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Using Causal Loop Diagramming to Explore the Drivers of the Sustained Functionality of Rural Water Services in Timor-Leste

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Abstract: It is recognized that international water sector development work has issues with a lack of sustained positive outcomes. A large driver of this outcome is how NGOs work with communities to implement and then manage water services. Many NGOs tend to focus their efforts on improving their reach and organisational growth by continually engaging in new projects. This behaviour is largely driven by short-term donor funding models that reward extended coverage, leaving little focus on sustained outcomes. Similarly, community-based management (CBM) schemes often impede sustained services as a result of the community's limited capacity to operate and maintain the technology. To explore these complicated drivers on water service sustainability, we used causal loop diagramming to analyse the key aspect influencing the combined dynamics between NGOs, donors and CBM. We demonstrate this methodology through a study in Timor-Leste, where we gathered data necessary to develop and apply causal loop diagrams to analyse rural water supply program outcomes. The analysis of these diagrams allowed identification of leverage points used to suggest structural changes for sustained benefits of water services. These structural changes emphasize the importance of increased robustness and reliability of water technology and the associated impact this has on community satisfaction and, conjointly, on water service sustainability.

Keywords: Timor-Leste; system dynamics modelling; donors; NGOs; water services; community management

1. Introduction

Water supply interventions in developing nations have historically had issues with a lack of sustained and positive project outcomes [1–6]. Thus, it is increasingly recognised that there is a need to evaluate the longer term impacts and sustainability of water supply interventions [3,7–10]. Unfortunately, evaluating sustainability is a concept that is in significant tension with the more concrete and measurable criteria that donors currently use to assess the success of programs [11]. For example, it is unusual for a donor to require a report on the longevity of a project after implementation. This lack of long-term responsibility is a well-known and ongoing issue, which Easterly [12] found in his study of numerous World Bank projects. This short-term thinking, in turn, motivates non-governmental organizations (NGOs) and international non-governmental organizations (INGOs) to focus on building infrastructure in order to improve their reach and create organisational growth by using short-term funding models that reward high levels of implementation. In sum, these NGO-funder dynamics, propagated by the lack of incentive to focus on sustained project or program outcomes, impedes

long-term thinking necessary to ensure proper operation and maintenance (O & M) systems are in place.

However, NGO-funder dynamics is only one (albeit significant) part of the sustainability puzzle. The literature also points to how the community interacts with the water system following implementation as an equally impactful driver of program success [13–16]. This is because the predominant management structure of rural water infrastructure in developing countries tends to follow what is known as a "community-based management" (CBM) scheme, one in which the community is solely responsible for the O & M of the water system. While CBM schemes often appear sensible in many rural water management contexts, there are inherent technical, social and economic constraints that introduce additional complexity and often inhibit sustained water service provision. In this case, "technical" constraints generally relate to the community's ability to properly operate and repair the water system [17,18]; "economic" constraints refer to the capacity of the community to afford O & M costs [19,20]; and lastly, "social" constraints generally refer to such aspects as the perceived demand for services, community organization and community member satisfaction with the intervention [3,21–23]. As a result of these frequently confounding constraints, many critics state communities inherently lack the necessary capacity to maintain their water systems without the help of the external support of governments or NGOs. This strongly demonstrates the need to consider how funder incentives drive NGO behaviour (NGO-funder dynamics), as well as the need to understand how the community (within some CBM scheme) effectively engages with the water system (CBM-service dynamics).

As such, the research presented here seeks to better understand the dynamic drivers of water service sustainability situated within this important nexus of donor funding, NGO operations and CBM. As a means to accomplish this goal, we showcase the utility of the causal loop diagramming of behaviours and norms around rural water supply projects across both international and local NGOs and stakeholder communities within the context of Timor-Leste. The questions that guided our research efforts are specifically: How does the nature of NGO involvement in water supply projects in Timor-Leste influence sustained water service provision? Similarly, what appear to be the primary drivers of community dynamics that influence sustained water service provision? Lastly, how do these two come together as a system to influence sustained water service provision?

To answer these research questions, we collect data using thematic analysis of NGO strategic documents and collected field data using ethnographic observations and interviews to create causal loop diagrams that represent the dynamic relationships of drivers between NGOs, donors and CBM schemes in Timor-Leste. These drivers are identified in the form of feedback loops. We then use these feedback loops to highlight "leverage points" that drive the dynamic influence between these stakeholders and, ultimately, program success. Lastly, we use these leverage points to inform plausible programmatic changes that would contribute to sustained adequate water supply provision in Timor-Leste. The first important step in this process was to formulate a preliminary conceptual framework or "dynamic hypothesis" to provide a roadmap for data collection and analysis.

2. NGO, Donor and CBM Dynamic Hypotheses

In the domain of system dynamics, causal loop diagrams (CLDs) qualitatively present the dynamic influences between factors thought to influence a particular system behaviour. The unit of analysis or driving force of dynamic behaviour within CLDs is feedback loops that represent circular causality between model variables [24,25]. Feedback loops may be characterized as either reinforcing (virtuous or vicious) or balancing (stabilizing or goal-seeking). Figure 1, in the tradition of Sterman [26], illustrates an example of a reinforcing loop (crowd panic increases/decreases as more/less people are seen running) and a balancing loop (increasing predator numbers will control an increase in prey numbers, but as prey numbers drop, they will cause predator numbers to fall, as well, which will allow prey numbers to increase, and so on). In CLDs such as these, the arrows reflect an influence where a change in one variable will cause a change in a second variable. A + sign at the end of the arrow indicates

that the change is in the same direction (*i.e.*, an increase in variable x will cause an increase in variable y; a decrease in x causes a decrease in y), whereas a $-$ sign at the end of an arrow indicates that the change is in opposite directions (*i.e.*, an increase in x causes and decrease in y). A reinforcing loop, indicated by an R and curly arrow ⟲R, is one where the effect of an increase or decrease in a variable is magnified over time and iterations. A balancing loop, indicated by a B and a curly arrow ⟲B, is one where the effect of an increase or decrease in a variable is resisted over time and iterations.

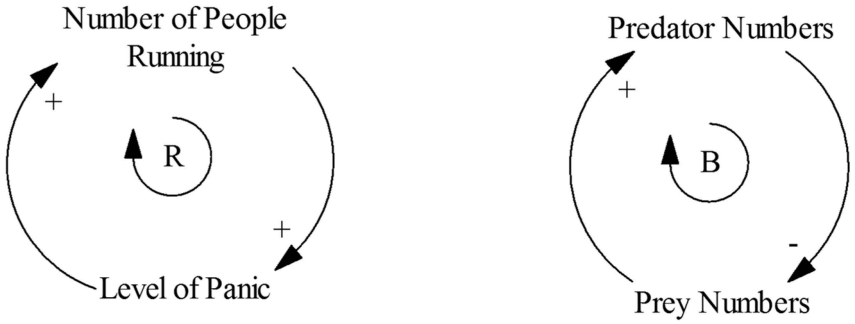

Figure 1. Example reinforcing feedback loop (**left**); and balancing loop (**right**).

Below, we develop a preliminary CLD used to describe our "dynamic hypothesis" for NGO-funder dynamics and CBM-service dynamics. We first present the tightly-coupled NGO-funder dynamics through an analysis of NGO strategic plans in eight large Australian international development NGOs who are active in water supply programs. We then proceed with a description of the CLD hypothesized to drive CBM-service dynamics based on the water sector literature.

