Social Sustainability of Sanitation Infrastructure in Developing Communities

By

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ABSTRACT

Kaminsky, Jessica Ann (Ph.D., Civil, Environmental & Architectural Engineering)

Social Sustainability of Sanitation Infrastructure in Developing Communities

Dissertation directed by Assistant Professor Amy Javernick-Will

In this dissertation I build theory of the social sustainability of onsite household sanitation infrastructure by leveraging organizational theory, using data collected from rural households in Guatemala and Bangladesh. The overarching research question asks *what causes high failure rates in onsite household sanitation systems*? This work is important because of the large number of people served by onsite technology types and also because of high observed rates of infrastructure abandonment. Since sanitation technologies are vitally important to public and environmental health, universal coverage is an urgent goal. Unfortunately, it is far from being met. As a first step towards addressing this problem, I use a literature review and expert panel to identify factors important to the sustainability of sanitation infrastructure. This work (Chapter 2) identified the importance of social factors and also showed that interactions between various factors explained the contention regarding the importance of ten factors. As such, the rest of my research focused on the topic of social sustainability, with the methodological goal of retaining attention to complexity. To build theory of social sustainability I use constructs of legitimacy and status from organizational theory. While organizational theory has never before been applied to infrastructure systems, it deals with groups of people using technology to achieve shared goals, and this is precisely what we see with infrastructure. I analyze household level interview data from Bangladesh using crisp set Qualitative Comparative Analysis to describe sanitation abandonment as a form of organizational decoupling (Chapter 3) by contrasting households with socially sustainable or socially unsustainable infrastructure. This research shows that neither a lack of demand nor economic barriers caused sanitation abandonment in the communities selected for this research. Instead the causal mechanism is decoupling, which is founded on perceptions of efficiency (whether or not desired infrastructure services are actually achieved) and competing rational myths (beliefs regarding how and why things ought to be done). This analysis leads us to suggest that, due to the impact on social sustainability, odor management should be required in the updated definition of improved sanitation as we revise and replace the Millennium Development Goals. This research also empirically identifies pathways that Guatemalan households took to achieve socially sustainable sanitation infrastructure (Chapter 4). The most practically useful of these shows that the combination of consequential legitimacy (a moral understanding of outcomes) and comprehensibility legitimacy (a cognitive model connecting outcomes to processes) leads to a socially sustainable outcome in a full 50% of the household cases studied for this work. Taken together, these findings explain and will allow us to better design sanitation infrastructure, technical knowledge mobilization, and educational outreach to support socially sustainable infrastructure.

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It seems a rare opportunity to be able to thank some of the many people who have helped shape who I am and what this dissertation has grown into. As such, I beg the reader's forbearance for the length of this section, which to me still feels as though I have left out far too many important people.

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I must also thank the rest of my wonderful family. My parents Jim and Bonnie instilled a love of learning in me from the beginning, and my stepmother Julie, stepsiblings Regina, John Michael, and Nicole, and brothers and sisters in-law Alice, Chris, Joe, and Amber have (hu)manned the pit crew since I first got to know them. My parents-in-law Joe and Martha also deserve enormous credit for this work. Martha slept on our couch for months when James was first born, and when she went home she and Joe and I were better friends and family than ever.

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Finally, though, it is difficult to avoid hyperbole as I try to express my gratitude to my excellent advisor, Dr. Amy Javernick-Will. She began teaching me how to write grants even before I was officially enrolled; any success I may eventually enjoy in academia will be due to the training she has given me. Dr. Javernick-Will is always right about all things academic; while it has sometimes been a struggle against my ego to take her advice, I am always better for it. She and I share a love for qualitative research methods. To avoid hyperbole and to try to tell the true story of my appreciation for her, I turned to the methods she trained me in. I conducted an email survey of 20 of her current and past graduate students and undergraduate research assistants, asking each for 10 words or phrases that they felt best described her. I used an emergent in vivo coding scheme to represent the responses. These codes were placed in Wordle, an online word cloud generator, to create the following visual representation of how Dr. Javernick-Will's students think of her. Size is representative of relative frequency; the word cloud is presented below.

Those participating were warned their responses would be anonymous but not confidential so I could thank them, too. In no particular order, their names are John Wanberg, Kaitlin Litchfield, Jeff Walters, Cristina Poleacovschi, Aaron Opdyke, Eric Antillon, Barbara Anderson, Shaye Palagi, Jessica Byrne, Celeste Havener, Alayna Wachter, Duygu Akalp, Kyle Kwiatkowski, Christopher Senesi, Elizabeth Jordan, Paul Arnold, Maryam Sanaei, Florence Berteaux, and Nathaniel Sobin.

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Any errors or omissions that might remain in this dissertation are my sole responsibility and should not be attributed to any of the excellent people mentioned here.

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CHAPTER 1: INTRODUCTION

The world over, onsite household sanitation infrastructure is failing at an unacceptably high rate. In the United States, at least 10% of septic systems (EPA 2010) (serving about 25% of US households (EPA 2008)) have failed. In rural Ghana, the failure rate appears to be closer to 40% (Rodgers et al. 2007). Sanitation infrastructure is one of humankind's greatest accomplishments in public health (BMJ 2007). However, billions of people still go without access to improved sanitation (Baum et al. 2013; WHO/UNICEF JMP 2008), and the high failure rates just cited means that millions to billions more people may have briefly had access but do so no longer.

There are a myriad of issues feeding this problem, and its complexity is one reason why, despite significant investment and true gains in coverage, the world is not on track to meet the Millennium Development Goal for sanitation (WHO/UNICEF JMP 2008). This dissertation attempts to contribute to solving this problem, ultimately using a new theoretical perspective from organizational theory to do so. Its overarching research question is *what causes high failure rates in onsite household sanitation systems*?

I should pause here to note that I do not believe that simply by getting the designs right we can utterly solve this problem; that type of technological determinism has no place in research spanning the technology-society nexus. However, I do believe that engineering and construction play an important role in the process. After all, engineering is the application of science for the use or benefit of people. Pretending to leave people out of this equation (as engineers are often charged with doing) is an absurdity. Leaving the science out of infrastructure is also absurd; this is why engineers must play a role in solving this problem. In other words, while appropriate design and construction does not guarantee infrastructure sustainability, it is surely a prerequisite.

DISSERTATION SUMMARY

As a first step in this research, forty factors important to the sustainability of onsite household sanitation systems were developed from the engineering literature and an expert panel. In this dissertation, I use social sustainability in a limited sense to mean that people use and maintain sanitation systems over time. While this is related to (important) social sustainability questions involving external stakeholders and social justice, these are not the questions asked here. The results of this study may be found in Chapter 2 of this dissertation. Two of the findings were that social factors are important and that interactions between factors explained controversy regarding the importance of ten of the identified factors. As such, I set out to study the social sustainability of sanitation infrastructure in a way that would allow me to include contextual knowledge and to retain complexity in the analysis. Unfortunately, however, we lack theory of social sustainability specific to infrastructure.

The key insight that led to the use of organizational theory in this context came from the novel Texaco (Chamoiseau 1998, Prix Goncourt 1992), where basic infrastructure is seen as a legitimating force for a squatter community. This suggested organizational theory, where legitimacy has been empirically observed to impact organizational continuity. One major contribution to theory from this research, therefore, is theorizing the infrastructure system as a form of human organization. While in the past organizational theory has been fruitfully applied to study engineering projects and firms, it has never before been applied to infrastructure systems. I make the theoretical argument for this in Chapter 3; here I simply note that an organization is defined as a collectivity of people using technology to achieve shared goals, exactly as a community (the collectivity of people) use sanitation infrastructure (the technology) to achieve shared goals

(as reported by our research participants, and including convenience, odor management, good health, and environmental protection).

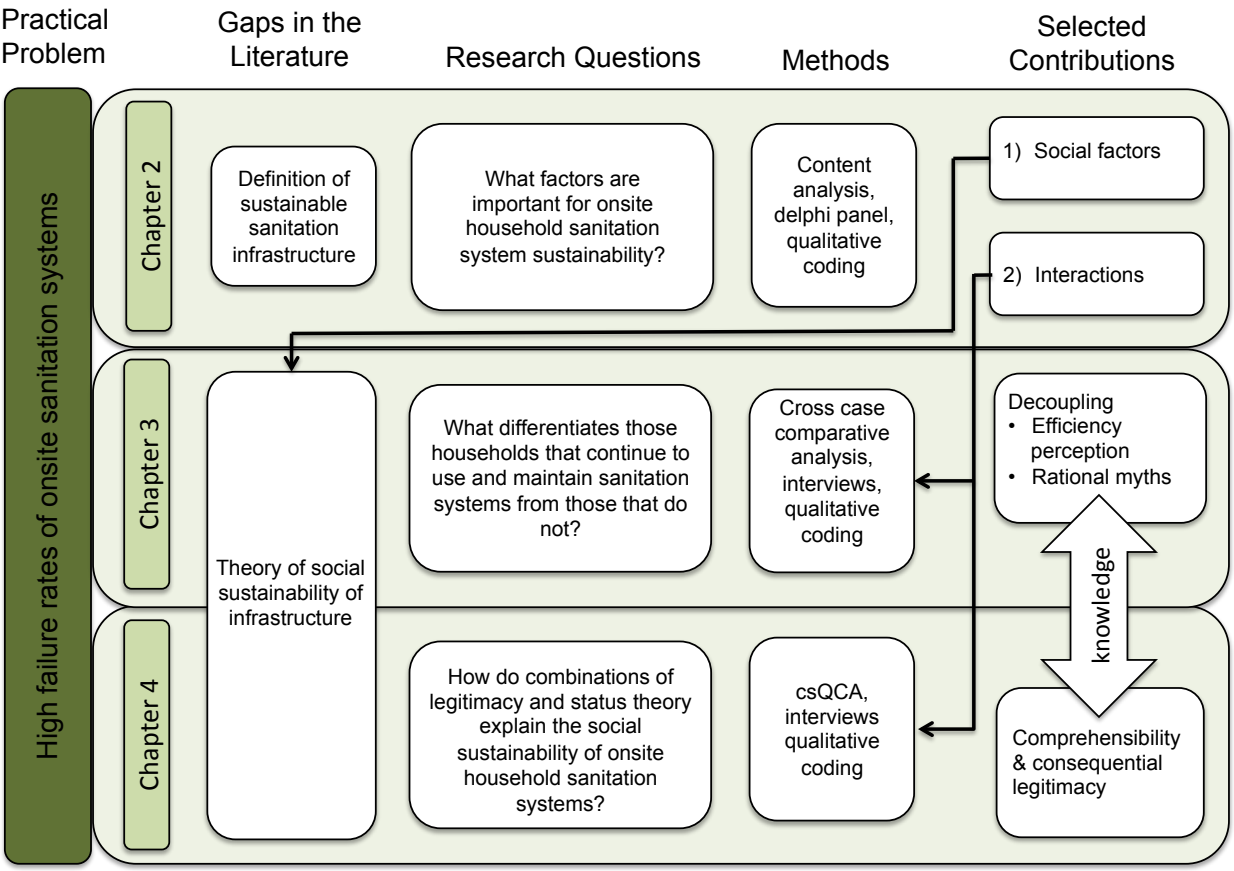
Through this theoretical insight, I use a variety of qualitative analysis methods to argue that the combination of legitimacy and status constructs, taken from organizational theory, provide an excellent explanation of why some households achieve sustainable sanitation and why some do not. In Chapter 4, I use legitimacy and status constructs to develop a number of pathways that households have taken to achieve sustainable sanitation practices. These pathways are founded on comprehensibility and consequential legitimacy, meaning that morally based benefits (such as public health protection) and an understanding of how desired benefits are achieved (such as germ or miasma theory) are key to socially sustain(ed/able) sanitation practice.

In Chapter 3, I use the legitimacy construct to describe the problem of socially based sanitation failures as an issue of organizational decoupling. Decoupling is a process whereby organizations adopt structural change without corresponding change in practice; a classic example is the adoption of equal opportunity hiring offices without corresponding changes in minority employee representation. In the communities studied for this research, nearly every household has personally invested resources to construct sanitation infrastructure. However, in many cases, this infrastructure has fallen into disrepair. In the cases studied, the problem was not a lack of demand for sanitation services, as both the sustainable and unsustainable households cite approximately the same desired benefits and motivations for sanitation. Nor yet was this an economic problem; while extremely poor, households have managed to provide both the funds and labor needed for initial construction and thus could probably also afford the less economically lumpy (though still significant) costs of operation and maintenance. Instead, communities decouple sanitation structure and practice, adopting sanitation ceremonially.

To summarize, this dissertation develops a new way of thinking about the problem of socially sustainable infrastructure. My hopes for this research are several. Theoretically, I hope it serves as the starting point of a rich stream of research analyzing infrastructure systems as organizations, with the goal of improving social sustainability of infrastructure. I also hope that it begins a theoretical conversation regarding the nature of the social sustainability of infrastructure, and that I am fortunate enough to participate in these conversations for many years to come. Practically speaking, I hope that this research will help practitioners design and construct socially sustainable sanitation infrastructure, with the goal of improving longitudinal coverage rates and thereby improving public and environmental health protection for all people.

Figure 1-1 visually summarizes the work done in this dissertation. Findings from Chapter 2 led to the identification of the major theoretical gap addressed in this dissertation, and also guided the methods selected for the research. Finally, results from two different datasets using two different analysis methods gave results linked by the common thread of knowledge. More detailed contributions are shown in Chapters 2, 3 and 4 and are summarized in the concluding chapter.

FIGURE 1-1: RESEARCH DESIGN



RESEARCH CONTEXT

The data for Chapters 3 and 4 were collected in Bangladesh and Guatemala. This focus is practical, as there are a large number of communities that meet our criteria for selection in these contexts, including recent adoption of sanitation infrastructure, usage rates, and extremely limited economic situations. In addition, these contexts are a form of convenience sampling, as personal connections to local research assistants enabled data collection. Beyond these pragmatic motivations, however, there is an underlying theoretical perspective at work, and this should be made explicit. Both in this dissertation and in my larger research interests I am focused on infrastructure provision in underdeveloped communities that lack basic infrastructure services. By this focus I intend to suggest that there are differences in providing infrastructure in different contexts, and that these differences impact project outcomes such as budget, schedule, and the longer term benefits that the projects are intended to provide. As I am arguing for contextual differences, it is important to spend some time describing the context in which this research was carried out. To generalize the context, the communities studied in this research are poor and rural. They live on marginal land with few and infrequent government or infrastructure services. With a very few exceptions households have built their own sanitation infrastructure over the past decade. While a variety of latrine designs are seen, most are standard pit latrines. In all cases, homeowners are directly responsible for all system operation and maintenance. The underlying key commonality for this research is change in infrastructure technology.

BANGLADESH

The four Bangladeshi communities selected for this research are located in the Barisal district. These communities are small (fewer than 100 households in each), poor (approximate average annual per capita income of $80 USD), and rural. The communities selected for this research all report adopting sanitation infrastructure in the last 5-10 years. Households in some of the communities had contact with the non-governmental organization (NGO) BRAC (formerly the Bangladesh Rural Advancement Committee, now known only as BRAC) and some had also had health and hygiene training from the NGO World Vision. A few households also referenced contact with government officials and a health clinic, but neither is located near the communities and neither has visited for many years. Many households reported regular flooding, and one community was located on an island. In many cases this meant that the installed latrines were technically inappropriate and cannot provide treatment. Almost all the latrines were the ring-slab design common to Bangladesh. In this design, concrete rings line a hand-dug pit, which is covered by a slab. Slabs are made of wood, plastic, or concrete. Privacy enclosures, when present, are typically made from plastic or plant material. The few toilets that did not conform to this design were instead connected to short pipes leading to a nearby ravine rather than a pit.

GUATEMALA

The three Guatemalan communities selected for this research are located in the municipality of San Antonio Aguas Calientes. Like the Bangladeshi communities included in this research, the communities are small (fewer than 50 households in each), poor (approximate average annual per capita income of $200 USD), and rural. The communities have been formed in the last decade; some households were using sanitation infrastructure before the move and some were not. Also like the Bangladeshi communities, at least one is located on marginal, floodplain land. The latrines in these communities ranged from standard pit latrine designs (the most common) to offset pour flush designs. In the past they have had some contact from NGO although the community cannot usually remember which ones. There is some small connection to a health clinic and to the municipal officials, but neither is located in the community and the community reports they only visit during election season.

RESEARCH METHOD OVERVIEW

This section presents an overview of the multi-method approach I used to answer my research questions. These methods included three data collection methods (a content analysis of journal articles, an expert panel, and household level interviews) and two data analysis methods (qualitative analysis and crisp set qualitative compariative analysis (csQCA)).

DATA COLLECTION: CONTENT ANALYSIS

The first phase of our research performed a literature review and expert panel evaluation of factors leading to sustainable household onsite sanitation. This work began by reviewing literature from the online Engineering Village, Web of Science and ASCE journal databases from 2000-2011. 873 citations were reviewed for topical relevance. These citations were narrowed to 29 articles that specifically dealt with the particular technology of interest. These articles were qualitatively coded using QSR NVivo 10 (QSR International Pty Ltd. 2012) to develop a list of factors important to the sustainability of household onsite sanitation systems. These factors were presented to an expert panel for further evaluation using the Delphi method. Details on the results of this analysis may be found in Chapter 2.

DATA COLLECTION: DELPHI METHOD

The Delphi method is a way of eliciting expert knowledge on complex topics while avoiding common sources of bias (Hallowell and Gambatese 2010). Developed by the RAND Corporation (Helmer-Hirschberg 1967) it

has recently been used by construction researchers to answer questions on topics as diverse as worker safety (Hallowell and Calhoun 2011) to disaster recovery (Jordan et al. forthcoming). For this research, 14 experts were qualified to participate. These experts represented knowledge from a diverse array of backgrounds, including academics, regulators, international development practitioners, O&M providers, and manufacturer/designers.

Each expert was asked to take an online survey independently to comment on and rate the importance of the factors developed from the literature. A total of four survey rounds were performed. The first asked for comments on the factors developed from the literature. The second asked for ratings of each factor using a 5-point Likert scale. The third and fourth rounds provided the experts with the rating they had previously made, and a median and range of ratings from the group. They were then asked to reevaluate their own rating and, if their rating changed or deviated from the group, explain why. In the fourth round, the experts were also asked to select three most important and three least important factors. More details on the Delphi method, analysis, and results may be found in Chapter 2.

Data Collection: Interviews

Chapter 3 and Chapter 4 both depend on household interview data collected in Guatemala and Bangladesh. These interviews used open-ended questions in a semi-structured format. With the consent of the research participant, the audio of each interview was recorded. These recordings were later transcribed and (in the case of the Bangladeshi interviews) translated to English. The Bangladeshi interviews resulted in 585 pages of transcribed text; the Guatemalan interviews resulted in 159 pages of transcribed text. All the interviews performed for this dissertation used the same interview guide; this data collection tool may be found in Appendix A.

Data Analysis: Qualitative Coding & Analysis

Qualitative coding was the analytic technique that prepared data for analysis in all three of my dissertation chapters. In Chapter 2 I coded typed text provided by an expert panel, and Chapter 3 and Chapter 4 I coded transcribed interview text. In each case, I examined lines of text and assigned it to one or several qualitative codes. These codes may be thought of as tags that identify a coded portion of text as an instance of an archetypal idea. Later analysis can then more easily process large amounts of textual data either (for example) by performing analysis on the presence or absence of coded occurrences (as I did with crisp set qualitative comparative analysis (csQCA) in Chapter 4) or by using these codes to organize, count and locate archetypes to aid a more traditional qualitative analysis (as I did in Chapter 3).

Data Analysis: csQCA

Qualitative Comparative Analysis is a method ideal for the analysis of combinations of variables. This method incorporates some of the benefits of both quantitative and qualitative methods by using set theory to develop groups of causal conditions that lead to the outcome of interest (in this case, socially sustainable sanitation systems). Here, I performed qualitative coding of household interview data to identify the presence or absence of references to conditions theorized to affect that outcome. This study employed csQCA, meaning measurement was of the more simple presence or absence rather than a fuzzy set measurement. This coding was used to develop a truth table matrix representing all household cases and the sustainability outcome. This truth table was then analyzed using the csQCA technique and the fuzzy set Qualitative Comparative Analysis (fsQCA) software (Ragin et al. 2013). This allowed us to see what combinations of factors lead to socially sustainable or unsustainable sanitation systems. For more details on the csQCA method, analysis, and results, please refer to Chapter 4 and Appendices B & C.

DISSERTATION FORMAT

This dissertation follows a journal article format. Chapters 2, 3, and 4 are independent articles, related by subject matter but formatted separately due to publication requirements. Chapter 2 has been accepted for publication in the upcoming Special Issue for Sustainability in the Journal of Construction Engineering and Management and at the time of submission of this dissertation was posted online ahead of print (Kaminsky and Javernick-Will 2013). I respectfully request that any citations to the work presented in Chapters 2 through 4 make reference to those published versions rather than to this dissertation. Although these articles are presented separately here, references are presented both separately with each paper and combined in a comprehensive list at the end of this document. Finally, the appendices include details regarding data collection tools, IRB approvals, and the csQCA analysis that could not be included in the journal articles themselves due to space limitations.

CHAPTER 2: CONTESTED SUSTAINABILITY FACTORS: THE CONSTRUCTION AND MANAGEMENT OF HOUSEHOLD ONSITE WASTEWATER TREATMENT SYSTEMS

Keywords: Sustainability, Onsite Wastewater Treatment, Rural Sanitation, Asset Management, Factors, Delphi Method

ABSTRACT

Onsite sanitation systems experience a high failure rate with resulting environmental and public health implications. In the USA alone, the EPA estimates that 10% of the 26 million homes served by onsite systems have failed. If this failure rate is extrapolated to the 8% of the global population that the UN estimates have gained access to sanitation between 1990 and 2008, an additional 5 million failed systems have been constructed. To address issues like this, development theory currently emphasizes a blend of hardware (e.g. infrastructure, technology) and software (e.g. knowledge, institutions, education) in an effort to achieve sustainable development. However, we lack both theory that addresses this interaction and a definition of sustainable infrastructure. To begin to address this gap, an initial set of 40 factors that may contribute to sustainable onsite sanitation systems was identified from a literature review including the Web of Science, the Engineering Village, and the full record of ASCE from 2000 to July 2011. A panel of 14 experts including academics, regulators, international development practitioners, O&M providers, and manufacturer/designers was then assembled to identify any additional factors that may lead to resilient onsite systems and to evaluate each one using the Delphi method. The panel evaluated each factor iteratively in order to develop a measure of its importance to the sustainability of onsite sanitation infrastructure. Experts were also invited to provide and review comments explaining or discussing the ratings they provided, and to identify the factors they perceived to be the most and least important. Of the initial list of factors, 9 came to consensus as being important or very important, including factors such as owner occupancy, quality of installation or materials, and post-construction follow-up programs. In addition, 10 factors provoked particularly diverse, or contentious, opinions with ratings that more than doubled the target criteria for consensus. These contentious factors are analyzed to identify trends and debates in expert opinion that showcase future research needs as well as issues that practitioners must address to build sustainable systems.

INTRODUCTION

One of the commonly noted features of the construction industry is the particular nature of its projects. Infrastructure projects in particular are typically large in terms of scope and cost, are intended to be used for long time periods, and are delivered by a temporary project team made up of multiple and transient organizations (PMI 2008). Each construction project results in a unique product designed and constructed for a particular confluence of people, the natural environment, and financial constraints. Another defining feature of infrastructure projects is the long asset lifecycle. Historically, assets may have been designed without much consideration of what would happen after the design life had been exceeded. More recently, an industry-wide focus on sustainability has led to consideration of cradle-to-grave design; in other words, design and construction may now consider disposal the end of an asset's useful life. More recently yet, cradle-to-cradle design suggests that this focus must be expanded further in order to consider repurposing materials and assets to better serve the fundamental goals of sustainable development.

Of course, there is still a substantial debate regarding both the means and the ends of sustainable development. This is true both at a macro level and more specifically in the context of construction and infrastructure (Levitt 2007a). Generally, though, we may define development as "organized intervention in collective affairs according to a standard of improvement" (Pieterse 2001 p. 3) with *sustainable* development providing (still contested) criteria for that standard of improvement. Development theory and practice has moved away from the provision of just hardware (e.g. infrastructure, technology) to a combination of hardware and software (e.g. knowledge, institutions, education) (Pieterse 2001 p. 156). However, there is a dearth of research addressing what software is actually needed to support infrastructure development—in other words, what factors should be included in a definition of sustainability specific to the engineering and construction community. This paper contributes to the growing body of work in sustainable infrastructure by developing a preliminary list of those factors, focusing specifically on the subset of household onsite sanitation infrastructure. By this we mean any form of household sanitation infrastructure that meets international standards for improved sanitation (WHO 2012) that is not connected to a sewer. Some typical examples include septic tanks or ventilated improved pit latrines. Before presenting these results, we first discuss the research underpinnings in sustainable development, particularly as it relates to sanitation infrastructure.

SUSTAINABLE DEVELOPMENT

The construction community has only relatively recently begun to engage with the concepts of sustainability (Levitt 2007a). In a June 2012 title/abstract/keyword search of the online archives of the Journal of Construction Management (JCEM), the keywords 'sustainability' or 'sustainable' returned only 59 results. However, whereas prior to the year 2000 there were 1 or 0 articles each year, in 2010 there were 9 articles, and in 2011 there were 16. Clearly, the topic is of growing interest to construction researchers.

It is a common criticism that the term sustainable development means everything and nothing—in other words, that it is used for so many things that it has ceased to mean anything at all. For example, among the 59 articles appearing in our JCEM search, there are fundamental differences regarding exactly what is to be sustained by and for whom (for example, see Bakens 1997; Beheiry et al. 2006; L. Klotz and Horman 2009; Koo and Ariaratnam 2008; Laefer and Manke 2008; Shen et al. 2010; Valdes-Vasquez and L. E. Klotz 2012). However, while it may still be unclear as to what sustainable development means for the construction industry specifically, on a more general level the dominant (though certainly not only) theory is clear. The most commonly used definition should be credited to the Brundtland Commission (WCED 1987) and the economist Solow (1993). This combined view sees sustainability as something that preserves economic productive capacity for future generations while recognizing the needs of current generations and privileging the needs of the poor. The foundational concepts are consumption, intra- and inter-generational justice, and the commensurability of values. Also implicit in this definition are ideas of scarcity and a hard division between the natural (non-human) and social (human) units of analysis. This definition sees technology as an important tool to be used to improve economic productivity, but has little to say about how sustainable technology should be defined or operationalized.

SANITATION

Sanitation infrastructure is an important subset of the larger construction market. In the US, the US EPA estimates that almost $300 billion will be needed for clean water infrastructure over the next 20 years; $24 billion of that is earmarked for decentralized (septic) systems (US EPA 2008). While these numbers are enormous, the global market is even larger. The UN estimates that 2.5 billion people have no access to improved sanitation infrastructure, including 1.2 billion who have no facilities whatsoever (WHO/UNICEF JMP 2008). A large percentage of this demand will be met by leveraging onsite sanitation technologies. This

is especially true in rural contexts, where distances and increasing energy costs may make long force mains unsustainable, and to meet the demands of the exploding peri-urban and urban populations where issues such as land acquisition and tenure make the construction of new linear infrastructure a particularly complicated business (Nelson and Murray 2008).

