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EXPLORING THE USE OF SOCIAL NETWORK ANALYSIS TO INFORM EXIT STRATEGIES FOR RURAL WATER AND SANITATION NGOS

Jeffrey P. Walters¹

ABSTRACT

While integrated management schemes often improve resolution of technical issues with rural water and sanitation (WatSan) infrastructure, the challenges they can present are more complex. One example is the proper communication between stakeholders, a challenge that is magnified when the service is constructed and managed by a non-governmental organization (NGO) that later leaves the management structure. This study investigates an approach to visualize and quantitatively evaluate how communication between stakeholders influences resolution efforts, using social network analysis (SNA). The methods employed here are demonstrated with a case study in the municipality of Darío, Nicaragua, where a large WatSan NGO is planning its exit strategy. Survey data were used to construct weighted social networks representing the efficacy of communication links and pathways on WatSan service resolution. SNA was then used to evaluate the potential implications of the NGO's disengagement on communication networks, and thus, future resolution activities. The findings suggest the NGO must promote best practices and fortify existing communication ties between community water committees, municipal government, and material providers before disengaging from the management structure. This study demonstrates a novel application of SNA to visualize and analyze the influence of communication on rural WatSan service resolution activities, and presents a tool WatSan practitioners can use to inform their exit strategies.

KEYWORDS: Exit strategies; social network analysis; rural water service resolution; Nicaragua; developing countries

INTRODUCTION

A contemporary and increasingly prevalent belief within the international rural water and sanitation (WatSan) development sector is that community-based management (CBM) schemes are ineffective at providing sustained access to services. This is a shift from a long-held philosophy that communities should be solely responsible for maintaining their WatSan technology, typically by way of a community water committee (CWC). In contrast, studies have highlighted numerous cases where CWCs found it difficult, if not impossible to maintain the long-term functioning of their WatSan services (Carter 1999; Kleemeier 2000; Carter 2007; Komives et al. 2008; Lockwood 2002, 2011; Schouten et al. 2011; Whittington et al. 2008). Indeed, many experts contend that CBM is not a sustainable management scheme without reliable external backing from entities such as the local government, organizations, or government agencies, to provide technical, managerial, and financial support to communities (Whittington et al. 2008; Kristin Komives et al. 2008; Lockwood 2002, 2011; Schouten et al. 2011). However, one does not necessarily exclude the other. Many experts agree that CWCs should be the party responsible for performing basic and routine maintenance of their WatSan services, as well as ensuring the system

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is properly operated and used by community members (Harvey and Reed 2004; Musonda 2004; Gine 2008; Silva 2013; Montgomery and Bartram 2009; Schweitzer and Mihelcic 2012). Thus, the sector is rapidly progressing towards an integrated management philosophy that combines CBM and some form of external support, which Baumann (2006) calls “community management plus”, where the plus indicates pairing CBM with a consistent form of external support (Hutchings et al. 2015). Overall, the proponents of this scheme claim integrated management more aptly facilitates effective “resolution” of technical issues with WatSan infrastructure, thereby promoting long-term service functionality (Improve International 2014).

While in many cases integrated management schemes improve resolution efforts, the challenges they can present are more complex than those based purely on CBM (Ramalingham 2008; Amadei 2015; Neely 2015). These challenges are a result of variation in the type and quality of WatSan technology installed, continuity of support by the implementing agency or organization, and the associated influences these aspects can have on proper communication, and thus coordination, between service stakeholders (Carter 1999; Chambers 2005; Bartram 2009; Brikké 2000; Ramirez 2012; Lockwood 2011; Rietveld et al. 2007; Kaboyashi et al. 2014). Regarding the latter, Carter (1999) mentions effective resolution requires that, “communication lines between community and the backstopping agency [external entity] need to be clear, and response times need to be rapid.”(p.9). Kaboyashi et al. (2014) supports this point, stating that clear communication within the community itself, as well as with outside communities, is a key component for the “collective action” (p.1) needed to enable effective collaboration and knowledge exchange regarding a particular technical issue, and its resolution. Koboyashi et al. (2014) and Dwi Ari et al. (2014) go further to demonstrate a clear connection between communication links and pathways between water service stakeholders and the efficacy of water service resolution. Studies also indicate the WatSan technology type and sophistication can greatly influence the extent of external support required in any integrated management scheme, and the associated channels of communication required to support long-term resolution efforts (Harvey and Reed 2004, 2006, Kaboyashi et al. 2014). This, in turn, requires easy access to tools, materials, and stakeholder know-how necessary to perform routine maintenance and repair (Carter 1999; Lockwood 2002; Harvey and Reed 2006, Narayan 1995; Rietveld et al. 2007; Gine 2008; Godfrey 2009; Jones 2012). Lastly, communication within an integrated management scheme is often further complicated, or even hampered, in the common case where the service is constructed and managed by a non-governmental organization (NGO) that later disengages and places the responsibility of future service resolution on the remaining stakeholders (Brikké 2000). A key aspect of successful disengagement is retaining the integrity of adequate communication channels between various stakeholders, to seamlessly enable the continued operation and maintenance of WatSan services well after the NGO exits the service site. This requires the disengaging NGO to develop an exit strategy that, in part, establishes a healthy network of communication to facilitate future resolution activities (ACF 2007; Gardner and Greenblot 2005).