2.1. NGO-Funder Dynamics

To enable the creation of a CLD that represents the feedback structure hypothesized to cause the dynamic behaviour between NGOs and donors, we performed an analysis of current strategic plans for eight large Australian international water development NGOs. For this exercise, we chose: Save the Children, Care, WaterAid, World Vision, Oxfam, Caritas, Child Fund and Plan International [27–35]; shown in Table 1. This comparison shows these NGOs have a reasonably common set of high-level goals that focus more on internal organisational strategy than development outcomes. It can be seen that only two high-level goals are shared between all eight NGOs; one of which relates to general development outcomes; and the other is related to income growth. This comparison provides evidence that income growth and growth of reach are both of particular concern to NGOs. Although increased reach was not a high level goal in all NGO strategic plans, it was noted at either the high level or a lower level for all, but one NGO, and as such, it is pertinent to the following argument.

From the details provided in the strategic plans, income growth appears predicated upon increases in funding through government programs, corporate sponsorship and, to a lesser degree, public donations. The strategic plans surveyed also indicate that NGOs are concerned with acquiring flexible and diverse funding that is not tied to specific programs and outcomes in the same way that government grants and corporate sponsorship are. For example, Oxfam Australia states that that it will "Identify, pilot and implement new ways of generating income, particularly unrestricted income" [31] (p. 39). Untied or unrestricted funding can be used at the discretion of NGOs to research or pilot new techniques in development that may not be supported by government donors.

Table 1. Summary of the main goals in NGO strategic plans.

NGO/Topic	Advocacy/Influence	Stakeholder Engagement	Identity	Organisational Effectiveness	Income Growth	Collaboration	Development Outcomes	Increased Reach
Save the Children Australia		✔	✔	✔	✔		✔	✔
CARE Australia				✔	✔	✔	✔	✔
WaterAid Australia	✔				✔		✔	✔
World Vision Australia		✔			✔		✔	✔
Oxfam Australia	✔			✔	✔		✔	✔
CARITAS Australia	✔		✔	✔	✔	✔	✔	
Child Fund Australia				✔	✔	✔	✔	✔
PLAN International Australia	✔		✔		✔		✔	✔

Because many of these NGOs have a heavy reliance on government funding for their continued growth and development activities, they inevitably must work within the guidelines presented by governments. These guidelines tend to require reports of achievement of specific concrete goals. For example "Increased access to and use of safe water and sanitation" [36] is reported, in part, as the number of additional people who gained access to improved water sources over a project period. In order to maintain their reputation and gain further funding, NGOs need to report their achievement towards concrete, measurable goals, and so, the projects that they undertake are aimed at quickly impacting as many people as possible. This situation where "increased activity results in increased funding which results in increased activity" demonstrates what was previously mentioned as a virtuous cycle or reinforcing feedback loop. Figure 2 is a causal loop diagram, which shows this reinforcing feedback loop, connecting donor funding and evaluation to NGO budget and activities based on the findings from this analysis.

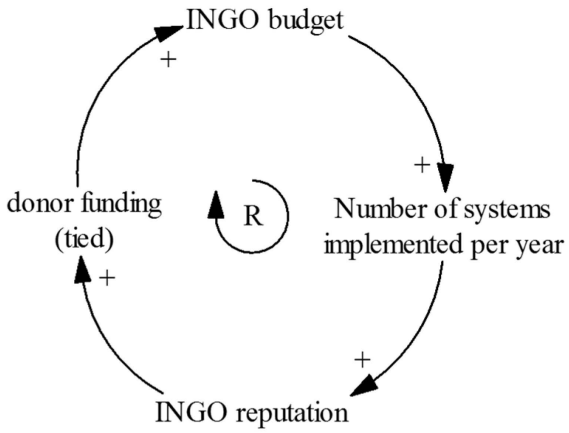

Figure 2. Causal loop diagram (CLD) illustrating that the type of projects implemented must improve the reputation of the international non-governmental organization (INGO) to ensure further funding.

Figure 2 shows that the drive for increased funding means that INGOs become focused on delivering concrete new successes. In this case, there is no financial reward for an INGO whose projects have long-term positive social outcomes, because they are measured on short-term concrete outcomes. In the water sector, as previously mentioned, INGOs respond to this demand by delivering and reporting successful projects increasingly in terms of numbers of new projects or increased (new) numbers of people accessing improved water sources [37]. As long as income growth remains a strong driver within the development sector and there is little donor focus on sustained outcomes, we can use this feedback loop as an accurate reflection of these dynamics.

However, our analysis indicates the existence of other important influences on NGO-funder dynamics. As noted previously, NGOs are concerned with finding funding sources that are less tied to specific outcomes. Figure 3 shows one way in which unrestricted funding may be applied to the previous CLD to break the cycle that sees a continual increases in measurable infrastructure. Despite the fact that NGOs usually receive no financial reward for creating long-term positive social outcomes, it is feasible that there are other rewards that would drive this behaviour. Anecdotally, intrinsic rewards for staff, when they see over time that they have made a positive difference, creates organisational payoffs in terms of morale and agency loyalty. Extrinsic rewards, such as agency reputation and the willingness of other agencies to collaborate with them, could also be seen to reward sustainable outcomes. For example Save the Children [27] is explicit in its strategic plan regarding the need to work through consortia to secure larger grants. Looking back to Table 1, it can be seen that these types of reward are acknowledged within the strategic documents as collaboration, identity and

stakeholder engagement, but they are much less consistent and more mixed in with other aims than financial growth.

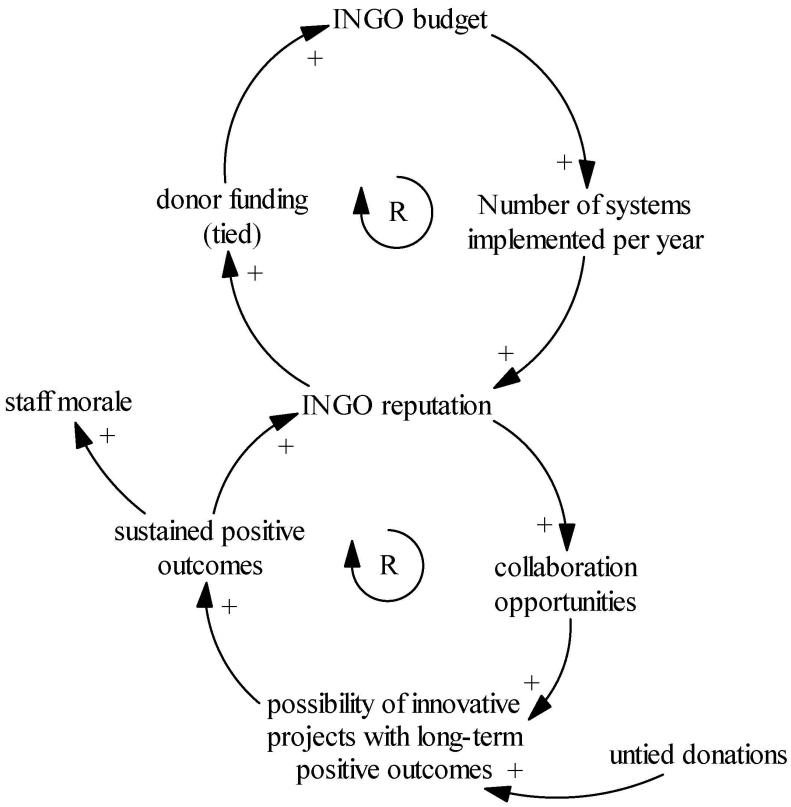

Figure 3. CLD of donor funding and untied funding effects on the types of projects undertaken by INGOs.