Sustainable development has been criticized as offering second-class or outmoded technology, something that only those without other options would put up with while the wealthy choose more resource intensive technologies that are assumed to be intrinsically better. However, reducing the resources required to install or operate a technology does not make it fundamentally worse. This criticism is a particular problem for sanitation technologies, with onsite systems somewhat universally experiencing a reputation as a stopgap until a sewer connection can be made (Etnier et al. 2005). However, in theory onsite technologies can provide excellent treatment while greatly reducing resource use both in construction and in operation as compared to a sewered system, especially in mountainous, low density, remote or rural areas—wherever long pipe runs or lift stations might be required. Unfortunately, in practice onsite sanitation systems experience a high failure rate (EPA 2008). This research addresses this issue by identifying factors that impact the sustainability of onsite sanitation systems.

METHOD

This project used multiple methods including a content analysis of relevant literature and a Delphi panel intended to elicit expert opinion. In addition, experts were invited to rank the most and least important factors. This process, described below, identified and rated the importance of factors that are important to the sustainability of onsite sanitation systems.

LITERATURE REVIEW

As the first step in the process to identify factors impacting the sustainability of onsite sanitation systems, a literature review was conducted. This literature review included the Engineering Village, the full record of ASCE, and the Web of Science from 2000-July 2011. The searches were limited to English language journal articles and included permutations of the keywords (sanitation or wastewater), (onsite or on-site), and (factor*) in the abstract, title, keywords, or topic of the articles. This intentionally broad search returned 873 non-unique citations. For this research, we were interested in articles that dealt directly with onsite sanitation systems at the household level. As a result, although we did not disqualify articles based upon technology type or system location, centralized or semi-centralized systems were excluded from the analysis unless the article also treated decentralized household systems. Based upon these qualification criteria, 49 relevant articles were identified from the abstract review for full-text review. Using the same criteria, 20 of these were eliminated from the detailed content analysis, while 29 were qualified for further study. These 29 articles were imported into QSR NVivo for coding and analysis. Iterative and exploratory coding schemes were used to identify factors mentioned in the articles as determinants of sustainable sanitation technology. We avoided limiting the definition of sustainability or the rigor with which these factors were evaluated in the reviewed articles. Once theoretical saturation had been reached and no additional factors emerged from the text, factors were categorized into a broader analysis framework of macro-categories. These categories were reviewed by the Delphi panel and were used to organize and rate the importance of the final list of factors developed through the literature review and panel process as described below.

DELPHI PANEL

The Delphi Method was originally developed by the RAND Corporation (Helmer-Hirschberg 1967). In past years it has proven to be a useful tool for obtaining insights from experts on especially complex issues in engineering. By soliciting interactive expert opinion in several iterative rounds, it may enable experts to

achieve consensus on complex topics. If consensus cannot be achieved, it collects information to understand why. Generally, this methodology asks expert panelists to independently rate the importance of a collection of factors. These independent ratings are done iteratively, allowing each expert to consider the opinions of other panelists with the ultimate goal of achieving consensus. This research follows guidance by Hallowell and Gambatese (2010) regarding methodological design for this use of this method in construction research.

RESEARCH DESIGN AND DATA COLLECTION

An expert panel was assembled to review, add to, and comment on the 36 identified factors and categories. Following Hallowell and Gambatese (2010) a list of criteria was developed to signify expert status, and each criterion was assigned points. Selection criteria for the experts may be seen in Table 2-1 below. In order to qualify as an expert for this study, each participant was required to score a minimum of 10 points.

TABLE 2-1: EXPERT QUALIFICATION CRITERIA

Points	Criterion
2	Each peer reviewed journal article about onsite sanitation
1/3	Member/Chair of a national committee about onsite sanitation
1	Year relevant professional experience in onsite sanitation
3	Faculty member at an accredited university with relevant research and/or coursework about onsite sanitation
2/4	Writer or editor of a book chapter/book about onsite sanitation
3	Professional registration such as PE relevant to onsite sanitation

After initial screening based on online information, a total of 19 potential experts were contacted. Of this number, 14 responded and were ultimately qualified to take part in the study. Two academics, two regulators, three international development practitioners, three O&M providers, and four manufacturer/designers are represented in the panel. These 14 experts have an average of 22 years each of experience in onsite sanitation. All 14 experts are currently based in the United States, although 4 of them reported significant experience working internationally. Four survey rounds were administered via an online survey powered by SurveyGizmo. In the first round, experts were able to comment on or add to factors identified in the literature review as well as suggest changes to the categorization. Each category of factors was presented on a separate page of the survey, which were randomized for each participant to minimize bias. Expert comments were considered to develop a comprehensive list of factors for the Delphi process. 40 factors were identified through the literature review and this first survey round. These 40 factors were organized into 6 categories, including Technical, Organizational, Economic, Knowledge, Motivation, and Other. These categories were developed through coding of the literature and were approved by the expert panel.

After this initial round, 3 additional rounds were completed through the Delphi process. Minor wording changes were made to 6 of the 40 factors between survey rounds 2 and 3 to clarify the meaning based on expert comments. Each expert rated each factor independently based on a 5 point Likert scale. For each round, the aggregate median and range of scores given by the panel for each factor and the expert's individual ratings from the previous round was reported back to each expert. Experts then reconsidered their previous ratings and provided comments indicating why they did or did not change their individual scores. In the final two rounds, comments from the previous round were provided anonymously along with the new aggregate median and range of scores. It should be noted that the final survey round experienced some respondent fatigue; several panelists expressed frustration with revisiting and considering the same factors so many times. However, all 14 experts responded to all 4 survey rounds.

A 5-point Likert scale was used, with a 1 signifying Very Unimportant, a 2 signifying Unimportant, a 3 signifying Neither Important Nor Unimportant, a 4 signifying Important, and a 5 signifying Very Important. Consensus was measured by absolute deviation of scores from the median, according to the following equation, where X is equal to the panelist rating and N is equal to the number of ratings:

$$Abs.Dev. = \frac{\sum|X - Median|}{N}$$

The target absolute deviation was 0.25, which translates to a high level of consensus.

In a third approach to our research question, during the final survey round experts were also asked to identify the three most and least important factors across all categories. One expert declined to answer this question due to time constraints.

RESULTS

This research ultimately identified 40 factors from the literature and expert panel. Of these 40, 9 reached consensus as being either Important or Very Important. In contrast, 10 factors were particularly contentious, with absolute deviations double the target. These sets of factors are discussed here.

FRAMEWORK DEVELOPMENT

36 factors and 6 categories of factors that contribute to sustainability emerged from the literature. These categories included economic, organizational, knowledge, motivation, technology, and other. The technology category was observed most frequently, appearing in 23 of 29 articles. In addition, 12 articles, or about 40% of those analyzed, mentioned only technology factors. One article mentioned only economic factors. With the exception of these 13 articles, which only mentioned either technology or economics, the remaining articles discussed, a combination of factors. This is interesting as there is no reason to believe that these two operate in isolation while other categories interact. In addition, this division is suspect because it mirrors common disciplinary boundaries between the social and hard sciences.

After technological factors, economic and organizational factors were mentioned most frequently. Both of these categories appeared in 12 of 29 articles. After this, motivation, knowledge, and other categories appear with 10, 8, and 6 articles citing the categories respectively. The 36 factors and 6 categories identified in the literature review were presented to the expert panel for comment and amendment. While the panel made no changes to the categories, the factors themselves were sometimes modified. Modifications included the addition of examples and the splitting, combining, and rewording of factors. The final list of 40 factors includes 7 economic factors, 7 organizational factors, 6 knowledge factors, 10 motivation factors, 7 technology factors, and 3 other factors (listed in Figure 1). The text in this figure is abbreviated; for example, in the Technology category, the first factor (Inappropriate Site Conditions) was presented to experts as "*OWTS [Onsite Wastewater Treatment Systems] are negatively impacted by inappropriate soils, slopes, proximity to groundwater or surface water, etc. In other words, OWTS technologies are just inappropriate in some areas.*"

FACTORS REACHING CONSESNSUS

Of the 40 factors presented to the expert panel, 9 reached consensus as being either Important or Very Important. These 9 are shown in Table 2-2. Immediately apparent is that these factors span the macro categories. Of particular interest are the technical factors, which deal with construction issues of material and installation quality rather than the actual technologies themselves. This is supported by comments supplied by the experts. For example, one expert stated, "*The current OWTS technologies are appropriate to address the potentially negative impacts of soils, slopes, proximity to groundwater or surface water, etc.*" One

O&M provider commented "*I agree that an OWTS can be affected by poor design, but do not run across many issues where the system is suffering due to a design error, generally the OWTS is negatively impacted by poor installation practices.*"

The non-technical factors that reached consensus often deal with post-construction issues. Emptying, how the system is used and by whom, and the organizations that exist to provide service or information for the systems are seen as universally important. These trends are particularly interesting given the diverse makeup of the expert panel. These factors appear to be highly relevant to sanitation workers, from small business owners (O&M providers in the USA) to international development workers managing multi-million dollar sanitation enterprises.

TABLE 2-2: FACTORS REACHING CONSENSUS

Category	Median* Range* Abs. Dev.	Factor
Economic	5 4-5 0.14	The costs of emptying the system negatively impacts OWTS. For example, systems may be allowed to overflow because of the cost of emptying.
Economic	4 3-5 0.21	Owner occupancy positively impacts OWTS. For example, if the household is not owner occupied, owners may not invest in appropriate system installation, repair, or emptying will occur. Alternatively, renters may not properly care for a system they do not own.
Knowledge	5 4-5 0.21	OWTS are negatively impacted because users do not know how to use them. For example, this might include what additives can or cannot be put through the system.
Organizational	4 3-4 0.14	The existence of local NGO/non-profits involved in sanitation issues positively impacts OWTS.
Organizational	5 4-5 0.14	The existence of local, for-profit businesses such as installers, pumpers, designers, repairmen, and spare parts suppliers positively impacts OWTS.
Organizational	5 4-5 0.14	Follow up programs after construction positively impact OWTS.
Other	5 4-5 0.14	OWTS are negatively impacted when it is difficult or inconvenient to properly dispose of septage.
Technical	5 4-5 0.07	OWTS are negatively impacted by poor quality installation.
Technical	5 4-5 0.21	OWTS are negatively impacted by poor quality materials.
*1 = Very Unimportant, 2 = Unimportant, 3 = Neither Important Nor Unimportant, 4 = Important, and 5 = Very Important		

DIVISIVE FACTORS

The following 10 factors were the most divisive; in other words, individual scores exhibited the highest absolute deviation from the median. These 10 factors had absolute deviations of at least twice the consensus

threshold, or at least 0.5. Since experts held diverse opinions on these factors, their comments were coded and analyzed to determine major themes. We present these themes along with selected comments that illustrate the identified themes below. While contextual issues (most commonly developed vs. developing community perspectives) appear in many discussions, more fundamental disagreements on these factors drive the lack of consensus for most. In each case, the discussion of these divisive factors tends to hinge on interactions, as highlighted in the discussion below.

Economic: Extreme poverty negatively impacts OWTS. For example, poor households may be less able to install, empty, or repair OWTS than a wealthier household. Assume neither is reached by a sewer connection. (Median: 4 Range: 3-5 Absolute Deviation: 0.50)

The first major theme identified for this factor is the recognition that being extremely poor correlates with not having a sanitation system or having an onsite system rather than a sewer connection. For example, one expert stated *"Globally, the bottom 40th of income groups by and large do not have access to hygienic and durable sanitation facilities. So yes, poverty is a major factor in the use and sustainability of onsite sanitation."* However, the second theme recognizes that this correlation does not signify causation; in other words, user poverty does not mean that sanitation systems fail, and nor does user wealth mean that sanitation systems will be successful. For example, *"Even the wealthy or well off are motivated to shop for the cheapest installation price. Few users truly invest the time to understand critical treatment process differences or the performance capabilities and limitations between alternatives, and even fewer consider the differences in long-term life-cycle costs or payback periods."* The final theme is a contextual one; these comments assume that one must have sanitation rather than considering contexts where this may not be the norm: *"If the person is at the poverty level they still need to ensure they have a working system which could cost them money."* This discussion emphasizes the interaction between the economic resources invested in sanitation and the varying motivation required to make that investment, perhaps contingent upon competing demands for resources.

Economic: The availability of installation subsidies negatively impact OWTS. For example, subsidies might cause households to not feel system ownership, might drive an inappropriate technology choice, or might not be equitable. (Median: 4 Range: 2-5 Absolute Deviation: 0.64)

Four major themes were identified in the comments regarding installation subsidies. The first group of opinion was that subsidies are helpful tools. For example, one expert noted that *"It will not be a negative impact - if two systems out of 10 are repaired, then this is an improvement."* However, at least one expert who advocated this theme appears to have been thinking of recent experience with large infrastructure projects rather than onsite systems. *"I actually disagree with this statement. Experience with the construction grants program which generated large subsidies for plant design and construction were largely very successful. Undoubtedly there may have been inappropriate technologies selected, but I think that has been true regardless of subsidies. The only inequitable concern I see would be if the subsidies were not either uniform or applied on a consistent scale."* The second theme is exactly opposite to this one; namely, that subsidies hurt the sustainability of onsite sanitation infrastructure. For example, *"30 years of subsidies taught that only wanted latrines are used latrines. Non-use is a negative impact."* The most common reason given for subsidy failure was *"Distorting of markets worldwide, a mess."* The third theme is concerned with the management of subsidies, including timing, equity, and implementation. *"This is important, but who manages the subsidies and how do we make the decision about which system gets subsidized."* Another expert noted that *"Financing approaches - including capital subsidies can have a profound impact on the use and sustainability of sanitation infrastructure. In developing countries, subsides for onsite sanitation have by and large not been properly implemented resulting in a process that undercuts effective demand for sanitation by the households which in term leads to limited use of the facility."* Finally, a contextual theme emerged. This fourth theme deals with comments stating that subsidies are typically not available for onsite systems in the geographical context that particular experts have experience in. Notes reflecting this perspective included comments such as, *"As far as I know there is not access to any subsidies to offset the costs of design or installation."* This discussion once

again emphasizes the relationship between economic resources (in this case, external to households) and user motivation for sanitation. Both this and the previous theme imply that both economic and motivation factors are necessary but not sufficient for sustainable sanitation.

Motivation: OWTS are negatively impacted because they are "Out of Sight, Out of Mind" until there is a problem. For example, this could mean that the process chain is underground and easy to ignore until there is a problem. (Median: 4 Range: 1-5 Absolute Deviation: 0.50)

Four themes were identified in comments given regarding this factor. The first and most prevalent was that this is a major *"90% of mentality"* issue for onsite sanitation systems. At least one expert believes that *"Out of sight and mind is the source of most problems not involving design."* These comments suggest that not only are users unaware of issues but rather that they may refuse to engage with sanitation technologies. "*Nobody wants to deal with their toilet other than for what it is intended for. And everyone hopes other than the occasional cleaning they do not have to pay more attention to it."* A second theme was a single expert who repeatedly stated that he did not understand what the factor was trying to address. A third was a single expert who repeatedly stated that he strongly disagreed that this was an issue while recognizing that it was a commonly held opinion: *"It's a totally overstated assumption and is commonly held - hence my major divergence from the median."* Finally, a fourth theme emerged from an expert who felt that it was a design flaw if systems were permitted to be invisible when there were problems. *"I prefer less "out of sight and mind" by having lids near the surface for accessibility, and vent pipes to define limits of field and aware of problems, if there are problems."* This discussion may address a management issue particular to sanitation. If indeed "*nobody wants to deal with their toilet*" it may mean that households are unlikely to seek knowledge about systems or even to pay enough attention to notice that there are issues. Alternatively, this discussion can be framed as treating the far larger issue of inadequate infrastructure maintenance and asset management. In other words, this discussion concentrates on the relationship between motivation and knowledge. This could impact the way infrastructure software such as O&M contracts should be constructed and regulated. Although this factor deals with systems that are already installed, it may also apply more generally to sanitation adoption practices in infrastructure poor communities.

Motivation: OWTS are positively impacted because users perceive them to be safe (structurally sound, hygienic, children can't fall in, etc.) (Median: 4.5 Range: 4-5 Absolute Deviation: 0.50)

While this factor did not reach consensus, it was not due to fundamental disagreement on the issue. Instead, responses were split evenly (7 and 7) between rating this as a 4—"Important" and a 5—"Very Important". A representative comment provided for this factor is *"If they [users] believe the systems are unsafe structurally or if they are going to have a negative impact on their and their family's health they are going to be reluctant to have them. Education is the best way to inform them about how they can stay safe how best to keep their system safe and healthy."*

Motivation: OWTS are positively impacted if users have a range of aesthetic/amenity options to choose from (styles, materials, colors of the above ground installation). (Median: 4 Range: 2-5 Absolute Deviation: 0.57*)*

Four themes were identified for this factor. The first were experts who generally agreed that aesthetics especially improve user satisfaction, create demand for systems, and thereby drive system sustainability: *"It is all about creating and meeting demand and creating more demand. Aesthetic aspects probably more than amenity options figure highly - see the parallel in virtually any other commercial product of lasting value."* However, a second theme recognized the importance of economics. This group of experts believed that *"Cheap dominates over aesthetics."* The third theme separates the aesthetics and amenities of the lavatory itself (used here to mean a room or structure with a toilet and possibly washing facilities that users interact with on a regular basis) and the underlying treatment infrastructure. *"Unsure about aesthetics and security questions. OWTS are generally below ground and not visible, unless you are talking about the WC itself - as in a pit privy. Then I think aesthetics/amenities and privacy/security are very important."* It is interesting to note

that this discussion further differentiates between the onsite technologies by suggesting that aesthetic options for the latrine's lavatory are more important than for septic or similar installations. Underlying contextual and experiential assumptions regarding typical minimum standards of lavatory installations for various technologies (for example, a septic tank in a US home vs. a latrine in a US park) may drive comments like *"I have a great collection of outhouse pictures, but for the most part this [factor] is not relevant in U.S."* Finally, the fourth theme notes that aesthetics ought not impact the technical performance of the infrastructure and therefore rates the factor as less important**:** *"I am assuming the aesthetic amenities do not have an effect on the goal of an OWTS (to treat wastewater prior to dispersal back into the environment). Therefore, the aesthetic amenity is neither important nor unimportant."* This comment explicitly assumes that technical performance is never compromised for aesthetic reasons. This discussion again focuses on the relationship between economic and motivational factors. Additionally, the fourth theme suggests that there may be a relationship between motivational and technical factors, while emphasizing that expert's belief in which of these factors should dominate.

Motivation: OWTS are positively impacted if users have a range of level of service provision to choose from. For example, this might be the type of treatment or how much treatment is possible with the technology. (Median: 4 Range: 2-5 Absolute Deviation: 0.57)

Three themes were identified for this factor. The first simply agrees with the stated factor. The second notes that *"there is not much selection in service"* and that therefore this factor is less important. The third theme is that users often do not care much about the technology itself and just want it to work, with various definitions of what that means. *"I don't think most users of OWTS want information on the technology itself to insure performance. They may want information instead on the reliability, ease of operation, health benefits - performance factors that result from the technology."* This discussion relates the type of knowledge that motivates users. Specifically, performance factors, such as convenience, are cited over technical as motivators for users.

Organizational: Government involvement in areas other than regulation (such as financing, installation, etc.) positively impacts OWTS. (Median: 4 Range: 2-5 Absolute Deviation: 0.50)

Four themes were identified for this factor. The first were experts who agreed that government involvement in areas other than regulation were beneficial for the sustainability of onsite sanitation systems. Noting the varying opinions on this topic, one expert commented *"I continue to disagree [with the rankings of other experts] because my experience shows that government involvement is a critical factor in large scale and sustainable programs."* The second were experts who believed either that government involvement beyond regulation tended to have negative impacts (*"Matters in the sense of regulation, not financing or implementation (messes it up too often)),"* that it was unnecessary (*"I need an example in which government involvement, other than regulation, is needed,"*) or even inappropriate (*"Government's role is to govern, not finance, install, etc.").* The third theme, mentioned by just one expert, was that regulation actually encompassed the other areas identified in the factor; *"Installation is part of the regulatory process."* As such this factor did not make sense to this expert. Finally, the fourth theme was the recurring contextual issue of experts not having experience with government involvement other than regulation and thereby ranking it as less important. For example, one expert noted that the impacts of this factor are *"country specific - in U.S. other government involvement is limited."* This discussion hinges on the proper relationship between government and market forces in the provision of basic infrastructure services. While all experts place regulation as a government responsibility, they are split regarding other aspects. As most of the experts involved in this research are professionally involved in the provision of these services either from the private or public spheres, inadvertent bias may be a particular issue with the responses to this factor.

Other: OWTS are negatively impacted by natural disasters. (Median: 4 Range: 1-5 Absolute Deviation: 0.64)

There were three themes identified for this factor. The first is a recognition that disasters do indeed negatively impact OWTS through physical infrastructure damage. *"This is a major contributor to poor sustainability of less durable onsite sanitation built by poorer households. Not just major natural disasters but annual flooding (as in Bangladesh, the Amazon, etc.) regularly and consistently wash away onsite sanitation facilities."* The second theme notes that although onsite sanitation systems are indeed impacted by disasters, they "*actually might be more resilient since they are inherently more redundant"* than other, more centralized, sanitation technologies. These experts rated this factor as less important due to this relative comparison. The third and final theme was a contextual issue of experts working primarily in areas largely unaffected by natural disasters: *"In our region, natural disasters are not real common & thus do not have a high percentage rate of impacting OWTS."* This discussion suggests the need for research quantifying environmental discharges from decentralized systems after disasters. While it may be true that initial damage and discharge due to these systems is less, it could also be true that over the long run discharges would be greater due to the larger challenge of repairs to decentralized, privately owned systems. This in turn suggests a relationship between technical, regulatory, and organizational factors in sanitation performance.

Knowledge: OWTS are negatively impacted because designers have insufficient knowledge of soils, slopes, proximity to groundwater or surface water, etc. (Median: 4 Range: 2-5 Absolute Deviation: 0.50)

Most experts rated this factor as either 4-Important or 5-Very Important. However, two experts rated this factor as 2-Unimportant. Two themes are apparent in the expert comments; the first agrees that onsite systems have been negatively impacted by insufficient designer knowledge. One expert noted *"There have been few designers with a thorough background in OWTS until recently."* The second believes that as this knowledge is required by regulation (*"Knowledge of designers should be trumped by knowledge of regulators")* or designer reputation (*"Don't feel it is an issue because if care is taken in choosing a good reputable designers they WILL have the knowledge of soils, slopes, etc."*), it is a given. Therefore this group believes that this factor is less of an issue, though one expert calls attention to contextual importance by commenting that *"Most counties that regulate OWTS permits require knowledge of these. May not be true where there is no institutional oversight either as a permit system or designer/installer certification. Without these importance of #5 [the factor] would be much higher."* Both of these groups believe that expert knowledge is important to building sustainable systems. This factor is likely most important in locations where regulation of decentralized systems is weak due to greater variability in knowledge. Generally, this discussion is based on the relationship between knowledge and regulatory motivation.

Technology: OWTS are negatively impacted by inappropriate soils, slopes, proximity to groundwater or surface water, etc. In other words, OWTS technologies are just inappropriate in some areas. (Median: 4 Range: 2-5 Absolute Deviation: 0.50)

There were two themes identified for this factor. Expert comments indicated that there was general agreement that "*for any of the above factors there are engineering designs that can be utilized to ensure there is an appropriate design.*" In other words, experts believe that existing onsite sanitation technologies are sufficient to provide treatment in virtually every situation. However, others noted that these technologies must be designed and constructed appropriately; for example, *"If it is poorly located, the best design will not work."* Both these themes appeared in comments from single experts (*"The appropriate technology needs to be used for the area. An educated designer and installer should be able to identify if an area needs more or possibly less technology"*); difference in ratings appears to pertain to which theme the expert prioritized. Generally, experts believe that while adequate technology exists, it may not necessarily be applied correctly. In other words, it describes a relationship between technical performance and knowledge.

MOST/LEAST IMPORTANT

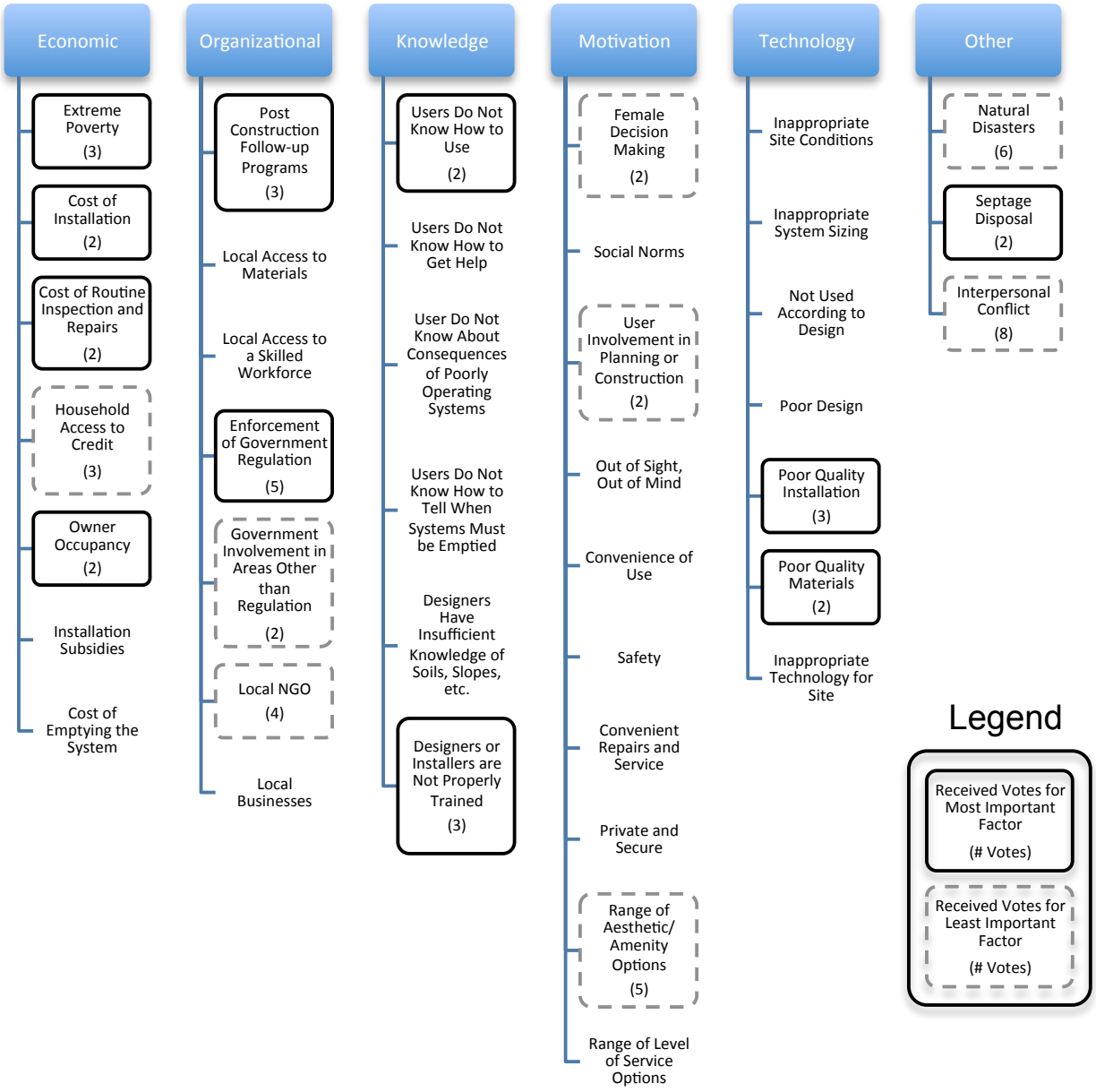
After the Delphi process was complete, each expert was asked to select three *most important* and three *least important* factors. One expert chose not to answer this question. Figure 1 shows the factors that received at

least 2 votes for either Most or Least Important. Factors within the Economics and Organizational categories received many votes for both Most and Least important. The Organizational category received the highest number of votes for Most Important. Factors in the Economic and Knowledge categories also received a high number of votes for Most Important. The specific factor that received the most votes for Most Important deals with the enforcement of government regulation. Interestingly, a regulator cast only 1 of the 5 votes for this factor.