This paper asserts that improving understanding on how communication channels influence resolution efforts could enable NGOs in particular to plan and execute more effective exit strategies for international WatSan development interventions that are based on integrated management schemes. Thus, the aim of this research was to develop a technique to evaluate the potential impacts of NGO disengagement on the vital communication channels that facilitate effective WatSan service resolution. The technique proposed to accomplish this objective was social network analysis (SNA). Based on the aforementioned challenges with integrated management schemes, the aspects of interest investigated here with SNA were (i.) communication

links and pathways between WatSan service stakeholders and their influence on resolution efforts, (ii.) the influence technology, problem and repair type has on communication links and pathways, and (iii.) the potential implications of NGO disengagement on resolution communication and efficacy. The associated questions that served as a guide for these research efforts were:

- **RQ1:** Who do stakeholders communicate with to resolve issues with WatSan services?
- **RQ2:** How does the problem or technology type influence this communication?
- **RQ3:** How important is each service stakeholder in terms of their influence on communication links and pathways for effective service resolution?

The sections that follow outline the steps taken to answer these research questions. These steps are demonstrated herein through a case study performed in the municipality of Darío, Nicaragua, where a large WatSan NGO is planning its exit strategy. The findings afforded through these methods are used to inform recommendations for how the disengaging NGO can best fortify existing communication channels and practices to mitigate issues with WatSan service resolution in Darío, and to highlight the utility of using SNA as a tool to facilitate exit strategy planning activities.

METHODS

This section presents the mixed-methods approach used to develop social networks to visualize and analyze communication between WatSan service stakeholders in Darío, Nicaragua. A methodology based on SNA was chosen for its ability to quantitatively infer how communication links and pathways influence resolution efforts. In particular, social networks were analyzed to evaluate stakeholder importance (RQ3) based on their positioning (RQ1) within the social network (Scott 2001; Wasserman and Fraust 1994). Survey-based interviews were used to gather the data necessary to build, analyze, and interpret networks of stakeholder communication and importance. The data were first used to interpret the significance and meaning of network links on effective communication. This was accomplished by performing statistical association analysis of aspects of stakeholder communication, including communication links based on the perceived effectiveness of the resolution efforts, the timeliness of repair (Carter 1999), and frequency of service breakdowns. Social networks pertaining to both water and sanitation services were then analyzed to evaluate stakeholder communication and resolution efficacy, in particular, the potential impacts of the NGO's disengagement on communication links and pathways. A description of each of these steps is presented below.

Data collection

The municipality of Darío, Nicaragua was selected as the study site because it presented a case where a significantly large WatSan NGO was in the process of disengaging from an existing integrated WatSan service management scheme. The disengaging NGO (from now on referred to as NGO1) has been involved with WatSan projects in Darío for over 25 years. The municipality of Darío has a population of roughly 41,000 habitants, a large percentage of whom live within 160 rural communities located outside of the town center. To date, NGO1 has installed water and sanitation systems in 68 and 78 communities in Darío, respectively. While NGO1 intentionally keeps minimal post-construction involvement with communities, dedicated community educators within the organization maintain contact with CWCs to ensure proper management of the system

is taking place. In the case of a catastrophic system failure, NGO1 endeavors to provide the necessary funds or resources to fix the system.

While over the years various types of WatSan technologies have been installed in Darío by the government and other external organizations and agencies, the two primary forms of water service technologies are rope pump and electric pump systems, while the predominant sanitation technology are ventilated improved pit (VIP) latrines, or simple improved pit latrines (Figure 1).



Figure 1. The three primary WatSan technologies in Darío. Rope and electric pumped wells (left and middle, respectively), ventilated improved pit latrine (right).

Data collection followed an embedded multi-case study scheme, with the embedded unit of analysis set at the community level within the larger case study context treated at the municipality level (Yin 2002). The WatSan service problem was identified at the community level, where the source of resolution communication would thus originate, as CWCs would conceivably be the first to know if a technical issue were to arise. Data collection entailed conducting survey-based interviews with WatSan service stakeholders guided by both open and closed response survey questions. For water services, six distinct stakeholder groups were interviewed. At the community level, CWC members were interviewed. At the municipality level, interviews took place with the local government, NGO1, the material and construction provider, two ministry-run water service providers: ENACAL (Nicaragua Water and Sewer Company) and MARENA PINCHE (the Ministry of Environmental and Water Resources), and the national provider of electricity, Union Fenosa. In the case of sanitation services, four stakeholder groups were interviewed: the CWC, government, NGO1, and an in country NGO, from now on referred to as NGO2.

