19–30 years	54	29.8
31–50 years	54	29.8
51 years and over	46	25.4
Did not answer	24	13.3
Gender		
Male	90	49.7
Female	81	44.8
Did not answer	10	5.5
Employment		
Employed	53	29.3
Unemployed	118	65.2
Did not answer	10	5.5
Location		
City center	58	32.0
City periphery	17	9.4
Outlying areas	95	52.5
Did not answer	10	5.5

the same house as before the earthquake; 22.8% were living at the same location but in a new or reconstructed house; 25.1% were living in temporary camps. The remainder was living with friends, relatives, or in another location. Contingency plots were developed breaking down the results based on gender, geographic origin, and employment status, and statistically tested.

Interviews were carried out during both trips, and also by telephone from the USA. The 19 semi-structured interviews were also a purposive sample, seeking current residents of Léogâne, expatriate former residents of Léogâne, and NGO and government representatives working in the area. Unlike the surveys, the interviews were designed to gain more in depth insights into respondents' knowledge of, access to, and opinion about various water and sanitation systems; as well as their views of the responsibilities of various actors involved in the WASH sector. These interviews were conducted by one or two team members (with a translator when required) and digitally recorded. A standard set of discussion points and follow up questions were posed both to elaborate participants' answers and to probe for the reasons why particular statements or proposals were made. Each interview lasted approximately 45 minutes. The recorded interviews were transcribed in English and coded for analysis with ATLAS.ti (Berlin, Germany), a software package that allows for the qualitative analysis of large bodies of data. This was used to identify broad patterns of types of responses, common themes, actors mentioned, linkages between problems identified and solutions suggested, and to compare differing groups of interviewees. A separate protocol was also used to check for the presence or absence of certain basic ideas and concepts. This protocol used contingency tables to identify trends similar to those in the structured surveys: by age, gender, geographic origin, and employment status.

During the second trip in July–August 2010, the research team conducted a full-day participatory workshop, which added an even deeper level of deliberative participation, communication amongst stakeholders, and opportunities for participants to reflect on the process. The team trained 10 Haitian facilitators who conducted the entire workshop in

Table 2. Demographic information of workshop participants.

Location			Age					Gender		
City	Plain	Hill	18–20	20–29	30–39	40–49	50–59	Male	Female	NR
24%	61%	15%	3%	42%	27%	22%	5%	63%	23%	15%

Member of a civic assoc. or Haitian organization	Leader of a civic assoc. or Haitian organization	Owner of a business with at least one employee	Elected member of local government	Staff of foreign organization	Regular citizen with no affiliation
37%	22%	6%	7%	11%	16%

Kreyól, and the workshop involved 76 community stakeholders who were identified during the first trip. These local stakeholders and community leaders represented a range of CBOs, such as youth associations, women's organizations, local professional organizations, and small farmer's organizations. Table 2 shows how the participants identified based on location, age, gender, and affiliation, including No Response [NR].

As can be seen, the majority of participants were either leaders or members of local civic associations or CBOs; 69% were 20–39 years of age, and 63% were male. This is indicative of the prevalence of men in leadership and public positions in Haiti, and suggests that efforts at full social inclusion in participatory processes would have to make specific outreach to women and women's organizations in order to ensure more equal representation.[34]

During the workshop, participants were asked to propose, discuss, prioritize, and elaborate solutions to Léogâne's water and sanitation problems. During the morning sessions, the participants were broken up into five groups of 10–15 who brainstormed solutions. Facilitators asked each participant to introduce themselves and offer an 'action item' concerning how to improve the water supply and sanitation condition in their locality. These action items were discussed, clarified, written on a flip chart, and if needed combined and elaborated into unique ideas, and then voted on. By vote, these groups brought their five top ranking ideas to the general assembly, which included all workshop participants. The general assembly voted on the 25 solutions proposed by the five groups, and the five top ranking solutions were elaborated more thoroughly during afternoon breakout sessions into proposals for action which considered how the action could be implemented, and who should be involved. These ideas were again discussed, elaborated, combined and recorded on flip charts. Each group presented their plans to a second plenary session, where they were all voted on by the entire assembly. ATLAS.ti was used to quantify the frequency with which different kinds of centralized and decentralized water and sanitation options were mentioned in discussions, and emerged from voting. Pre- and post-workshop surveys with Likert Scale questions, as well as some open-ended questions, were used to gage participant satisfaction with the process and results.[35] In March 2012 members of the research team returned to Léogâne and invited the former workshop participants to a meeting where final reports on the research findings (translated into *Kreyól*) were distributed.

[34]Some women's organizations were included: MOFANM (*Mouveman des fanm*), OFAGL (*Organisazyon Fanm Gro-Morne Leogane*); and OFPL (*Organisazyon Fanm Progressiste Leogane*). Other women in attendance came from various youth organizations.

[35]A Likert scale is a psychometric scale frequently used in questionnaires. Respondents specify their level of agreement or disagreement on a symmetric agree-disagree scale for a series of statements. Thus, the range captures intensity of feelings for a given item.

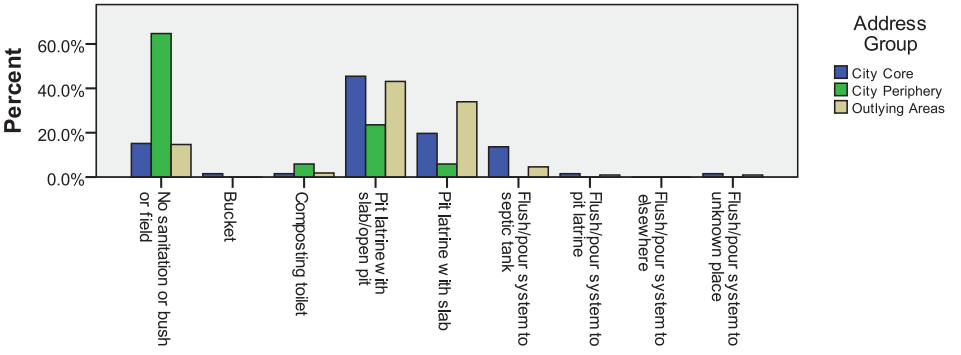

Figure 1. Survey response showing frequency of different sanitation types in city core, city periphery and outlying areas ($N = 171$).