Factors in the Motivation and Other categories received the highest number of votes for Least Important. Votes for the Least Important factors were heavily skewed towards the 'Other' category; specifically, factors of natural disasters and interpersonal conflict received a large number of least important votes. None of the factors in the Technology category received Least Important votes.

Experts with the same professional designation tend to vote the same way. Specifically, academics and regulators often vote for the same categories, as do O&M providers and manufacturer/designers. This is an interesting trend, as it may indicate a disconnect between OWTS professionals in the field and those who regulate systems or educate students. The international development practitioners do not tend to vote with other expert categories. It is possible this is due to contextual differences between US domestic and international experience. However, the single expert with international experience who does not work in international development does not tend to vote with the international development experts. Specific factors that received votes for both Most and Least important are discussed below and listed in Figure 2-1.

FIGURE 2-1: MOST/LEAST IMPORTANT FACTORS



7 factors, shown below in Table 2-3, received votes in both categories; that is, some experts rated these factors as most important while other experts rated them as least important. In each case, there is a single expert who is in opposition to others; there are no cases where a large number of experts disagree about these extreme characterizations. In addition, there are no cases where experts within a single professional designation disagree with each other. For example, there are no cases where different regulators thought the same factor was most and least important. The international development experts were most likely to disagree; they were the single opposing vote in 5 of the 7 factors below. In addition, they provided opposing votes for both of the factors that received 5 votes from professionally diverse experts. It is possible this is due to the difference in international versus domestic experience. Unfortunately, only one expert other than the international development practitioners reported international work experience. This expert voted for the factor regarding enforcement of government regulations as most important while an international

development expert voted for this factor as least important. This single instance at least demonstrates that international experience does not always explain the differences in voting seen below.

Finally, the factor describing NGO presence received 4 votes for Least Important although it came to consensus as an Important factor. This is due to one expert who felt that all but three factors should be 'very important' (for this expert, the NGO factor was 'important' but less so than other factors). Yet another expert stated he did not have sufficient experience with NGOs to oppose the group rating, but still chose NGO presence as least important when the choice was forced by question format. In addition, several experts commented on the variability of quality of NGO and therefore impact.

TABLE 2-3: FACTORS WITH CONFLICTING MOST/LEAST IMPORTANT VOTES

Votes for Most Important	Votes for Least Important	Category	Factor
2	1	Economic	Cost of routine installation and repair
2	1	Economic	Owner occupancy
5	1	Organizational	Enforcement of government regulation
1	2	Organizational	Government involvement in areas other than regulation
1	1	Knowledge	Users do not know how to tell when systems must be emptied
1	1	Motivation	Social Norms
1	5	Motivation	Range of aesthetic/amenity options

STUDY LIMITATIONS

This research project, like all others, has limitations due in part to inherent characteristics of the chosen methodology. The Delphi Method is useful in situations where there are many interacting factors. The results of this method identify areas where future research may be profitable. However, the results cannot be generalized in the manner of a large-scale statistical survey. Similarly, the research design purposefully included experts from diverse fields. However, the results do not permit generalizations regarding the opinions of certain types of respondents and are limited by the dominance of US-based expertise on our panel. The most obvious example of this are the differences in responses between the international development practitioners and the other groups, or between academics and regulators and O&M providers and manufacturer/designers. Additionally, this methodology did not address interactions between factors, although both the literature review and expert comments note the importance of these relationships.

The list of factors developed through this process is likely not exhaustive despite the literature review and expert comments. Indeed, during qualitative coding an additional factor emerged from expert comments regarding various factors: identity creation through infrastructure type. This factor was not identified until after the Delphi process was complete and as such was not evaluated in this research. This factor may be especially relevant to OWTS. In other words, it may be that part of the resistance to OWTS is that users identify modern, high-status people in legitimate communities with sewered technologies and therefore aspire to the same.

Finally, because this research relies upon content analysis and the subjective judgments of experts, future work should empirically evaluate these factors and their relationships between one another. This may be particularly fruitful for the divisive categories, and would serve to alleviate disagreement so that practitioners can be better informed when designing, construction and maintaining sanitation infrastructure in the field.

CONCLUSION

Theory suggests that both hardware (e.g. infrastructure, technology) and software (e.g. knowledge, institutions, education) is required to achieve sustainable infrastructure—and although we may still lack a definition of what is sustainable, we largely agree that our current practices are not. Sustainable development suggests criteria that impact the best practice design of both hardware and software. This research project contributes to the existing body of work in development theory by identifying factors involved in infrastructure sustainability—in other words, working towards theory defining what is necessary to achieve sustainable infrastructure. This project demonstrates the necessity of crafting technical designs that fit diverse and complex social situations, taking the latter as fundamental design criteria rather than a peripheral concern outside the demesne of engineers.

For example, experts agreed that factors such as user knowledge, installation and materials quality, and organizational support through businesses or NGO are important for onsite sanitation sustainability. Alternatively, factors such as government involvement in areas other than regulation are still contested as to how or if they contribute towards system sustainability. Generally, this research finds system software is more likely to be the root cause of system failure than the hardware itself, which experts believe is sufficient to meet the need so long as the software is in place. Additional research is needed to further explore the contributions and interactions of these factors as technology failure due to software is just as real a failure as that due to hardware.

The disagreement described here suggests that the pathways to sustainable infrastructure are multiple and varied. Some factors doubtlessly did not reach consensus due to the diverse contexts that the experts work in. In fact, expert comments call attention to factors that may be contingent upon context. For example, comments included statements like "*This is one that is potentially country specific*." Along these lines, it must be emphasized that neither this study nor the expert panel intend to suggest that local context does not matter, and nor do we support universal cookie cutter solutions to sanitation or sustainable development. However, this research identifies some factors that are so important they tend to transcend these boundaries; in other words, they may be low hanging fruit that should be targeted in any project. These results describe areas where additional research would be particularly profitable. In addition, these contentious factors should be examined empirically to evaluate their importance.

OWTS that perform admirably under controlled conditions and poorly in the real world emphasize the need for technical research aimed at matching technology to the larger system in which it operates. The theoretical lens of sustainable development, while contested and evolving, provides scientists and engineers with a valuable new approach to building better theory and better infrastructure.

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CHAPTER 2 REFERENCES

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CHAPTER 3: DECOUPLED PLUMBING: THE INTERNAL SOCIAL SUSTAINABILITY OF SANITATION ORGANIZATIONS

Keywords: Sanitation, legitimacy, organizations, developing communities, decoupling, social sustainability

ABSTRACT

Onsite household sanitation technologies such as septic tanks or latrines serve a large percentage of the world's population. Unfortunately, they experience high failure rates after construction, with resulting environmental and public health consequences. Previous work has suggested that these failures are often a result of our inability to navigate the technology-society nexus. In other words, they represent problems of social sustainability. In order to address this urgent problem, we build theory regarding the social sustainability of infrastructure systems by leveraging established organizational theory. To do this, we collect household level interview data in four communities in rural Bangladesh. Virtually all households in this research population have constructed onsite sanitation systems, typically using their own resources. However, almost half of these systems have since fallen into disrepair, mirroring the high socially based failure rates cited globally from similar systems. Using cross case qualitative analysis and legitimacy theory, we explored what differentiates those households that continue to use and maintain sanitation systems (those with socially sustainable systems) from those that do not (those with socially unsustainable systems). We found that households in the unsustainable group have adopted toilets ceremonially, with construction decoupled from the actual practice of maintaining and using the sanitation system. Understanding infrastructure abandonment as a form of organizational decoupling gives us a new way to analyze and try to solve the problem of post-construction infrastructure abandonment. Specifically, efficiency concerns (whether or not desired infrastructure services are actually achieved) and competing rational myths (beliefs regarding how and why things ought to be done) drive decoupling and lead to abandoned sanitation. In order to recouple sanitation structure and practice for continued use and maintenance of onsite systems, designs should consider both efficiency and competing rational myths. For example, by requiring odor management technology for all improved sanitation infrastructure we improve infrastructure efficiency (by delivering odor management) and also address the commonly held rational myth of miasma (odors causing illness). Therefore we suggest that, as we revise the almost expired Millennium Development Goals, technologies without odor management should be removed from our definition of improved sanitation due to negative contributions to social sustainability. Further, we observe that concern with status (likely stemming from Community Led Total Sanitation development methods) appears at a similar and high rate in both the socially sustainable and socially unsustainable household groups; it does not differentiate the two. Finally, technical support is needed to address efficiency concerns, share knowledge, and help households move away from ceremonial sanitation adoption and towards locally desired benefits such as improved convenience, odor management, and public health protection.

INTRODUCTION

Bangladesh is the world's 7th most populous country (World Bank 2011). Once a British colony, it is now a parliamentary republic with an elected national assembly. It is also an extremely poor country, with over 40% of the population living on less than the international poverty line of $1.25USD/day (World Bank 2011). In the year 2000, Bangladesh was one of the many countries targeted for improved sanitation infrastructure through the Millennium Development Goals (MDG) (UN 2000). Specifically, at the year 2000 baseline, just 39% of Bangladeshis had access to improved sanitation. By 2011, access to improved sanitation had greatly increased to almost 63% (UNDEP 2011). While these figures represent real progress towards the provision of basic infrastructure services to all people, they also represent the work that is left to be done. Firstly, nearly 40% of Bangladeshis are still without access to improved sanitation. More ominously, this figure may not represent the full magnitude of the challenge. Recent work has begun to question the definitions used to define improved sanitation. For example, definitions of improved onsite sanitation systems only measure the construction of new systems and do not require that constructed systems are in use. Unfortunately, global evidence suggests that many constructed systems have extremely high abandonment rates (CSIR 2007; Rodgers et al. 2007; WSP 2007) with related public and environmental health impacts.

The households selected for this research have adopted sanitation, by which we mean that they have built sanitation systems, almost always with their own means. However, about half of them (42%) are currently unmaintained and broken. This research asks *what differentiates those households that continue to use and maintain sanitation systems from those that do not?* As onsite technologies work well in controlled conditions, we locate both the problem of infrastructure abandonment and its solution at the technology-society nexus; in other words, as a problem of social sustainability.

POINTS OF DEPARTURE

Our research theorizes sanitation infrastructure as an organization and analyzes it with legitimacy theory. To provide the necessary theoretical background to answer our research question and explain why we took this approach, we begin by making a theoretical case for analyzing infrastructure systems as organizations. Next we review the literature regarding social sustainability in infrastructure. Finally, we describe the construct of legitimacy from organizational theory, which we use to analyze the dataset in this research.

INFRASTRUCTURE AS ORGANIZATION

The key theoretical contribution driving our analysis is expanding organizational theory to explicitly include infrastructure systems, similar to previous work that has analyzed construction projects using insights from organizational theory (for example, see Javernick-Will and Levitt 2010; Mahalingam and Levitt 2007; Sillars and Kangari 2004). Corresponding to organizational theory (Scott 1998), we note that in order to function, sanitation technologies require collectivities of people with common goals and an interest in the survival of the system, an environmental context, structured work responsibilities, and standards for defining and enforcing against deviant behavior. For convenience, we introduce the term *sanitation organization* to refer to the system we just described. We make this theoretical argument by considering what a sanitation system is and what it is supposed to do (De Laet and Mol 2000). We might, for example, define sanitation infrastructure by the physical, above ground components (such as a seat, a privacy enclosure, or a roof to protect from the weather). After all, this is what people use every day; this is likely what the average person would describe or show us when asked what sanitation is. In contrast, we might define sanitation by the components below ground which actually hold waste, such as rings of concrete and a slab that serves both as part of the below ground enclosure and also the above ground user interface. After all, a toilet unconnected to a receptacle and ultimately treatment might be better called a seat. Of course, these materials by

themselves are also not sanitation; they must be purchased, transported, and properly assembled and installed in order to be more than plastic, wood, and concrete. Similarly, the sanitation system needs people to use it and fix it when it breaks. In some instances, sanitation systems are supposed to increase incomes and nutrition by producing fertilizer for sale or to apply directly to subsistence crops. In other models sanitation is intended as a business to provide a livelihood for sanitation entrepreneurs, or even as a good that provides convenience, safety from assault, or improved marriage prospects for one's children. We might also define the sanitation system and its work by noting that it ought to provide not only income or a place to relieve oneself but also good health, and that it cannot do so without an appropriate environmental context, installation, maintenance and operation. It also cannot improve health unless not just single households, but entire (geographic) communities adopt the technology. In other words, sanitation technology must gather households, businesses and communities to work together. Beyond the local community, infrastructure may serve a nation building purpose, supporting national policies, drawing resources from multinational organizations, and eliminating social divides between people with and without access to infrastructure services such as sanitation. The various work that infrastructure systems do can only be achieved with the organized participation of people.

SUSTAINABILITY IN INFRASTRUCTURE

Our research deals with a particular part of social sustainability that is concerned with internal organizational participants, excluding both external stakeholders and social justice concerns. We are interested in the community that is a daily part of the sanitation organization through use and maintenance, which we call internal social sustainability. Without this type of social sustainability, infrastructure is abandoned and its benefits are not achieved. In recent years, social sustainability has become an issue of increasing interest to construction researchers (Levitt 2007b), who understand past construction research in terms of economic and environmental sustainability and call for further expansion into social sustainability. More recently yet, scholars have built frameworks for incorporating social processes into construction projects (Valdes-Vasquez and Klotz 2013; Valdes-Vasquez and Klotz 2013) and identified factors important for the sustainability of infrastructure (Kaminsky and Javernick-Will 2013; Shen et al. 2011). In addition, research has described perceived or real market advantages for firms concerned with sustainability (Beheiry et al. 2006; Lu et al. 2013) and interactions between infrastructural and social recovery after disasters (Jordan and Javernick-Will 2013). However, to date there have been no attempts to develop a theory specific to the internal social sustainability of infrastructure; this paper begins to address this gap in the literature.

LEGITIMACY

Legitimacy "is a generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions" (Suchman 1995 p. 574). More recently, Deephouse and Suchman (2008) further define legitimacy by noting that it is *dichotomous* (an organization is either legitimate or not, rather than more or less legitimate in comparison to another), that it is *non-rival* (one organization gaining legitimacy does not negatively affect another), that it is *homogenizing* (it produces conforming organizations according to whatever attributes or practices are seen as the most legitimate), and finally, that it is *political* (linked to authority, and may produce a right to act in a given arena). Legitimacy has been linked to the issue of organizational continuity that concerns us here (whether or not people continue to participate in sanitation organizations). For example, studies show that legitimacy helps organizations gain access to resources (Hall 1992; Suchman 1995), which are necessary for organizational survival. Similarly, in a study of 143 hospitals over 46 years, Ruef and Scott (1998) showed that both managerial and technical legitimacy influenced hospital survival, albeit in a manner dependent on the relevant institutional environment. In contrast, organizations that violate stakeholder expectations lose legitimacy and become vulnerable to challenge (Stjernberg and Philips 1993). Since these foundations, the

publication of two key works in 1995 (Scott 1995; Suchman 1995) encouraged the growth of legitimacy scholarship. More recent work differentiates between internal and external legitimacy (Drori and Honig 2013; Kostova and Zaheer 1999), how organizations can gain legitimacy (Golant and Sillince 2007; Lounsbury and Glynn 2001; Suddaby and Greenwood 2005), or lose it in a time of crisis (Sine et al. 2007). In construction research, legitimacy has been used in research examining conflict or cooperation on job sites (Anvuur and Kumaraswamy 2012; Leung et al. 2013).

We follow in this rich theoretical tradition and organize legitimacy into three categories taken from the literature (Scott 1995; Suchman 1995): pragmatic legitimacy (self interested calculations of an organization's most immediate audience), moral legitimacy, (positive normative evaluation of an organization and its activities), and cognitive legitimacy (organizational role in constituents' sense of cognitive coherence). For example, a pragmatic aspect of having access to a toilet is convenience, while a moral aspect is the protection of public health and a cognitive aspect is understanding the connection between germs and health.

Research Question and Brief Findings

In this paper we argue that, to explain the high rate of failed onsite sanitation systems, we need research at the technology-society nexus that analyzes infrastructure systems as organizations. Given the high observed rate of onsite sanitation systems that are abandoned or otherwise go unmaintained, we leverage organizational theory to answer the question *what differentiates those households that continue to use and maintain sanitation systems from those that do not?*

As will become apparent through our subsequent results and discussion, in this research we discovered that internal organizational participants (households) possessing unmaintained or unused infrastructure adopted sanitation ceremonially, and that this explains low rates of operation and maintenance (O&M).

Method

In this section, we begin by explaining the research design. Next we describe the data collection process and how these data were prepared for analysis. Finally, we describe procedures that were used to ensure research reliability and validity.

Research Design

For this project, we perform a qualitative cross-case analysis of interview data comparing groups of sustainable and unsustainable household cases. Individual households represent an embedded unit of analysis situated within both the communities they are geographically located in and also within the group of either sustainable or unsustainable households they belong to according to the operational definitions provided below. The interview method of data collection was selected due to its ability to develop rich data even in the context of developing communities, where infrastructure data is often limited or nonexistent. Following Yin (2009), case study methods were selected as the research question dealt with contemporary events, did not require control of behavioral events, and sought to understand why the observed phenomenon was occurring. The cross case comparison allows us to discern differences between groups of households that have or have not achieved socially sustainable sanitation. Finally, qualitative methods allow the collection of rich, contextual data appropriate to our exploratory research question. Findings are replicated across four case study communities.

DATA COLLECTION

Data collection took place in households located in four rural and economically disadvantaged communities in early 2013. The communities are located in the Barisal district of Bangladesh, and both have self-reported and researcher estimated annual household incomes between $300-600 USD. Households have an average of 5.5 people living in them, ranging from 1 to 16 people and the average annual per capita income in these communities is approximately $80USD. All communities reported that they ended the practice of open defecation in the past 5-10 years.

Communities were selected based on the knowledge of local sanitation officers in the Bangladeshi government and various local non-governmental organizations (NGO) in order to be similar in terms of geography, ethnicity, religion, and socioeconomic status. To qualify for participation in this research, households in each community were required to have installed toilets using onsite non-sewered technologies. The majority use ring slab pit latrine designs used only by the family living in the nearby household. While there were a few instances of relatives with separate houses sharing a toilet, none could be defined as public or community toilets. For this project, we operationalized socially sustainable sanitation as onsite sanitation that was not broken on the day of the visit and where residents reported performing maintenance after initial construction. In some cases, although maintenance had not been performed, the system was unbroken on the day of the visit. If these systems had been in operation for more than five years, they were classified as unsustainable. Alternatively, if the system had not yet been in operation for more than five years, it was removed from the analysis as a case with an indeterminate sustainability outcome, as it is possible that these systems have not yet required maintenance such as emptying the pit. It is worthy of note that many community members used local businesses that would empty latrine pits for a fee. Six household cases distributed between three of the four communities were removed from our analysis due to this criterion. This resulted in 84 households being classified as sustainable, and 62 households being classified as unsustainable. A trained bilingual research assistant who is local to Bangladesh collected the data. Interviews were conducted in the Bengali language common to Bangladesh.

Each household in the selected communities was approached and asked to participate in the project. Every household that agreed to participate was interviewed. Communities were visited up to five times over a week each in order to reach every possible household. In total, 154/162 (95%) households consented to participate. In two cases, the audio recorder failed and the interview data were lost, resulting in analysis of 152 households. To elicit detailed, contextual responses, questions were semi-structured but open ended. For example, interviews asked respondents “Why did you want a toilet?” “What is a toilet good for?” and “Are toilets worth the trouble? Why or why not?” The audio of each interview was recorded using a cell phone, which is less unusual and intrusive in the research setting than a dedicated audio recorder. After the interviews were complete, the audio was transferred to a computer for concurrent transcription and translation to English.

DATA ANALYSIS

After data collection was complete, the translated transcriptions were imported to the NVivo 10 software package (QSR International Pty Ltd. 2012) for formal qualitative coding (Miles and Huberman 1994; Saldaña 2009). The translated transcriptions produced approximately 585 pages of text for analysis. This process involved iteratively reading the transcript data against a coding dictionary that matched archetypes of statements to legitimacy and status constructs. This coding dictionary was developed iteratively during coding, as we considered each sentence and generalized individual statements to qualitative codes, or archetypes. Based on the literature, we assumed that all types of legitimacy contributed to supporting sustainability unless respondents specifically said otherwise. For example, one respondent described

unpleasant odors emanating from their sanitation system: "*It spreads a bad smell when the wind blows*". We coded this statement to pragmatic legitimacy as it deals with a direct personal effect of participation in the sanitation organization. This particular coding instance is expected to detract from legitimacy as a 'bad' odor was specified. The archetype—odor management—was added to our coding dictionary so that any subsequent instances of this archetype could be consistently coded. This process resulted in 1912 coding references across the entire dataset. No construct was referenced at a significantly different rate from the aggregate ($p \leq 0.025$) in any community.

VALIDITY AND RELIABILITY

Validity and reliability checks are intended to improve the quality of research results. Both qualitative and quantitative research designs have developed a variety of standard procedures that, when used properly, help ensure 1) that researchers are carefully defining both what they are measuring and how they are measuring it (construct validity), 2) that the results appropriately represent the data set (internal validity), 3) that the results represent the larger research population the results are claimed to generalize to (external validity), and finally 4) that another researcher, using the same tools, would find the same results (reliability). This study addressed these concerns by using constructs from existing literature, performing intercoder reliability checks (97% agreement across four interviews), multiple coding iterations, and by developing a coding dictionary and research database.

RESULTS

In this section, we show that efficiency (or the attainment of infrastructure services from built infrastructure) is not driving construction. Next we provide evidence that households adopt sanitation infrastructure due to various concerns with legitimacy, which do not vary between the groups of households with and without sustainable sanitation infrastructure.

INEFFICIENT INFRASTRUCTURE

To begin, we describe the household's experience of sanitation infrastructure, and whether or not it is producing desired outcomes. In 88% of cases, households made financial or labor contributions in order to get a sanitation system. While NGO and government officers have had a presence in the community, it is not the case that they provided a sanitation system to each household. Individual households took the initiative to change, and we should note that these changes are not insignificant to the households. Based on household reported data, the cost to purchase the slab and rings and transport them to the village is the equivalent of about $9USD, with additional labor to dig the pit, additional cost and labor to build an enclosure, and possibly an additional cost for a seat and a container to hold water for flushing. We estimated annual household income to range from $300-$600USD. The cost for just the rings, slab, and transport is thus over 15% of monthly earnings at the top of our income range, and is more than a quarter of monthly earnings at the lower end.

Households report the cost to have a plumber empty the pit is about $2USD, or almost a full day's wages, making them reasonably expensive technologies. Alternatively, new rings are purchased or the existing rings are pulled out of the full latrine in order to place them in a new pit. Still, the former is expensive (more than 3 days' wages) and the latter involves the hazards of direct contact with waste that has not been treated in any way and is certainly a distasteful task. Beyond the work of moving the toilet, several households had stories of people falling into full latrines: "*The slab was poor in quality. My son fell down into the hole because the slab broke. It looked like taking a bath*." Similarly, while 79% of households mentioned odor management ("*[With a toilet] there will be no bad smell*") some of this number also complained about the smell from the latrines:

"*They have a poor toilet. The bad smell could be smelled from the house*." As will be discussed below, when bad odors are connected with health impacts ("*If you have a headache, build my toilet yourself!*") households may doubt that even fully functional latrines can actually improve health outcomes. Similarly, they may use one that is not technically able to provide treatment through inappropriate design or construction: "*We don't clean the pit. This is an island. During the rainy season we let the waste flow through the water.*" As actually constructed, the toilets in the communities selected for this research are not efficient. They are expensive, involve repeated dirty work, do not improve health, and often produce unpleasant odors. They are, in a word, inefficient.

LEGITIMATE OUTCOMES & PROCESS

The next step of our analysis was to separate the statements we mapped to legitimacy constructs into items that dealt with the outcomes of sanitation and items that dealt with the process of sanitation (how sanitation ought to be done). Within each of these categories we discuss different sources of legitimation, following the description given by Suchman (1995) with the addition of two constructs that emerged during the analysis (inertia legitimacy and status).

PRAGMATIC OUTCOMES

One source of pragmatic legitimacy is the expected value of organizational participation. It deals with direct, pragmatic benefits. For our case, these are the direct benefits, or services, that users expect to receive if they participate in the sanitation organization. Some of the services that were referenced often in our data were cleanliness, hygiene, odor management, aesthetics, separating insects or livestock from waste, and convenience. Virtually every household in both the sustainable and unsustainable groups referenced this type of legitimacy (99% vs. 98%). The data suggests that all households understand the potential infrastructure services that they might receive if they were to participate in a sanitation organization, and that this is not sufficient for socially sustainable sanitation.

One household in each group did not reference pragmatic legitimacy. As these households appear to be outliers, we discuss them individually. The sustainable household that did not reference this type of legitimacy built their own toilet (another type of pragmatic legitimacy) because they believe that a toilet is the modern thing to do (moral legitimacy) and because they are ashamed to do otherwise (status). They mentioned that they primarily built a toilet in fear of violent reprisal if they did not ("*The government ordered to burn the tree toilets. Then we built a toilet.*"). The unsustainable household that did not reference this type of pragmatic legitimacy also built their own toilet (pragmatic legitimacy), although it has since broken and goes unrepaired. They spoke to a visiting NGO about their toilet (moral legitimacy) and understand there is a connection to environmental harm (moral legitimacy). However, the force of inertia went against sustainable sanitation adoption: "*I am too old to do that…We can't [change]*."

MORAL OUTCOMES

One source of moral legitimacy is socially valued accomplishments. In other words, organizational outputs are judged as morally worthwhile or not. In our data, the outputs of sanitation organizations that emerged from the data during coding are public health and environmental health. In every instance these were seen as morally positive. The former dealt primarily with preventing disease epidemics ("*If I practice open defecation there will be diseases*"), and the latter with water or air pollution ("*If people practice open defecation the air and water will be polluted*"). Overall, this type of moral legitimacy was referenced more often in the sustainable household group (80% vs. 71%). This pattern also held true in each of the four communities as well as across the aggregated groups of sustainable vs. unsustainable households.