Of the 40 communities sampled, 34 had well-sourced water supply systems: 22 were in the form of electrical pumps, 12 were rope pumps, and the remaining six communities were comprised of those using unprotected sources, and alternative water supply technologies such as gravity-fed systems. For sanitation systems, 29 of the 40 communities had improved sanitation infrastructure in the form of VIP latrines installed by NGO1. The designation of an “improved” sanitation system was based on the World Health Organization’s definition as one that separates human excreta from human contact, either in the form of basic pit or VIP latrines (JMP 2015).

To gather the necessary data to build social networks, stakeholders were asked questions pertaining to their communication with other project stakeholders in the event of WatSan service issues, where CWCs in particular were asked to indicate the most common technical issue. Typically, SNA treats communication as binary connections (network “edges”), between actors

(network “nodes”), where the network structure is of primary interest (Scott 2000; Wasserman and Faust 1994). In this study, however, an important structural characteristic was not only the existence of a communication link (edge) between stakeholders (nodes), but also the efficacy of the communication itself (edge weight); where within the weighted network the communication link was intended to represent a level of efficacy for resolution. As such, in addition to asking interviewees who they spoke with in the event of a problem, they were also prompted to categorically score the time it took to typically resolve the problem, the frequency in which the WatSan technology typically breaks down, and to present their opinion on the utility or efficacy of the communication with said stakeholder. For time, a higher edge score was given for a shorter duration of time to resolve the issue, where the scores were (4) – days, (3) – weeks, (2) – months, and (1) – years/never. For frequency of break downs, a higher score was given for a lower frequency, where the scores were (5) – hardly ever, (4) – yearly, (3) – monthly, (2) – weekly, (1) – daily. For the stakeholder’s opinion on efficacy, a higher score was given for a more favorable level of efficacy from (4) – very good, (3) – good, (2) – mediocre, and (1) – not good at all. In this way, it was possible to construct weighted networks representing aspects of WatSan resolution efficacy.

Data analysis: Statistical association of communication links

Before creating and analyzing social networks, statistical associations were conducted to interpret statistical dependence between communication links based on the aforementioned aspects of resolution efficacy (i.e., perceived efficacy, time to resolve issue, and frequency of breakdowns). In addition, statistical association were performed to evaluate if communication links were dependent on technology or problem type (RQ2), or on the stakeholder that initially installed the service (an intuition based on field observation). These pertinent categories for statistical association analysis resulted in three types of link-node relationships using both nominal (e.g., frequency of breakdown) and ordinal (e.g., the particular stakeholder) categorical variables. Type 1 relationships were used to identify dependencies between communication and overall resolution efficacy based on the perceived (opinion-based) efficacy indicated by the stakeholders, the time it typically took to resolve the issue, and the frequency of breakdowns (i.e., ordinal variables). Type 2 relationships were used to identify dependencies between communication and technology, the nature of the problem, and on the entity who initially installed the service. Type 3 relationships were used evaluated dependencies between the technology itself on the time and frequency of repairs. Evidence of a statistical association was based on the null-hypothesis (H_0), which indicated there was no statistically significant relationship regarding the interpreted meaning of the communication link, based on the Pearson’s chi-square test. An overview of these statistical tests are listed below:

Type 1: Communication and Resolution Efficacy

- *Communication/Efficacy*: Stakeholder communication and the resulting (perception-based) efficacy of the resolution effort; H_0 : Communication and the perceived efficacy of resolution effort are statistically independent.
- *Communication/Time*: Stakeholder communication and the resulting time it takes to resolve the issue; H_0 : Communication and the amount of time it takes to resolve the issue are statistically independent.

- *Communication/Frequency*: Stakeholder communication and the resulting frequency of break downs; H_0 : Communication and the frequency of break downs are statistically independent.

Type 2: Communication and Technology, Problem, and Installer

- *Communication/Technology*: Stakeholder communication given the type of technology; H_0 : Communication and the type of technology are statistically independent.
- *Communication/Problem*: Stakeholder communication given the nature of the problem; H_0 : Communication and the problem type are statistically independent.
- *Communication/Installer*: Stakeholder communication given the entity that initially installed the technology; H_0 : Communication and who installed it are statistically independent.

Type 3: Technology – Repair Time and Break down Frequency

- *Technology/Time*: Type of technology and the associated time it took to repair; H_0 : Technology and the amount of time it takes to resolve the issue are statistically independent.
- *Technology/Frequency*: Type of technology and the associated frequency of break downs; H_0 : Technology and frequency of breakdown are statistically independent.