Results

Sanitation practices

As in the rest of Haiti, Léogânais have coped with informal decentralized sanitation measures for some time. The survey data presents a baseline portrait of current sanitation measures amongst different populations in the area. Figure 1 represents the frequency with which survey respondents used different types of sanitation facilities. The sanitation facilities most widely used on a daily basis were 'pit latrine/open pit' ($\sim$40% of all respondents), 'pit latrine with slab' ($\sim$25%), 'no sanitation' ($\sim$15%) and 'flush/pour system to septic tank' (6%). Amongst those from the city periphery, up to 60% used 'no sanitation, bush or field'. When asked to rank problems associated with different types of sanitation facilities, 'bad odors' and 'harassment by animals' were indicated more frequently than other choices for the two different types of latrines. A 'lack of privacy' topped the list of complaints for respondents who had 'no sanitation'. A significantly greater number of respondents who had no sanitation or used a latrine indicated that they had to share these facilities with other households.

The survey also gave us an indication of preferences for future sanitation options among different groups, which is a crucial starting point for any participatory engineering effort (Table 3). Over half of the respondents (64.6%) indicated that they used a 'dry decentralized' form of sanitation, such as a latrine, before the earthquake. However, of these respondents, only 21.5% selected this kind of sanitation as their preferred choice for the future. By contrast, though only 8.8% of the respondents indicated use of a 'water carriage' system of sanitation prior to the earthquake, 64.6% selected this option as their preferred option going forward. Very few respondents expressed preference for a 'hybrid' form of sanitation. Although about one in five of the respondents indicated having 'no sanitation system' prior to the earthquake, all of those respondents expressed preference for some other form of sanitation.

Synthesis of interview results

Interviews with a range of actors in the 'WASH Cluster', supplemented by physical observations, indicated that a wide variety of decentralized sanitation technologies were being built on a piecemeal emergency basis by a number of different international organizations throughout the camps for internally displaced people. The WASH Cluster Sanitation Strategy Final Draft, issued on 7 March 2010, noted that:

Table 3. Percentage of participants using different sanitation sources before the earthquake and their preferences for rebuilding, divided by age group, employment, gender, and location.

	Water carriage		Dry		Hybrid		No sanitation	
	Pre-quake ($n = 16$)	Preference ($n = 117$)	Pre-quake ($n = 117$)	Preference ($n = 39$)	Pre-quake ($n = 2$)	Preference ($n = 11$)	Pre-quake ($n = 36$)	Preference ($n = 0$)
Total	8.8%	64.6%	64.6%	21.5%	1.1%	6.1%	19.9%	0.0%
Age group								
0–30 years ($n = 57$)	12.3%	80.0%	64.9%	18.2%	1.8%	1.8%	21.1%	0.0%
31–50 years ($n = 54$)	11.1%	75.5%	64.8%	18.9%	1.9%	5.70%	22.2%	0.0%
51 years and over ($n = 46$)	4.3%	53.3%	82.6%	33.3%	0.0%	13.30%	13.0%	0.0%
Employment								
Employed ($n = 53$)	15.1%	66.7%	66.0%	21.6%	3.8%	11.80%	15.1%	0.0%
Unemployed ($n = 118$)	6.8%	71.6%	69.5%	24.1%	0.0%	4.30%	23.7%	0.0%
Gender								
Male ($n = 90$)	14.4%	70.5%	66.7%	22.7%	2.2%	6.8%	16.7%	0.0%
Female ($n = 81$)	3.7%	69.6%	70.4%	24.1%	0.0%	6.30%	25.9%	0.0%
Location								
City core ($n = 58$)	16.9%	72.4%	64.4%	17.2%	1.7%	10.30%	16.9%	0.0%
City periphery ($n = 17$)	0.0%	82.4%	35.3%	11.8%	0.0%	5.90%	64.7%	0.0%
Outlying areas ($n = 95$)	6.3%	66.3%	76.8%	29.3%	1.1%	4.30%	15.8%	0.0%

> The choice of technologies to be used to meet the sanitation needs requires a flexible approach, taking into account a number of issues including access to sites, space, and site characteristics. Alternative solutions must be considered and these include: trench latrines, pit latrines, elevated latrines (with or without UD), chemical/portable toilets, biodegradable bags, bucket latrines, carton box latrines, potties for children, and the collection of plastic bags used for defecation through the waste management stream. (WASH Strategy, 7 March 2010, 4)

Which alternative to implement, and how exactly to do so, are essentially engineering decisions that were being made informally or on an ad hoc basis. Notes from a WASH Cluster meeting indicated that trucks were coming from Port-au-Prince to empty latrines at the temporary camps for internally displaced persons (IDP) around Léogâne, but according to DINEPA staff 'a more long-term solution is to find municipal land to empty waste'. When NGO staff asked for guidance on what construction model to follow, they were told by DINEPA:

> DINEPA: It is suggested that you see the manual published by Prof. Reed on sanitation [available on the website]. You have basically the norms of the world – 30 meters between a latrine and any drinking water. But then you have the specificities of Haiti. We will provide a document of general reference, and a document on Haiti specifically.
>
> Q: What is the view on the old latrines that are found in every village? Should they be discarded and people told to abandon them?
>
> DINEPA: It really depends. There is no right or wrong answer. Most of the latrines here have no way to empty them without jumping down into them. They fall straight into the water table. If it can be reoriented and rebuilt nearby it should be. You can move the superstructure if there is one . . . Most important is the sensibilities of the people.