STATUS OUTCOMES

In addition to legitimacy, status was mentioned in 84% of household cases as an outcome of sanitation technology (privacy, prestige, shame: "*If my relatives come to visit me and I don't have a toilet, it will raise a negative impression about me*"). It too was present at approximately the same rate in the household groups with sustainable and unsustainable sanitation (86% vs, 82%). Status theory is developed in existing organizational literature and is known to impact organizational survival; it is also known to be analytically distinct from legitimacy (Deephouse and Suchman 2008). Taking note of the status construct leads us to an important finding regarding violence in infrastructure uptake. Our analysis links to the Community Led Total Sanitation methods that have been used extensively in Bangladesh (Hanchett et al. 2011; Kar and Chambers 2008). These methods aggressively attempt to inspire shame that triggers communities to adopt sanitation technologies for every household on their own initiative. The analysis here shows that while these methods may indeed be able to coerce initial construction, they do not cause sustainable use in many cases and come with other negative consequences. Fear of violence was mentioned in 15 households in our dataset as a motivator for building a toilet. Of these 15, nine have achieved sustainable sanitation and six have not. This rate is not higher than that achieved in the larger research population. Other respondents attributed widespread sanitation uptake to this violence, suggesting that this factor may have gone underreported: "*Everyone in this community had a tree toilet. I myself broke some of them with the local government people. I provoked others to burn tree toilets. We did it to keep our environment clean*." Households do indeed report building toilets to avoid violence. However, even when these toilets continue to be used, the lack of maintenance and appropriate design and construction mean that they are likely a net loss for public health in terms of both increased violence and of concentrated, collocated fecal waste.

PRAGMATIC PROCESS

A source of pragmatic legitimacy is an organization being responsive to constituents' larger interests through some form of control enacted by the constituent. To operationalize this for our sanitation organization, we coded all instances of financial or labor based participation; that is, at some point in the infrastructure lifespan, the household either built or maintained a toilet themselves or paid someone else to do it for them. This indicates a certain level of control over the system, and aligns with considerable discourse in the development community regarding the need for household participation in development and the improved outcomes that are (sometimes) claimed to result from it (Cooke and Kothari 2001; Khwaja 2004; Roma and Jeffrey 2010). This type of legitimacy is the only theoretical construct in our dataset that was referenced at a statistically significant different rate between our two groups ($p<0.01$). 100% of sustainable households referenced it compared to just 71% of unsustainable households. However, we should note that this is an artifact of our definitions; we operationalized sustainability in part by requiring homeowner maintenance.

MORAL PROCESS

A source of moral legitimacy is socially valued techniques and procedures. For example, the majority of readers of this article might prefer a science-based hospital with an 80% survival rate to a shaman with a 100% survival rate if medical care were needed. Belief in the process and how it relates to valued outcomes (e.g., that the provided medical care is actually causing survival) is important. Some of the valued organizing principles of society that emerged from our data were Modernity, Knowledge, and leading a Neat and Clean Life. In our dataset, 35% of both the sustainable and the unsustainable groups referenced this type of legitimacy. Unsustainable households referenced this construct more often in two of the communities; in the other two the sustainable household group referenced it more often. The subcontracts varied, with Modernity referenced by approximately 30% of each group ("*It is the era of modern civilization*"), Knowledge referenced more often (11% vs. 6%) in the sustainable group ("*There are two causes [of poor sanitation]. It's because of*

illiteracy and poverty"), and A Neat and Clean Life referenced more often (1% vs. 10%) in the unsustainable group ("*If we want to lead a neat and clean life we need a toilet*").

Another source of moral legitimacy is the moral standing of an organizational type, such as sewered infrastructure vs. onsite infrastructure. 43% of households referenced this construct, with no significant difference between the sustainable and unsustainable groups. For sanitation, we might note that it is common for onsite technologies to be perceived as second class as compared to a sewered system (Kaminsky and Javernick-Will 2013). In this research context, where sewered technologies are unknown or at least presently impossible for an individual household to achieve, open defecation is seen as morally inferior to the use of a toilet: "*Open defecation is not good. It is better to have a toilet*." It is worthy of note that what is seen as 'good' is the physical presence of a toilet; a functional toilet was not specified.

Yet another source of moral legitimacy is the charisma of an alter. While in past literature (Suchman 1995) this has been defined as dealing with individuals, for this project we included connections to both individuals and organizations. For example, respondents described linking connections to NGO or government agencies as important to sanitation adoption. Overall, about 40% of households in both the sustainable and unsustainable groups mentioned this type of moral legitimacy. In this dataset, there was also no significant difference between these groups in terms of if the altars were internal to the community (family or neighbors) or external (NGO, government, businesses, other communities). Most of the connections were external, however, with respondents reporting that neighbors generally minded their own business about sanitation matters: *"I don't usually go to or talk to the other families about the toilet."*

COGNITIVE PROCESS

One source of cognitive legitimacy is the availability of cultural models that furnish plausible explanations for both the existence and actions of an organization. For a sanitation organization, this would mean a model that explains why sanitation is important by defining sanitation and explaining the costs and benefits of having sanitation. In our data, we see that the majority of households in both groups reference a model of understanding for sanitation, albeit at a slightly higher rate for the sustainable household group (80% vs. 71%). The model given in every case was a connection between toilets and disease prevention. For example, "*If we practice open defecation there might be various diseases. That is why I built my toilet.*" However, this quote (and many like it) comes from a household with a broken system.

Another source of cognitive legitimacy is shared meaning such that alternative arrangements become unthinkable. This construct was identified by statements like "*I give more importance to the toilet than to the house. Even he who has no house, should have a toilet*". This type of legitimacy appeared slightly more often in the unsustainable household group (24%) than in the sustainable household group (19%). While both groups said that a household must have a toilet, the unsustainable group lacks connections between the treatment the toilet is providing, how that treatment is provided, and the taken for granted motivation for (and subsequent construction of) a toilet.

In addition to cognitive legitimacy types that have been previously identified in the literature, a construct emerged from our data that we call inertia legitimacy (statements of habit like "*I am habituated to use a toilet from my childhood*"). Inertia is different than existing constructs because there is an inherent difference between not being able to think of an alternative arrangement (an existing cognitive legitimacy construct) and being used to one of many alternatives (for example, being habituated to using a toilet although one's neighbor does not, making the alternative a daily reality rather than an unthinkable occurrence). Inertia was referenced in a total of 17 household interviews, 10 of which were in unsustainable cases. In all sustainable households in this group, inertia was in support of sanitation technologies. Each of the sustainable households that mentioned inertia said something like *"I can't poop outside. I'm not habituated."*

Alternatively, in the unsustainable households, the force of inertia is against sanitation technologies; in all but one case, respondents said they were "*helpless*" or had "*no ability*" to change. While inertia was observed in just 12% of cases, when it did appear it had a near universal match to the sustainability outcome once the direction of inertial force for social sustainability was identified, suggesting the need for further investigation. In addition, we suggest that the reason it appears relatively rarely is not because it is unimportant but because of the particular cases selected for this project. Inertia stems from habit and the costs of changing an existing practice. In our current research, we observe inertia legitimacy in the few cases where households have used sanitation technologies for a long time. Alternatively, when inertia legitimacy is referenced in unsustainable household cases, it appears as a perceived inability to change to the new technology. As our cases have recently transitioned from one practice to another (open defecation to some form of toilet, sustainable or not) this too is infrequently observed. Future work should investigate this construct in different organizational settings where it may occur more frequently.

LEGITIMACY

To summarize, if sanitation organization membership and benefits are driven by the quest for legitimacy we might expect to see different types of legitimacy between the group that has achieved sustainable sanitation and the group that has not. In other words, we might think that households that are aware of the benefits of sanitation would possess sustainable systems. However, this is not what we observed in our data, as shown in Table 3-1.

TABLE 3-1: LEGITIMACY CODING

Legitimacy Construct	Sustainable (n = 84)		Unsustainable (n = 62)	
	Households	Percentage	Households	Percentage
Pragmatic	84	100%	62	100%
Moral	80	95%	59	95%
Cognitive	67	80%	44	71%
*p≤0.05				

We found that the groups of households with sustainable and unsustainable sanitation systems do not differ significantly in the types of legitimacy that they reference. In fact, while for simplicity it is not presented here, they do not significantly differ in any of the sub-types of legitimacy defined by Suchman's typology (1995). They do not differ for either the process or the outcomes of sanitation infrastructure. They do not differ in terms of one group having an understanding of benefits that would lead to market demand (pragmatic legitimacy). They do not differ in terms of the personal connections they have to others (moral legitimacy) nor yet in the existence of cognitive models to explain the importance of sanitation (cognitive legitimacy). Rather than being a null result, this finding leads us to understand the key issue at stake in these sanitation organizations: the construction of a toilet is alone sufficient to permit membership in the sanitation organization. By constructing a toilet, households gain legitimacy benefits even when, scientifically speaking, they do not gain the actual benefits corresponding to that legitimacy. Continued use and maintenance—possessing a functional toilet—is not required. This is a problem because unless all households have a functional toilet, none will achieve the desired collective benefit of improved health.

DISCUSSION: CEREMONIAL ADOPTIONS & DECOUPLING

In our data, we observe that households build toilets and then subsequently do not use or maintain them. Households cite benefits of sanitation even when they are not actually experiencing them. Despite the many reported drivers and a financially proven motivation for change, 43% of households (62) were classified as

unsustainable, generally because their toilet was broken on the day of the visit. Even if respondents felt strongly that they could not practice open defecation, many continued to use a broken or overflowing toilet: "*Like our toilet, we can't build a new toilet that is why we are using our toilet. But we don't poop outside*." As such, we propose this as an example of decoupling, or ceremonial technology adoption, where formal structure (such as sanitation infrastructure) and actual practice (such as infrastructure use or maintenance) are not necessarily related.

In organizational research, decoupling has been observed in many settings dating back to Meyer and Rowan (1977). Meyer and Rowan suggest that structural changes are made in order to enhance legitimacy rather than because of efficiency: "ceremonial activity is significant in relation to categorical rules, not in its concrete effects...a sick worker must be treated by a doctor using accepted medical procedures; whether the worker is treated effectively is less important" (Meyer and Rowan 1977). Similarly, from a ceremonial point of view, a household must have a toilet; whether or not the infrastructure can protect health as it is actually used is unimportant. The desired legitimacy benefits are achieved after the ceremonial structural change rather than being a function of achieved outcomes of the change that would also require change in practice.

The primary reason Meyer and Rowan give for decoupling is rational myths. As we live our lives, we develop various rational myths to explain institutional processes, techniques, tools, or structures. In other words, rational myths are how things ought to be done. Independent of their efficiency, their omission is perceived as negligent or irrational. Even accepted and highly rationalized models are actually rationalized myths. They are a (useful and important) way of understanding that are nevertheless just models—reflective of reality but neither perfectly objective nor yet error free. As we do not have perfect information, we select tools depending on their perceived appropriateness, or legitimacy, for the task at hand. Similarly, households may construct a sanitation system ceremonially because they believe it is the legitimate thing to do, independent of any infrastructure services they may (or may not) achieve by doing so.

Relatively little empirical work has been done to investigate decoupling in organizations (Boxenbaum and Jonsson 2008). However, the work that has been done supports the occurrence of decoupling. For example, Brunsson and Olsen (1993) studied reform at Swedish Rail, finding that even a radical organizational reform had little impact on daily operations. Similarly, Kostova and Roth (2002) measured the ceremonial adoption of organizational practices due to legitimation pressures in multinational corporations. Similarly, socially unsustainable sanitation infrastructure occurs because households are able to gain the legitimacy of using sanitation infrastructure after just construction, without actually contributing to collective sanitation goals (like public health protection) by also maintaining the toilet. There are various ways practitioners, academics, and infrastructure users can work to disrupt this problematic mechanism. For example, in many (more developed) communities this problem has been avoided by adhering to centralized, professionalized utility management. Unfortunately, at the present time this is an unrealistic goal for many rural developing communities. In the meantime, the more immediate goal must be to ensure that legitimacy is only awarded for a functional toilet. This may even require de-legitimating non-functional toilets, although it is possible this strategy could instead cause households to abandon the structures built in ceremonial adoption. Further research is needed to determine how best to design educational outreach to ensure that households' infrastructure can provide collective benefits.

Thinking about the social sustainability of sanitation in terms of decoupling and legitimacy theory gives us yet another way to try to solve the problem. Considering various cognitive models of understanding should change preferred designs with the goal of improving O&M rates. This understanding may help us modify designs so that sanitation infrastructure is perceived as more efficient, thereby driving efficiency-based rather than ceremonial technology adoptions. For example, air pollution (moral legitimacy) was mentioned in 10% of household cases ("*The main problem is air pollution. Our toilet causes air pollution*.") and odor

management (pragmatic legitimacy) was mentioned in 79%. This may suggest that there is a significant presence of belief in miasma theory in these households. Miasma theory suggests that poisonous vapors in the air from rotting organic matter cause diseases such as cholera. This view has been commonly held throughout history and indeed was one of the drivers for the sanitary evolution of cities such as Paris and London (Jephson 1907). Certainly as a scientific community we must remain committed to the scientific models for sanitation that have greatly improved human health over the past century (BMJ 2007). However, by recognizing these various modes of understanding, we can develop designs that address both miasma and germ theories. In other words, sanitation technologies should be designed and constructed to provide a high level of treatment. There is no reason that these designs cannot also provide for the protection that would be specified by miasmatic theories. By providing odor management techniques such as a water seal or ventilated designs, we can both address these concerns and make the user experience more pleasant. Practically speaking, this suggests that we should bar the simple pit latrine design from the definition of improved sanitation due to its negative impacts on social sustainability, much as we would remove a design that did not actually separate people from waste on technical grounds.

Another strategy for avoiding ceremonial adoption and subsequent decoupling is knowledge outreach. We need education to help households understand how sanitation systems work and to understand that this process is an important component to achieving desired outcomes. In addition, we need to connect households to technically trained people so that households may outsource some of the needed knowledge work much as households in the more developed world do. By improving the performance of sanitation through technical knowledge, we may drive households further towards efficiency-based adoption. An important challenge to this last recommendation is that it may not appear to be scalable; we are suggesting technical assistance for every household in the world. The inconvenient truth here is that all construction projects are necessarily unique. Each project must account for site-specific conditions (e.g. the presence of particular soils), generalizable scientific principles (e.g. percolation rates in those particular soils), and local beliefs and knowledge (e.g., miasma theory). Local and external knowledge must be blended to achieve sustainability.

CONCLUSION

"*Definitely there is a problem [with open defecation]. Otherwise the government would not tell us to build toilets*."

In the cases described here, sanitation technology was adopted ceremonially. Our research unpacks seemingly simple statements similar to that above to try to build theory regarding the internal social sustainability of sanitation infrastructure. Households adopted sanitation technologies for many reasons. Some did so out of fear of violence ("*If we practice open defecation the government will burn…so we were bound to build our toilet no matter if we were starving or not, we had to build the toilet*." Others built it because they wanted to be part of the modern world ("*I want to move on with the times*") or to protect public health ("*If we use a sanitary toilet it will cause no problems to the nearby families. Like…no disease*"). Over and over again, however, we see that households have ceremonially adopted toilets in a way that (from our scientific point of view) cannot actually deliver the outcomes they desire. Legitimating isomorphic forces have caused virtually every household in these communities to build a toilet. What they have not achieved are the possible and locally desired benefits of sanitation technology such as the protection of human and environmental health, odor management, or improved safety.

In this paper, we theorized sanitation infrastructure as an organization. Using cross case qualitative analysis and legitimacy theory, we sought to understand what differentiates those households that continue to use and maintain sanitation systems (those with socially sustainable systems) from those that do not (those with socially unsustainable systems). In addition, we proposed inertia legitimacy, a new construct, and noted the

importance of status. Finally, this research empirically demonstrates ceremonial technology adoption, or in other words the decoupling of structure and practice that drives socially unsustainable sanitation. It also suggests an interesting future research question. If efficiency concerns and competing rational myths are causing decoupling, can we eliminate it by addressing these issues through a combination of design modifications and educational outreach? This question is practically important as it has the potential to improve sanitation sustainability worldwide, thereby improving public and environmental health outcomes.

This question is also theoretically interesting, as it would give us new insight on the ways that organizations work. There is limited research to describe if decoupling can be maintained over time; however, Edelman (1992) presents evidence that suggests symbolically hired employees attempted to fulfill their mandate, suggesting that decoupling may break down over time. If decoupling breaks down, ceremonial sanitation adoptions may eventually lead to changed practices. Alternatively, it may mean that the ceremonial structural changes (the toilets themselves) may be abandoned to match the practice. If we are to achieve the former instead of the latter, there are ongoing requirements for technical support and for building knowledge of how technology can achieve socially desired outcomes rather than on the ceremonial adoption of sanitation technology itself.

As with any research, there are important limitations that must be acknowledged. Interview based data collection methods must acknowledge potential issues with free recall (Singleton and Straits 2004). Especially when dealing with a taboo topic like sanitation, we must consider that our data may be biased by respondents giving what they perceive to be socially desirable answers (Podsakoff et al. 2003). Indeed, in our analysis above we noted a contrast between the percentage of households that reported violence as a factor for adopting sanitation (10%) and quotes that suggest it was much more widespread. However, in this context we expect the major instance of giving socially desirable answers would be regarding the actual use of the sanitation system rather than construction or motivations regarding it. This potential issue was mitigated by the fact that the infrastructure was directly observable by the research team. Additionally, we do not intend to suggest by this paper that there are not places where households are actually too poor to construct infrastructure, nor yet that there are not places where market demand for sanitation does not yet exist. However, in the communities selected for this research, these factors were not causing unsustainable sanitation practices. Instead, structure and practice were decoupled because of ceremonial technology adoption.

To summarize, this research:

1) Extended organizational theory to explicitly include infrastructure systems,
2) Built theory of the social sustainability of infrastructure, and
3) Developed decoupled, ceremonial infrastructure adoptions of toilets as a new explanation for socially unsustainable sanitation

Organizational theory helps us understand the forces driving socially unsustainable sanitation systems. We "say that the engineers will solve a specific problem or that the secretaries will perform certain tasks without knowing who these engineers or secretaries will be or exactly what they will do" (Meyer and Rowan 1977 p. 349). Similarly, households say that sanitation adoption will solve certain problems without knowing how or if this will happen. Unfortunately, in the case of technology, without appropriate means we cannot reach desired ends. Our work suggests that globally we will see increased number of households with systems that are not maintained as time passes. The challenge is to discover ways to recouple the structure and process of sanitation technologies. The encouraging side of this finding is that households are already aware of the legitimate benefits of sanitation, and have already ceremonially adopted toilets to help them achieve those benefits. What is needed now is a way to transform these magical talismans into functional technology.

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CHAPTER 4: THE INTERNAL SOCIAL SUSTAINABILITY OF SANITATION INFRASTRUCTURE: A SET THEORETIC APPROACH

Keywords: Social sustainability, sanitation, developing communities, csQCA, set theory, legitimacy, status, organizations

ABSTRACT

While the construction of sanitation infrastructure is one of humankind's greatest public health achievements, its benefits are not enjoyed by all. Part of the problem is that infrastructure coverage has not yet reached at least 2.5 billion people. However, the true of extent of this staggering problem is even larger than this number suggests because of high rates of post-construction failures. Scholars have suggested that failures of social sustainability are in part responsible. In this research, we target this problem by extending nascent theory of the social sustainability of infrastructure. To do so, we apply crisp set qualitative comparative analysis (csQCA) to household level interview data collected from households in rural Guatemala. These households defy the global odds in that they have both adopted and maintained sanitation infrastructure over time. Our application of set theory allows us to describe the various pathways that have caused socially sustainable uptake. We find that three combinations of legitimacy and status theory explain 85% of household cases at a consistency of 0.97, and that this explanation is better than that provided by either status or legitimacy theory alone. This finding allows us to contribute to organizational theory as well as social sustainability theory for constructed infrastructure systems. The most practically useful pathway covers 50% of household cases and shows that the combination of consequential legitimacy (a moral understanding of outcomes) and comprehensibility legitimacy (a cognitive model connecting outcomes to processes) is a powerful way to achieve socially sustainable sanitation infrastructure. This finding can inform the development of research-based educational outreach in support of the social sustainability of infrastructure.

INTRODUCTION

Out under the pepper trees of Guatemala, households in three small communities have achieved what current development discourse would suggest is almost impossible. Although extremely poor and rural, over the past two decades homeowners have quietly adopted sanitation technologies and, more importantly, continued to use them. When something breaks, they fix it. When a latrine pit fills up, they dig a new one.

To anyone firmly embedded in the modern project and unfamiliar with the development literature, this might seem a commonplace. Sanitation infrastructure, after all, has been identified as one of the greatest improvements for human health in the history of mankind (BMJ 2007). Unfortunately, as infrastructure development efforts fortified by the Millennium Development Goals (UN 2000) have intensified, improved data have shown the enormous number of people still lacking access to improved sanitation (2.5 billion (WHO/UNICEF JMP 2008) or perhaps a billion more (Baum et al. 2013). They have also shown the enormous number of sanitation systems that quickly fall into disuse or disrepair after construction, with failure rates frequently ranging upwards of 50% (Rodgers et al. 2007; WSP 2007). The sanitation technologies in use are well proven under controlled conditions, although there are certainly many instances of inappropriate technology use. For example, in the US state of Alabama studies show that onsite technologies inappropriate to soils are very common, with correspondingly high failure rates (He et al. 2011). However, both the research literature and a diverse array of sanitation experts state that technologies exist to provide adequate waste treatment (Kaminsky and Javernick-Will 2013). We suggest that poor technology selection and low rates of operation and maintenance (O&M) instead represent technology failures situated at the technology-society

nexus; in other words, when technology interacts with society, things get complicated. These complications are important, and correspond to calls in the literature for problematizing definitions of sanitation coverage to encompass far more than the simple presence or absence of physical infrastructure (Bartram 2008).

In contrast to the failures so common in the literature, why have households in the communities that we describe in the opening paragraph both adopted and maintained a sanitation system? In other words, what has caused these households to adopt socially sustainable sanitation practices? To answer this question, we apply and analyze legitimacy and status theory to household level data from three communities, with the goal of improving theory regarding the social sustainability of infrastructure. In addition, this analysis permits us to make a contribution to organizational theory by measuring the explanatory power of status and legitimacy empirically in a sanitation organization. It also allows us to contribute to practice by identifying causal combinations of factors that have led to sustainable sanitation outcomes, which in turn will allow practitioners to better design and construct their projects.

POINTS OF DEPARTURE

This research extends theory of the social sustainability of infrastructure; specifically, we use legitimacy and status theory as a way to operationalize the internal social sustainability of sanitation infrastructure. This infrastructure is theorized as an organization (see Chapter 3 of this dissertation); we call this a *sanitation organization*. By sanitation organization, we mean that we include collectivities of people using technology rather than just the materials themselves. The household is our unit of analysis; as with any organizational type, the collective actions of individual organizational constituents cause organizational continuity or failure. The sanitation organizations selected for this research have all been successful, with a large majority (85%) of households achieving a socially sustainable system. As such, we seek to understand the various pathways by which they have done this.

SOCIAL SUSTAINABILITY OF SANITATION INFRASTRUCTURE

Sustainability is a complex concept that has been used for everything from deep ecology theory (Sessions 1995) to corporate greenwashing of standard operating procedures (Laufer 2003). In this research, sustainability refers to technology practices that may be continued, or sustained, indefinitely. A triple bottom line perspective (Elkington 1998; Levitt 2007b) describes economic, social, and environmental factors of sustainability. Others have added institutional factors (Ostrom et al. 1993; World Bank 2003); for built infrastructure, we should certainly add technical performance. At a minimum, to be in use indefinitely, an infrastructure system needs economic support for construction, operation, maintenance, and replacement; it needs institutional support to deliver parts and technical knowledge; it needs to protect the environment such that waste build up does not make its physical location otherwise uninhabitable; it needs to support and be supported by social systems, and finally it needs to be technically able to deliver the services it was intended to provide. We might say a sanitation organization needs resources to be first constructed and then kept operational; that there must be a way to design and deliver those resources, that it needs to treat or at least separate waste from the environment and those living in it; that the local population needs to understand why they should bother with the system at all; and that it must be designed and constructed to a sufficient standard as to be able to do what is intended. In the case of an environmentally focused technology like sanitation, the environmental and technical pillars are similar. In the case of a technology with a technical intent other than environmental protection (for example, transport) these pillars are more distinct. Regardless of the extent of overlap between pillars, however, the failure of one means the failure of all through technology discontinuance. In the literature, discontinuance is defined as "a decision to reject an

innovation after having previously adopted it" (Rogers 2003 p. 190). For sanitation, this is the commonly observed problem of abandoned infrastructure and the loss of possible health and environmental benefits.

To date, a majority of infrastructure research addresses the technical pillar of sustainability. Similarly, construction research has long addressed the economic pillar of sustainability and more recently has begun to expand into environmental sustainability. In contrast, we lack research addressing the social pillar of sustainability (Levitt 2007b), although researchers have begun to answer this call. For example, Valdez-Velasquez and Klotz (2013) used an expert panel to build a framework for incorporating social considerations in construction processes. This work identifies four conceptual areas of past construction research dealing with social considerations, including Community Involvement (for example, Boudet et al. 2011; El-Diraby and Wang 2005), Corporate Social Responsibility (for example, Beheiry et al. 2006; Lu et al. 2013), Safety Through Design (for example, Gambatese et al. 2005; Hallowell and Calhoun 2011), and Social Design (for example, Javernick-Will and Scott 2010; Kaminsky and Javernick-Will 2013; Love et al. 2012; Oates and Sullivan 2012).

This last category includes improving designs by considering the intended use of the project by end users; it is here that we place our research. Our practical goal is to better understand the O&M phase of infrastructure lifecycle use so that we can change designs and construction practices to better serve this phase. In this paper, when we discuss social sustainability we are specifically referring to the O&M phase of the infrastructure lifecycle and also specifically to the people interacting with or using the infrastructure on a regular basis. With the exception of studies investigating energy usage, this research area is not well established in the existing construction literature. This is the first research that analyzes causal combinations of legitimacy constructs leading to internal social sustainability of sanitation infrastructure, and it is also the first to combine status and legitimacy theory to refine our previous attempt (see Chapter 3 of this dissertation) to theorize the internal social sustainability of infrastructure.

LEGITIMACY

Organizational *legitimacy* "is a generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions" (Suchman 1995 p. 574). Generally, research has shown that legitimate organizations have improved chances of survival (Ruef and Scott 1998); it is this effect that interests us. Research in organizational legitimacy may be traced (controversially; see Deephouse and Suchman 2008 p. 50; Meyer and Scott 1983 p. 201) back to Weber (1946). However, while neoinstitutional theorists were interested in the construct (for example, see Dowling and Pfeffer 1975; Meyer and Rowan 1977; Meyer and Scott 1983; Pfeffer and Salancik 1978) it was not until 1995 that two key works (Scott 1995; Suchman 1995) enabled the rapid growth of legitimacy scholarship.