Evaluation of these three types of link-node relationships followed the method for statistically analyzing associations between pairs of categorical variables described by Agresti and Finlay (1997). Pearson’s chi-square (χ^2) test for significance was used because the comparison of categorical variable pairs in this case were composed of both nominal and ordinal variables, and other similar tests (i.e., gamma, Kendall’s tau-b or tau-c, Spearman’s rho-b and rho-c, and Somers’-d) generally require both categorical pairs to be ordinal (Agresti and Finlay 1997). The process of analyzing each relationship type used the following five steps, per Agresti and Finlay (1997):

1. Constructing a contingency table for each pairing of categorical variables for each link-node relationship type
2. Constructing an expected frequency table (f_e) with each cell being the expected frequency based on each cell of the contingency table, where for each cell: $f_e = \left(\frac{\text{column total}}{\text{total sample size}}\right)(\text{row total})$
3. Calculating the chi-squared statistic using the tables in step 1 and 2, where: $\chi^2 = \sum \frac{(f_o - f_e)^2}{f_e}$, and f_o is the relative cell in the contingency table
4. Calculating the p -value for the chi-square test of independence using the chi-squared score and the degree of freedom (df) for each pairing’s contingency table, where: $df = (\text{num row} - 1)(\text{num col} - 1)$.
5. Comparing the p -value with the desired level of significance α set at 0.05 to evaluate statistical significance such that a p -value < 0.05 rejects the null-hypothesis and assumes statistical dependence.

Data analysis: Social networks

Identifying and weighing communication links between stakeholders varied in difficulty, form, and subjectivity. Identifying and link weights between CWCs and the other stakeholders was a relatively trivial and straightforward task, since each of the CWC stakeholders clearly indicated the stakeholder they communicated with given an issue, and the time, frequency of the repair, and perceived efficacy associated with this communication, using the scoring rubrics mentioned previously. However, this process was more complicated and nuanced when talking with external support stakeholders, as their responses were less clear regarding their lines of communication. Thus, it was often necessary to interpret communication links based on their responses. The quote below from a government stakeholder presents an exemplar of these types of stakeholder communication interpretations in [brackets]. In this interview, the government evaluated the communication link as resulting in a “good” (network edge weight 3) resolution effort that typically took a “week” (network edge weight 3) to complete.

As the municipal government, we have a diagnostic and a method to receive information on all of the problems with water and sanitation faced by the communities. We compare these problems with the budget that we have, and prioritize the repairs that we do. In the case where the municipal government is not able to do the repairs themselves, or if they do not have the necessary funds, we ask for help from ENACAL, MARENA PINCHE, and local organizations [NGO1, and NGO 2]. If there are problems with the electricity, we contact the electric company and they solve the problem [Union Fenosa].

Once communication links were ascertained between all of the stakeholder, a three-column weighted edge-list (origin-target-weight) was built and imported into Gephi version 0.9.1 (Gephi 2015). Communication networks were built in Gephi to supplement the evaluation of stakeholder importance by providing a visual backdrop with which to convey the research findings. Network edges (links) were treated as “directed” (i.e., arrows instead of lines), as the direction of communication between stakeholders was a meaningful attribute of network structure. This allowed for the evaluation of communication links and their strengths as they “flowed” from each stakeholder to the other. While the positioning of nodes within social networks is structurally arbitrary, two nodal distributions within Gephi were chosen in particular to visualize the geospatial relationship between stakeholders (GeoLayout), and to pull apart and visualize each node, link, and node grouping (Fruchterman Reingold force-directed algorithm).

Weighted centrality measures based on these network diagrams were used to identify stakeholder importance through identifying direct and indirect communication links. For direct communication links, degree-in and degree-out centrality were calculated to measure direct communication with and from each stakeholder, respectively. For indirect links (i.e., pathways), betweenness centrality was calculated to score stakeholder importance based on their capacity to bridge shortest (and therefore, most efficient) paths of communication between other stakeholders (Freeman 1977; Borghatti 2005). An additional network analysis based on Freeman centralization (network centrality) was used to supplement these “actor” level centrality comparisons by showing the proportion of importance from the most important stakeholder compared to the other stakeholders (Freeman, 1979).

Because it is not possible to calculate centrality for weighted networks in Gephi, each score was instead calculated in R-Project using the package “tnet” (Opsahl et al. 2010). Centrality scores

were calculated using Equations 1, 2 and 3 below, for degree and betweenness centrality, and overall network centralization, respectively. In Equations 1 and 2, α represents a tuning parameter that can be used to balance the importance placed on links and their weights (Opsahl et al. 2010). In this study, α was taken as 0.5, meaning the weights and links were considered equally important in calculating centrality.