This exchange indicates that it was known that latrines were being built too close to water sources, with the risk of contaminating the shallow aquifer water table in Léogâne. Some community-based interviewees felt there were problems with this approach: 'It is very difficult to deal with the NGOs like Save the Children and ACTED who come and build very shallow latrines, just 1 meter, and they create more problems than they solve' (Interview, government staff, 29 July 2010). Other interviews revealed that some foreign NGO staff members had no familiarity with current sanitation practices, and there was evident lack of coordination in planning and building decentralized systems, including the emptying of latrines. As DINEPA's national director of sanitation eventually noted,

> The system of shared toilets [le système de toilette/Lakou] or other models proposed by the International Red Cross and partners . . . in each case must be referred to the established law, because the NGOs, in failing to do so, can cause serious problems of urban planning.[36]

Other NGO actors were trying to implement what they considered to be more sustainable forms of sanitation, even though questions remained about the capacity to scale up such projects. One international NGO working in the city was introducing biocomposting toilets:

> We are also building composting toilets here, for our warehouse; and will then take them out into the community. The first one we built was for use by the local volunteers – and they have taken to it, they take care of it, clean it, keep it supplied. People from both sides of the spectrum have bought into it – those living in shacks with no wash facilities, and those with houses with flush toilets. We'll install them in the local volunteers' communities, and they will

[36] Petit, "Présentation Stratégie Assainissement de la Direction de l'Assainissement, DINEPA."

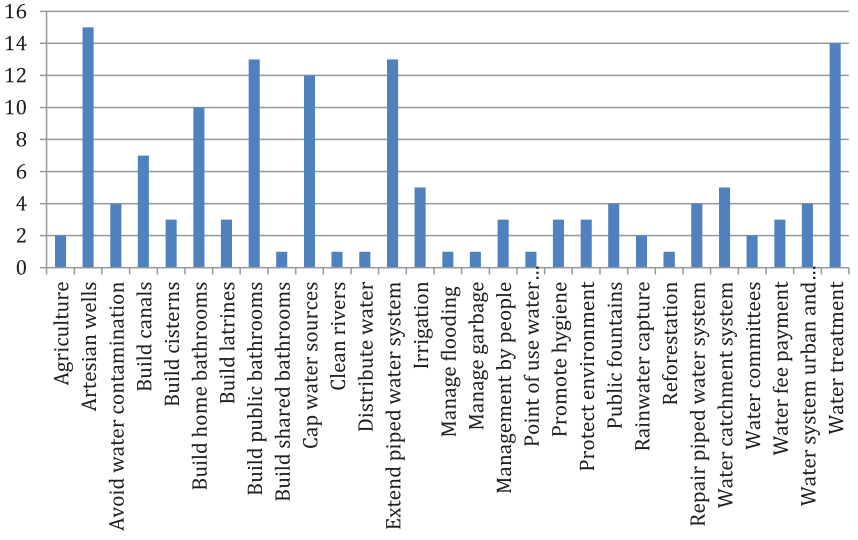

Figure 2. Workshop ideas for Leogane water and sanitation initiatives.
Source: Counted based on ATLAS.ti coding of written notes from five morning workshop sessions.

> be partly public. The volunteers will be like ambassadors into their communities. (Interview, NGO staff, 29 July 2010).

The NGOs composting-toilet team had also produced a hand-made illustrated booklet entitled 'If You Give A Town a Toilet', which told the story in pictures and simple words of how a toilet can 'Save the World' by improving hygiene, health, the environment, and social relations in general. Their efforts were assisted by another NGO Sustainable Organic Integrated Livelihoods, known as SOIL, which provided technical support for the project. SOIL had experience building composting toilets in Cap Haitien, and were awarded a US$800,000 contract from OXFAM Great Britain to build them in Port-au-Prince after the earthquake.[37]

While none of our interviewees specifically mentioned dry composting toilets, 7 out of 8 were familiar with beneficial reuse of human excrement, and 9 out of 11 were favorably disposed to beneficial reuse when prompted. One farmer noted that 'sometimes the waste is collected and . . . used as compost in the fields. The municipality has a truck . . . but only sometimes'. Overall two-thirds of interviewees (e.g. six of eight residents of Léogâne and four of seven Haitian professionals who had lived in the USA) specifically mentioned latrines – a decentralized approach – in conversations about the solution to Léogâne's sanitation problems. One of these plainly stated: 'I would say build more modern like types of latrines'. Another stated 'if you build it properly it reduces the risk of disease and it's more sanitary'. Eight interviewees (e.g. five residents of Léogâne, two Haitian professionals who had lived in the USA, and one government official) mentioned flush toilets, with one very directly stating 'people should move to flush toilets'. Other issues raised by interviewees included problems with the cleaning of latrines in IDP camps, lack of oversight in their use by children, and the need for hygiene education.

[37]"If You Give a Town a Toilet," handmade booklet observed at Hands on Disaster Relief center, Léogâne, Haiti. On SOIL, see http://www.oursoil.org/who-we-are/mission/ (accessed August 7, 2014) and Kilbride et al., "Piloting Ecological Sanitation."

Table 4. Top voted ideas in workshop to solve water and sanitation problems in Léogâne.

(1) Protect the environment in the city and in the plain, from upstream to downstream
(2) Promote Hygiene, repair and extend the quantity of pipes bringing water into people's home, dig artesian wells, build public fountains with potable water, and build modern bathrooms in each home
(3) It is important that each community has its own water system; build both public and private toilet facilities and have people pay for the service
(4) Protect water sources, treat the water, and build canals for irrigation purposes
(5) Dig more artesian wells, lay down more pipe; and we also need a monitoring committee and to plant more trees

Synthesis of workshop results

The workshop was structured to allow the participants to discuss a wide range of water and sanitation issues for Léogâne, thus rather than isolating sanitation problems from questions of potable water, they treated them as a combined problem. Figure 2 displays the number of times different solutions were mentioned during the workshop breakout sessions, coded and counted using ATLAS.ti. Of the phrases that relate to sanitation, building 'public bathrooms' (13) was mentioned more frequently than building 'home bathrooms' (10), 'shared bathrooms' (1), or 'latrines' (3).