Following in these footsteps, this research draws on Suchman's typology of legitimacy (Suchman 1995). Specifically, Suchman's typology identifies the following types of legitimacy:

- *Pragmatic Legitimacy*, or self interested calculations of an organization's most immediate audience, including
    - *Exchange Legitimacy*, or support based on the expected value to particular constituents
    - *Influence Legitimacy*, or socially constructed benefits based on the organization being responsive to a constituent's larger interests, and
    - *Dispositional Legitimacy*, or the perceived persona of the organization.
- *Moral Legitimacy*, or positive normative evaluation of an organization and its activities, including
    - *Consequential Legitimacy*, or socially valued accomplishments,
    - *Procedural Legitimacy,* or socially valued techniques and procedures, and

    - *Structural Legitimacy*, or the moral standing of an organizational category (e.g. a school vs. drug dealers), and
    - *Personal Legitimacy,* or the charisma of an individual leader.
- *Cognitive Legitimacy*, or the organizational role in constituents' sense of cognitive coherence, including
    - *Comprehensibility Legitimacy,* or the availability of cultural models that furnish plausible explanations for the organization and its endeavors, and
    - *Taken-for-Granted Legitimacy*, or shared meaning such that alternative arrangements become unthinkable.

Legitimacy has been further differentiated into internal and external legitimacy (Kostova and Zaheer 1999). External legitimacy is conferred by external stakeholders (for example, a regulatory agency), while internal legitimacy is instead concerned with organizational participants (for example, employees or homeowners in our sanitation organization). External legitimacy has a well documented impact on organizational survival. For example, in a sample of 143 hospitals, Ruef and Scott (1998) found that managerial and technical forms of legitimacy improved organizational survival rates over a 46 year period. Similarly, Singh et. al. (1986) showed that external legitimacy underlies the liability of newness and has an effect on the organizational survival of social service groups, and Baum and Oliver (1992) show that daycares with links to highly institutionalized (and legitimated) organizations have higher survival rates.

In this paper we are instead concerned with internal legitimacy, which is not as well studied. Drori and Honig (2013) provide a longitudinal single case study researching a life cycle of internal organizational legitimacy, and Kostova and Roth (2002) describe the adoption of corporate practices by organizational subunits. In addition, Kaminsky and Javernick-Will (see Chapter 3 of this dissertation) examine individual legitimacy types and internal social sustainability. However, no existing studies deal with combinations of organizational legitimacy types and internal social sustainability. Our research addresses this gap by empirically measuring the explanatory power of combinations of legitimacy constructs in three sanitation organizations.

STATUS

Like legitimacy, status emerged from this and previous (see Chapter 3 of this dissertation) data as an important consideration for sanitation organization sustainability. Also like legitimacy, status has been shown to impact organizational outcomes. For example, enhanced organizational status has been shown to result in positive economic returns for banks (Podolny and Phillips 1996), to increase the market value of biotech startups (Stuart et al. 1999), to enable wineries to command higher prices for their products, even after controlling for quality (Benjamin and Podolny 1999), and to predict if colleges were invited to participate in NCAA postseason basketball tournaments independent of performance (Washington and Zajac 2005).

Status and legitimacy, as defined in the literature, overlap both with each other and with the construct of organizational reputation (which we do not deal with here) (Deephouse and Suchman 2008 p. 60). Certainly all three are concerned with social or cultural aspects of organizations and must be carefully defined in order for the distinction to be analytically and practically useful. In a recent examination of the differences, Deephouse and Suchman (2008) have proposed that legitimacy is dichotomous (while status is a relative ranking); that legitimacy is non-rival (while status more closely resembles a zero sum game), that legitimacy is homogenizing (while status is segregating), and finally that legitimacy is political (while status is honorific). However, the empirical literature differentiating these concepts is extremely limited. For example, Deephouse and Carter (2005) claim to be the first study to empirically evaluate the difference between

organizational legitimacy and reputation. Similarly, this study is the first to empirically evaluate the difference between internal legitimacy and status.

We operationalize status by noting that legitimacy is based on an individual's perception of an organization, while status is based on what that individual perceives others will think of her due to her participation. The status of an organization is not the same as the individual status of any single constituent. However, we argue that we can use the former as a proxy for the latter as perceived by internal organizational participants. Being part of a high status organization (for example, attending a particularly prestigious university) impacts individual status. Similarly, participation in a sanitation organization is a differentiator that impacts household status. Even (or perhaps especially) in contexts where we take sanitation services for granted, thinking about people who do not have a toilet available to them suggests low status and marginalized members of society. These parallels show that when we think of our participation in an organization in terms of our own status, we are also making explicit our personal opinions of the organization's status.

Here we introduce a differentiation between internal and external status, mirroring that used in the legitimacy construct. As organizational status is socially constructed, it may be perceived differently by internal and external stakeholders (or even by subsets within these groups). We are interested in internal status, which we define as *organizational status as perceived by internal organizational constituents.* Internal and external organizational status may be the same or different for a given organization, and may compliment or damage each other. For our case, an example of differential internal and external status is a community where the adoption of an improved latrine design is perceived as high status (internal organizational status) while an external person from a community with sewers might instead perceive a sanitation organization using latrine technology as low status. If internal stakeholders become aware of the external perception (or vice versa), it may eventually change their own status perception.

To summarize, in this research we ask why households in the research population both adopted and maintained a sanitation system? In other words, what has caused these households to adopt socially sustainable sanitation practices? To answer this question and build theory of the social sustainability of infrastructure, we analyze legitimacy and status constructs using the csQCA method. Anticipating our results, we find that the combination of legitimacy and status provides a better explanation of the sustainable outcome than either alone. More specifically, we find that the combination of comprehensibility and consequential legitimacy lead to sustainable outcomes in 50% of cases, and that just three combinatorial pathways can explain 85% of cases at a consistency of 0.97.

METHOD

In this section we describe the research design, data collection and analysis procedures used in this research. We use a two-stage research method, where qualitative coding of interview data is used to develop a truth table for crisp set Qualitative Comparative Analysis (csQCA). As such, the intermediate results of the qualitative coding process is included in the analysis section here while the csQCA results are reserved for the subsequent results and discussion section.

RESEARCH DESIGN

This research sought to identify combinations of theoretical constructs that lead to internally socially sustainable sanitation outcomes. As such, csQCA was selected as the research method. csQCA is based in set theory, and was originally intended for the analysis of an intermediate number of cases, where there are too many for traditional qualitative analysis and too few for statistical analysis, leaving a gap in the literature (Ragin 2008 p. 25). Its advantage is the analysis of combinations of causal conditions, rather than a regression

analysis that instead evaluates constructs individually (Ragin 2008; Ragin et al. 2013; Rihoux and Ragin 2008). In this application we use it as a tool to perform Boolean simplification on combinations of theoretical constructs, resulting in a precise and rigorous analysis of data. To develop the inputs for this analysis, household level interview data were captured and qualitatively coded for the presence or absence of legitimacy and status constructs. This process developed a theoretical for each household in the research population. In addition, each household was evaluated to determine if it had or had not achieved internal socially sustainable sanitation per the operational definition described below. These data were used to develop a truth table that was analyzed using csQCA. For the dataset used in this research, the infrastructure system of interest is a geographically bounded sanitation organization made up of individual households and the sanitation technologies employed at each. We should note that this sanitation organization is certainly influenced by alters both outside of its geography and alters inside its geography who choose not to be a part of the sanitation organization. However, the unit of analysis remains the household, embedded in the larger unit of the geographically based sanitation organization.

Following Yin (2009) this research followed standard procedures to ensure construct, external, and internal validity. Construct validity means that the theoretical constructs identified were appropriately and consistently defined and measured. To enhance construct validity, we used constructs previously established in the literature and continued adding household cases until theoretical saturation had been reached. Additionally, we developed a coding dictionary to clearly operationalize the constructs and to ensure that codes were applied consistently. External validity was addressed by considering multiple household cases across three communities and by connecting our results to the existing literature. Internal validity was addressed by the use of the csQCA method, with any criteria required for analysis (such as assuming that the presence of legitimacy would contribute to sustainability) taken from the literature. In addition, the method was used to measure the relative strength of legitimacy and status theory in various combinations, allowing us to improve the robustness of our results by triangulating findings. Internal validity was also addressed by multiple iterations of coding to ensure no coding instances had been inadvertently neglected. Finally, reliability was ensured by a research protocol that included interview guides, the coding dictionary, and full procedures for the csQCA analysis.

DATA COLLECTION

Three small rural communities in Guatemala were selected for this research. Each of these communities has achieved an unusually high level of sanitation coverage by our definition (85% of participating households); as such they are seen as extreme cases in which to analyze our embedded household unit of analysis. While in the same geographic region, these communities are not adjacent to each other. The communities all use onsite sanitation technologies, ranging from open pit latrines to pour flush latrines. When full, latrine pits are abandoned in place and (usually) a new one is dug to replace it. Rarely, the waste itself is removed from the pit instead. Two visits were made to each community in an attempt to increase the response rate. There were a total of 68 households in these three communities. Of this number, 43 consented to participate in our research (11/21, 7/12, and 25/35). All but five households were reached during these two visits; in other words, 20 declined to participate. In one instance the audio recorder failed and the interview data was lost, resulting in the analysis of 42 households.

At each household we administered a semi-structured interview, based around an interview guide with open-ended questions but intended to flow like a conversation rather than a survey. The questions attempted to elicit detailed and personal answers regarding motivations and experiences regarding sanitation systems. For example, participants were asked "*Why did you build your toilet*?" and "*Is a toilet worth the trouble? Why or why not*?" Adult family members participated in the interviews. The interviews were administered in Spanish by a trained Guatemalan national in an additional attempt to increase respondent ease with the

research process and to enable improved understanding of the local context. Each interview was recorded with the participants' consent. The interviews were later transcribed in entirety for analysis as described below.

QUALITATIVE DATA ANALYSIS & RESULTS

The interview transcriptions were imported into QSR NVivo 10 (QSR International Pty Ltd. 2012) for qualitative coding. Qualitative coding organizes qualitative data according to predefined or emergent categories (Miles and Huberman 1994; Saldaña 2009). For this project, our codes were predefined by theory, using Suchman's (1995) typology for legitimacy. In addition, a status construct emerged from the data during coding. Coding was performed in Spanish; all translations presented here are the first author's. Coding was performed iteratively by the first author. Additional household cases were added (in units of additional communities) until theoretical saturation had been achieved and new data could be represented completely by existing codes. During this process a coding dictionary was developed to define explicitly what was coded to each legitimacy construct. For example, if a household referenced personal hygiene it was coded to exchange legitimacy, and a corresponding entry was made in our coding dictionary. Table 4-1 below shows additional examples from our coding dictionary and the resulting 471 total coding references.

TABLE 4-1: SELECTED CODING DICTIONARY AND REFERENCES FOR ALL INTERVIEWS

Theoretical Construct		Selected from Coding Dictionary*	Count** of References	% of References
Pragmatic	Exchange	Cleanliness	155	33%
		Personal Hygiene		
		Odor Management		
		Insects or Livestock Contamination		
		Convenience		
		Waste Goes Away		
	Influence	Labor	48	10%
		Financial Contribution		
	Dispositional	None	0	0%
Moral	Consequential	Public Health	59	13%
		Pollution		
	Procedural	Modernity	36	8%
		Knowledge		
	Structural	The Right Way	59	13%
	Personal	Internal to Community	29	6%
		External to Community		
Cognitive	Comprehensibility	Health & Sanitation Causality	34	7%
	Taken for Granted	That's The Way It's Done	22	5%
Status		Avoid Complaints	29	6%
		Privacy		
		Total References	471	100%

*Selected for brevity; those shown were referenced for 10% or more of total references made to the construct.
**Households may reference constructs more than once.

Next, each household was classified as either having an internally socially sustainable or unsustainable sanitation system. To be classified as having a socially sustainable system, owners had to report having done maintenance on the system after initial construction (typically either replacing a broken part or digging a new pit after an existing one became full) and the system could not be broken on the day of the visit. If a young system (less than five years old) was unbroken but no maintenance was reported, it was removed from the analysis as a case with unknown sustainability outcome, as it is possible that no maintenance was required during that time frame. This removed two households from our analysis. It is extremely unlikely, however, that a large family using a pit latrine would not have to empty or replace it at least every five years. As such if a system appeared unbroken but no maintenance was reported for longer than five years it was assumed to be full and unusable, and was therefore classified as unsustainable. By these definitions, a total of 85% (34 of 40) of participating households had achieved socially sustainable sanitation across the three communities, broken down in 79%, 90%, and 100%.

These data were organized into a matrix truth table with each row representing an individual household and each column representing the various qualitative codes. A 1 was placed in a cell if a particular household had referenced a particular theoretical construct; a 0 was placed if that household had not referenced that construct. No attempt was made to convert these values into fuzzy sets by use of relative frequencies or similar mechanisms, because the authors felt that this would mostly represent respondent loquacity rather than a measure of any particular construct. A final column was appended to the truth table to represent the sanitation outcome; a 1 was placed if that household had achieved socially sustainable sanitation by our definition, and a 0 was placed if it had not. Table 4-2 shows a summary of the number of households that referenced each construct. We should note that the 100% coverage in influence legitimacy (which deals with participant control over an organization, operationalized here as instances of labor or financial contributions) is an artifact of our coding scheme; to be classified as sustainable households were required in part to have participated in or financed construction or maintenance.

TABLE 4-2: QUALITATIVE CODING RESULTS SUMMARY

		Sustainable		Unsustainable	
		Count	Percentage of Households	Count	Percentage of Households
Number of Households		34	100%	6	100%
Pragmatic	Exchange	33	97%	5	83%
	Influence	34	100%	4	67%
	Dispositional	0	0%	0	0%
Moral	Consequential	24	71%	3	50%
	Procedural	12	35%	2	33%
	Structural	27	79%	4	67%
	Personal	13	38%	2	33%
Cognitive	Comprehensibility	18	53%	1	17%
	Taken for Granted	12	35%	4	67%
Status		14	41%	3	50%

csQCA Analysis

The truth table developed in the qualitative analysis phase was then imported into the fsQCA software package (Ragin et al. 2013). Adopting QCA terminology, moving forward the legitimacy and status constructs are called conditions and each household is called a case. For QCA analysis, the data must show variation in terms of having cases with both the presence and absence of each condition. In other words, conditions that are present in nearly all or nearly none of our cases cannot be analyzed meaningfully. These are called domain conditions because they do not vary across cases. These conditions may or may not contribute to the outcome; however, there is not sufficient variation in the data to make this determination. For this project, domain conditions were defined as any condition where more than 75% of household cases referenced or did not reference a construct. These domain conditions (including exchange, influence, dispositional, and structural legitimacy) were removed from further analysis at this time. Removing these from the analysis is not intended to suggest that we believe these types of legitimacy are not important, but rather only that our cases do not show sufficient variation to reasonably evaluate them. Three of these conditions were types of pragmatic legitimacy, and one was a type of moral legitimacy. Unfortunately, our data cannot demonstrate empirically whether these conditions are required or not. In addition, several additional analysis criteria must be established to perform Boolean minimization. For this project, we required consistency (a measure of "how closely a perfect subset relation is approximated" in the case data (Ragin 2008 p. 44)) greater than 90% and the count of cases set to two or more.

Results & Discussion: Pathways to Internal Socially Sustainable Sanitation

This section describes the results of the csQCA analysis. We begin by presenting the results of a necessity/sufficiency analysis that looks at each construct individually. Next, we discuss the results regarding combinations of legitimacy theory constructs only. The third step is the results of the analysis that combined both status and legitimacy theory; this combination is found to have the greater explanatory power. Findings for each of these sets of results are highlighted and discussed further in the concluding sections along with research limitations and recommendations for future work.

Necessity and Sufficiency Analysis

Table 4-3 below shows the necessity and sufficiency of each construct in our analysis. The necessity column may be understood as the number of socially sustainable household that included the construct. For example, in our data 41% of our socially sustainable household cases were coded to the status construct. In contrast, the sufficiency score describes the extent to which cases including a construct were socially sustainable (Ragin 2008). For our data, 82% of household cases coded to the status construct were socially sustainable. A sufficiency of 80% is commonly used as being "almost always sufficient" (Ragin 2000 p. 110) to achieve the outcome. In other words, most of our constructs in isolation could be considered as sufficient for achieving internal socially sustainable sanitation. These high sufficiency scores suggest that in this particular context the various conditions are highly substitutable; and we would expect that there are multiple pathways to achieve socially sustainable sanitation rather than just a single one. This agrees with calls in the literature to reduce emphasis on individual analytic types of legitimacy in favor of a more holistic and intertwined understanding (Deephouse and Suchman 2008 p. 68). To meet this need, we proceed with the combinatorial analysis.

TABLE 4-3: NECESSITY & SUFFICIENCY OF CONDITIONS FOR THE INTERNALLY SOCIALLY SUSTAINABLE OUTCOME

Construct	Necessity	Sufficiency
Exchange	0.97	0.87
Influence	1.00	0.89
Dispositional	0	0
Consequential	0.71	0.89
Procedural	0.35	0.85
Structural	0.79	0.87
Personal	0.38	0.87
Comprehensibility	0.53	0.94
Taken For Granted	0.35	0.75
Status	0.41	0.82
Inertia	0.97	0.87

PATHWAYS TO SOCIALLY SUSTAINABLE SANITATION: LEGITIMACY THEORY

Here we describe the results of the csQCA analysis using only the legitimacy constructs taken from Suchman (1995); they do not include status. This analysis looks at combinations of legitimacy constructs rather than each in isolation. Three pathways emerge from the data, which together achieve 41% coverage of the observed cases at a consistency of one. In other words, 41% of the sustainable household cases are represented by these pathways. This is a very low coverage that suggests there is not a set theoretic relationship: "with observed consistency scores below 0.75, it becomes increasingly difficult on substantive grounds to maintain that a subset relation exists, even a very rough one" (Ragin 2006 p. 3). This low coverage means that the dataset has a large number of contradictory configurations. In other words, there are many cases where the same set of conditions has led to conflicting outcomes.

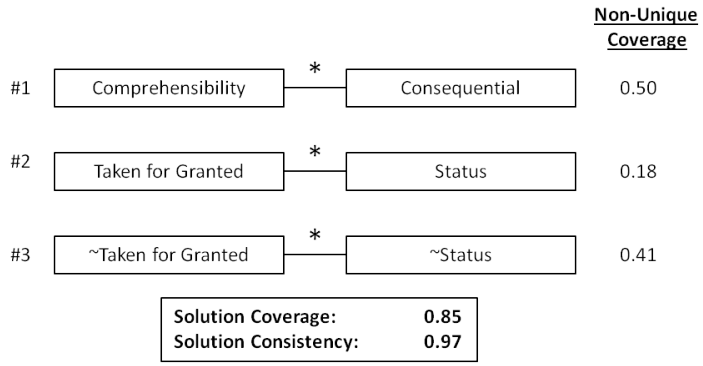
For example, there were three cases that combined the presence of consequential, procedural, and personal legitimacy with the absence of taken for granted and comprehensibility legitimacy. Two of these cases showed the sustainable outcome; one did not. Due to this contradiction, this combination did not meet our consistency criteria and as such the three cases were excluded from the pathway analysis. The case that did not achieve sustainable sanitation was a household that reports having a sanitation system for 20 years. It broke, and they did not fix it although they continue to use it. They believe that having a toilet is the responsible thing to do, and this is a principle they value (procedural legitimacy). This household reported getting information about the system from a nurse at the regional health center and also (in the past) from the NGO World Vision (personal legitimacy). They report using a toilet in order to protect the environment and the health of the neighbors (consequential legitimacy). In contrast, one of the sustainable cases reports having a toilet for about 10 years. They built it themselves, and dig a new pit for the latrine each year. They note the importance of cleanliness and protecting the environment (consequential legitimacy), and say that they learned to build a toilet when the adult male in the household was outside the community (personal legitimacy). Later an outsider arrived to talk about producing fertilizer from the waste (personal legitimacy). They feel that this learning (procedural legitimacy) led them to adopt a sanitation system. Neither of these cases notes a connection to protecting health, and neither describes a model of understanding for how a sanitation system would help them achieve what they report as benefits of having a system. The presence or absence of our legitimacy constructs cannot help us understand the difference between these two cases; they present the same profile. However, there are standard techniques that we may use to help resolve contradictory configurations. These techniques include adding or replacing conditions to the model, revisiting the operationalization of the conditions or outcome, or revisiting case data for more traditional

qualitative analysis in order to further build case knowledge (Rihoux and Ragin 2008 p. 48). Qualitatively, for example, we might point out that the cases reference a difference principle for procedural legitimacy (knowledge vs. responsibility), and that we might expect that sanitation adoption founded on knowledge to be more sustainable than one that is not. In this case, the unsustainable case seems to have adopted the sanitation technology ceremonially, similar to what has been described in Kaminsky and Javernick-Will (see Chapter 3 of this dissertation) in Bangladesh. In order to resolve the contradictory cases, and as we have observed that status is often referenced in the dataset, we add this construct to our analysis.

PATHWAYS TO SOCIALLY SUSTAINABLE SANITATION: STATUS & LEGITIMACY THEORY

When we add the status construct to our analysis, the percentage of household cases covered by these pathways increases from 41% to 85%, with a consistency of 0.97. This is a considerable advantage in explicative power at no cost to parsimony. The combination of status and legitimacy theory provides a much better explanation of our cases than either alone. Figure 4-1 shows the pathways that emerge from the analysis of the combined legitimacy and status constructs. The order of the constructs presented below is not intended to imply temporality or any other hierarchical order; each construct represented in each pathway is equally important and occurs in combination rather than in any sequence. The coverage numbers given below are not unique; in other words, some households are covered by more than one pathway. Using standard set theory symbology, the * in the figure below represents the Boolean AND, while the ~ represents the Boolean NOT.

FIGURE 4-1: PATHWAYS TO SUSTAINABLE SANITATION



The first pathway shown covers 50% of the sustainable household cases. This pathway requires the presence of both comprehensibility and consequential legitimacy. It is reasonable that these two legitimacy types often appear together. Comprehensibility legitimacy (*"As I said, there's a lot of sickness caused by that [open defecation]")* means that households described a cognitive model of understanding explaining sanitation systems. In other words, here households have a rational model that explains how and in what manner sanitation produces the various outcomes households desire. Consequential legitimacy is a morally based outcome like public health or environmental protection (*"[We built a toilet] so as not to go around contaminating….We made that decision in order to not impact the neighbors by just going to the mountain."*). Most households referencing this construct described a causal connection between sanitation services and health outcomes, scientific or otherwise.

The second pathway covers seven (18%) household cases. For these cases, the presence of both taken for granted legitimacy and status leads to the sustainable outcome. These households are unusual cases. Three of these households are second generation users of sanitation technology. A fourth moved to the community several weeks prior to the interview from a more developed area. A fifth works for the government health

department. The last two are technology innovators who have constructed their own sewers, which discharge in a nearby ravine. One of these two reports attending a number of workshops regarding health and sanitation. In other words, this group is made up of people who either through long experience or self-driven and extensive education has come to see sanitation as a necessity.

The third pathway is NOT taken for granted and NOT status. This pathway covers 41% of household cases, and covers 24% of cases uniquely. This pathway describes cases where the commonality is the absence of both status and taken for granted legitimacy. This does not mean that all other types of legitimacy are also absent. Rather, comprehensibility, consequential, procedural, and personal legitimacy (all the non-domain legitimacy constructs included in this analysis) are present or absent in various permutations, or subsets. Since theory tells us that the presence of legitimacy improves survival outcomes, this means that these various legitimacy types lead to the sustainable outcome somewhat interchangeably. For these cases, the belief that the system is perceived as legitimate is more important than the specific source of that legitimacy. This corresponds both to our necessity/sufficiency analysis above and to calls in the literature for more holistic understanding (Deephouse and Suchman 2008 p. 68). In one case, the household did not mention any of the constructs included in this analysis. Instead, this household primarily referenced structural legitimacy (one of our domain conditions), saying that "*It's not good to go to the mountain [defecate outside]…one must use the toilet, that is good.*" In addition, in all but this one case, either comprehensibility or consequential legitimacy was present, suggesting again that these two constructs are particularly important for sustainable sanitation.

Comparing the first and second pathways (which uniquely cover 38% of all cases) suggests that the combination of comprehensibility and consequential legitimacy is interchangeable for the combination of taken for granted legitimacy and status. This makes sense. On one hand, we have social support for a sanitation organization founded on understanding of both process and outcome. On the other, we have social support founded on a sense of inevitability and dismay of what others would think if sanitation were abandoned. It also makes sense that inevitability is not seen very often in our dataset considering the relatively short period of time that the study households have had sanitation systems. The absence of taken for granted legitimacy in so many household cases may simply refer to the relatively short period of time that sanitation technologies have been present in these communities. Indeed, Suchman's (1995) paper distinguishes a temporal factor in his typology. He places taken for granted legitimacy in the continual category and comprehensibility and consequential legitimacy into the episodic category. It is possible that with the passage of time the episodic forms of legitimacy will transform into (or join and complement) the continual ones. This would merge comprehensibility into taken for granted legitimacy, and consequential to procedural legitimacy. Procedural legitimacy, of course, did not appear in our pathways at all. Future research could measure various types of legitimacy longitudinally or across cases with different lengths of exposure to sanitation to understand if this transition does indeed occur. Regardless of if the continuous legitimacy types replace or complement the episodic types, however, this is an encouraging finding for practitioners that suggests educational outreach designed around building comprehensibility and consequential legitimacy can initiate socially sustainable sanitation uptake.

The required absence of status in the third pathway is interesting as the existing literature does not make a similar temporal distinction between micro constructs. The literature does tell us that while status supports organizational success, success does not necessarily grant status (Deephouse and Carter 2005). This suggests that the limited time sanitation has been present in these communities should have little impact on the prevalence of the status construct. However, by referring back to Table 4-3 we can see that it scores lower in both necessity and sufficiency than any construct except taken for granted legitimacy. It may be that sanitation systems adopted due to concerns with status are not maintained (or, are not socially sustainable)

because maintenance is something the neighbors cannot see. In other words, the presence of a sanitation system may be sufficient to raise status even if it is not kept up.

LIMITATIONS & FUTURE WORK

An important limitation of this research is a potential issue in the direction of causality. In other words, like any non-longitudinal research design, we cannot perfectly establish if our conditions caused our outcome or if in fact the outcome caused the conditions. Here we must depend on the literature. While both legitimacy and status are thought to enhance the prospects of success, empirical data suggests that reverse causality is tenuous at best (Deephouse and Carter 2005; Deephouse and Suchman 2008). An example for the status construct is the social exclusion of the newly wealthy in elite circles; although successful, they are not automatically accorded status. For our analysis, this suggests that building status and legitimacy supports internally socially sustainable sanitation infrastructure rather than previously internally socially sustainable infrastructure being perceived as granting high status or legitimacy.

Another research design limitation is the issue of free recall (Singleton and Straits 2004; Spradley 1979). In other words, it is possible that during our interviews, respondents simply did not think of something important, resulting in a construct falsely being coded to absence when it is in fact present. We attempted to minimize this problem by using various wordings to ask the same question several times over the course of the interview (Spradley 1979) and also by requiring two of any combination for our analysis (Ragin 2008). However, this is an inevitable limitation of our data collection design. Similarly, as with all interview-based methods, it is possible that some respondents gave certain answers because they believed they were socially expected (Podsakoff et al. 2003); this could certainly impact reports of using sanitation technologies. However, as infrastructure was physically observable by the interviewer, the opportunity for giving such answers was minimized.