Furthermore, including staff morale and untied funding into Figure 3 adds a secondary reinforcing loop with a longer term development agenda that would have a positive impact on the reputation of INGOs. This additional loop shows that sustained positive outcomes could be used to leverage further government funding on the basis of INGOs gaining a reputation specifically for the longevity of positive impacts. What ultimately results from this analysis is a dual feedback structure shown in Figure 3, which serves as our dynamic hypothesis on NGO-funder dynamics.

2.2. CBM: Service Dynamics

Here, we present the feedback structure hypothesized to cause the dynamic behaviour between communities (within a CBM scheme) and their water services using feedback structures explicitly defined in the water sector literature. In a significant review of rural water and sanitation program outcomes in Timor-Leste, Willetts [38] presents Figure 4 as a set of virtuous and vicious cycles (reinforcing feedback loops) in community water management. The diagram presented in Figure 5 includes transparent accounting, trust (as willingness to pay), funding shortfalls and community management capacity (as fees spent) as drivers for program success or failure. A similar set of feedback mechanisms can be found to exist in a recent study on community-led water service management programs in Central America by Davis [39], where community satisfaction and payment were found to either enable or prohibit project success.

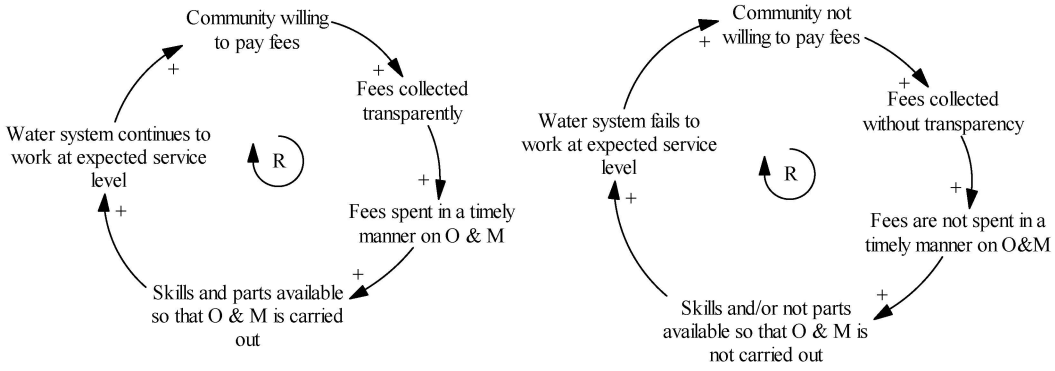

Figure 4. CLD, adapted from Willetts [38], vicious (left) and virtuous (right), in community-based management (CBM) of (rural) water systems in Timor-Leste. O & M, operation and maintenance.

In agreement with Willetts' feedback structure, in a study using the input from water sector experts, Walters and Javernick-Will [40] found that the most influential feedback loop included water system functionality, community financial support and effective management. Thus, a unifying aspect shared between these aforementioned feedback loops identified in the literature, and one which we will maintain within our dynamic hypothesis of CBM-service dynamics, appears to be the importance of community satisfaction and involvement as a driver of payment for the proper maintenance of the water system.

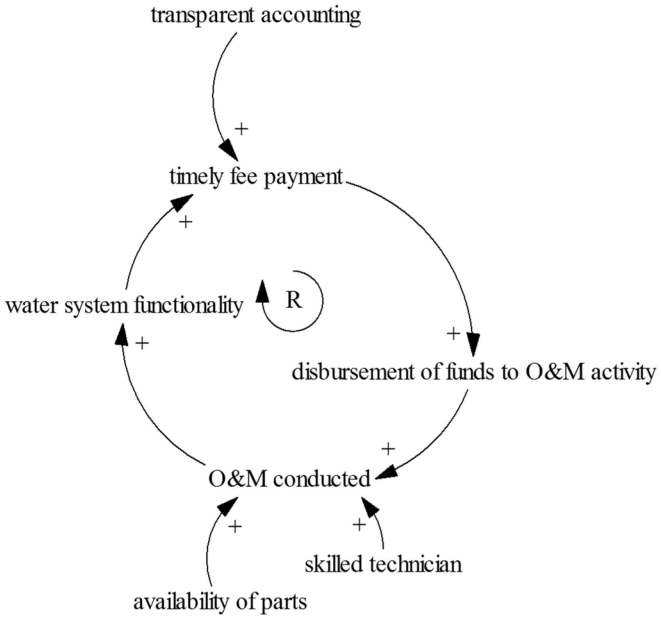

Figure 5. CLD of community CBM-led maintenance, adapted from Figure 4.

2.3. Point of Departure

The dynamic hypotheses presented in Figures 3 and 4 for NGO-funder and CBM-service dynamics, respectively, informed our data collection and analysis. Our attention was thus focussed on important drivers influencing NGO and CBM practices with rural water supply systems. Significant in this analysis are budgets and training at the NGO and INGO levels, as well as user costs, the reliability of new systems and the amenity of new systems in terms of water quality, water quantity and time or distance to taps. Then, using system dynamics methods, we highlight the relationships between these

factors in CLDs. These diagrams are then used to understand the plausible points of intervention in the system to drive the implementation of sustained adequate rural water supply in Timor-Leste.

3. Materials and Methods

The data we used to develop and analyse the CLDs representing NGO-funder and CBM-service dynamics were gathered through surveys, interviews and ethnographic observation performed in rural Timor-Leste communities. Below, we describe each of these data collection methods, along with an explanation for how these data were used to create the diagrams.

3.1. Surveys and Interviews

Developing an understanding of the way that residents in rural *aldeia* (small village) in Timor-Leste manage their water supply required a combination of surveys, interviews and participative observation. Surveys and interviews were conducted at each household within each of the five villages (*aldeia*) sampled. These five villages were selected based on variations in the functionality of the community water system, as indicated by local sources. The research team (researcher and translator) were escorted around each of the five *aldeia* by a village dignitary. At each household, whoever was home was asked to participate in the interview. Interviews were conducted in five villages; in the first *aldeia*, interviews were conducted at 14 of the 29 households in the *aldeia*; in the second *aldeia*, interviews were conducted at 15 of the 18 households in the *aldeia*; in the third *aldeia*, interviews were conducted at 31 of the 51 households in the *aldeia*; in the fourth *aldeia*, interviews were conducted at 18 of the 21 households in the *aldeia*; and in the fifth *aldeia*, interviews were conducted at 16 of 31 households in the *aldeia*. Interviews were conducted with any member of a household, so that a range of perspectives could be garnered. Demographics included males and females aged from 18 to 70 with various levels of education and positional responsibility in the *aldeia*. Each household interview was unique, as we often needed to specifically respond to the interviewee and the situation. Because of this, interviewees who were comfortable to chat in front of the group were often asked more probing questions than those who were obviously ill at ease with the attention. However, each interview included the following questions at a minimum:

- How many people live in this household?
- Who collects water for this household?
- Where is the water collected from?
- How long does it take?
- How much water is collected for the household each day?

Further questions, given the flow of conversation, included:

- What do you do if there is no water available?
- What have been the biggest changes for you since a water system was implemented in your *aldeia*?
- What does the GMF (Groupo Maneja Facilidade) do in this *aldeia*?
- Can you describe what you use water for in a typical day?
- Is there anything else that you want to tell me about the water situation?