Workshop participants identified a much wider array of *combined* water and sanitation initiatives than did government or NGO interviewees. The five most highly ranked proposals in a democratic voting process developed by the workshop participants throughout the day are listed in Table 4.

These proposals contain a variety of references to both centralized and decentralized systems for water and sanitation. The second proposal makes a clear reference to 'modern bathrooms' in every home. In Haiti, the term 'modern bathrooms' typically refers to a water closet which may be either a centralized or decentralized sanitation solution. The third proposal also suggests a desire to see more access to sanitation in both 'public and private bathrooms', while also expressing a desire for consistent levels of service 'in each neighborhood'. Although there are different ways that sanitation services could be provided to a neighborhood, no preference for a centralized approach was articulated.

The average importance given by workshop participants to 'constructing more high-quality household latrines', and 'constructing public restrooms with shower facilities' was > 4.7 (on a 1–5 Likert scale) in both pre- and post-workshop surveys. In answer to the question 'What should be done to improve water supply and sanitation in Léogâne? Just list 1 or 2 things', prior to the workshop building latrines was mentioned 14 times, toilets 9 times, and sanitation 4 times; after the workshop building latrines was mentioned 12 times, toilets 11 times, and sanitation 11 times. This places each of these amongst the three highest action items, and when combined makes sanitation by far the most important area to take action, along with the over-arching 'Environment' theme that emerged in workshop discussions (Table 5).

Overall, $\sim$95% of the respondents characterized the workshop as 'a success', with $\sim$79% strongly agreeing and $\sim$19% agreeing with its conclusions. There was an evident interest in stakeholder consultation, and an acknowledged vision of community-led development, assisted by foreign expertise. When pressed during the workshop to identify who would be involved in the five selected projects, and how they would take action, the afternoon breakout sessions brought about a vote that what is needed is 'a well thought out agreement between the state (national government), local and international organizations

Table 5. Workshop pre- and post-survey: areas to take action on water and sanitation in Leogane.

	Pre-survey (Q5) ($N = 68$)	Post-survey (Q31) ($N = 73$)
Artesian wells	16	7
Pipes	14	9
Latrines	14	12
Toilets	9	11
Canalization	9	5
Planning/management	7	1
Hygiene training	7	3
Treated water	6	9
Fountains	5	0
Sanitation	4	11
Education	3	7
Environment	1	13
Reforestation	1	9

Notes: *Question 5*: Kisa ke ou pense ki ta dwe fet pou ameliore system dlo ak keksyion sanitasyion nan Leogane? di mwen 2 bagay selman [What should be done to improve water supply and sanitation in Leogane? Just list 1 or 2 things]. *Question 31*: Di mwen 2 a 3 bagay ke semine sa a te identifie kom saki pi prese pou ki ta fet [Briefly describe 2 or 3 major priorities identified for further action at the workshop].

with international financing'. Yet participants emphasized that such financial and technical aid must be in partnership with local organizations and actors. Nearly 80% of workshop participants also agreed strongly that *they could take actions* that would potentially bring about change for the better.

Discussion

In this section of the discussion we use contingency analyses and interpretation of the interviews and workshop to explore different visions of various groups and potentially differential effects of various sanitation approaches. It is important to understand the 'translation' processes between local understandings, established 'facts', and various types of 'expert knowledge', including the expertise of engineers, policy-makers, relief agencies, etc., as they interact with local stakeholder visions. It should also be understood that the urban planning context in Haiti is extremely fragmented, being scattered across seven or eight different ministries with differing responsibilities at the national-level, and urban planning 'still does not exist as a profession'.[38]

Contingency analysis on pre-earthquake sanitation and reconstruction preferences

The contingency analysis on pre-earthquake sanitation conditions revealed significantly different levels of access to water carriage sanitation by gender, geography, employment status, and age. Of males, 14.4% had a water carriage sanitation system before the earthquake, compared to only 3.7% of females. Of those in the city core, 16.9% had a water carriage system, compared to only 6.3% of the outlying areas, and none in the city periphery. At 15.1%, the employed were more than doubly likely to have had water carriage systems than the unemployed. It was also doubly likely that survey participants under 50

[38]Etienne, "Urban Planning and the Rebuilding," 171.

years had access to water carriage than older participants, of whom only 4.3% had access. Unemployed females and rural residents were more likely than employed males in the urban core to rely on dry decentralized systems before the earthquake. These discrepancies in access signal that male professionals in the city center (including government representatives, DINEPA employees, and foreign experts) may be unlikely to make inclusive and appropriate engineering decisions if the voices of those groups who already lacked access to water carriage systems were not heard.[39]

The survey offered a quick way to gain data on social and geographical differences in access to sanitation systems. Differences were also observed between groups in the percentage who lacked sanitation altogether. While slightly more than one in five of participants 50 and below had no sanitation, only 13% of those over 50 reported this pre-earthquake condition. More females (25.9%) lacked sanitation system than males (16.7%). Of the employed, 15% did not have a sanitation system, compared to 23.7% of the unemployed. Over half of participants from the city periphery (64.7%) did not have a sanitation system, while only 16.9% of the city core and 15.8% of the outlying areas lacked sanitation systems. Together this analysis suggests that the unemployed, females under 50 years old, and individuals from the city periphery were the most likely group to have not had any sanitation prior to the earthquake.