Weighted degree (in or out) centrality

$$C_D^{w\alpha} = k_i \times \left(\frac{s_i}{k_i}\right)^\alpha \tag{1}$$

Where:

k_i : represents the traditional formula for degree centrality of a binary network, $C_D(i) = \sum_j^N x_{ij}$, where i is the node of interest and j are all the other nodes

s_i : represents the traditional formula for weighted degree centrality of a binary network, $C_D^w(i) = \sum_j^N w_{ij}$, where i is the node of interest and j are all the other nodes

N : represents the total number of nodes

Weighted betweenness centrality

$$C_B^{wa} = \sum_{j \neq i \neq k} \frac{g_{jk}^{w\alpha}(i)}{g_{jk}^{w\alpha}} \tag{2}$$

Where:

$g_{jk}(i)$: represents the number of shortest paths between nodes j and k that are enabled by passing through node i .

g_{jk} : represents the total number of shortest paths that exist between nodes j and k

w : represents the weight of the link

Network centrality

$$C_B = \frac{\sum_{i=1}^N [C'_{B,D}(p^*) - C'_{B,D}(p_i)]}{\max \sum_{i=1}^N [C'_{B,D}(p^*) - C'_{B,D}(p_i)]} \tag{3}$$

Where:

$C_{B,D}$ = the normalized score for betweenness or degree-based centralization

$C'_{B,D}(p^*)$ = the most central node based on betweenness or degree centrality

$C'_{B,D}(p_i)$ = betweenness or degree centrality for each node in the network

$\max \sum_{i=1}^N [C'_{B,D}(p^*) - C'_{B,D}(p_i)]$ = the maximum network centrality based on betweenness, for a wheel or star = $N^3 - 4N^2 + 5N - 2$, used to normalize the network centrality score

N = the total number of nodes

RESULTS & DISCUSSION

In this section, insights gained through the previously outlined methods are summarized and interpreted by first looking at the results from the statistical association analysis of communication links. Using the information from this link analysis, the social networks for water and sanitation are analyzed to identify the most important stakeholders using the previously mentioned centrality analyses. Finally, key interpretations of these results are used to inform potential implications of NGO1 disengagement to inform recommendations for how NGO1 can best exit the municipality of Darío.

Association analysis: Link meaning and significance

Of the eight statistical tests for link-node associations performed for each of the three types of categorical relationships mentioned in the previous section, two were statistically significant for water services, and one was statistically significant for sanitation services, while link-node relationships based on technology and problem type, were found to be insignificant. A summary of the analyses for all eight statistical associations for both water and sanitation, are shown in Table 1.

For water services, the majority of problems ($n = 34$) were malfunctioning pumps or pump system infrastructure ($n = 20$), or water shortages due to diminishing ground water sources ($n = 14$). As these were the principle issues in the communities sampled, statistical association testing only considered these problem categories. Statistically significant relationships were found between CWC communication and the amount of time it took to resolve the issue (Communication|Time, $p = 0.0029$), and the influence the initial installer had on communication (Communication|Installer, $p = 0.0005$). Some of the least statistically significant associations were communication based on the type of problem (Communication|Problem, $p = 0.7763$), the association of communication and the frequency of technical issues (Communication|Frequency, $p = 0.7338$), and to a lesser extent, the association of communication based on technology type (Communication|Frequency, $p = 0.1711$), thereby answering RQ2 regarding the influence of problem or technology type on stakeholder communication. Thus, communication links (weighted edges) within the social networks for water service resolution were based on, and interpreted as, resolution timeliness.

For sanitation, the only statistically significant relationship existed between CWC communication and the level of efficacy (Communication|Efficacy, $p = 0.0011$), where the other associations, especially communication and frequency of breakdowns (Communication|Frequency, $p = 0.932$), were either not significant or applicable. The negligible variability in technology-types, along with the high percentage of services that had been installed by NGO1, made any statistical comparisons between sanitation technology on communication or service functionality irrelevant. As a result, Table 1 shows that viable comparisons existed only for communication and perceived efficacy, frequency, and problem. In addition, a viable calculation of the statistical association between communication and the time to resolve the service issue was not possible, as each CWC indicated a score of 2 (months), regardless of the stakeholder communication link. Given these results, communication links (weighted edges) within the social network for sanitation services, were relate to perceived efficacy of resolution.

Table 1. Analysis of statistically significant link-node associations

WATER				
Association	<i>n</i>	χ^2	<i>df</i>	<i>p</i>
Communication Technology	34	7.75	5	0.1711
Communication Problem	34	1.78	4	0.7763
Communication Installer	38	22.07	5	0.0005*
Communication Efficacy	37	21.18	15	0.1312
Communication Time	37	34.48	15	0.0029*
Communication Frequency	38	15.72	20	0.7338
Technology Time	33	2.75	3	0.4318
Technology Frequency	33	3.08	4	0.5445
SANITATION				
Association	<i>n</i>	χ^2	<i>df</i>	<i>p</i>
Communication Technology	--	--	--	--
Communication Problem	29	4.74	3	0.1919
Communication Installer	--	--	--	--
Communication Efficacy	29	32.72	12	0.0011*
Communication Time	--	--	--	--
Communication Frequency	29	5.66	12	0.9320
Technology Time	--	--	--	--
Technology Frequency	--	--	--	--

*reject H_0 at $\alpha = 0.05$

-- indicates a statistical association was not possible

Social network analysis: Stakeholder importance

Based on the findings from the statistical association analyses, resolution efficacy as a result of communication links (and their weights) were interpreted as timeliness of resolution for water services, and as perceived efficacy for sanitation services. These two networks are visually represented in Figure 2, which presents networks displayed with GeoLayout, and the Fruchterman Reingold force-directed algorithm. The weights of directed arrows are displayed as bolder lines having the highest weight. To aptly display the connection between the different stakeholders, only the external support entities are indicated on these graphs, where the non-labeled nodes represent the communities sampled.