3.2. Ethnographic Participative Observation

Staying with a family in each village for 3 to 4 days allowed us to have longer conversations with the family members and to participate in daily activities, including collecting water and food, cooking and washing up. This formed the basis for participative observations, which were diarised every day. The researcher's perspective as a "cultural outsider" was balanced by the translator who was happy to provide cultural information and who understood, through her lived experience, the routines of life in an *aldeia*. These rich interactions allowed us to gain deep, process-based insight into community dynamics.

3.3. Developing Causal Loop Diagrams

CLDs were formulated in an iterative process based on analysis of data from the three sources described above. These diagrams were then post-tested for verity with local NGO staff. We then conducted a further interrogation of model implications (*i.e.*, if factor *X* increases, does factor *Z* increase or decrease? Do we know why?) through critical analysis with fellow colleagues and practitioners.

4. Results and Discussion

Here, we present and discuss the results from our data collection and analysis using the CLDs created from the data. First, we present and discuss the CLDs for the CBM schemes in Timor-Leste, focusing our attention specifically on water quality, quantity of time to access, the system and cost, and then proceed with the presentation and discussion of CLDs representing local NGO dynamics. We then combine these CLDs to display the interrelation and dynamics between NGOs, funders and communities. We conclude by discussing the practical implications of this structure in the form of leverage points that inform improvements in water service programming.

4.1. CBM Dynamics in Timor-Leste

For local NGOs and small rural communities in Timor-Leste, the factors that appeared to drive the longevity of water systems after implementation were dominated by the design, implementation and maintenance phases of spring-fed systems in particular. In Timor-Leste, most small rural water systems are designed by local NGOs or small business, ratified and funded by an INGO or government agency and, thereafter, maintained by the community through a GMF (Groupo Maneja Facilidade), which is a local CBM group. GMFs are generally chosen by the community, are given some training and are expected to volunteer their time to maintain a water system that is used by the whole community. These GMFs are legislated under Decree Law No. 4/2004, and their activities are further outlined in the Timor-Leste Rural Water Supply Guidelines [41].

Limitations to successful CBM in Timor-Leste, which appear to be in agreement with those illuminated in the highly-regarded study of CBM programs in Africa by Harvey and Reed [23], include a lack of long-term incentives for individuals to manage the supply, emigration from the community, lack of trust in the committee (usually related to lack of transparent accounting), funding shortfalls for larger repairs and lack of external support or communications for CBM projects. As the reader will notice, this follows a similar scheme to that identified by Willetts [37], which we presented earlier as our conceptual framework for CBM-service dynamics. Interpreting and adapting these cycles to standard system dynamics notation, and teasing apart some of the influences, results in Figure 5, which identifies more accurately the direction of causal influences within the feedback loop. We note that Willetts uses Figure 4 purely as a simplified descriptive tool and makes no assertions based on the interpretation of it. Therefore, redrafting of the virtuous and vicious cycles into the CLD presented in Figure 5 gives a more nuanced understanding of cause and effect within even this simplified schema.

Our previous causal structure based on Willetts' [37] in Figure 4 indicates that the transparency of fee collection has an impact on the disbursement of funds. Figure 5 presumes that while the transparency of accounting will impact the willingness of community members to pay fees, it does not have a direct impact on the disbursement of available funds, as these are disbursed based on the GMF's capacity to manage the O & M of the water system. Similarly, in Figure 4, the conduct of O & M appears to be influenced by three factors: disbursement of funds, availability of skilled technicians and availability of parts. Figure 5 makes it clear that while O & M is impacted by these factors, the availability of parts and skilled technicians are not directly affected by the disbursement of funds. Thus, while our preliminary conceptual representation of community dynamics based on Willetts' designation of vicious and virtuous cycles in community water management in Timor-Leste highlights an existing feedback loop, this is slightly inaccurate as an analysis tool for indicating possible points of intervention in the continued functioning of rural water supply systems.

In assessing the other drivers of sustained functionality, through GMFs, the amenity of the water system was found to be crucial, that is: what is the value to users of the water supply, and what value is added to the lives of users? Factors identified within water systems as being crucial to maintaining good health are water quality, time or distance to access, quantity available, reliability of access and cost and ease of management [42]. With the exception of management, these factors are also identified as shortcomings in the measurement of Millennium Development Goal 7c "to halve the proportion of people who are unable to reach or to afford safe drinking water". Clasen [43] notes the this goal is measured on the basis of households using an improved water source, but that this does not take proper account of the reliability, quality, quantity or time to access water and that these are all significant factors in the improvement of health. For this paper, water quality, time to access water and quantity of water available are grouped together as "amenity" due to their nature as being relatively fixed once a water system has been implemented in a community. The reliability of access and the cost of water can change after a system is implemented and are therefore considered separately.

4.1.1. Amenity: Water Quality, Quantity and Time to Access

Using the results of ethnographic observations and interviews regarding the availability of improved water sources in Timor-Leste, we found it apparent that the overall amenity of new systems is low: most citizens still need to boil water in order to ensure its safety, and few have enough water available to drink, cook, wash clothes and bathe without resorting to unimproved sources. The quantity of water made available through most new systems is not predicated on the full needs of an expanding village population, but based on either the minimum standard or the recommended standards for current household needs only of 30 to 60 L per person per day [41].

Surveys and interviews were conducted in five villages with spring-fed water systems, in 2013. On the basis of these, it is apparent that the amount of water each household collects, each day, is based on the amount that can be carried, the distance to be carried and on the household needs for cooking, drinking and minimal cleaning. Regardless of the number of people living in a household, the quantity of water carried to each household is rarely more than 100 L and is mostly significantly less than this (see Figure 6).

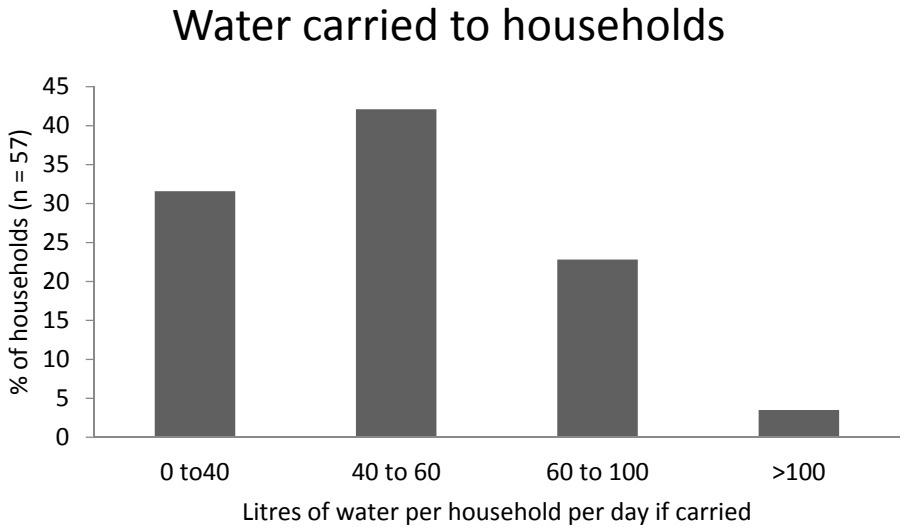

Figure 6. Water used at the household level [44].