This suggests that even if a centralized water carriage sanitation system were to be implemented in the city center, that there would likely be uneven social impacts. A large proportion of the unemployed and rural population, including a higher percentage of women than men, would likely lack access to any centralized system since they would not own property with connections to the system. Thus there are social justice implications to the implementation of centralized engineering solutions; yet neither discussions within the WASH cluster NGOs implementing what we characterize as quick fixes, nor the longer range plans of DINEPA addressed such concerns. The interview and workshop results suggest that many people in Léogâne are aware of this issue, insofar as they call for a combination of both centralized and decentralized, household and shared, public and private sanitation options. Our methodology suggests that only by starting from local knowledge about such issues can they be made visible within the decision-making process. Using multiple participatory methods can help engineers to recognize that there is not a one-size-fits-all solution, and to identify possible permutations.

With respect to reconstruction preferences (see Table 3), the contingency analysis revealed a statistically significant difference in the paper survey results by age and geography, but not by gender or employment status. Those under 30 years of age had a much stronger preference for a water carriage system compared to older age groups ($p < .05$). The city periphery (82%) showed the strongest preference for water carriage, followed by the city core (72%) and outlying areas (66%). Though it is not clear why, in general it seems that younger individuals from the periphery of the city were the most in favor of water carriage, perhaps because they lacked access to it while also perceiving it as more ‘modern’. Engineering decisions would need to address the strong preference for and expectation of water carriage sanitation amongst a group who had high hopes for it, but were living in areas where public centralized sewage treatment was least likely to be built due to funding challenges and geographic dispersal.

[39]For further discussion of women and gender issues in the water and sanitation system in post-earthquake Haiti see Sheller et al., “Gender, Disaster and Resilience.”

Analysis of interview and workshop data

Though there is some discrepancy in opinion between water carriage and dry decentralized sanitation, it does seem that the majority of interviewees did not object to continuing to have to share sanitation facilities between households. Six participants (e.g. four residents of Léogâne, one Haitian who has lived in the USA and one NGO/American) believe that it would be acceptable to share sanitation facilities among households in the future, compared to only two (both Haitians who had lived in the USA) who did not. Citing a common experience of local residents, '[in] the small towns, some people have latrines, like community latrines that a lot of peasants use'.

Workshop opinion favored an integrated sanitation solution including water carriage systems in 'modern', 'private', and 'home' bathrooms *but also* 'public', potentially 'shared', bathrooms that might involve latrines in 'each neighborhood'. In one of the morning breakout sessions, for example, it was put forward that 'Empotan pou chak zon gen system pou trete dlo a e unstale nan chak lakou kay twalet piblik' which translates as 'It is important for each neighborhood to gain a water treatment system and to install in each shared household yard [*lakou*] a public toilet'. This indicates an awareness of local cultural practices, in which multiple inter-related families share common cooking, washing, and toilet facilities, which is quite distinct from the alternative vision of a 'modern toilet' in each home. This is a distinctive Haitian cultural tradition, with which foreign engineers would likely not be familiar, and more urbanized or middle class Haitians may have rejected, but which was still considered acceptable to a cohort of people in this region.

It is notable that while DINEPA was doing little at the time to address sanitation issues, and NGOs were taking quick fix or piecemeal approaches (digging temporary latrines at IDP camps, or building biocomposting toilets), the workshop participants took a comprehensive approach that seemed to recognize the interaction between different elements of the water/sanitation system (e.g. they noted that water sources would be polluted if latrines were built too close to them; that upstream watersheds needed to be protected and reforested; and that flooding would need to be prevented). Thus they recognized not only the interaction between potable water and sanitation systems, but also the interaction between human and natural systems. It is this holistic approach to sanitation that seems to have produced 'protecting the environment' as the number one concern when a vote was taken amongst all 76 participants. In other words, despite the apparent preference among survey participants for water carriage sanitation systems and unlike the piecemeal efforts of governmental and NGOs who operated in separate sector, the interviews and the workshop suggest that local stakeholders envisioned an integrated solution in which improved water and sanitation would be joined with environmental protection, source water protection, and reforestation efforts. They also wanted to be *part of* the planning and implementation.

In stark contrast, a manager in DINEPA stated that their process was 'dictatorial', meaning that they currently did not have any consultation with local communities or municipalities about what their water and sanitation needs were, nor did they currently invite them to participate in the planning process. This undercut their own planning documents, as well as any environmental protection policies:

> Q: What about public participation? People's preferences make a big difference in how people use the system. So what is your process?
>
> A: So far, for urban projects, it has been I would say a dictatorial process. We just came in, the needs are so big. We don't think about what the environmental impact will be – you just do it. (Interview at DINEPA office, 2 August 2010)

While national institutions and NGOs were in some cases drafting plans for local involvement in infrastructure planning, these plans appeared to be largely on paper, as people of all levels in Léogâne were generally not informed of them. Participation must go beyond incorporating people as customers or clients in market-oriented service provision. Recent research suggests the need to approach the users of public services such as water and sanitation as both consumers and citizens, with subsidies and redistribution serving to support certain basic human rights.[40] For example, a representative of an NGO active on the ground in Léogâne stated that people would be given 'one choice' and that if this choice was not appropriate for local needs they could 'sell it for parts'. Their concern was with a quick response to the immediate needs, and it was admitted by some WASH cluster participants that their meetings were too fast-paced, frequent, and lacked translation for local government officials, who had therefore stopped attending.

We believe that participatory engineering could have helped to mediate between the needs of government organizations and foreign NGOs to be seen to be making decisions and taking immediate actions within each UN cluster area, and the needs of the CBOs and earthquake-affected people to have more input into the process and the opportunity to articulate and reflect on the interdependencies between different systems. Between the temporary measures being implemented by NGOs and the longer range plans being developed by government agencies such as DINEPA, there should have been time and space for a middle-range participatory planning process. When we returned to the community to distribute our research report in March 2012, there had still been little progress on sanitation plans and meeting participants wanted the report not only to be given to DINEPA, to NGOs, and to local government (which we did), but also wanted it to be given media coverage on local radio stations to help generate public discussion. They saw it as part of a wider opportunity for public discussion of infrastructural engineering in their region.