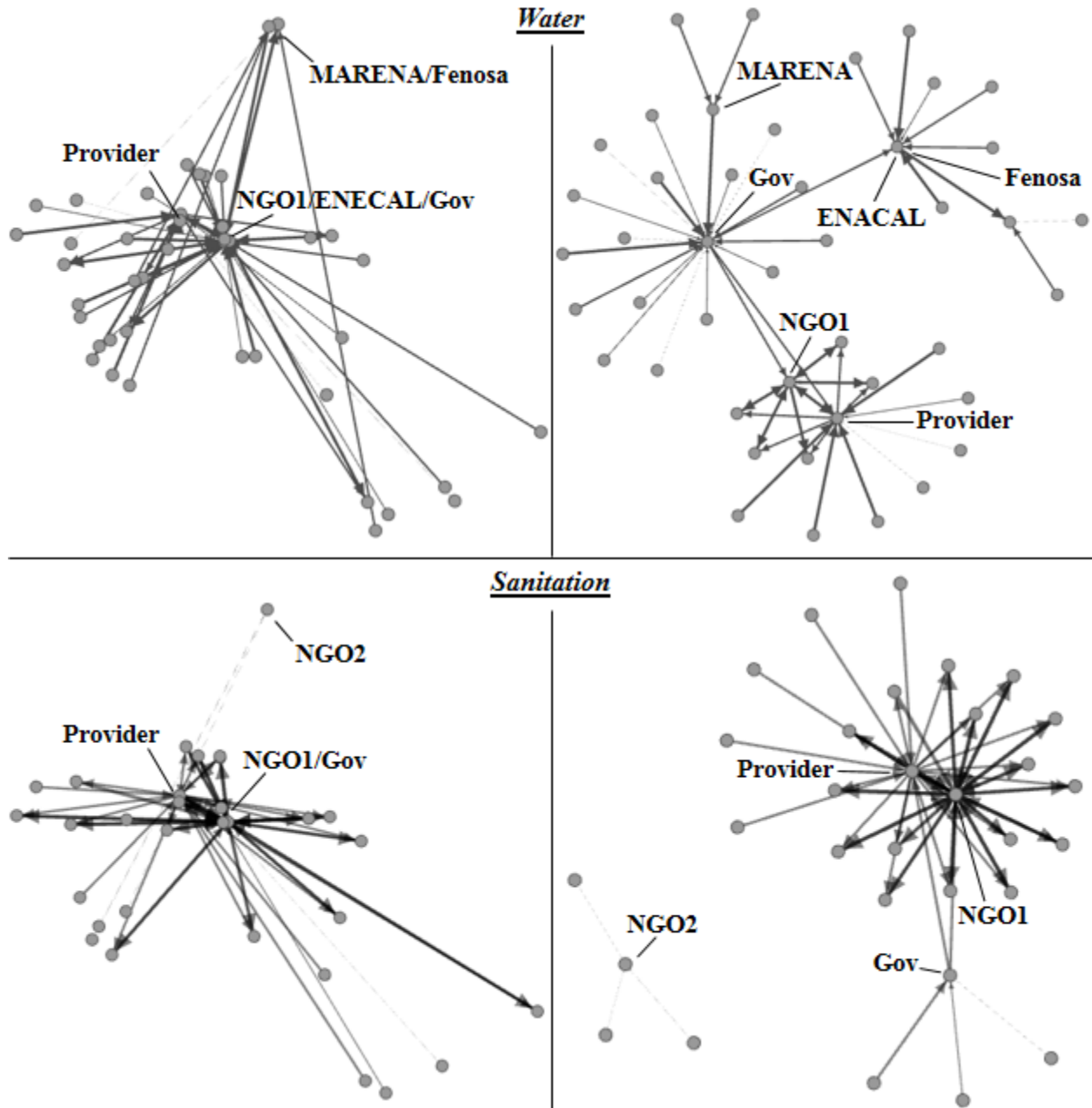


Figure 2. Social network graphs for water (top) and sanitation communication (bottom); left: GeoLayout; right: Fruchterman Reingold force-directed algorithm

The ranked weighted centrality scores for each network are shown in Table 2. For water services, the government was found to be the most central based on weighted degree-in centrality (33) and betweenness centrality (187). Based on the assumption that these weighted social networks offer insight into overall stakeholder influence on resolution efficacy demonstrates that the government is the most influential in the resolution of water service issues. Overall, the government, NGO1 (betweenness 125) and provider (betweenness 42) were found to most efficiently (shortest paths) form communication pathways between the communities and external sources. Figure 2 (top right) shows NGO1 was an influential player in bridging communication

between the government and provider, and in a similar way, shows how the ministry agencies ENACAL and MARENA PINCHE are tightly connected to the municipal government. However, ENACAL and MARENA PINCHE were found to have moderate influence on resolution efforts overall, as seen with their low scores for degree and betweenness centrality in Table 2.