It was observed that water was rarely carried to the house for washing clothes or bathing purposes. In households where water is available directly to the house or yard, it was observed that bathing is often conducted in purpose built structures, usually a concrete slab and *mandi* (small open concrete water tank), surrounded by bamboo walls. Washing of clothes is also done at home if water is piped to

the house. If water is plentiful, but only available at a nearby water point, then bathing and washing might be conducted at the water point depending on privacy, gender and local agreements about communal use of water points. If water supply from the protected source is limited, then bathing and washing are conducted at the nearest (or best) alternative source: a river, pond or spring. The need to carry water, even a short distance, results in a significant reduction of amenity, as bathing and washing water is not carried back to the household. One of the rare exceptions to this is for women who have recently given birth. It is traditional for postpartum mother and child to be confined to their own house for a period of time, and the mother is not expected to work, cook or go out to wash. Family and friends help by contributing their labour to provide water, meals and child care for older children.

Figure 6 shows total quantities of water carried from taps to households. When the same data are used to analyse the amount of water available at the household for each person in the house, the range of water supply is between 2.5 L per person per day and 36 L per person per day (see Figure 7). The higher volumes here reflect two unusually small households and where a woman had recently given birth.

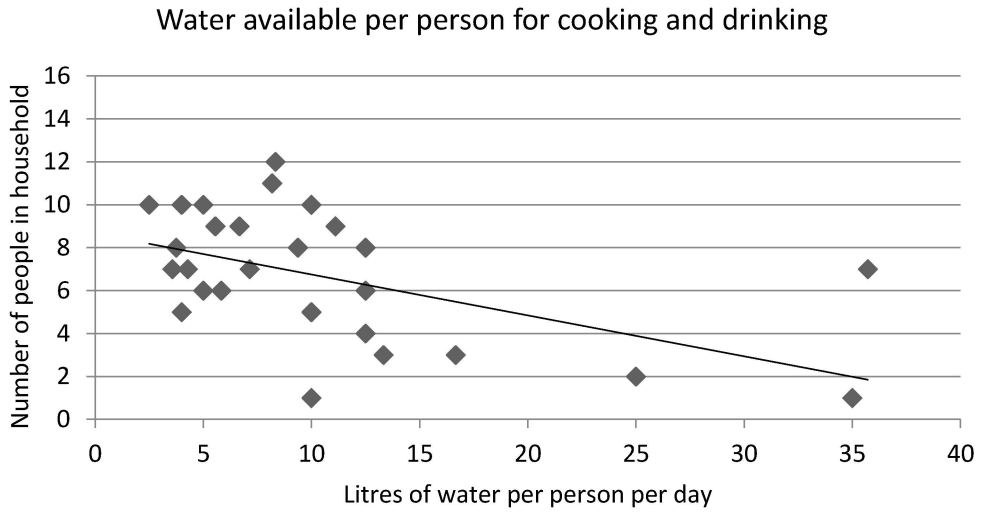

Figure 7. Water available per person at households [44].

4.1.2. Reliability

Grumbley and Hamel [45] report an overall lack of technical reliability of newly-implemented systems in Timor-Leste, combined with the likelihood of breakage through natural phenomena or through various forms of vandalism (see Figure 8). New systems are therefore unlikely to remain in a fully-functional state for very long. The wet and dry seasonal climate sees reduced water flow from springs towards the end of the dry season, which impacts the refill rates of tanks and therefore the amount of water available at the taps. Together, poor functional reliability and seasonal fluctuation in water flow mean that communities do not come to "depend" on the water system as a source of everyday water. The lack of dependability of the systems creates a situation where communities and individuals have less investment in the ongoing repair and maintenance of the system as a whole. Our interview data support the case that communities are often prepared to (or resigned to) access unimproved water sources on a regular basis. For example, this excerpt from the field notes indicates that in one *aldeia*, an old lady who lived alone indicated that normally, she: "Goes to the tank to wash her clothes. If the tank is dry then she just waits because she is too old and frail to carry water from the spring. If this goes on for long she will carry water from the spring but will seriously constrain the amount that she uses." [46].

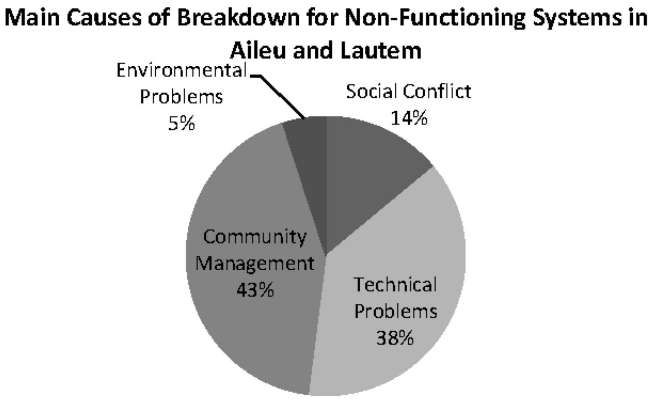

Figure 8. The main causes of the breakdown for non-functioning water supplies in two rural districts in Timor-Leste [45].

4.1.3. Cost

Rural water supply in Timor-Leste, as managed through GMFs, requires each household to pay a monthly fee as a contribution towards ongoing maintenance and repairs of the system. The fee is supposed to be set according to community agreements. In reality, the fee is usually the amount suggested by the implementing local NGO, at around 25 c per month per household. From interviews, it appears that this amount was generally considered to be fair and a relatively easy amount for most people to pay; one response, via an interpreter, was "25 c (per month) is ok; it doesn't matter, it is easy and he could pay more" [46]; this response was quite consistent across villages, and deeper questioning indicated that many families would pay up to $1 per month, if they are happy with the water system.

Overall, in terms of amenity, there is evidence that while cost to users is not onerous, the reliability of the system, the quantity of water available and the quality of water remain problematic. There is also evidence that amenity is increased when water is available to households without the need to transport it from a distance. Ideally, water should be available by pipe or hose to the yard of each household. The CLD shown in Figure 9 represents the assertion that the amenity of design has a direct influence on community satisfaction, which will, in turn, influence the willingness of the community to maintain (or contribute to the maintenance) of the system. Once built, the amenity of the system tends to remain static: the initial stages of the design and building of the system must include the highest amenity for every community member, as these factors tend not be influenced by ongoing processes.

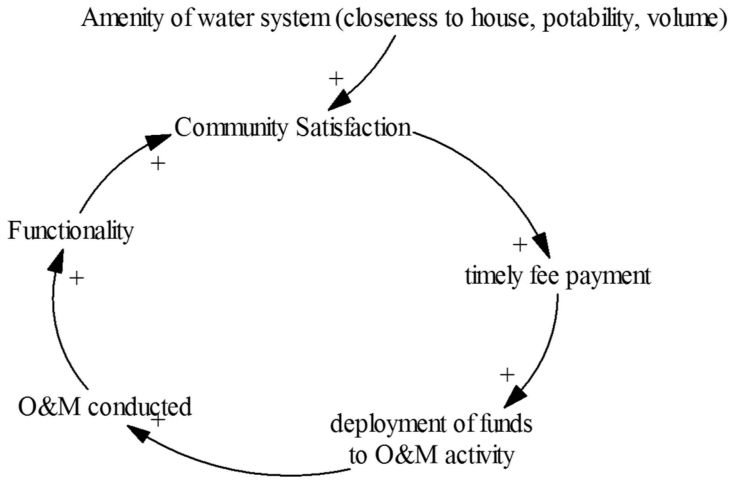

Figure 9. CLD of amenity, satisfaction and maintenance.

4.2. Local NGO Dynamics in Timor-Leste

It is known that pilot studies are often much more successful than any following roll out of up-scaled projects based on them. In discussing this type of phenomenon, Mansuri and Rao [47] state that: "it is difficult to replicate the success of a highly motivated group of charismatic individuals who are able to sustain a long-term vision of structural transformation through dedication, patience, and creativity. When tasks are handed over to salaried professionals, motivated by more mundane preoccupations such as wages and promotions, incentives change." [47] (p. 332).