Developing mental models

By involving multiple stakeholders in collectively constructing a social learning process, for example, through community workshops and other democratic processes, mental models can be generated to visually depict alternative perspectives. Mental models are cognitive representations of how groups of similarly minded people interact with the world, frame problems, and make decisions.[41] Using ATLAS.ti network maps constructed from the interviews, as well as notes from meetings with various officials and the coding of opinions expressed during the workshop, we developed three comprehensive mental models of engineering practice relevant to the sanitation regime. The schematic models below identify the main problems, solutions, and actors that various types of respondents referred to when prompted to address the water and sanitation problems in Léogâne.

(1) *Engineering as part of NGO emergency relief* (Figure 3): The main problem is identified as immediate access to water and sanitation. This produces an emergency relief solution, centered on free water trucking and building of shallow latrines. Efforts are decentralized and vary in terms of focus (drinking water versus sanitation) and service area (from individual settlements to community clusters). The NGO actors generally work with others in the WASH Cluster, and have some interaction with the Mayor's Office, which is viewed as a weak actor without capacity to implement anything or even participate fully in planning processes. In most cases,

[40] Furlong, "The Dialectics of Equity."
[41] Mathevet et al., "Water Management."

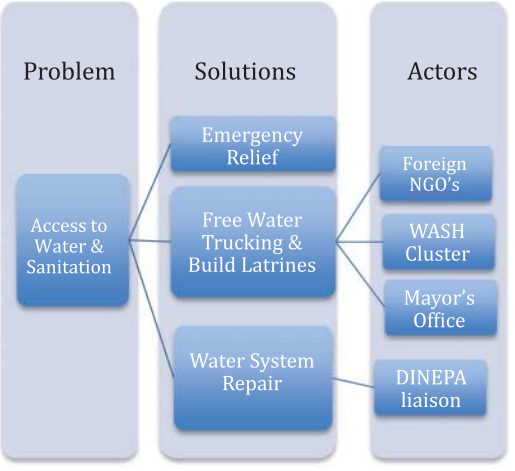

Figure 3. The 'Emergency Relief' NGO Model.

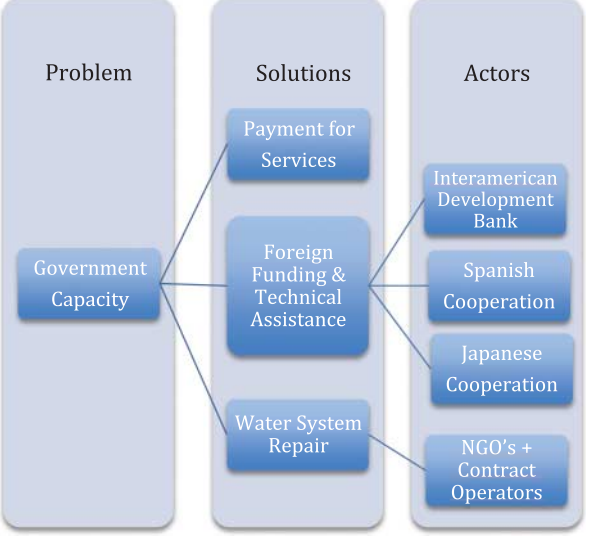

Figure 4. The DINEPA 'Water Management' Model.

installation and service are provided free of charge on a short-term basis, with no provision for long-term operational costs. Some NGOs were also working closely with DINEPA to help re-build the piped water system in Léogâne, but this was done without any local consultation or participation. While some relief agencies planned to begin local consultation, WASH cluster meetings indicate that others simply withdrew services within a year, when their funding for free services such as water trucking ran out.

(2) *Engineering in the government approach* (Figure 4): The main planning being implemented by DINEPA focused only on centralized provision of piped drinking water in the urban core of the City of Léogâne, and ignored sanitation for the time being. The restored system was to be publicly owned but managed by new

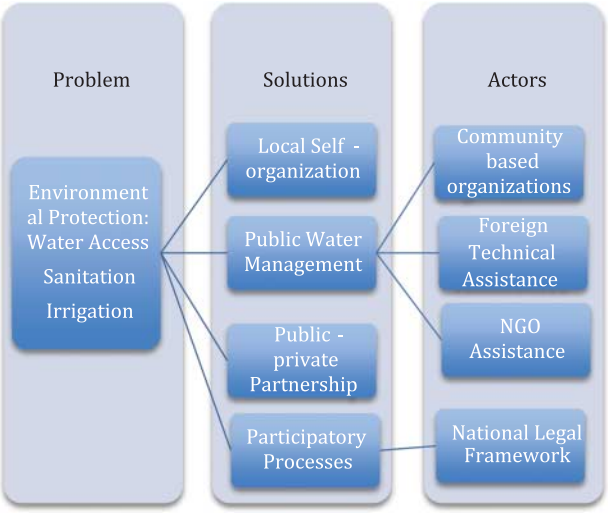

Figure 5. The Community 'Participatory' Model.

regional offices of DINEPA, with management gradually transferred to public or private operators under regulatory oversight on a regional and national basis. They envisioned the main problem as one of government capacity. The solution was to gain international funding and foreign technical assistance to build modern centralized infrastructure; and to then keep the system running with payment for services to contract operators. Users would pay based on metered consumption, with revenues remaining at the regional level to implement repairs and manage the system; however, no data was collected on the willingness or ability of people to pay.[42] Current DINEPA plans under development for sanitation include payment not for use, but for the emptying of latrines.