For sanitation, the provider had the highest betweenness and degree-out scores (291 and 66, respectively), meaning they were significantly more influential in executing resolution efforts. These are intuitive results, as NGO1, being the primary installer of the technology, would logically be the first touch-point by the community (degree-in score 52), later transitioning communication and resolution efforts to the construction provider, and the communities they serve.

Network centrality scores differed significantly between water and sanitation networks, as summarized on the bottom of Table 2. Because the water network has a larger number of nodes (44) compared to the sanitation network (33), it is expected that it would have a proportionately lower network centrality score compared to the sanitation network. However, network centrality analyses reveal a three, four and six-fold difference in network centrality scores between water and sanitation networks based on betweenness, degree-in, and degree-out centrality scores, respectively. This finding reinforces the assertion that for sanitation services one particular stakeholder – in this case the material provider – has a comparatively far greater influence on communication within the resolution network.

Table 2. Weighted centrality score ranks for water (time, 44 nodes) and sanitation (efficacy, 33 nodes)

WATER (TIME)					
Betweenness ^a		Degree – In ^b		Degree – Out ^c	
Government	187	Government	33	NGO1	24
NGO1	125	Provider	26	Provider	24
Provider	42	NGO1	25	Government	8
ENACAL	26	ENACAL	18	--*	--*
MARENA	20	MARENA	7	--*	--*
SANITATION (EFFICACY)					
Betweenness ^d		Degree – In ^e		Degree – Out ^f	
Provider	291	NGO1	52	Provider	66
NGO1	182	Provider	25	NGO1	56
Government	100	--*	--*	Government	6
--*	--*	--*	--*	--*	--*
--*	--*	--*	--*	--*	--*

*Indicates scores that are negligible or 0
 Network centrality: ^a0.101; ^b0.017; ^c0.012; ^d0.284; ^e0.047; ^f0.062

Implications and recommendations

Key recommendations exist for NGO1 based on the implications of the findings presented above. A summary of these findings, their implications on future resolution efforts, and associated recommendations for how NGO1 can minimize potentially adverse impacts from their disengagement, are shown in Table 3.

For water services, the results imply both positive and negative impacts on future resolution efforts as a result of NGO1’s disengagement, based on the existing capacity for resolution with the current service stakeholders, and the implications of their relative importance on resolution efficacy. The degree-in and betweenness centralities for water service social networks (based on timeliness) showed a high level of direct communication already exists with the government, who

also provides the greatest level of indirect influence on resolution activities. This result proves favorable for the future impact of NGO1's disengagement on resolution efforts, implying the most influential communication channels for resolution operate independent from NGO1. Unfortunately, despite having the greatest influence on resolution efforts, the data showed, in general, that government-led water service resolution was slower (months) than the majority of the other stakeholders (days and weeks). This is shown visually in Figure 2, where the majority of the network edges entering the government node are fainter lines. While conceivably the hope of NGO1 is to hand off responsibility of water service management to local stakeholders, these findings show that the government may not be able to provide the timeliest resolution. Potentially the provider, who has a relatively high betweenness and degree centrality score for timeliness, could fill, or reinforce, this role. However, as can be seen in Figure 2, and as is shown in the betweenness centrality scores in Table 2, the tightly connected communication between NGO1 and the provider could fracture the necessary communication channels that enable beneficial communication links between the communities, provider, and government. This suggests that NGO1 should ensure communication channels are adequately bridged. One approach could be to develop a transparent communication protocol directing who CWCs should talk in the event of an unmanageable service issue, highlighting the important connection between the government and provider. Additionally, because NGO1 appeared to have the highest scores for timeliness (see Figure 2), implies NGO1 should convey best practices and community interaction protocol to all remaining stakeholders – including ENACAL and MARENA PINCHE who were found to work closely with the government – before fully disengaging.

For the sanitation service resolution efforts (based on stakeholders' perceived efficacy), the findings are somewhat similar, and potentially more encouraging, than those found for water service resolution. In this case, the provider was found to be most influential on effective sanitation service resolution overall (betweenness 291, degree-out 66), also receiving generally high scoring of efficacy from the CWCs, as shown in Figure 2. This implies the provider is already a critical part of the communication network for service resolution, independent from NGO1. Compared to the NGO1 (degree-in 52), however, the provider receives considerably less communication from the CWCs (degree-in 25), once again highlighting the need for NGO1 to promote clear lines of communication from the CWCs to the provider. Additionally, an evident gap exists regarding current and future government involvement (betweenness 100, degree-out 6) in sanitation infrastructure installation and resolution. Thus, NGO1 should confirm the government's plans with sanitation infrastructure management before executing their exit strategy, and see if it is possible to encourage improvements in their existing programs.