The tendency within development for NGOs to conduct pilot studies using foreign professionally-qualified development staff and then upscale through the recruitment of local NGOs and poorly-qualified local staff creates issues around expectations and goals. For local NGO staff (such as those interviewed in this study) implementing the upscaled project plans of international NGOs, the factors that motivate are more likely to be pragmatic—wages and promotions—than entirely founded on an altruistic, utopian ideal of equality of resource access for all. Townsend and Townsend (2004) [48] summarise the motivations of expatriate and local NGO staff: "Motivations are necessarily complex, and the vast majority are not motivated primarily by considerations of care and caring".

Additionally, when motivation is altruistic (or caring): "The audit culture, through its concentration on accessible and readily measurable 'indicators' (and often on financial input rather than output), not only costs time but tends to distort staff motivation and behaviour. Caring, then, is increasingly audited for procedural efficiency, for cost cutting and for service delivery rather than for the difference actually made."[48].

In Timor-Leste, unemployment is high, estimated at 18.4% in 2010 [49], with ~80% of residents reliant on subsistence farming for survival [50]. Our interviews and observations both pointed to the significance of waged work in increasing cash flow for rural families. Local NGO staff were observed to be motivated by and trained towards completion of a number of systems per year, rather than focusing on sustained quality outcomes. For locally-staffed NGOs, the drivers of work quality, through participatory practices and good design, are likely to be in tension with, or undermined by, the drivers of project completion and reporting. Figure 10 indicates this tension as a strong reinforcing loop between payment and completions, but no apparent feedback loops associated with robustness of engineering (*i.e.*, the quality or durability of the technology used) and building water systems, nor with the use of participatory practices in the field. Robust implementation and the use of participatory practices, in this example, do not influence the ongoing activity of local NGOs, whereas the numbers of systems completed do.

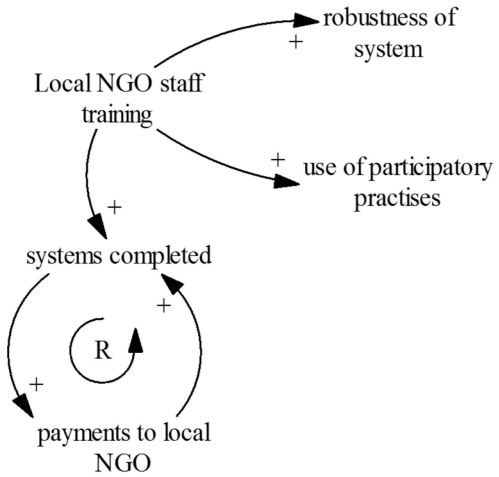

Figure 10. Feedback to local NGOs; payment on the basis of completions rather than quality of implementation.

Based on these CLDs, creating feedback between local NGOs and their use of participatory practice and robust implementation would require an influence that makes community satisfaction and sustained water supply visible and that creates an appropriate incentive to maintain a particular standard. Thus, it appears that no amount of incentive would change behaviour if the skills and understanding for good practices do not exist or if there is an equally strong balancing loop that reduces the incentive. An example of this might be the increased time taken to complete each system when participatory community development practices are fully implemented.

4.3. Combined Influence of NGO, Donors and CBM

So far, this paper has presented a number of CLDs that effectively stand alone as a way to describe the dynamics of NGOs and communities. One of the strengths of the system dynamics modelling, however, is that these CLDs can be combined to create a broader picture of the situation and improve our understanding of the relationships between different levels of interaction. Bringing together Figures 3, 5, 9 and 10 and including factors, such as cost per system, creates a CLD that explicates the connections between donors and local water systems' implementation (Figure 11).

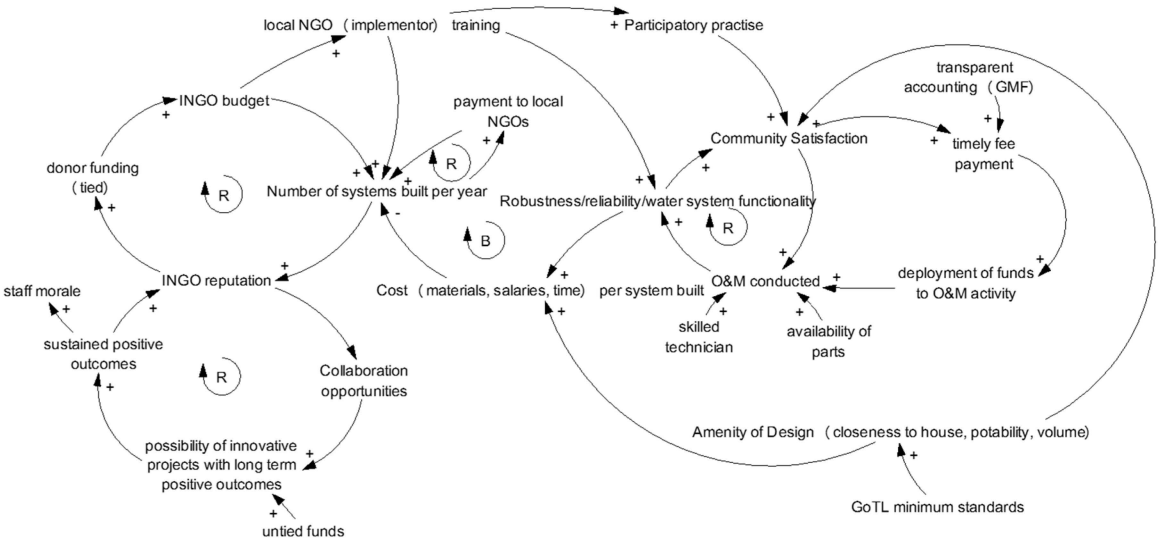

Figure 11. Combined CLD showing multi-level influences in community water systems' implementation. GMF, Groupo Maneja Facilidade.

We realize that Figure 11 does not designate all of the possible causal loops, as this would be particularly difficult to read. It is worthwhile noting, however, that while there are several clear reinforcing loops, the balancing loops are all those that include costs, being as it is the only variable that acts to directly reduce the number of systems built per year. Here, we make the assumption that the higher the amenity and robustness of the system, the higher the costs will be. This effectively points out that if NGOs focus on high amenity and high robustness, each system will cost more, but there will be payoffs in terms of community satisfaction and a higher likelihood of repair and maintenance of systems over time. Thus, all of these factors will be necessary to ensure sustained adequate water supply.

Martens [51] posits that almost all types of aid organisations, including non-government organisations (NGOs) and multilateral development banks (MDBs), exist in order to trade off transaction costs against certainty and negotiated aims and outcomes. He states that "the feedback loop between recipients and decision-makers is broken" [51] (p. 1), meaning that recipients of aid (individuals or countries) have little say in the application or timing of aid. Figure 11 supports this assertion, as the only identifiable feedback between community satisfaction and INGOs is the balancing

loops that create the tension between community satisfaction and increasing reach of NGOs. Indeed, there is no causal loop that rewards INGOs or local NGOs for working with communities to develop sustained adequate water supply.

Using the information available regarding the existing causal loops in Figure 11, there are several informative leverage points that may be used by practitioners to influence the outcomes of water system implementation. Figure 11 clearly indicates that points of intervention must have a way to increase the community satisfaction/O & M loop. Following community satisfaction back through its pathways (arrows that feed into community satisfaction), we find the following influence chains:

- GoTL (Government of Timor-Leste) minimum standards → amenity → community satisfaction

Increasing amenity either through legislation or by other means would thereby contribute to higher satisfaction. Other means to improve amenity would include voluntary instigation of more robust systems that include household pipes and accessible point of use water treatment.