(3) *Participatory engineering approaches with local stakeholders* (Figure 5): Finally, local interviewees and workshop participants suggested multiple solutions customized to the needs of the urban, peripheral, and outlying zones of the city. They recognized the need to address protection of source waters and the environment in general, irrigation, water treatment, public and private drinking *and* sanitation facilities. They also suggested that people are willing to pay for and co-manage services. They also noted the need for a national legal framework. They identified the main problem as being a comprehensive one of sustainable water access, sanitation and irrigation. While local stakeholders recognized the need for foreign technical assistance and NGO assistance, they also clearly identified local self-organization and the use of water committees as possible solutions, and included participatory processes in their vision of rebuilding.

In Table 6, we compare and contrast these mental models of engineering practice. The two rows depict the emergency relief, and government models. Column 3 depicts how they are being implemented in Léogâne, a traditional engineering approach that does not involve much participation. Informed by our study, Column 4, however, is added to show

[42]For our own initial study of willingness to pay see Galada et al., "Attitudes Toward Post-Earthquake Water and Sanitation Management."

Table 6. Participatory methods for engineering work in post-disaster contexts.

Current models of engineering practice in Leogane	Goal, time frame and, spatial scale	Traditional engineering approach	Participatory engineering approach	Potential methods for stakeholder engagement	Example questions
Emergency relief approach by NGOs	• Solve immediate and acute problems quickly • Local in scale (e.g. IDP camp) • Temporary solution without long-term viability	Blindly implement 'tried and tested', off the shelf, or otherwise available/known approaches and technologies, so as to address the immediate need. Typically performed by 'experts' without boots on the ground, or by local individuals who have consulted with the experts. Though those specifying these technologies may not be engineers, this activity determines the fate and level of treatment of wastewater and, by consequence, the associated public health and ecological impacts. As a result this is 'incidental engineering'	Develop list of technically viable alternatives that are implementable given the site conditions Present these options to local stakeholders, for reaction/vetting Select those options that are most generally found to be acceptable, and/or that are synergistic/harmonious/complimentary with local needs/goals/customs	• Surveys to collect baseline data and discover relevant stakeholder groups • Focus groups with full range of stakeholders • One-on-one meetings • Demonstrations	Which of the possibilities on this short list of approaches do you think would work best? Are there other approaches that you think would work better? Where would the best option go? Who would be likely to use it? Who would be unlikely to use it? How could implementation be customized to maximize benefits?

Top-down Urban Planning Approach by DINEPA	• Mid-range time frame oriented toward rebuilding • Scaled to urban infrastructure systems, often centralized • Medium-term solutions, for example, piped water system repair and building drainage ditches	Problem definition and solution are determined by the planning agency before the expert team of engineers are put under contract. The contracted scope of work is very explicit, and the engineer is given very little freedom to deviate from it. Engineer is not authorized or expected to collect on-the-ground investigations that might suggest an alternative solution	Planning agency requires the contracted team of experts to perform site investigations and collect data that will be used to define the detailed scope of work. Experts are having regular meetings with both local stakeholders and the planning agency and providing the bridge between the two. Ideally create an iterative decision-making process built up over time using workshops and decision support models	• Interviews to assess various mental models • Day-long Stakeholder Workshop to deliberate and learn about different needs, visions and engineering options • Decision support models to guide assessment of options and how best to implement	What worked and what did not work previously? What new approaches will work best regionally? What other regional stakeholders should be engaged in the process? What are your visions and values for this whole watershed? What technical information could assist your decision-making? Have all groups been represented? What improvements could be made to this plan?

how participatory engineering approaches can be incorporated into the actions of engineers involved at either scale.

Engineers enter post-disaster contexts through multiple entry points. In the Emergency Relief Model engineers are asked to address local and acute problems rapidly and quickly. Because of the time crunch, they typically implement 'tried and tested', off the shelf, or otherwise available/known approaches and technologies. In these contexts the engineering is typically performed by 'experts' (e.g. engineers) who do not have boots on the ground (or who only visit the site briefly), or by local individuals (including NGO staff who are not engineers) who consult with them. Though those specifying these solutions under the engineering relief model may not technically be engineers, because this activity determines the fate and level of treatment of wastewater and, by consequence, the associated public health and ecological impacts, emergency relief efforts produce 'incidental engineering'.

At this scale, participatory engineering approaches could start not with one seemingly 'optimal' strategy, but rather with a list of technically viable alternatives. These options could be presented to local stakeholders for reaction/vetting. Those options that are found to be most acceptable or that are synergistic/harmonious/complimentary with local needs/goals/customs could then be selected for implementation. Simple participatory strategies could include focus groups, one-on-one meetings, and technology demonstrations that seek to rapidly determine: Which of the possibilities on this short list of approaches do locals think would work best? Are there other approaches that could work better? Where would the best option go? Who would be likely to use it? Who would be unlikely to use it? How specifically could implementation be customized to maximize benefits? By seeking answers to basic questions like these even limited, piecemeal engineering projects can better address local needs. As a result, they also stand a greater chance of being initially accepted, and maintained long after the relief workers have left.

In the Government Model, engineers are typically engaged as consultants to a planning agency (like DINEPA) that has already 'framed' the problem for them. The contracted scope of work is ultimately very explicit, and the engineer is typically given very little freedom to deviate from it, or to conduct on the ground investigations that are not explicitly spelled out and that might suggest an alternative solution. Because the solution has been prescribed to them, engineers working in such arrangements are limited to a technician's role. By contrast, the planning agency could more efficiently use the engineer's full range of knowledge regarding the limitations and applicability of multiple approaches by requiring her/him to perform relevant site investigations and data collection as the first task of the contracted effort. By structuring the contract this way, engineers would play a role in actually defining the detailed scope of work based on their assessment of local conditions. Through the requisite meetings with both local stakeholders and the planning agency, they would ultimately become a crucial bridge between the two groups.