Table 3. Summary of findings, implications, and recommendations for NGO1

	Findings	Implications	Recommendations for NGO1
WATER	The majority of CWCs communicate with government despite initial installation by NGO1	NGO1 disengagement impacts on existing communication networks could be less pronounced	Further encourage and facilitate the communication between CWCs and government
	Highest betweenness centrality based on timeliness: Government, followed by NGO1/provider	Government is most influential in bridging communication and resolution efforts, however, this resolution is generally executed in a less timely fashion than the other external stakeholders The link between NGO1 and provider could be broken when NGO1 disengages	Fortify existing communication and knowledge exchange between the government and provider Encourage more effective resolution practices in government policy
	Highest degree-in centrality based on timeliness: Government followed by the provider	The government and provider are communicated with most often when communities have water service issues	Promote existing communication channels between the CWC and government and provider
	Highest degree-out centrality based on timeliness: NGO1 followed by the provider	Most communication with CWCs takes place from NGO1 and provider	Encourage communication from government and provider to CWCs
SANITATION	Highest betweenness centrality based on perceived efficacy: Provider followed by NGO1	Provider most effectively bridges communication and resolution efforts	Ensure CWCs maintain primary contact with the provider in the event of a service issue Investigate ways to build capacity of the local government
	Highest degree-in centrality based on perceived efficacy: NGO1 followed by the provider	NGO1 is communicated with most often given issues with sanitation services	Promote CWC communication with the provider Investigate ways to build capacity of the local government
	Highest degree-out centrality based on perceived efficacy: Provider followed by NGO1	Provider is in contact most with the other stakeholders	Promote existing communication channels between the provider and CWCs Investigate ways to build capacity of the local government

CONCLUSIONS

This study investigated a means to evaluate the impacts of NGO disengagement on WatSan service resolution, focusing specifically on the impacts of disengagement on the communication channels that facilitate effective resolution of technical issues. The methodological approach chosen to accomplish the research objective was the creation and analysis of social networks representing stakeholder communication links and pathways associated with resolution efforts. To demonstrate the research methods, a case study was conducted on rural WatSan technology resolution in Darío, Nicaragua, where a major NGO (NGO1) is in the process of leaving the service site.

Through the analysis of communication networks for service resolution, it was possible to offer recommendations to NGO1 by addressing the research questions proposed at the start of this paper related to the structure of WatSan resolution communication networks (RQ1), the influence problem and technology type have on communication (RQ2), and the importance of each stakeholder for resolution efforts based on their connectivity within the network (RQ3). In particular, analysis of social networks showed the current communication links and pathways between WatSan service stakeholders in Darío are moderately well suited for NGO1's

disengagement. For water services, analysis of social networks showed the majority of communities, represented by community water committees (CWCs), contacted the government in the event of water service issues, and indicated that the government was the most influential in orchestrating water service resolution efforts overall. However, based on the CWC assessment of timeliness overall, the government was generally less effective when compared to the other stakeholders. In addition, NGO1 was found to be a vital bridge between the government and material and construction provider. For sanitation services, network analyses showed the crucial influence of the provider on resolution activities, and the need for NGO1 to encourage improvements in the administrative capacity of the government to bolster future resolution efforts following NGO1's departure. These findings demonstrate the need for NGO1 to encourage best practices for government-led service resolution, especially regarding timeliness, conjointly strengthening the existing connection between CWCs, providers, and ministry agencies. This could be accomplished through the formation of a communication protocol that outlines the communication process, along with preferred best practices to be executed throughout the resolution cycle. These recommendations align with theory and practice in the sector related to the general importance of post-construction support communication (Carter 1999; Harvey and Reid 2004), and the need to develop and fortify communication channels and best practices between internal and external project stakeholders (Montgomery et al. 2009; Brikké, 2000; ACF 2007; Gardner and Greenblot 2005).

Overall, the quantitative identification of the most influential stakeholders through evaluating their direct and indirect communication channels using SNA (centrality analysis), informed clear exit strategy recommendations regarding how NGO1 can fortify stakeholder communication before leaving Darío. In addition, the use of network graphs to display the interaction of communication provided a visual backdrop to interpret and make sense of these results. As such, this study demonstrates a novel application of SNA to visualize and analyze important communication links and pathways for rural WatSan service resolution. It is unlikely that the recommendations presented here are generalizable in other project or program contexts. For example, NGOs that stay for a shorter time (i.e., three to five years), use a different form of management strategy, or operate within a different cultural and socio-economic context, would invariably imply a distinct array of recommendations based on differently structured social networks. In highlighting these common distinctions, however, demonstrates the merits of this approach, as it offers an adaptable methodology NGOs and practitioners can use to plan exit strategies that facilitate effective resolution efforts through the formation of proper communication networks between permanent WatSan service stakeholders.

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