- Local NGO training → participatory practice → community satisfaction

Improving the training of local NGOs to incorporate genuine participatory practise and creating links between the application of participatory practice and payments provides another method of increasing satisfaction. Ultimately the improvement in community participation should also lead to an improvement in amenity as communities are free to choose water supply strategies that will provide the highest amenity.

- Local NGO training → robustness → community satisfaction

Training for robust implementation would see local NGO staff well qualified to create water systems that are appropriate for different contexts and responsive to community desires, rather than implementing the current "one size fits all" system.

These leverage points in the broader dynamics of rural water implementation are examples of influences that exist and of influences that could be brought into existence. From Figure 11, it is possible to see that increases in robustness and reliability have a positive impact on community satisfaction, but also drive up the costs of implementation. Ultimately, in order to see sustained adequate water supply delivered through spring-fed, community-managed water systems, it will be important for communities' satisfaction to become part of a reinforcing feedback loop that impacts the behaviour of both local and international NGOs. As this is currently non-existent, it may be worthwhile to initiate a form of reward system that sees that communities and local NGOs are rewarded on the basis of sustained water delivery. Additionally, as more and more new systems are implemented, it becomes more urgent that we look back to see if the old systems are still working. Ultimately, if old systems are breaking down, then reporting merely on new user access convolutes the true impact, as the numbers of people who can reliably access plentiful, good quality water is not increasing at the rates that are reported.

5. Conclusions and Implications

This paper has applied causal loop diagramming techniques from the system dynamics field to understand a key set of drivers affecting the building and maintenance of small, spring-fed water systems in rural areas of Timor-Leste. Development activities tend to be predicated on "idealist" thinking that stems from the successful delivery of well-resourced pilot projects. When reality intrudes on this form of idealism, with its messiness, uncertainty, lack of results and unexpected outcomes, it is essential to try to see the activity in its real aspects as opposed to its ideal aspects. In the water sector, this includes looking at all stakeholders and the drivers of particular behaviours related to the design, building, use and maintenance of water systems. In this study, we focused our intention on developing CLDs that include relationships between donors, international NGOs, local NGOs and

communities, as stakeholders of water supply activities. Within this paper, we identified the feedback loops that drive particular behaviours within the sector and highlighted some areas where changes may be applied to garner better results in terms of sustained adequate water supply. Areas of future focus could include the training of local NGO staff in both the technical and philosophical aspects of water supply development and careful application of contracts to ensure that individuals are rewarded on the application of participatory practices rather than solely on the reporting of infrastructure built. In addition, there may be room for some type of exogenous encouragement related to evidence of long-term (3+ years) functionality of the systems built. This could be enacted by either donors or by international NGOs applying untied funding and could apply to communities or to implementing NGOs. Also highlighted is the need for improvement of water service amenity, especially with regard to distance. A tap or hose to the yard, with enough water for all household uses and some gardening, has an amenity high above that of carrying water any distance. The act of carrying water creates an inevitable and undesirable minimisation of water use within households.

At the level of INGOs and donors, the current focus on short-term, project-based reporting is driving increased reach, in line with the Millennium Development Goals, without the concurrent improvements in amenity or reliability that would deliver sustained adequate water supply at the community level. Thus, we argue that using, for example, "sustained adequate water supply" as the criteria for success would focus INGOs on the drivers of the sustained functionality for community-managed water supply, such as the satisfaction for end users, as opposed to focusing primarily on building infrastructure in order to improve their reach and create organisational growth.

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References

1. WASH Sustainability Charter, Sustainablewash.org. Available online: http://sustainablewash.org/wash-sustainability-charter (accessed on 4 January 2016).
2. Musonda, K. Issues Regarding Sustainability of Rural Water Supply in Zambia. Master's Thesis, The University of South Africa, Pretoria, South Africa, 2004.
3. Carter, R.C.; Tyrrel, S.F.; Howsam, P. The Impact and Sustainability of Community Water Supply and Sanitation Programmes in Developing Countries. *Water Environ. J.* **1999**, *13*, 292–296. [CrossRef]
4. Harvey, P. Myths of the Rural Water Supply Sector. Rural Water Supply Network Prospective No. 4. Available online: www.ircwash.org/sites/default/files/RWSN-2010-Myths.pdf (accessed on 4 January 2016).
5. Haysom, A. *A Study of the Factors Affecting Sustainability of Rural Water Supplies in Tanzania*; MCS Water Management, Community Water Supply Option Cranfield University, Institute of Water and the Environment: Silsoe, UK, 2006.
6. Pezon, C.; Fonseca, C.; Butterworth, J. Background Paper: Pumps, Pipes and Promises; Costs, Finances and Accountability for Sustainable WASH Services. In Proceedings of the IRC Symposium 2010: Pumps, Pipes and Promises, The Hague, The Netherlands, 16–18 November 2010.
7. Fogelberg, K. Looking back to move forward in strength: Monitoring of water system sustainability. *Knowl. Manag. Dev. J.* **2009**, *5*, 229–245. [CrossRef]
8. Hoque, B.; Juncker, T.; Sack, R.; Ali, M.; Aziz, K. Sustainability of a water, sanitation and hygiene education project in rural Bangladesh: A 5 year follow up. *Bull. World Health Organ.* **1996**, *74*, 431–437. [PubMed]
9. Montgomery, M.; Bartram, J.; Elimelech, M. Increaseing Funcional Sustainability of Water and Sanitation Supplies in Rural Sub-Saharan Africa. *Environ. Eng. Sci.* **2009**, *26*, 1017–1023. [CrossRef]
10. WaterAid. Sustainability Framework. Available online: http://www.wateraid.org/what-we-do/our-approach/research-and-publications/view-publication?id=0b45ec09-e7d2-43e1-9423-c00f5ff4e733 (accessed on 4 January 2016).