Finally, legitimacy and status are socially constructed, and as such are likely to vary in different cultural and/or socioeconomic contexts. To increase theoretical robustness, future research should analyze legitimacy and status constructs in communities where low or more balanced levels of sustainability have been achieved. This latter would enable sufficient variation for analysis to look not only at combinations of legitimacy but potentially cases where it is absent altogether. Similarly, it would be interesting to use diffusion theory to repeat the analysis for categories of adopters; in other words, households that adopted sanitation early or late. Looking at these different contexts might also increase case variation enough to enable the analysis of our domain conditions.

CONCLUSION

Our primary objective for this paper was to extend theory of the social sustainability of infrastructure. While there have been calls for this work (Levitt 2007b), to date very little research has been performed. Our previous work (see Chapter 3 in this dissertation) uses legitimacy theory as a first step in building theory of social sustainability specific to infrastructure. The current paper builds on this past work in two ways. First, we add status to legitimacy theory and use these as components in our theory of social sustainability. In addition, we look at combinations of micro level legitimacy constructs. This allows us to determine combinations of legitimacy types that are contributing to social sustainability. By using csQCA and set theory, we are able to retain attention to complexity and consider the various contexts in which legitimacy and status are relevant. Our findings show that the combination of status and legitimacy theory provides a superior explanation to either construct alone. This advances the theory of the social sustainability of infrastructure

by using a new method in a geographic context different to that previously researched to support the utility and generalizability of this theory.

This finding also allows this work to contribute to organizational theory. While status and legitimacy are both recognized as important social constructs with connections to organizational outcomes and survival, they have rarely been empirically measured. This paper does this for a sanitation organization, and is also a first attempt to compare status and legitimacy constructs to determine how they interact to produce organizational survival. In addition, we introduce the idea of internal status, mirroring the internal-external distinctions extant in the legitimacy literature. These contributions can help scholars better understand the relationships between status and legitimacy, which in turn will help practitioners to improve organizational outcomes.

Finally, the detailed findings of this study can aid professionals to better design, construct, and manage sanitation infrastructure. We found that understanding how infrastructure works (comprehensibility legitimacy) and what the societal level consequences of its presence or absence are (consequential legitimacy) leads to socially sustainable sanitation infrastructure in many cases. Alternatively, a sense of status and taken for granted legitimacy can also lead to sustainability. However, as this latter is not something that practitioners can change, the former is a more practically useful finding. Building education and outreach programs founded on both the process of how infrastructure works and the societal level outcomes resulting from infrastructure may significantly improve uptake. An additional practical finding of this study is that an understanding of the individual pragmatic benefits of infrastructure is present in nearly every household case. In other words, both households with and without socially sustainable sanitation infrastructure are aware of pragmatic benefits such as odor management and convenience. This suggests that education strategies founded only on these practical benefits may be misplaced; while it seems reasonable that this understanding would be necessary for sanitation uptake, our data show that it is not sufficient.

We situate this paper in the sustainability literature, and understand these claimed contributions similarly. In other words, improved social sustainability will improve economic sustainability by helping firms and owners alike achieve successful projects, and by helping the people nearby to live healthy, connected, and economically productive lives. Improved social sustainability will improve environmental sustainability both by reducing the use of materials for unused infrastructure and by separating and treating human waste from both people and planet. We do not claim that improved social sustainability improves technical sustainability, other than by noting that the technology is a means rather than an end, and that as such by improving the end that the technology serves we also justify the reason for its existence. Our hope for this research is that an improved theory of social sustainability specific to infrastructure can enable the construction of infrastructure that is better aligned to the needs and worldviews of the people who are using it. This is important for communities across the globe; anywhere, in fact, where people construct their lives on the foundation of our shared infrastructure.

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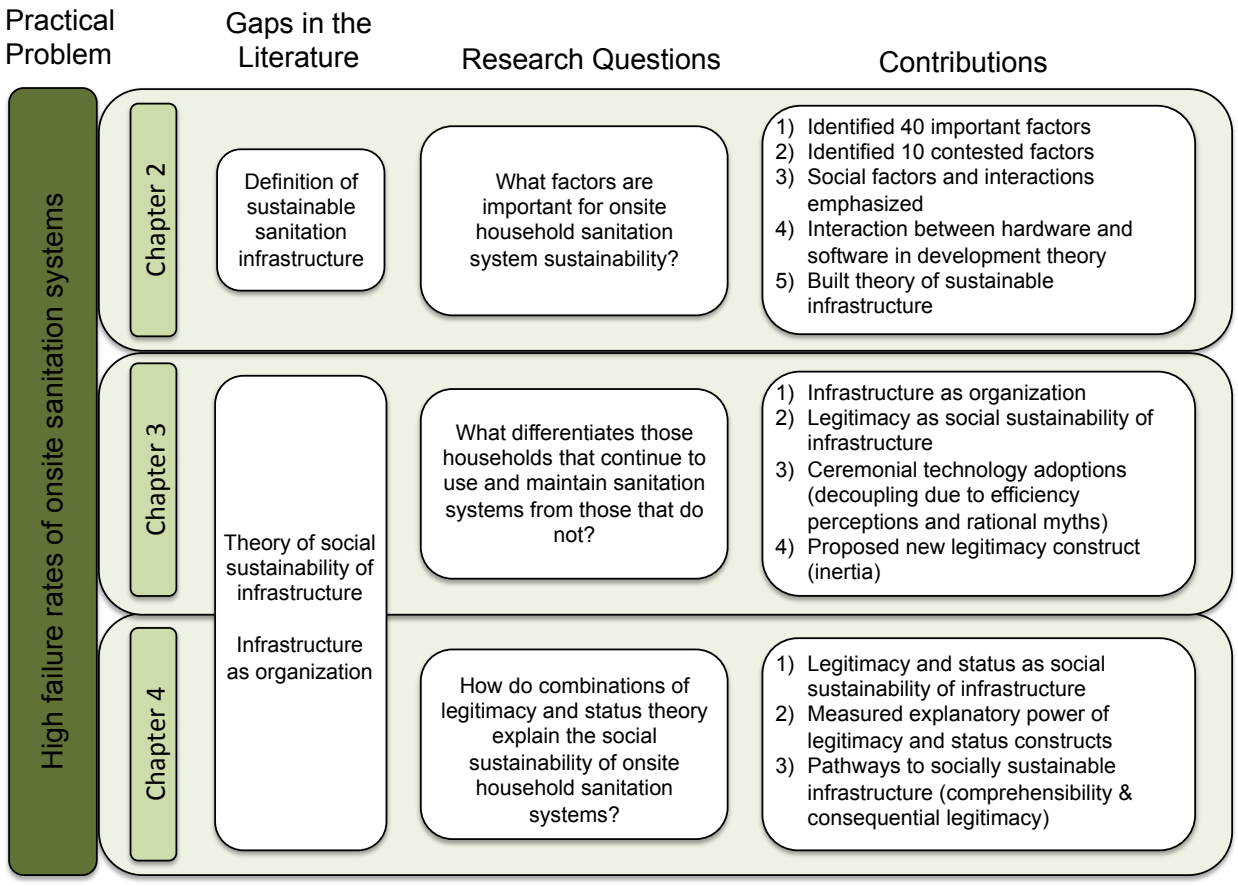
CHAPTER 5: SUMMARY & CONCLUSIONS

The three research chapters in this dissertation describe a process of theory building for the social sustainability of sanitation infrastructure, answering the overarching research question of *what causes high failure rates in onsite household sanitation systems*? This is an urgent question, due to the high global failure rates of onsite sanitation infrastructure and the resulting negative impacts on human and environmental health. The brief answer is that failure rates are caused by the social mechanism of decoupling, and that the solution is targeted education and technical outreach.

Chapter 2 of this dissertation develops a list of factors important to the sustainability of onsite sanitation infrastructure, drawn from the engineering literature and an expert panel. Social factors and interactions between factors emerged as particularly important. This led me to the work in Chapter 3, where I analyzed household interview data from Bangladesh to discover decoupling as the mechanism driving socially unsustainable sanitation adoption. It also led me to the work in Chapter 4, where I analyzed household interview data from communities in Guatemala that have achieved a high level of sustainability. This allowed me to develop pathways showing how households had made that achievement, and found that comprehensibility and consequential legitimacy are extremely important for socially sustainable sanitation.

Figure 5-1 summarizes the contributions made in this dissertation.

FIGURE 5-1: DISSERTATION SUMMARY



CONTRIBUTION TO THEORY

The most significant theoretical contribution of this dissertation is thinking of an infrastructure system as an organization to build theory of the social sustainability of infrastructure. Theorizing beyond the hardware (as shown in Figure 5-2) gives us a new way to examine all infrastructure systems with particular attention to how they interact with social systems, itself a gap in the literature.

FIGURE 5-2: CECI N'EST PAS UNE TOILETTE

Ceci n'est pas une toilette
(this is not a toilet)
Conceptual thanks to René Magritte

In addition to this overarching contribution, the specific findings of each chapter stand as contributions. Chapter 2 identifies 40 factors that either the literature or an expert panel found to be important for sanitation sustainability. In addition, I described ten factors where the literature and experts disagreed, making these an excellent source of ideas for future research. Chapter 3 applies legitimacy theory to sanitation systems and showed how this analytic lens can usefully theorize social sustainability for sanitation infrastructure. This chapter shows sanitation abandonment as an instance of decoupling, where concerns with efficiency and competing rational myths cause a disconnect between structure and practice. Chapter 4 extended this work by looking at the causal combinations of factors that lead to social sustainability of sanitation infrastructure, and also adds status theory to legitimacy theory to measure relative explanatory power of these theories. It shows that comprehensibility and consequential legitimacy are important in explaining sustainable sanitation adoption. This progression of research led us to identify the importance of the technology-society nexus, model how they might interact in a particular context, and then use existing theory in a new context to rigorously describe and understand it. All these contributions feed into a gap in the literature first identified through the Chapter 2 research: namely, the lack of theory describing social sustainability as it relates to infrastructure.

CONTRIBUTION TO PRACTICE

The findings of this dissertation can also be used to improve the social sustainability of sanitation infrastructure. The work presented here gives us a roadmap to understand what educational outreach will be effective in promoting sustainable sanitation uptake. Specifically, comprehensibility (cognitive models of how sanitation relates to desired outcomes) and consequential legitimacy (morally based outcomes of sanitation infrastructure such as public or environmental health protection) are important tools to be used by practitioners when providing education about sanitation systems. Also, the theory of decoupling gives us a new way to understand why we see extremely high rates of sanitation infrastructure abandonment.

The work done in this dissertation suggests that these unsustainable systems are not caused due to a lack of practical motivation of homeowners, nor yet due to economic barriers. While those may impact some households, the cases presented here were instead decoupling structure and practice. By changing designs, providing technical support, and providing education intended to help resolve competing rational myths we can improve sanitation sustainability.

FIGURE 5-3: CONTRIBUTIONS TO THEORY AND PRACTICE

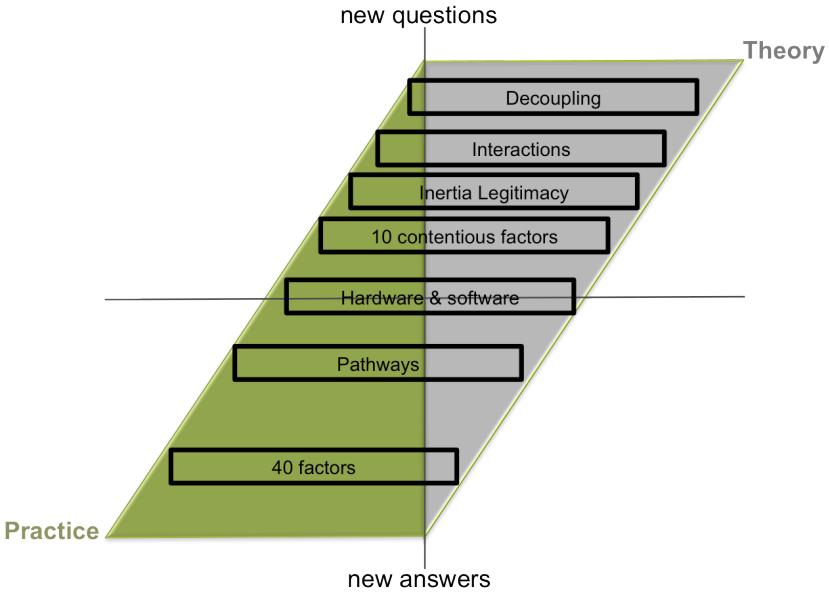


Figure 5-3 maps the various contributions of this dissertation in terms of their interest to both theory and practice. Like any dissertation, the contributions are biased towards theory. However, like any good engineering dissertation, there are also strong contributions to practice and a practical aspect to each; the tendency towards theory may be seen as places where more research is needed to better enable these contributions to be used in the field.

LIMITATIONS & SUGGESTIONS FOR FUTURE RESEARCH

An important limitation of this research is a potential issue in the direction of causality. In other words, like any non-longitudinal research design, I cannot perfectly establish if the conditions caused the outcome or if in fact the outcome caused the conditions. However, my claim is based on in depth case knowledge. In addition, we can depend on the literature. While both legitimacy and status are thought to enhance the prospects of success, empirical data suggests that reverse causality is tenuous at best (Deephouse and Carter 2005; Deephouse and Suchman 2008). An example for the status construct is the social exclusion of the newly wealthy in elite circles; although successful, they are not automatically accorded status. For our analysis, this suggests that building status supports internally socially sustainable sanitation infrastructure rather than previously internally socially sustainable infrastructure being perceived as granting high status.

Another research design limitation is the issue of free recall (Singleton and Straits 2004; Spradley 1979). In other words, it is possible that during our interviews, respondents simply did not think of something important, resulting in a construct falsely being coded to absence when it is in fact present. I attempted to minimize this problem by using various wordings to ask the same question several times over the course of the interview. However, this is an inevitable limitation of our data collection design. Similarly, as with all interview-based methods, it is possible that some respondents gave certain answers because they believed they were socially expected (Podsakoff et al. 2003); this could certainly impact reports of using sanitation technologies. However, as infrastructure was physically observable by the interviewer, the opportunity for giving false answers was minimized.

A related issue to free call is the bias introduced by which individuals were interviewed for each household. In most cases a single adult participated, although occasionally more than one adult contributed to the conversations. As interviews were conducted during the day, we often spoke to housewives (the most commonly reported occupation for female respondents) and elderly, handicapped, and un- or underemployed men. While I initially intended to interview each adult in each household, it proved logistically infeasible. Even when more than one adult was at home, they often preferred to have a single person interviewed or to

have multiple people contributing to a single interview. Overall, in both Guatemala and Bangladesh, almost 70% of respondents were women. As women are typically the caregivers in households (Bianchi et al. 2000) this may have biased responses towards caring for others. It may also have meant that we tended to speak to people who were not primarily responsible for the construction of the systems. However, we expect that women are responsible for the maintenance and care of sanitation infrastructure. As this longer term O&M work was the focus of this dissertation, I do not expect this bias to reduce the validity of the findings.

It is also possible that those people who chose not to participate in the research were different than those who did. Our research addressed this issue in two ways. First, we made multiple return trips to the community to improve the response rate, and ultimately a high percentage of households chose to participate. In Chapter 3, where I compared households with and without socially sustainable sanitation, we achieved a 95% response rate that suggests this type of bias was minimal. In addition, if there were a systematic bias among those who declined to participate, I would expect that it would be a bias towards those who have not adopted sanitation and were ashamed to say so. The work in Chapter 4 was most interested in those households who had adopted sanitation technologies, and as such the impact of this type of bias on our findings, while still real, is minimized.

Finally, legitimacy and status are socially constructed, and as such are likely to vary in different cultural and/or socioeconomic contexts. To increase theoretical robustness, future research should analyze legitimacy and status constructs in different cultural and socioeconomic contexts, as well as places with longer experience with sanitation infrastructure. Similarly, it would be interesting to use diffusion theory to repeat the analysis for categories of adopters; in other words, households that adopted sanitation early or late. Looking at these different contexts might also increase case variation enough to enable the analysis of the domain conditions that were unavoidably excluded from the csQCA analysis described in Chapter 4. Future analysis might also attempt a fuzzy set measurement and analysis of status and legitimacy.

Finally, both personal networks and comprehensibility appeared to be of importance for many pathways. This suggests the need for social network analysis of sanitation knowledge flow and the creation or mapping of technology education schemes against legitimacy and status theory. This work could be paired with longitudinal studies of sanitation organization sustainability in an experimental research design to measure the impact of specific educational curricula intended to build various types of legitimacy.

A Humble Attempt at Some Big Thoughts, or, So What & What Next?

Through this research, I came to see sanitation technology abandonment as an example of organizational decoupling, or the separation of structure and practice. This is a totally new way of thinking about this problem, and I hope that it will enable us to make real improvements in the provision of sanitation infrastructure services worldwide. Before it can reasonably do so, however, more work is needed. We now have new perspective on the problem we are facing. However, we need to know how to solve this problem. Unfortunately, the existing literature on decoupling is limited. It does not tell us how (or if) decoupling persists or breaks down over time, nor yet how we may accelerate the breakdown. We also do not understand how decoupling relates to technology diffusion and initial adoption patterns. In other words, we need research that can help us disrupt the decoupling mechanism. This research project will not be a minor undertaking. However, its implications are of vital importance for both infrastructure sustainability and also for organizational theory and practice. If we can understand how to disrupt decoupling, we will improve the social sustainability of infrastructure. We may also be able to (for example) understand how to move beyond diversity policies and offices to actually diversifying the people involved in many highly segregated professions and practices. As someone whose research interests also extend to engineering education and workforce diversification, this is a personally important link between two otherwise disparate research

streams. Also linking these research streams together is the finding that education and knowledge mobilization may be a key to breaking down decoupling. This finding appeared both in the Guatemalan data that looked at almost entirely successful cases (comprehensibility legitimacy), and also in the Bangladeshi data that looked at both successes and failures (breaking down rational myths, and improving efficiencies through technical knowledge). Two different data sets and two different methods emphasize the importance of this factor, and it will be key as the work moves forward. One future step that would further validate this theory would be research in a context where not everyone had constructed a toilet. Our theory suggests that legitimacy concepts influence these structural changes, and so I would expect to observe differences between groups with and without a constructed toilet.

More generally, this research caused me to think of infrastructure systems as organizations. For me personally, this was an intellectually stimulating process. More importantly, however, I believe that there is enormous potential for applying organizational theory to infrastructure systems with the goal of improving infrastructure's social sustainability. By expanding our point of view and changing our unit of analysis from the construction firm or project to the full, longitudinal infrastructure system, we may be able to learn how to make different parts of this integrated system work together better.

We have now spent decades listening to science and technology studies practitioners describe engineers as novelists, as people who dream up (infra)structures in which people live out their lives (Latour 1996). These structures both constrain and enable human capabilities (Sen 1999). It is this potential—the potential to build structures that maximize individual freedom and choice for all people—that underlies the engineering profession I am honored to have a place in. If this dissertation has accomplished nothing else, I hope it will serve both as a voice emphasizing this responsibility and also as a small step towards building the knowledge needed to fulfill it.

APPENDIX A: INTERVIEW GUIDES

This appendix contains the interview guides used in this research. The questions are presented in Bangla and Spanish (which were used in the field) and for reference in English (the language of this dissertation). The same questions were used for the research presented in Chapter 3 and Chapter 4. While these questions shaped each interview, in many questions additional follow up questions were asked to gather the needed information or clarify a point. This means that the questions were asked differently in many cases, which may increase this type of data collection error. However, the goal should be to reduce total error, and by clarifying questions and following up as needed I feel we were better able to capture the desired information.

1. How and when did you and your family come to live here?
2. How many people live in this house? How many are adults?
3. Do you have a functional toilet right now? If not, did you have one before and why don't you now?
4. How long have you had your toilet?
5. Have you ever had to replace or fix your toilet? Can you describe what happened? Did anyone help you or give you advice?
6. Do you use your toilet regularly? Why or why not?
7. Can you tell me about the history of sanitation in your town? Clean water?
8. Can you please describe how your toilet works? Is it private or shared?
9. Would you prefer to keep using this type of toilet or change to a different one? If you'd like to change, please describe what you'd change to and why you'd prefer it.
10. Does anyone in the community use a different kind of toilet? How do you know?
11. Do you think that sanitation in your town is excellent, average, or poor? Why?
12. Why did you want a toilet?
13. Who helped you build your toilet? Who did you help build his or hers?
14. What do you do to maintain your toilet? Who gave you help or advice about this?
15. What problems have you had with your toilet? Who gave you advice or help about these problems?
16. What problems have your neighbors, friends or family had with their toilets? Who gave them advice or help about these problems?
17. Are toilets worth the trouble? Why or why not?
18. Who in the community helps lots of other people with sanitation problems or improvements? What sorts of things do they do in order to help?
19. Has the community ever worked together to try to improve sanitation infrastructure? Can you tell me the story?
20. What is a toilet good for?
21. What jobs do people in your family have?
22. How much money does your household earn every month?

What about friends, family, neighbors, masons, hardware store, government, health clinic, NGO, other organizations?

Nombre de Comunidad y Persona:

1. ¿Por qué y cuándo se vino a vivir usted y su familia aquí?
2. ¿Cuántas personas viven aquí en su casa? ¿Cuántas son adultas o mayores de 18 años ?
3. ¿En este momento, tienen ustedes un inodoro que funciona bien? (*Si, esperar resuesta*) Si no, ¿tuvieron uno anteriormente?, y ¿por qué no lo tienen ustedes ahora?
4. ¿Cuánto tiempo han tenido ustedes el sistema sanitario?
5. ¿Alguna vez han tenido que arreglar o reemplazar su sistema sanitario? ¿Puede describir que pasó? ¿De quién recibieron ustedes ayuda o consejos sobre este trabajo?
6. ¿Usualmente usan ustedes su sistema sanitario, o van ustedes al monte? ¿Por qué?
7. ¿Puede usted contarme sobre cómo y cuándo empezaron a usar el sanitario en este barrio? ¿Y el agua potable?
8. ¿Cómo funciona su sistema sanitario? ¿Es privado o compartido entre familias?
9. ¿Quieren ustedes continuar usando este sistema sanitario que tienen ahora, o prefieren cambiarlo para otro diferente? Si quieren ustedes cambiarlo, ¿por qué tipo? Y ¿por qué quieren ustedes cambiarlo?
10. ¿En su comunidad, hay personas que usan otro tipo de sistema sanitario? ¿Quienes? Y ¿cómo sabe usted?
11. ¿Piensa usted que el sistema sanitario en su barrio es excelente, bueno o malo? ¿Por qué?
12. ¿Por qué quisieron (construir) ustedes un sistema sanitario?
13. ¿Quienes se ayudaron a ustedes a construir su sistema sanitario? ¿A quién ayudó usted construir el suyo?
14. ¿Qué hacen ustedes para mantener su sistema sanitario en buen estado? ¿De quién recibieron ustedes ayuda o consejos sobre esto trabajo?
15. ¿Han tenido problemas con su sistema sanitario? ¿De quién recibieron ustedes ayuda o consejos sobre estos problemas?
16. ¿Han tenido problemas sus vecinos, familia o amigos con sus sistemas sanitarios? ¿De quién recibieron ellos ayuda o consejos sobre estos problemas?
17. ¿Piensa usted que los sistemas sanitarios valen la pena? ¿Por qué?
18. ¿Quién de la comunidad ayuda mucha a otras personas con los problemas o para mejoras del sistema sanitario? ¿Qué hace para ayudar?
19. ¿Alguna vez ha trabajado junto toda la comunidad para mejorar sanitación en este barrio? ¿Puede describir que pasó?
20. ¿Para qué es bueno o vale la pena un sistema sanitario?
21. ¿Qué trabajo tienen los miembros de su familia?
22. El año pasado, ¿cuánto ganó su familia?

Pregunte sobre amigos, familia, vecinos, albañiles, ferreterías, puestos de salud, ONG, y otro organizaciones. Escriba TODAS las nombres mencionadas en la otra pagina.

ব্যক্তি ও সম্প্রদায়ের নামঃ .....

1. এখানে মোট কতজন লোক বাস করে? তাদের মধ্যে পূর্ণবয়স্ক লোক কতজন?
2. আপনার মতে, আপনার এলাকার যে ল্যাট্রিন ব্যবস্থা আছে, তার মান খুব ভাল, মোটামুটি ভাল অথবা খারাপ? কেন?
3. দয়া করে আপনার বাসার ল্যাট্রিন ব্যবস্থা বর্ননা করুন।

   এটা কিভাবে কাজ করে?

এটা কোথায়?	ঘরের মধ্যে	ঘরের বাহিরে
এটার ধরনঃ	ব্যক্তিগত	সম্মিলিত

4. আপনি এখানে কতদিন থেকে বসবাস করছেন? কতদিন থেকে আপনার বর্তমান ল্যাট্রিন ব্যবস্থা আছে?
5. আপনি কেন আপনার বর্তমান ল্যাট্রিন তৈরি করার সিদ্ধান্ত নিয়েছিলেন?
6. আপনি কি আপনার ল্যাট্রিন সবসময় ব্যবহার করেন? কেন অথবা কেন নয়?
7. আপনার ল্যাট্রিন কখনো কি ব্যবহার এর অনুপযোগী ছিল? যদি থেকে থাকে, তাহলে দয়া করে বর্ননা করুন।
8. আপনার যে ল্যাট্রিন ব্যবস্থা রয়েছে, তা নিয়ে আপনি কি কি ধরনের সমস্যার সম্মুখীন হচ্ছেন/ হয়েছেন?
9. ল্যাট্রিন কিভাবে ব্যবহার কিংবা দেখাশুনা করতে হয় তার উপর আপনি কি কোন প্রশিক্ষন গ্রহন করেছেন? যদি করে থাকেন, তবে কোথা থেকে প্রশিক্ষন গ্রহন করেছেন?
10. সরকার কিংবা কোন NGO কি আপনার ল্যাট্রিন নির্মান কিংবা রক্ষণাবেক্ষণ এর জন্য কোন প্রকার আর্থিক সহযোগিতা দিয়েছে? যদি দিয়ে থাকে, তাহলে দয়া করে বর্ননা করুন।
11. এরকম কোন দল/সমাজ আছে যারা ল্যাট্রিন নির্মান করে এবং মেরামত করে থাকে? যদি থেকে থাকে তবে দয়া করে বর্ননা করুন।
12. এখানে কি অন্য কোন সংস্থা আছে যারা ল্যাট্রিন নির্মান বা মেরামত করে থাকে? যদি থেকে থাকে তবে দয়া করে বর্ননা করুন।
13. দিনের পর দিন আপনার ল্যাট্রিন দেখাশুনা করার জন্য আপনার কি কি জানা দরকার বলে আপনি মনে করেন?
14. আপনি কি বর্ননা করতে পারবেন যে আপনার ল্যাট্রিন যদি ভেঙ্গে যায় তাহলে আপনি কি কি করবেন?
15. আপনার মতে সবচেয়ে গুরুত্বপূর্ণ বিষয়গুলো কি কি যা আপনার মত ল্যাট্রিন যাদের আছে তাদেরও জানা উচিত বলে আপনি মনে করেন?
16. ল্যাট্রিন মেরামত এর যন্ত্রাংশসমূহ কেনার জন্য আপনি কোথায় যাবেন?
17. খুচরা যন্ত্রাংশসমূহ কেনার জন্য আপনার কতক্ষন সময় লাগবে?
18. সরকারী কোন কর্মকর্তা কি আপনার ল্যাট্রিন (স্বাস্থ্যব্যবস্থা) সম্পর্কে জিজ্ঞেস করেছেন? যদি করে থাকেন, তবে তিনি কি জিজ্ঞেস করেছিলেন একটু বর্ননা করুন।
19. আপনার কি মনে হয় যে, ল্যাট্রিন ব্যবস্থা বিভিন্ন রকম সমস্যা সমাধানে সহায়ক? কেন কিংবা কেন নয়?
20. আপনার পরিবারের সদস্যগণ কি কি পেশায় নিয়োজিত?
21. গত বছরে আপনার পরিবারের মোট বার্ষিক আয় কত ছিল?