In this more participatory approach interviews and focus groups would first be used to identify relevant stakeholders, and begin to define stakeholder's values, desires and preferences. Going beyond this, though, workshops would be used to generate options and potentially evaluate multiple criteria, including visions and values for an entire watershed or region. The stakeholder workshop piloted as part of this study represents one efficient methodology for eliciting stakeholder input into what actually are quite complex engineering planning studies. Working under the Government planner, participatory engineers would have goals similar to those working through the Relief Model, though at a larger scale and over a longer time frame. They would also mine crucial local knowledge to determine, for example, what worked and what did not work previously? Based

on past experience what new approaches will work best regionally? What other regional stakeholders should be engaged in the process? Why? What is their stake?

Not only do such participatory processes feed into decision support methodologies for complex contexts,[43] they also help to build the very social capital and inter-organizational capacity that is needed for long-term sustainability. Our work on sanitation issues in Léogâne suggests that participatory processes can reveal key information to inform engineering judgment, decisions, and prescriptions. Moreover, we demonstrate through a relatively straightforward set of methodologies how basic, yet crucial local knowledge can be elicited, and integrated into engineering decision-making. In support of this conclusion, US engineers who worked in post-earthquake Haiti and participated in an NSF-sponsored workshop organized by the Earthquake Engineering Research Institute in September 2010, for example, advocated multi-disciplinary interventions in international disaster zones including social scientists embedded with engineering teams in order to support engineering practice with a high degree of social and cultural expertise and inclusion of local actors. The Workshop's report on future research needs identified community-based participatory research (CBPR) as a crucial area for further development in post-disaster situations.[44] We have shown that even in the midst of a complex post-disaster crisis it is possible for engineers to work with stakeholder groups to rapidly generate pertinent contextual information, participation processes, and social learning contexts that offer different visions and priorities than those used by ad hoc NGO interventions (often determined by outsiders) or top-down government action plans.

Conclusion

Our research identified important gaps in communication between national-level planners, international NGOs, and local citizens, civil society organizations, and local government officials. This gap reinforced divergent visions of what needed to be done, and how the recovery and reconstruction effort should proceed. It suggests that a better understanding is needed of the relationship between the desire for local knowledge and participation, on the one hand, and the actual capacity, means, and appropriate interactional settings for carrying it out. NGOs generally offered what we call 'incidental engineering' interventions, to the best of their ability, in whatever small area they worked. Because of a lack of coordination with the government and finite availability of resources, NGO strategies, while helpful during the immediate phase of post-disaster response are often criticized for creating dependencies that cannot be supported in the long term. Even more importantly, however, in their ignorance of local histories of participation and community organization, they may actually be undermining local social organization and 'social capital' that exists amongst CBOs as well as bypassing existing national legal frameworks and policy directives.

To the extent that sustainable development strategies are informed by local participation, the current governmental and non-governmental water and sanitation strategies are fundamentally problematic. Although DINEPA was supposedly created to implement long-term sustainable and participatory approaches, and has much of the paper mandate for this, it did little along these lines. They were instead bypassing participatory processes at exactly the point in time when they are most necessary to determining the long-term direction of

[43] Elghali et al., "Decision Support Methodology."

[44] The lead author co-chaired this workshop and helped edit the report: EERI, The 12 January 2010 Haiti Earthquake, 4.

infrastructure decisions in Haiti. While the agency's middle-range plan went beyond short-term fixes and may provide drinking water to some of the urban dwellers in Léogâne, it will not address the broader set of water and sanitation needs articulated by local stakeholders. Such pre-determined solutions circumvent precisely those social learning processes that might engage multiple stakeholders and take into account complex system interactions.[45]

While the community-based participatory model is in line with the national legal framework that DINEPA is pursuing, our workshop participants placed stronger emphasis on community participation (and demonstrated a willingness to participate). Our interactions with stakeholders indicate that local understanding of the nature of the water and sanitation problem is comprehensive, as are the breadth and extent of locally proposed solutions. This integrated vision of actors, resources, and dynamics[46] is in stark contrast to the government plan that more than a year and a half after the earthquake was just beginning to address urgent sanitation needs. Public sanitation facilities are one option identified by the stakeholder participants that could be, but are not, included in the government's plan.

These results are, of course, limited by our use of purposive sampling techniques that may not have been representative of the entire population. The paper survey included a significantly higher percentage of participants from the outlying areas than from the city center or its periphery. The short-term nature of a RAPID grant also prevented us from engaging in or assessing a longer-term participatory process linked to the engineering work undertaken by DINEPA. The study also required us to make interpretations of the various results, which may differ somewhat from the actual viewpoints of the study participants (e.g. with respect to the definition of a 'modern toilet'). Nonetheless, this multi-method approach by an interdisciplinary team of both engineers and social scientists gives detailed insight into the types of participatory processes that infrastructure planners and engineers could use first to elicit and document local knowledge and preferences, and then use as a template for participatory planning and management of infrastructure systems. This kind of a process did not take place in the effort to rebuild Haiti, but if undertaken systematically could help to generate far greater stakeholder participation in planning, rebuilding and infrastructure management efforts and hence contribute to the long-term sustainability of such efforts.

Modeling the complex post-disaster coordination of participatory processes in contexts like post-earthquake Haiti is crucial to understanding potential pathways for sustainable engineering. Participatory approaches that engage local stakeholders are increasingly viewed as necessary elements of transnational engineering projects, yet there are substantial gaps in the achievement of such laudatory goals. We conclude that greater attention by both engineers and social scientists to multi-stakeholder arenas, interactions amongst actors, and unfolding decision-making processes, can contribute to better post-disaster engineering. Local participation in post-disaster engineering projects is important not merely as window dressing for projects driven by outside decision-makers and planners (whether governmental or non-governmental), but we argue can actually provide better and more comprehensive solutions to complex problems that cut across coupled human physical systems, can help to build in local capacity, and ultimately can shore up the sustainability of the entire infrastructure system and thereby reduce social vulnerability when the next disaster comes along.

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[45] Grin et al., *Transitions to Sustainable Development*.

[46] Similar to the ARDI approach advocated by Etienne et al., "ARDI."

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