11. AusAid. Australia's International Development Cooperation: Statistical Summary 2008–2009. Available online: http://dfat.gov.au/about-us/publications/Pages/statistical-summary-2008-2009-australia-s-international-aid-program.aspx (accessed on 4 January 2016).
12. Easterly, W. The cartel of good intentions: The problem of bureaucracy in foreign aid. *J. Policy Reform* **2002**, *5*, 223–250. [CrossRef]
13. Kaliba, A. Participatory Evaluation of Community Based Water and Sanitation Programs: The Case of Central Tanzania. Ph.D. Thesis, Kansas State University, Manhattan, KS, USA, 2002.
14. Shaw, D. An Assessment of Rural Water Supply Sustainability in Monze District, Zambia. Ph.D. Thesis, University of Bristol, Bristol, UK, 2012.
15. Srikanth, R. Challenges of sustainable water quality management in rural India. *Curr. Sci.* **2009**, *97*, 317–325.
16. Thorston, R. Predicting Sustainable Performance of Household Satisfaction of Community-Oriented Rural Water Supply Projects: Quantitative Evaluation of Evidence from Ghana and Peru. Ph.D. Thesis, University of North Carolina, Chapel Hill, NC, USA, 2007.
17. Gine, R.; Perez-Foguet, A. Sustainability assessment of national rural water supply program in Tanzania. *Nat. Resour. Forum* **2008**, *32*, 327–342. [CrossRef]
18. Silva, F.; Heikkila, T.; Filho, F.; Silva, D. Developing sustainable and replicable water supply systems in rural communities in Brazil. *Int. J. Water Resour. Dev.* **2013**, *29*, 622–635. [CrossRef]
19. Mukherjee, N.; Wijk, C. *Sustainability Planning and Monitoring in Community Water Supply and Sanitation: A Guide on the Methodology for Participatory Assessment (MPA) for Community-Driven Development Programs*; World Bank Water and Sanitation Program (WSP): Washington, DC, USA, 2003.
20. Jimenez, A.; Perez-Foguet, A. Challenges for Water Governance in Rural Water: Lessons Learned from Tanzania. *Water Resour. Dev.* **2010**, *26*, 235–248. [CrossRef]
21. Schweitzer, R.; Mihelcic, J. Assessing sustainability of community management of rural water systems in the developing world. *J. Water Sanit. Hyg.* **2012**, *2*, 20–30. [CrossRef]
22. Whittington, D.; Davis, J.; Prokopy, L.; Komives, K.; Thorston, R.; Lukacs, H.; Bakalian, A.; Wakeman, W. How well is the demand-driven, community management model for rural water systems doing? Evidence from Bolivia, Peru and Ghana. *Water Policy* **2009**, *11*, 696–718. [CrossRef]
23. Harvey, P.A.; Reed, R.A. Community-managed water supplies in Africa: Sustainable or dispensable? *Community Dev. J.* **2007**, *42*, 365–378. [CrossRef]
24. Richmond, B. *An Introduction to Systems Thinking*; High Performance Systems, Inc. STELLA: Lebanon, NH, USA, 2001.
25. Richardson, G.P. Reflections on the foundations of system dynamics. *Syst. Dyn. Rev.* **2011**, *27*, 219–234. [CrossRef]
26. Sterman, J. *Business Dynamics; Systems Thinking and Modelling for a Complex World*; McGraw-Hill: Boston, MA, USA, 2000.
27. Save the Children. Strategic Plan 2013–2015. Available online: https://www.savethechildren.org.au/__data/assets/pdf_file/0018/6336/Pauls-report-V4.pdf (accessed on 4 January 2016).
28. CARE Australia. CARE Australia Strategy 2010–2015. Available online: http://www.care.org.au/strategy (accessed on 4 January 2016).
29. WaterAid Australia. *Sustainability of Rural Water Supply in Timor-Leste: How Big is the Challenge and How Are We Going to Tackle It?*; WaterAid Australia: East Melbourne, Australia, 2010.
30. WaterAid Australia. Our Strategy. Available online: http://www.wateraid.org/au/who-we-are/our-strategy (accessed on 4 January 2016).
31. World Vision Australia. Supplement to How We Performed to Our Strategy in 2013. Available online: http://www.worldvision.com.au/Libraries/Annual_Report_2014/Strategy-FY13-Supplementary-information.pdf (accessed on 4 January 2016).
32. Oxfam Australia. The Power of People against Poverty: Oxfam Australia Strategic Plan 2014–2019. Available online: https://www.oxfam.org.au/wp-content/uploads/2014/03/2014_strategic_plan_fa_web5.pdf (accessed on 4 January 2016).
33. CARITAS Australia. Strategic Directions 2013–2018 CARITAS Australia. Available online: http://www.caritas.org.au/docs/publications-and-reports/strategic-directions.pdf (accessed on 4 January 2016).

34. ChildFund Australia. ChildFund Australia Strategic Plan 2011–2015. Available online: http://www.childfund.org.au/sites/default/files/publications/ChildFund%20Australia%20Strategic%20Plan%202011-15.pdf (accessed on 4 January 2016).
35. PLAN Australia. Champion for Human Rights: Plan International Australia Strategic Plan 2012–2016. Available online: https://www.plan.org.au/~/media/Documents/Strategy%20Policies%20and%20Procedures/Plan-Strategic-Plan-2012-2016.ashx (accessed on 4 January 2016).
36. DFAT. *Aid Program Performance Report 2012-13*; Republica Democratica de Timor-Leste. DFAT, AG: Canberra, Australia, 2013.
37. DFAT, AG. Timor-Leste. Available online: http://aid.dfat.gov.au/countries/eastasia/timor-leste/Pages/default.aspx (accessed on 4 January 2016).
38. Willetts, J. *A Service Delivery Approach for Rural Water Supply in Timor-Leste: Institutional Options and Strategy*; Institute for Sustainable Futures, University of Technology Sydney for BESIK (Timor-Leste Rural Water Supply and Sanitation Program): Sydney, Australia, 2012.
39. Davis, S. Six Factors for Improving Rural Water Services in Central America. Available online: https://improveinternational.wordpress.com/2014/03/31/six-factors-for-improving-rural-water-services-in-central-america/ (accessed on 4 January 2016).
40. Walters, J.P.; Javernick-Will, A.N. Long-term Functionality of Rural Water Services in Developing Countries: A System Dynamics Approach to Understanding the Dynamic Interaction of Factors. *Environ. Sci. Technol.* **2015**. [CrossRef] [PubMed]
41. GoTL. Timor-Leste Rural Water Supply Guidelines. Available online: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwij1ObL15TKAhXDEHIKHbADDzsQFggfMAA&url=http%3a%2f%2fwww.besiktimor.org%2fPortals%2f0%2fDocuments%2fWSGuidelines%2fSection%25201%2520english%2520final%25202_96dpi.pdf&usg=AFQjCNGjw-gGnopE3iRZzpTz3LuOsYltag&cad=rja (accessed on 4 January 2016).
42. Hunter, P.R.; MacDonald, A.M.; Carter, R.C. Water Supply and Health. *PLoS Med.* **2010**, *7*, e1000361. [CrossRef] [PubMed]
43. Clasen, T.F. Millennium Development Goals water target claim exaggerates achievement. *Trop. Med. Int. Health* **2012**, *17*, 1178–1180. [CrossRef] [PubMed]
44. Neely, K. Research Field Notes, August 2013 to November 2013. unpublished work.
45. Grumbley, A.; Hamel, S. Accountability and Sustainability of Rural Water Supply and Sanitation Infrastructure in Timor-Leste. Available online: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwiqvve52pTKAhWq9HIKHVcxC0sQFggcMAA&url=http%3a%2f%2fwww.ircwash.org%2fsites%2fdefault%2ffiles%2fGrumbley-2010-Accountability.pdf&usg=AFQjCNFOowD2PWXuvS294RGwQ66HEapGOA&cad=rja (accessed on 4 January 2016).
46. Neely, K. Research Field Notes, 31 October 2013. unpublished work.
47. Mansuri, G.; Rao, V. Community-Based and -Driven Development: A Critical Review. *World Bank Res. Obs.* **2004**, *19*, 1–39. [CrossRef]
48. Townsend, J.G.; Townsend, A.R. Accountability, motivation and practice: NGOs North and South. *Soc. Cult. Geogr.* **2004**, *5*, 271–284. [CrossRef]
49. CIA. The World Factbook: Timor-Leste. Available online: https://www.cia.gov/library/publications/the-world-factbook/geos/tt.html (accessed on 4 January 2016).
50. Department of Agriculture. Timor-Leste Village Poultry Health and Biosecurity Program, Australian Government. Available online: http://www.daff.gov.au/animal-plant-health/animal/timor-leste-village-poultry-health-and-biosecurity-program (accessed on 21 August 2014).
51. Martens, B. Why Do Aid Agencies Exist? *Dev. Policy Rev.* **2005**, *23*, 643–663. [CrossRef]