APPENDIX B: CSQCA OF THE GUATEMALAN DATASET

This appendix provides additional details of the csQCA analysis that has been submitted for publication in the journal paper format above. I report an intermediate level of minimization rather than a more complex solution (with an increased number of pathways resulting) or a fully simplified version (requiring prime implicant assumptions in the minimization process) (Ragin 2008 p. 164). For these intermediate solutions, and based on our theoretical knowledge, we assumed that the presence (rather than absence) of each of the conditions contributed to a positive outcome.

CODING DICTIONARY

This section lays out what was coded to each construct. In addition I define the sustainable and unsustainable outcome coding.

1. **Exchange Legitimacy**: Hygiene or own family's health, avoid repeated work, save the use of land, for children's use, assign a specific place as a toilet, odor management, aesthetics/beauty, keep insects or animals out, convenience, cleanliness, prevent assault, safety, save money, greywater disposal
2. **Influence Legitimacy**: Financial or labor contributions to system, user modifications to design
3. **Dispositional Legitimacy**: Organization as autonomous, coherent and morally responsible actor (e.g., shares our values, trustworthy, decent, wise)
4. **Consequential Legitimacy**: Community/public health, societal welfare, protect neighbors, water or air pollution, environmental contamination/protection
5. **Procedural Legitimacy**: Modernity, logic, reason, civilization, respect, knowledge
6. **Structural Legitimacy**: Leaving town because of sanitation status, a certain technology is bad/good, we feel better doing it this way
7. **Personal Legitimacy**: Family member encouraged me to, community member encouraged me to, external person or organization encouraged me to
8. **Comprehensibility Legitimacy**: Any X causes Y; microbes, toilets prevent disease, open defecation causes disease
9. **Taken-for-Granted Legitimacy**: Can't remember not having one, imagine not having one!, misunderstand question because assumption of toilet is so fundamental, everyone poops therefore toilet
10. **Inertia Legitimacy** (proposed construct): It's always been done this way, it's how my parents did it, change is difficult, this is how everyone does it, I've always done it this way
11. **Status**: Marriage prospects, guests, praise, complaints, shame, privacy, avoid violence

1. **Sustainable Outcome** (coded as 1): Household reports continued use and household reports O&M and system is unbroken on day of visit
2. **Unsustainable Outcome** (coded as 0): Absence of any of the conditions for the sustainable definition, except
    a. **Indeterminate Outcome** (removed from analysis): Operation for less than 5 years, no O&M reported, household reports use, unbroken on day of visit

TRUTH TABLE

To support complete reproducibility, the resulting truth table used for csQCA analysis is reproduced below in Table B-1. This table does not include two cases where sustainability could not be determined as discussed in Chapter 4 above.

TABLE B-1: TRUTH TABLE

Case	Exchange	Influence	Dispositional	Consequential	Procedural	Structural	Personal	Comprehensibility	Taken-for-Granted	Status	Inertia	Outcome
Abel	1	1	0	0	1	1	1	0	1	1	0	1
Edwi	1	1	0	1	0	1	0	1	1	0	1	1
Herm	1	1	0	0	0	1	0	0	1	1	0	1
Iren	1	1	0	0	0	1	1	0	1	0	0	1
Mari1	1	1	0	0	0	1	0	0	1	1	0	1
Mari2	1	1	0	1	1	1	1	1	0	0	0	1
merc	1	1	0	1	1	0	0	0	0	0	0	1
vn81	1	1	0	1	0	1	0	0	0	0	0	1
Albe	1	1	0	1	0	1	0	0	0	0	0	1
juan1	1	1	0	1	0	1	0	1	0	1	0	1
Juan2	1	1	0	1	1	0	1	0	0	0	0	1
mart	1	1	0	1	0	0	1	1	1	1	0	1
sabi	1	1	0	1	0	1	1	1	0	1	0	1
sant	1	1	0	1	1	1	1	0	0	1	1	1
02Ma	1	1	0	1	0	1	0	1	1	0	0	1
03ju	1	1	0	1	1	1	1	1	0	1	0	1
04ma	1	1	0	1	0	1	1	1	0	0	1	1
05Ed	1	1	0	1	1	0	1	1	0	0	1	1
06be	1	1	0	1	1	1	0	1	0	0	0	1
07Be	1	1	0	1	1	1	0	1	0	1	1	1
08Ju	1	1	0	0	0	1	0	1	0	1	0	1
09Ro	1	1	0	0	1	1	0	0	0	0	1	1
11cu	1	1	0	1	1	0	0	1	0	1	1	1
13Ma	1	1	0	0	0	1	0	0	0	1	0	1
14Ma	0	1	0	0	0	1	0	0	0	0	0	1
15Ti	1	1	0	0	0	1	1	0	0	0	0	1
16Ma	1	1	0	1	0	0	0	1	1	0	0	1
17Ma	1	1	0	1	0	1	0	1	1	0	0	1

Case	Exchange	Influence	Dispositional	Consequential	Procedural	Structural	Personal	Comprehensibility	Taken-for-Granted	Status	Inertia	Outcome
18Ma	1	1	0	1	0	1	1	0	1	1	1	1
21Mi	1	1	0	1	0	0	0	0	1	0	0	1
22Ma	1	1	0	1	0	1	0	1	0	0	0	1
23Ma	1	1	0	0	0	1	0	0	0	0	0	1
24Ma	1	1	0	1	0	1	0	1	0	0	0	1
fran	1	1	0	1	1	1	1	0	1	0	0	0
gilb	1	1	0	1	1	1	1	1	1	1	0	1
01le	1	1	0	1	1	1	1	0	0	1	1	0
12ag	1	1	0	0	0	0	0	0	0	1	0	0
19Je	0	1	0	0	0	1	0	0	1	0	0	0
20Su	1	0	0	1	0	1	0	1	1	1	0	0
25Ma	1	0	0	0	0	0	0	0	1	0	0	0

SUSTAINABLE SANITATION

NECESSITY/SUFFICIENCY

As described in the paper provided previously, the first step of the analysis process was to review the necessity and sufficiency scores of each theoretical construct in order to remove any domain conditions. Equations for necessity and sufficiency are given in Equations 1 and 2 below, where X is the condition and Y is the outcome.

EQUATION 1: NECESSITY

$$Necessity = \frac{\sum(\min(X_i Y_i))}{\sum Y_i}$$

EQUATION 2: SUFFICIENCY

$$Sufficiency = \frac{\sum(\min(X_i Y_i))}{\sum X_i}$$

The necessity score describes whether or not cases with the same outcome share causal conditions. For example, in the data below, 0.97 of cases with the sustainable outcome were coded to Exchange legitimacy. The sufficiency score describes whether or not cases with the same causal conditions share the same outcome. For example, in the data below, 0.87 of cases coded to Exchange legitimacy belong to the set with the sustainable outcome.

Table B-2 below shows these scores for the sustainable outcome.

TABLE B-2: NECESSITY/SUFFICIENCY FOR THE SUSTAINABLE OUTCOME

Construct	Necessity	Sufficiency
Exchange	0.97	0.87
Influence	1.00	0.89
Dispositional	0	0
Consequential*	0.71	0.89
Procedural*	0.35	0.85
Structural*	0.79	0.87
Personal*	0.38	0.87
Comprehensibility*	0.53	0.94
Taken For Granted*	0.35	0.75
Status*	0.41	0.82
Inertia	0.97	0.87
*Carried forward for analysis		

Domain conditions do not show sufficient variation to meaningfully evaluate by the QCA method. We can certainly say that they are almost always or almost never present. However, conditions that are always present would simply appear in every pathway. This does not provide us with useful knowledge. Similarly, conditions that are never present would never appear in a pathway, or would unnecessarily complicate the results by adding pathways that cover a very small percentage of cases. This goes against the principle of law of parsimony by creating combinations with extremely limited explanatory power (Ragin 2008 p. 119). We excluded all conditions that had a necessity score above 0.75, meaning that Exchange, Influence, and Structural legitimacy were excluded. Similarly, Dispositional legitimacy did not appear in any of our interviews and as such never appears in pathways. As such we excluded it from further QCA analysis. Inertia legitimacy had a necessity score of just 0.24 and as such was also excluded from further analysis.

This research investigated legitimacy theory constructs alone and in combination with Status theory. We present these analyses separately.

PATHWAYS

This section describes the process undertaken to develop the pathways presented in Chapter 4.

LEGITIMACY THEORY ONLY

Outcome: outcome (sustainable sanitation outcome)
Conditions: Consequential, Procedural, Personal, Comprehensibility, Taken for Granted
Assumptions for Intermediate Solution: Consequential (present), Procedural (present), Personal (present), Comprehensibility (present), Taken for Granted (present)
Frequency Count: 1 Consistency Requirement: 0.9

TABLE B-3: PATHWAYS ANALYSIS, LEGITIMACY THEORY ONLY

Pathway	Raw Coverage	Unique Coverage	Consistency	Cases
~Taken-for-Granted * Comprehensibility	0.352941	0.117647	1.000000	Mari2, Juan1, sabi, 03ju, 04ma, 05Ed, 06be, 07Be, 08Ju, 11cu, 22Ma, 24Ma
Personal*~Procedural	0.176471	0.000000	1.000000	Iren, mart, sabi, 04ma, 15Ti, 18Ma
~Personal*Procedural	0.147059	0.029412	1.000000	merc , 06be, 07Be, 09Ro, 11cu
Personal*~Consequential	0.088235	0.000000	1.000000	Abel , Iren, 15Ti
Procedural*~Consequential	0.058824	0.000000	1.000000	Abel , 09Ro
Comprehensibility*Personal	0.205882	0.000000	1.000000	Mari2 , mart, sabi, 03ju, 04ma, 05Ed, gilb
Comprehensibility*Procedural	0.205882	0.000000	0.205882	Mari2, 03ju, 05Ed, 06be, 07Be, 11cu, gilb
Taken-for-Granted* ~Comprehensibility* ~Procedural*Consequential	0.058824	0.000000	1.000000	18Ma, 21Mi
Taken-for-Granted* ~Comprehensibility* ~Personal*Consequential	0.029412	0.000000	1.000000	21Mi
Solution Coverage: 0.617647				
Solution Consistency: 1.000000				

This analysis results in a large number of pathways and an unexceptional coverage. In order to further simplify the solutions, we added the requirement that two cases had to share the same configuration in order to be included in the analysis.

Outcome: outcome (sustainable sanitation outcome)
Conditions: Consequential, Procedural, Personal, Comprehensibility, Taken for Granted
Assumptions for Intermediate Solution: Consequential (present), Procedural (present), Personal (present), Comprehensibility (present), Taken for Granted (present)
Frequency Count: 2 Consistency Requirement: 0.9

TABLE B-4: PATHWAYS ANALYSIS, LEGITIMACY THEORY ONLY, REQUIRE TWO CASES

Pathway	Raw Coverage	Unique Coverage	Consistency	Cases
~Taken-for-Granted*~Procedural* Consequential	0.205882	0.000000	1.000000	vn81, Albe, juan, sabi, 04ma, 22Ma, 24Ma
~Taken-for-Granted*~Personal* Consequential	0.264706	0.029412	1.000000	merc, vn81, Albe, juan, 06be, 07Be, 11cu, 22Ma, 24Ma
~Taken-for-Granted*Comprehensibility* Consequential	0.323529	0.088235	1.000000	Mari, juan, sabi, 03ju, 04ma, 05Ed, 06be, 07Be, 11cu, 22Ma, 24Ma
Solution Coverage: 0.411765				
Solution Consistency: 1.000000				

While this simplified the number of pathways appearing in the solutions, it also reduced the coverage of 41%. The coverage in both of these solutions is lower than preferred, due to contradictory cases. As such, the status construct was added to the analysis in order to resolve these cases and improve the solution.

LEGITIMACY THEORY & STATUS THEORY

Outcome: outcome (sustainable sanitation outcome)

Conditions: Consequential, Procedural, Personal, Comprehensibility, Taken for Granted, Status

Assumptions for Intermediate Solution: Consequential (present), Procedural (present), Personal (present), Comprehensibility (present), Taken for Granted (present), Status (present)

Frequency Count: 1 Consistency Requirement: 0.9

TABLE B-5: PATHWAYS ANALYSIS, LEGITIMACY & STATUS THEORY

Pathway	Raw Coverage	Unique Coverage	Consistency	Cases
~Status*~Taken-for-Granted	0.411765	0.117647	1.000000	Mari2, Merc, vn81, Albe, Juan2, 04ma, 05Ed, 06be, 09Ro, 14Ma, 15Ti, 22Ma, 23Ma, 24Ma
~Taken-for-Granted*Comprehensibility	0.352941	0.117647	1.000000	Mari2, Juan1, sabi, 03ju, 04ma, 05Ed, 06be, 07Be, 08Ju, 11cu, 22Ma, 24Ma
Personal*~Procedural	0.176471	0.029412	1.000000	Iren, mart, sabi, 04ma, 15Ti, 18Ma
~Status*~Personal*Consequential	0.323529	0.147059	1.000000	Edwi, merc, vn81, Albe, 02Ma, 06be, 16Ma,17Ma, 21Mi, 22Ma, 24Ma
Status*Taken-for-Granted* ~Comprehensibility	0.117647	0.058824	1.000000	Abel, Herm, Mari1, 18Ma
Status*Taken-for-Granted*Personal	0.117647	0.000000	1.000000	Abel, Mart, 18Ma, gilb
Status*Comprehensibility*Personal	0.117647	0.000000	1.000000	sabi, 03ju, gilb
Solution Coverage: 0.941176				
Solution Consistency: 1.000000				

In a subset-superset analysis, we examine each pathway given above in more detail to determine if there are more parsimonious solutions that provide similar consistency and improved coverage.

TABLE B-6: SUBSET/SUPERSET ANALYSIS

Pathway 1: ~Status*~Taken-for-Granted			
Subsets	**Consistency**	**Raw Coverage**	**Combined**
~TfG*~Status	1	0.411765	0.638472
~TfG	0.916667	0.647059	0.792242
~Status	0.869565	0.588235	0.735647

Pathway 2: ~Taken-for-Granted*Comprehensibility			
Subsets	**Consistency**	**Raw Coverage**	**Combined**
~TfG*Comprehensibility	1	0.352941	0.591111
~TfG	0.916667	0.647059	0.792242
Comprehensibility	0.947368	0.529412	0.720294

Pathway 3: Personal*~Procedural			
Subsets	**Consistency**	**Raw Coverage**	**Combined**
personal*~procedural	1	0.176471	0.417978
~procedural	0.846154	0.647059	0.758869
Personal	0.86667	0.382353	0.593098

Pathway 4: ~Status*~Personal*Consequential			
Subsets	**Consistency**	**Raw Coverage**	**Combined**
~status*~personal*consequential	1	0.323529	0.565945
~personal*consequential	0.933333	0.411765	0.635240
~status*consequential	0.937500	0.441176	0.657536
~status*~personal	0.875000	0.411765	0.618822
consequential	0.888889	0.705882	0.818895
~personal	0.840000	0.617647	0.737244
~status	0.869565	0.588235	0.735647

Pathway 5: Status*Taken-for-Granted*~Comprehensibili			
Subsets	**Consistency**	**Raw Coverage**	**Combined**
status*taken-for-grant*~comprehensibili	1	0.341278	0.341278
taken-for-grant*~comprehensibili	0.666667	0.176471	0.248525
status*~comprehensibili	0.750000	0.176471	0.341278
status*taken-for-grant	0.857143	0.176471	0.400735
~comprehensibili	0.569830	0.470588	0.569830
taken-for-grant	0.750000	0.352941	0.482640
status	0.823529	0.411765	0.591608

Pathway 6: Status*Taken-for-Granted*Personal			
Subsets	**Consistency**	**Raw Coverage**	**Combined**
status*taken-for-grant*personal	1.000000	0.117647	0.341278
taken-for-grant*personal	0.833333	0.147059	0.357689
status*taken-for-grant	0.857143	0.176471	0.400735
status*personal	0.875000	0.205882	0.437574
taken-for-grant	0.750000	0.352941	0.482640
personal	0.866667	0.382353	0.593098
status	0.823529	0.411765	0.591608

Pathway 7: Status*Comprehensibility*Personal			
Subsets	**Consistency**	**Raw Coverage**	**Combined**
status*comprehensibili*personal	1.000000	0.117647	0.341278
comprehensibili*personal	1.000000	0.205882	0.451468
status*comprehensibili	0.888889	0.235294	0.472789
status*personal	0.875000	0.205882	0.437574
comprehensibili	0.947368	0.529412	0.720294
personal	0.866667	0.382353	0.593098
status	0.823529	0.411765	0.591608

Review of the above tables suggests that Procedural legitimacy should be removed from the analysis as high consistency solutions may be obtained in its absence. While Pathway 3 shows that the absence of Procedural legitimacy covers a large number of cases, this is due to the relatively low rate at which it appears. Upon rerunning the analysis, we find that Procedural legitimacy may be removed from the analysis without impacting the coverage score. As such this is an improved solution.

Outcome: outcome (sustainable sanitation outcome)
Conditions: Consequential, Personal, Comprehensibility, Taken for Granted, Status
Assumptions for Intermediate Solution: Consequential (present), Personal (present), Comprehensibility (present), Taken for Granted (present), Status (present)
Frequency Count: 1 Consistency Requirement: 0.9

TABLE B-7: REMOVE PROCEDURAL LEGITIMACY

Pathway	Raw Coverage	Unique Coverage	Consistency	Cases
~Status*~Taken-for-Granted	0.411765	0.117647	1.000000	Mari2, Merc, vn81, Albe, Juan2, 04ma, 05Ed, 06be, 09Ro, 14Ma, 15Ti, 22Ma, 23Ma, 24Ma
~Taken-for-Granted*Comprehensibility	0.352941	0.117647	1.000000	Mari2, Juan1, sabi, 03ju, 04ma, 05Ed, 06be, 07Be, 08Ju, 11cu, 22Ma, 24Ma
Personal*~Consequential	0.088235	0.029412	1.000000	Abel, Iren, 15Ti
~Status*~Personal*Consequential	0.323529	0.147059	1.000000	Edwi, merc, vn81, Albe, 02Ma, 06be, 16Ma,17Ma, 21Mi, 22Ma, 24Ma
Status*Taken-for-Granted* ~Comprehensibility	0.117647	0.05882	1.000000	Abel, Herm, Mari1, 18Ma
Status*Taken-for-Granted*Personal	0.117647	0.000000	1.000000	Abel, Mart, 18Ma, gilb
Status*Comprehensibility*Personal	0.117647	0.000000	1.000000	sabi, 03ju, gilb
Solution Coverage: 0.941176				
Solution Consistency: 1.000000				

Further review shows that high consistency and coverage solutions may be found without the use of Personal legitimacy; as such it was also removed. This reduces the solution coverage to 82%, but keeps consistency at 100% and reduces the number of pathways from seven to four.

Outcome: outcome (sustainable sanitation outcome)
Conditions: Consequential, Comprehensibility, Taken for Granted, Status
Assumptions for Intermediate Solution: Consequential (present), Comprehensibility (present), Taken for Granted (present), Status (present)
Frequency Count: 1 Consistency Requirement: 0.9

TABLE B-8: REMOVE PERSONAL LEGITIMACY

Pathway	Raw Coverage	Unique Coverage	Consistency	Cases
~Taken-for-Granted*~Status	0.411765	0. 235294	1.000000	Mari2, merc, vn81, Albe, Juan, 04ma, 05Ed, 06be, 09Ro, 14Ma, 15Ti, 22Ma, 23Ma, 24Ma
Comprehensibility* ~Taken-for-Granted	0.352941	0. 176471	1.000000	Juan1, sabi, 03ju, 04ma, 05Ed, 06be, 07Be, 08Ju, 11cu, 22Ma, 24Ma
Status*Taken-for-Granted*~Comprehensibility	0.117647	0.117647	1.000000	Abel, Herm, Mari, 18Ma
Consequential*Comprehensibility *~Status	0.294118	0.117647	1.000000	Edwi, Mari, 02Ma, 04ma 05Ed, 06be, 16Ma,17Ma, 22Ma, 24Ma
Solution Coverage: 0. 823529				
Solution Consistency: 1.000000				

Finally, an analysis was run that investigated the impact of requiring at least two cases that had the same combination of causal conditions. For this analysis we initially reintroduced all the non-domain causal conditions; however, as may be seen below personal and procedural legitimacy do not appear in any of the resulting pathways. This solution reduces coverage to 0.85 and consistency to 0.97; however, it also reduces the number of pathways to three. Although all the conditions were included in the analysis, neither procedural nor personal legitimacy appear in the pathways, supporting the analysis above.

Outcome: outcome (sustainable sanitation outcome)
Conditions: Consequential, Procedural, Personal, Comprehensibility, Taken for Granted, Status
Assumptions for Intermediate Solution: Consequential (present), Procedural (present), Personal (present), Comprehensibility (present), Taken for Granted (present), Status (present)
Frequency Count: 2 Consistency Requirement: 0.9

TABLE B-9: REQUIRE TWO CASES

Pathway	Raw Coverage	Unique Coverage	Consistency	Cases
~Status*~Taken-for-Granted	0.411765	0.235294	1.000000	Mari2, merc, vn81, Albe, Juan, 04ma, 05Ed, 06be, 09Ro, 14Ma, 15Ti, 22Ma, 23Ma, 24Ma
Status*Taken-for-Granted	0.176471	0.117647	0.857143	Abel, Herm, Mari1, mart, 18Ma, gilb, 20Su
Comprehensibility*Consequential	0.500000	0.264706	0.944444	gilb, 24Ma, 22Ma, 17Ma, 16Ma, 11cu, 07Be, 06be, 05Ed, 04ma, 03ju, 02Ma, sabi, mart, juan, Mari, Edwi
Solution Coverage: 0.852941				
Solution Consistency: 0.966667				

There are five household cases (21Mi, 13Ma, 08Ju, Sant, Iren) with a sustainable outcome that are not included in these pathways. All five of these cases show either status or taken for granted legitimacy (rather than both or neither); all but one also has either consequential or comprehensibility legitimacy (rather than both).

UNSUSTAINABLE SANITATION

NECESSITY/SUFFICIENCY

The next step in the analysis was to negate the outcome and reanalyze necessity and sufficiency for the unsustainable outcome. These results are presented in Table B-10 below. Generally, the low sufficiency scores suggest that the absence of any single type of legitimacy is not sufficient to cause the unsustainable outcome. The standard cut off for a condition being necessary is 0.9. While none of our conditions meet this cut off, comprehensibility legitimacy comes close at 0.83. This suggests that this condition in particular is causally important for unsustainable sanitation.

TABLE B-10: NECESSITY/SUFFICIENCY FOR THE UNSUSTAINABLE OUTCOME

Construct	Necessity	Sufficiency
~Exchange	0.17	0.50
~Influence	0.33	1.00
~Dispositional	1.00	0.15
~Consequential	0.50	0.23
~Procedural	0.67	0.15
~Structural	0.33	0.22
~Personal	0.67	0.16
~Comprehensibility	0.83	0.24
~Taken For Granted	0.33	0.08
~Status	0.50	0.13
~Inertia	0.83	0.16

By looking at the necessity scores, we can see that ~Dispositional, ~Comprehensibility, and ~Inertia would be classified as domain conditions; in other words, they are so often present that there is insufficient variation to analyze them using QCA. Similarly, ~Exchange is also a domain condition because it is so rarely present. The sufficiency scores are very low, meaning that no factor in isolation is sufficient for the negative (or unsustainable) outcome. The one exception to this is ~Influence legitimacy, which has a perfect 1.00 score. However, this is an artifact of our operational definitions for sustainability, which required financial or labor contributions to the system, which was coded to Influence legitimacy. In sum, Table B-10 shows that no single factor in isolation is sufficient for the unsustainable outcome. In contrast, the absence of comprehensibility and inertia legitimacy are the most necessary conditions for the absence of sustainability. We exclude dispositional legitimacy from this statement; while it does have a perfect necessity score of 1.00 it was not observed in any of our household cases, sustainable or otherwise, and as such it does not seem to be relevant to the outcome of interest.

PATHWAYS

In order to further test the causal conditions, we then examined the negation of the outcome variable against four combinations of causal conditions, guided by our analysis above. The inputs to and abbreviated results from these analyses are shown below in Table B-11. The results shown in this table required only one instance of each combination of conditions due to the small number of cases with the unsustainable outcome.

In analysis 4, where we excluded both Personal and Procedural legitimacy, we were not able to complete this analysis using our previously established consistency criteria of 0.8. In every case, the sets defined by these conditions had conflicting positive and negative outcomes. In other words, the causal conditions were duplicated between cases with positive and negative sustainability outcomes. When we added the personal condition back to the analysis, this issue was resolved, with the personal condition differentiating between the previously conflicting cases. As such it is an important condition to include. The reversal of this (including procedural but not personal) resulted in very low coverage of our cases. Both Analysis 1 and Analysis 3 give acceptable coverage of our cases. However, Analysis 3 is simpler both in terms of the inputs and the resulting pathways. As such this is our preferred solution, and the detailed results are presented below.

TABLE B-11: PATHWAYS TO UNSUSTAINABLE SANITATION

Conditions	Analysis 1	Analysis 2	Analysis 3	Analysis 4
Consequential	X	X	X	X
Personal	X	Excluded	X	Excluded
Comprehensibility	X	X	X	X
Taken for Granted	X	X	X	X
Status	X	X	X	X
Procedural	X	X	Excluded	Excluded
Solution Coverage	0.666667	0.166667	0.666667	0
Number Pathways	5	1	4	0

Outcome: ~outcome (unsustainable sanitation outcome)
Conditions: Consequential, Personal, Comprehensibility, Taken for Granted, Status
Assumptions for Intermediate Solution: Consequential (present), Personal (present), Comprehensibility (present), Taken for Granted (present), Status (present)
Frequency Count: 1 Consistency Requirement: 0.9

TABLE B-12: ANALYSIS 3 PATHWAYS

Pathway	Raw Coverage	Unique Coverage	Consistency	Cases
Status*Taken-for-Granted*Comprehensibility*~Personal	0.166667	0.000000	1.000000	20Su
Status*Taken-for-Granted*~Personal*Consequential	0.166667	0.000000	1.000000	20Su
~Status*Taken-for-Granted*~Comprehensibility *~Personal*~Consequential	0.333333	0.333333	1.000000	19Je, 25Ma
~Status*Taken-for-Granted*~Comprehensibility *Personal*Consequential	0.166667	0.000000	1.000000	fran
Solution Coverage: 0.666667				
Solution Consistency: 1.000000				

If we require two instances of condition combinations to perform the analysis, the third pathway in the table above is the only one that results in the analysis. This pathway requires the absence of all legitimacy types except Taken for Granted legitimacy, supporting the previous analysis. It is worth noting that personal legitimacy appears in each pathway, although it was excluded from the sustainable out come. This suggests that the causal relationships described here are not symmetric. In other words, a condition that supports a positive outcome does not necessarily cause the negative outcome if absent, and vice versa. The ability to identify non-symmetric relationships such as this is one of the strengths of set theory and QCA.

APPENDIX C: CSQCA ANALYSIS OF THE BANGLADESHI DATASET

As part of the csQCA analysis of the Guatemalan dataset presented in Chapter 4, I performed qualitative analysis to better understand the data. However, until this point I have not yet presented a csQCA analysis of the Bangladeshi dataset, which is dealt with in Chapter 3. This is an important analysis to improve the validity of the results; as such it is presented here.

To perform this analysis, we developed a truth table from the NVivo coding as we did previously for the Guatemalan data. There are 150 households in this dataset. As before, we excluded cases with indeterminate sustainability. This removed four cases from the analysis, leaving us with 84 sustainable cases and 62 unsustainable cases.

TRUTH TABLE

As before, we present the truth table for the Bangladeshi dataset to promote research repeatability and reliability.

TABLE C-1: TRUTH TABLE

Case	Exchange	Influence	Dispositional	Consequential	Procedural	Structural	Personal	Comprehensibility	Taken For Granted	Status	Inertia	Outcome
1_02	1	1	0	1	0	0	0	1	0	1	1	0
1_03	1	1	0	1	1	1	1	1	1	1	0	0
1_04	1	0	0	1	0	0	0	1	1	1	0	0
1_05	1	0	0	1	0	0	0	0	1	1	0	0
1_06	1	1	0	0	0	0	1	0	1	1	0	0
1_07	1	1	0	1	1	1	1	1	0	0	0	1
1_08	1	1	0	1	1	0	0	0	0	1	0	1
1_09	1	1	0	0	0	0	1	0	0	1	0	1
1_10	1	1	0	1	0	1	1	1	0	1	0	1
1_11	1	1	0	1	0	0	0	1	1	1	0	1
1_12	1	1	0	1	1	0	1	1	0	1	0	0
1_13	1	0	0	1	0	0	1	1	1	1	1	0
1_14	1	1	0	1	0	0	0	1	0	1	0	1
1_15	1	1	0	1	0	0	0	1	0	1	1	1
1_16	1	1	0	1	1	1	0	1	0	1	0	1
1_17	1	1	0	1	1	0	0	1	0	0	0	1
1_18	1	1	0	1	0	0	0	1	1	1	0	1
1_20	1	1	0	1	0	1	1	1	1	0	0	0
1_21	1	1	0	0	0	1	1	1	0	1	0	0
1_22	1	1	0	0	0	1	0	0	0	1	0	0

Case	Exchange	Influence	Dispositional	Consequential	Procedural	Structural	Personal	Comprehensibility	Taken For Granted	Status	Inertia	Outcome
1_23	1	1	0	1	0	0	0	1	0	0	0	1
1_24	1	1	0	1	0	0	1	1	0	1	0	0
1_25	1	1	0	1	1	1	1	1	0	0	0	1
1_26	1	1	0	1	1	0	1	1	0	1	0	1
1_27	1	0	0	1	0	1	1	1	1	1	0	0
1_28	1	1	0	0	0	0	1	0	0	1	1	1
1_29	1	0	0	1	1	0	0	1	0	1	0	0
1_30	1	1	0	0	0	1	1	0	0	1	1	0
1_31	1	1	0	1	1	0	1	1	0	1	0	1
1_32	1	0	0	1	0	1	0	1	0	1	0	0
1_33	1	1	0	1	1	1	0	0	0	1	1	1
1_34	1	1	0	1	0	0	0	1	0	1	0	1
1_35	1	1	0	1	0	1	1	1	0	1	0	1
1_36	1	1	0	1	0	0	0	0	0	1	0	1
1_37	1	1	0	1	0	0	1	1	0	1	0	1
1_38	1	1	0	1	1	0	1	1	0	1	0	0
1_39	1	1	0	1	0	0	1	1	0	1	0	0
1_40	1	0	0	1	0	1	1	1	0	1	0	0
1_41	1	1	0	1	1	0	1	1	0	1	0	1
1_42	1	1	0	1	0	1	1	0	0	1	1	1
1_43	1	1	0	1	0	1	0	1	0	1	0	0
1_44	1	1	0	1	0	0	1	1	0	1	0	1
1_45	1	1	0	1	0	0	0	1	1	1	0	1
1_46	1	1	0	1	0	0	0	1	0	1	0	0
1_47	1	1	0	1	0	0	0	1	0	1	0	1
1_48	1	1	0	1	1	0	0	1	0	0	1	1
1_49	1	1	0	1	0	1	0	1	0	1	0	1
2_01	1	1	0	1	1	1	1	0	0	1	1	0
2_02	1	1	0	1	1	0	1	0	0	1	0	1
2_03	1	1	0	1	1	1	0	1	0	1	0	1
2_04	1	1	0	1	0	0	1	1	1	1	0	1
2_05	1	0	0	0	1	1	1	0	1	0	0	0
2_06	1	1	0	0	0	1	0	0	0	1	0	1
2_07	1	0	0	1	1	0	0	0	0	1	0	0
2_08	1	1	0	0	1	1	1	0	1	1	0	1

Case	Exchange	Influence	Dispositional	Consequential	Procedural	Structural	Personal	Comprehensibility	Taken For Granted	Status	Inertia	Outcome
2_09	1	1	0	1	1	0	1	0	1	1	0	0
2_10	1	0	0	0	1	0	0	0	0	0	0	0
2_11	1	1	0	0	1	1	0	0	1	1	0	1
2_12	1	1	0	1	1	1	0	0	0	1	0	1
2_13	1	1	0	1	1	1	0	1	0	1	0	0
2_14	1	1	0	1	1	1	0	1	1	1	0	1
2_15	1	1	0	1	0	0	0	1	0	1	0	0
2_16	1	1	0	1	1	1	0	0	0	1	0	0
2_17	1	1	0	1	0	0	0	1	1	1	0	1
2_18	1	1	0	1	0	0	0	1	0	1	0	1
2_19	1	1	0	1	0	0	0	1	0	1	0	1
2_20	1	1	0	1	1	1	1	1	0	1	0	1
2_21	1	1	0	0	1	0	0	0	0	1	0	0
2_22	1	1	0	0	1	1	1	0	0	1	0	1
2_24	1	1	0	1	0	1	1	1	0	1	0	1
2_25	1	1	0	1	0	1	1	1	0	1	0	1
2_26	0	1	0	1	0	0	1	0	0	1	1	0
2_27	1	1	0	1	1	0	1	1	1	1	0	0
2_28	1	1	0	1	1	0	0	1	1	0	1	1
2_29	1	1	0	1	0	0	0	1	1	1	0	1
2_30	1	0	0	1	0	0	0	1	0	1	0	0
2_31	1	1	0	1	0	0	0	1	0	1	0	1
2_33	1	1	0	1	0	0	1	1	0	1	0	0
3_01	1	1	0	1	0	0	1	1	0	0	0	1
3_02	1	0	0	1	1	0	1	1	0	1	0	0
3_03	1	1	0	1	1	0	1	1	0	1	0	1
3_04	1	1	0	1	0	0	1	1	0	1	0	1
3_05	1	1	0	1	1	1	0	1	0	1	0	1
3_06	1	1	0	0	1	0	0	0	0	1	0	1
3_07	1	1	0	0	0	0	0	0	1	1	0	1
3_08	1	1	0	1	0	1	0	1	0	1	0	1
3_09	1	1	0	1	1	1	1	1	0	1	0	1
3_10	1	1	0	1	0	0	1	1	0	1	0	1
3_11	1	0	0	1	0	1	0	1	0	1	0	0
3_12	1	1	0	1	1	0	0	1	0	1	0	1

Case	Exchange	Influence	Dispositional	Consequential	Procedural	Structural	Personal	Comprehensibility	Taken For Granted	Status	Inertia	Outcome
3_13	1	1	0	1	0	1	0	1	0	0	0	1
3_14	1	0	0	1	0	0	1	1	0	0	0	0
3_15	1	1	0	1	1	0	0	1	0	0	0	0
3_16	1	1	0	1	0	1	1	1	0	1	0	1
3_17	1	1	0	1	0	0	0	1	1	0	0	0
3_18	1	1	0	1	0	1	0	1	0	1	0	1
3_19	1	1	0	0	0	0	0	0	1	1	0	1
3_20	1	1	0	1	0	1	1	1	0	1	0	1
3_21	1	1	0	1	0	0	0	1	0	0	0	1
3_22	1	1	0	1	0	0	1	1	0	1	0	1
3_23	1	1	0	1	1	1	1	1	0	1	0	1
3_24	1	1	0	1	0	1	0	1	0	1	0	1
3_25	1	1	0	0	0	1	0	0	0	1	0	0
3_26	1	0	0	0	0	0	0	0	0	1	0	0
3_27	1	1	0	1	0	1	1	1	1	0	0	0
3_28	1	0	0	1	0	1	0	1	0	1	0	0
3_29	1	1	0	1	0	0	1	1	0	1	0	0
3_30	1	1	0	1	1	0	0	1	0	1	0	1
3_31	1	1	0	1	0	0	0	1	0	1	0	1
3_32	1	1	0	1	0	0	0	0	0	0	0	0
3_33	1	1	0	1	0	1	0	1	0	0	0	1
3_34	1	1	0	0	1	0	0	0	0	1	0	0
3_35	1	1	0	1	0	0	1	1	0	1	1	0
3_36	1	1	0	1	0	1	0	1	0	1	0	0
3_37	1	1	0	1	0	0	1	1	1	1	0	1
3_38	1	1	0	1	0	0	1	1	0	1	0	1
3_39	1	1	0	1	1	1	0	1	0	1	0	0
4_01	1	1	0	0	1	1	0	0	0	1	1	0
4_02	1	1	0	1	0	1	0	1	0	0	0	0
4_03	1	1	0	0	1	1	0	0	0	0	0	0
4_04	1	1	0	0	0	1	1	0	0	1	0	1
4_05	1	1	0	0	0	1	1	0	1	1	0	0
4_06	1	0	0	0	0	0	0	0	0	1	1	0
4_07	1	1	0	0	0	1	0	0	1	1	0	1
4_08	1	1	0	0	1	1	0	0	1	1	0	0

Case	Exchange	Influence	Dispositional	Consequential	Procedural	Structural	Personal	Comprehensibility	Taken For Granted	Status	Inertia	Outcome
4_09	1	1	0	0	0	0	0	0	0	0	0	1
4_10	1	1	0	1	0	0	0	1	0	1	0	0
4_11	1	1	0	1	1	0	0	0	0	1	0	1
4_12	1	1	0	0	1	0	0	0	0	1	0	0
4_13	1	1	0	0	0	0	0	0	1	1	0	1
4_14	1	1	0	1	0	1	0	1	0	1	0	1
4_15	1	1	0	0	0	0	0	0	0	1	0	0
4_16	1	1	0	1	0	0	0	1	0	1	0	1
4_17	1	1	0	0	0	1	0	0	0	1	1	1
4_18	1	1	0	0	1	1	0	0	1	1	0	1
4_19	1	1	0	0	1	0	1	0	0	0	1	0
4_20	1	0	0	1	0	0	0	1	0	1	0	0
4_21	1	1	0	1	0	1	0	1	0	0	0	1
4_22	1	1	0	1	0	1	1	1	0	1	0	1
4_23	1	1	0	1	0	1	0	1	1	1	0	0
4_26	1	1	0	1	0	1	0	1	0	1	0	0
4_27	1	1	0	0	0	1	0	0	0	1	0	1
4_28	1	1	0	1	0	0	0	1	0	1	0	1
4_29	0	1	0	0	1	0	1	0	0	1	0	1
4_30	1	1	0	1	0	0	0	1	0	1	1	0
4_31	1	1	0	1	0	1	0	1	0	1	0	1

NECESSITY/SUFFICIENCY ANALYSIS

The first step of our analysis was to calculate the necessity and sufficiency of each condition for the Bangladeshi dataset and compare it to the scores from the Guatemalan dataset. The results of this analysis are presented below. The necessity-sufficiency tables are calculated using the sustainable cases in both contexts. As such, although there is a very different rate of achieving sustainable sanitation between them (and expected differences between these groups), these figures are both looking at households with the sustainable outcome.

TABLE C-2: NECESSITY/SUFFICIENCY FOR THE SUSTAINABLE OUTCOME

	Necessity		Sufficiency	
Condition	**Bangladesh**	**Guatemala**	**Bangladesh**	**Guatemala**
Exchange	0.99	0.97	0.58	0.87
Influence	1.00	1.00	0.66	0.89
Dispositional	0	0	-	0
Consequential	0.80	0.71	0.60	0.89
Procedural	0.35	0.35	0.57	0.85
Structural	0.44	0.79	0.59	0.87
Personal	0.39	0.38	0.57	0.87
Comprehensibility	0.71	0.53	0.61	0.94
Taken for Granted	0.19	0.35	0.52	0.75
Status	0.86	0.41	0.59	0.82
Inertia	0.08	0.24	0.41	0.89

First, I examine the domain conditions. In the Guatemala analysis, we included exchange, influence, dispositional, structural, and inertia legitimacy in our domain conditions, using the criterion of a necessity higher than 0.75 (or, similarly, lower than 0.25) as a condition that did not present sufficient diversity for QCA analysis. Again, we emphasize that these are not conditions that are deemed unimportant, but rather ones that cannot be evaluated with the Guatemalan dataset. In the Bangladeshi analysis, exchange, influence, dispositional, consequential, status, and inertia meet this domain criterion. In other words, we see that Exchange and Influence legitimacy are present in virtually every sustainable household case across both datasets, and that Dispositional is not present in either. Exchange legitimacy deals with the pragmatic benefits; it makes sense that these would be the easiest to conceptualize and make explicit during an interview, so we are not surprised that these are almost always present in both. Influence legitimacy (which deals with homeowner financial or labor contributions to the system) was universally present in sustainable cases in both datasets. However, as in Chapter 4, we note that this is an artifact of our classification system that (in part) required homeowner participation for a household to be assigned the socially sustainable outcome. As noted previously, influence legitimacy is present in both sustainable and unsustainable cases. In Guatemala, the sufficiency score for influence legitimacy is 0.89, which beats our 0.80 criterion for being sufficient for the outcome. However, in Bangladeshi the sufficiency score for influence legitimacy is lower at 0.66. Practically, this 0.66 score means that a full third of households who made a financial or labor based contribution to their systems did not achieve a sustainable system. In both contexts, we suggest that this is linked to ceremonial technology adoption, as described in Chapter 3. Households financed structural change (to install sanitation) but did not have correspondingly changed practices.

Dispositional legitimacy was not observed in either context. This strongly suggests that this condition is not (or is very rarely) relevant to the social sustainability of sanitation systems. Dispositional legitimacy deals with the way that people may personify an organization (for example, thinking that a company is looking out for the interests of its employees, or alternatively that it is only out for profit). People do not seem to interact with their sanitation systems in this way. However, we do feel that the absence of this legitimacy type serves to validate the importance of those that were observed, and also of the validity of the legitimacy constructs. Similarly, inertia legitimacy did not achieve the coverage necessary to be included in either analysis. This is a new construct that has not been previously noted in the legitimacy literature. I feel it is valuable to maintain it even though it was not observed at a large frequency in these particular datasets. This is because inertia legitimacy deals with the way things have always been done. In these particular research contexts, sanitation systems are new. Typically, households have only had sanitation for five or 10 years. In this context, it is not

surprising that inertia is typically observed only in rare cases where people have had long experience with sanitation technologies. In further support of this, inertia legitimacy was observed in just 8% of the Bangladeshi cases and 24% of the Guatemalan cases. As people had a longer experience with sanitation in Guatemala, this makes sense. As such, although this construct cannot be included in the QCA analysis here, we do note its presence and feel that it would be valuable to investigate in different contexts.

Consequential legitimacy and status were both observed at a high rate in the Bangladeshi data, meaning that both of these would be classified as domain conditions, while they were less common in the Guatemalan dataset. The high rate of consequential legitimacy corresponds with the analysis presented in Chapter 4, where I suggested that over time it is possible that the combination of consequential and comprehensibility legitimacy could come to be represented by the combination of status and taken for granted legitimacy. In that paper, I also observed there that status does not have a temporal dimension noted in the literature. Here we can begin to make that comparison, as the Bangladeshi context has a shorter experience with sanitation technologies than the Guatemalan context. As we would expect from this prediction, in Bangladesh we see a higher necessity score for both comprehensibility and consequential legitimacy and a lower necessity score for taken for granted legitimacy. However, we do not see the same relationship for status. There are two competing (and complementary) explanations for this. One is the distinction between status and legitimacy from the literature noted previously. The second is the heavy use of Community Led Total Sanitation (CLTS) methods (Kar and Chambers 2008) in the Bangladeshi context. These methods are shame based; development practitioners attempt to instill a sense of shame regarding open defecation. This was discussed in Chapter 4, along with the connection between these methods and interpersonal violence. The use of these methods likely explains at least part of the strong connection between sanitation and status observed in the Bangladeshi dataset.

Similarly, in the Guatemalan context, structural legitimacy was included as domain criterion, while in Bangladesh it was observed less frequently and does not make this cutoff. Structural legitimacy deals with morally perceived categories of organizations; for our data, it means that a household reported that a certain practice was the right thing to do while another was the wrong thing to do. I suggest that there is a temporal effect here also. In Guatemala, where sanitation has been present longer, people have a stronger feeling that it is morally right. In the Bangladeshi communities, where sanitation is newer, households are closer to open defecation practices and are understandably less likely to condemn recent practices to the status of immorality.

Pathways To Sustainable Sanitation

Once the domain conditions are removed from the Bangladeshi dataset, we are left with procedural, structural, personal, comprehensibility, and taken for granted legitimacy. We note that this means that the pathway resulting from this analysis will not be the same as those resulting from the analysis of the Guatemalan dataset as two of four conditions in those pathways are now excluded domain conditions.

The first step was to run a subset/superset analysis. This allows us to see the coverage and consistency that the pathways developed in the Guatemala give us for the Bangladeshi data. In other words, although two of these conditions are domain conditions we can force a solution to use those conditions to see its effect. Initially we look only at the successful Bangladeshi cases, as the pathways for the Guatemala dataset were developed looking at communities where the vast majority of households had achieved sustainable sanitation. One pathway in that analysis required the presence of either comprehensibility or consequential legitimacy along with the absence of Status and Taken for Granted legitimacy. Here we represent that pathway by looking at subsets with only comprehensibility or consequential legitimacy.

TABLE C-3: SUBSET/SUPERSET ANALYSIS

Subsets	Consistency	Raw Coverage	Combined
Comprehensibility*Consequential	1.000000	0.714286	0.840918
Comprehensibility	1.000000	0.714286	0.840918
Consequential	1.000000	0.797619	0.888619
Status*Taken For Granted	1.000000	0.178571	0.420459

Our previous analysis of the Guatemalan data showed the Status*Taken for Granted pathway covering 18% of households, while the Comprehensibility*Consequential pathway covered about 50% of successful household cases. Here we see a similar coverage for the Status*Taken for Granted pathway and a higher coverage for the Comprehensibility*Consequential pathway. In other words, we can explain a similar and high percentage of sustainable household cases with these pathways.

Unfortunately, however, when we add the unsustainable cases to the analysis, we see low consistency scores. This means that many unsustainable cases show the same combination of conditions but a different outcome. Similarly, if we attempt to develop pathways using these conditions, we cannot complete the analysis as none of the sets meet our consistency criterion.

Subsets	Consistency	Raw Coverage	Combined
Comprehensibility*Consequential	0.618557	0.714286	0.368394
Comprehensibility	0.612245	0.714286	0.358569
Consequential	0.603604	0.797619	0.357238
Status*Taken For Granted	0.576923	0.178571	0.140153

Next, we include these conditions and (as we did in the Chapter 4 analysis) require a count of at least two instances of our cases, a consistency of at least 0.9, and assume that the presence of each type of legitimacy supports the sustainable outcome. We again emphasize that due to the differing domain conditions, these pathways cannot be the same as those produced from the analysis in Guatemala. Our current analysis leads to a single logical pathway that includes the presence of four types of legitimacy; however, it represents an extremely low coverage of just 6% of cases.

Outcome: outcome (sustainable sanitation outcome)
Conditions: Taken for Granted, Comprehensibility, Personal, Structural, Procedural
Assumptions for Intermediate Solution: Taken For Granted (present), Comprehensibility (present), Personal (present), Structural (present), Procedural (present)
Frequency Count: 2 Consistency Requirement: 0.9

TABLE C-4: REQUIRE TWO CASES

				Cases
Comprehensibility*Personal* Structural*Procedural	0.059524	0.059524	0.833333	1_03, 1_07, 1_25, 2_20, 3_09, 3_23
Solution Coverage: 0.059524				
Solution Consistency: 0.833333				

Next, we ran a subset/superset analysis looking at all combinations of all conditions, regardless of whether or not they are classified as domain conditions. To summarize the findings of this analysis, there is no

combination of legitimacy and status conditions that can consistently explain a significant percentage of the Bangladeshi dataset. However, if we apply the pathways from the Guatemalan context to the sustainable Bangladeshi cases only, we see similar coverage rates in both contexts. In other words, the pathways serve to explain the sustainable cases in both communities, and cover the unsustainable cases in Guatemala also. The group it does not serve is the unsustainable Bangladeshi cases.

DISCUSSION & CONCLUSION

To explain why these household cases do not conform to the theory, we leave csQCA for more traditional qualitative analysis, drawing from the analysis presented in Chapter 3. In that chapter, we describe how households adopt toilets as a talisman. In other words, they do have a model of understanding that links sanitation systems to (for example) improved health outcomes. However, if that model only encompasses having a toilet (and not maintaining it) then the model supports construction but not maintenance.

The households in both contexts that have achieved socially sustainable sanitation systems show similar profiles of our legitimacy and status constructs; just under 20% of cases reference a combination of status and taken for granted legitimacy, and 50-70% reference a combination of comprehensibility and consequential legitimacy. As discussed above, the slightly longer experience with sanitation in the Guatemalan dataset seems to explain the differences in the occurrence of individual constructs; this observation is founded in the literature and the relationships we would expect based on that literature are observed here. This suggests that the legitimacy constructs provide a theoretical basis of the end goal for education outreach for households in order to improve sanitation coverage. However, the more in depth qualitative analysis supplements this understanding such that we understand that we must move beyond providing information to households and instead move to help them achieve actionable knowledge. Motivations for sustainable sanitation coverage are present; what is lacking is technical knowledge that would help households move from adopting a toilet as a talisman to having a system that will be kept functional in the long term. Our current dataset cannot be recoded to capture these differences in a way that would be meaningful for csQCA analysis. Future work could collect more data using different questions intended to draw out respondents on the smaller number of constructs that have emerged from our analysis. For instance, from Chapter 3 we should discover more detailed understanding of the various rational myths that households use to understand their sanitation systems. This is linked to Chapter 4's emphasis on the importance of comprehensibility and consequential legitimacy. Similarly, future research should map current educational (or software) development outreach efforts against legitimacy theory. This will help us understand what knowledge we are attempting to transfer. Our current research suggests that an emphasis on moral outcomes (environmental and public health, rather than pragmatic benefits) and cognitive models of understanding (germ theory) are important to achieving sustainability. Educational outreach should be sure to target these areas.

APPENDIX D: IRB APPROVALS

University of Colorado Boulder

Institutional Review Board
563 UCB
Boulder, CO 80309
Phone: 303.735.3702
Fax: 303.735.5185
FWA: 00003492

12-Apr-2013

Continuing Review Approval - Expedited

Kaminsky, Jessica
Protocol #: 11-0180
Title: Social Networks and Knowledge Dissemination

Dear Jessica Kaminsky,

The Institutional Review Board (IRB) has approved this continuing review in accordance with Federal Regulations at 45 CFR 46.

Approval Date: 12-Apr-2013
Expiration Date: 11-Apr-2014
Documents Approved:
Documents Reviewed: HRP-212: FORM - Continuing Review;
Review Cycle: 12 months
Expedited Category: 7

Click here to find the approved documents for this protocol: Approved Documents

Regulations require that this protocol be renewed prior to the above expiration date. The IRB will provide a reminder prior to the expiration date, but it is your responsibility to ensure that your continuing review is received in sufficient time to be reviewed prior to the expiration date.

Changes to your protocol must be submitted to the IRB for review and approval prior to their implementation. This includes changes to the consent form, principal investigator, protocol, etc.

All events that meet reporting criteria must be submitted within 5 business days from notification of the event. Any study-related death must be reported immediately (within 24 hours) upon learning of the death.

The IRB has approved this protocol in accordance with federal regulations, university policies and ethical standards for the protection of human subjects. In accordance with federal regulation at 45 CFR 46.112, research that has been approved by the IRB may be subject to further appropriate review and approval or disapproval by officials of the institution. The investigator is responsible for knowing and complying with all applicable research regulations and policies including, but not limited to, Environmental Health and Safety, Scientific Advisory and Review Committee, Clinical and Translational Research Center, and Wardenburg Health Center and Pharmacy policies. Approval by the IRB does not imply approval by any other entity.

Please note change as of October 8, 2012: If you have any informed consent, assent, or parental permission forms, the IRB has administratively revised the header of these documents to reflect the current template. For your reference the IRB approval date has been revised due to this change. As indicated on our website, expiration dates are no longer included on the documents. Please ensure you are using the correct IRB Approved versions of all documents throughout your study.

Please contact the IRB office at 303-735-3702 if you have any questions about this letter or about IRB procedures.

Douglas Grafel
IRB Admin Review Coordinator
Institutional Review Board

University of Colorado Boulder

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29-Aug-2011

Exempt Certification

Kaminsky, Jessica
Protocol #: 11-0370
Title: Causes for Sustainable Maintenance and Operation of Onsite Sanitation Systems

Dear Jessica Kaminsky,

The Institutional Review Board (IRB) has reviewed this protocol and determined it to be of exempt status in accordance with Federal Regulations 45 CFR 46.101(b). Principal Investigators are responsible for informing the IRB of any changes or unexpected events regarding the project that could impact the exemption status. Upon completion of the study, you must submit a Study Closure via eRA. It is your responsibility to notify the IRB **prior** to implementing any changes.

Certification Date: 29-Aug-2011
Exempt Category: 2
Associated Documents:* Protocol; Recruitment Email Text; Consent Script; Initial Application - eForm v3;
Number of subjects approved:8

* Approved documents can be found by logging into the eRA system, opening this protocol, and navigating to the "Versions" folder.

The IRB has reviewed this protocol in accordance with federal regulations, university policies and ethical standards for the protection of human subjects. In accordance with federal regulation at 45 CFR 46.112, research that has been approved by the IRB may be subject to further appropriate review and approval or disapproval by officials of the institution. The investigator is responsible for knowing and complying with all applicable research regulations and policies including, but not limited to, Environmental Health and Safety, Scientific Advisory and Review Committee, Clinical and Translational Research Center, and Wardenburg Health Center and Pharmacy policies.

Please contact the IRB office at 303-735-3702 if you have any questions about this letter or about IRB procedures.

Institutional Review Board

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