28th WEDC Conference Kolkata (Calcutta), India, 2002

SUSTAINABLE ENVIRONMENTAL SANITATION AND WATER SERVICES

Application of system dynamics for RWSS analysis

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RURAL WATER SUPPLY and sanitation (RWSS) intervention and its impact on rural community is a complex phenomenon. Interrelations of various factors and pre-assessment of perceived change in community with time due to development interventions are critical aspects to assess. Numerous works have been done in this area, nonetheless, analysis of RWSS intervention utilizing the concept of system dynamics (SD) is still perceived to be an innovative approach.

RWSS schemes are being widely developed on the concept of demand response, or internal response of community. However, the RWSS schemes developed on the basis of demand of the local people consists of interventions, which are externally driven such as creating awareness, capacity building and changing attitude of local people. The dominating role may be factors of internal demand or external drive in the whole system. This differs from scheme to scheme depending on various scheme specific characteristics. It is very important to understand the role of the factors (internal demand or external drive) to meet the basic objective of the intervention and sustainability of the RWSS system.

The paper introduces system dynamics (SD) and simple feedback system of cause and effect; it's potential for application in rural community development analysis, especially in RWSS interventions. Application of feedback system for RWSS schemes is made for a generic system demonstrating dynamic behavior and interrelation of various factors commonly used in demand responsive approach. Behavior of the demonstrated feed back system is discussed with the findings of field study made for Detailed Demand Assessment Study (DDAS). The DDAS was carried out for RWSS schemes financed by Rural Water Supply and Sanitation Fund Board (RWSSFB) in Nepal. This work is a separate research study utilizing the information of the DDAS field study to demonstrate versatility of SD and to contribute to some extent to the research need indicated in the earlier WEDC conference. The paper concludes with the future applicability of SD for its substantial advantage in addressing RWSS systems to get a holistic, interconnected and multidisciplinary analysis of cause and effects.

Feed back and system dynamics (SD)

A system is defined as "collection of interacting elements that function together for some purpose" (Nancy R. et al.). The systems approach emphasizes on the connections among the various parts, which constitutes the whole. The nature of systems view of a problem is to cut across disciplinary boundaries and to understand a problem from an integrated viewpoint.

SD is a field of study to address the dynamics of change in any system that contains quantities varying over time, that the forces producing the variability can be described causally and that important causal influences can be contained within a closed system of feedback loops (Nancy R. et al.). These three requirements are seen while addressing the problem definition step (first step) in the SD approach. The SD approach of problem analysis and simulation consists of six steps, presented in Table 1, however the paper only deals with the first two-step of the approach to address the system behavior of RWSS scheme, from development agency's viewpoint.

Problem Definition

RWSS system is dynamics of change that contains quantities, which vary over time, like willingness to pay and participate (WTP/P), demand, availability, incidence of disease (IOD), time saving, productivity, capacity, economic level, service level etc. These forces in RWSS intervention producing the variability can be described causally and causal influences can be contained within a closed system of feedback loops, which is demonstrated in the following section in a generic problem of demand response dynamics.

Table 1. Process of system dynamic approach

Conceptual	1. Problem Definition	Refinement
	2. System Conceptualization	
	3. Model Representation	
Technical	4. Model Behavior	
	5. Model Evaluation	
	6. Policy Analysis & Model Use	Application

RWSS problem is seen from the internal demand of community and external intervention as a single system. Introduction of new RWSS system is the result of internal demand, however intervention for capacity building process of the community is externally driven. From the demand side, the governing factors are demand, availability of water, economic and social benefits and willingness-to-pay. Cultural values, people's attitude and awareness are the other factors influencing the system. These are managed externally and are needed for maintaining the system and its sustainability. On top of this, all are varying over time.

Water availability within the community determines the time to fetch the water needed for better health, hygiene and sanitation. Even if, water is available, the community should be well aware to use it optimally and effectively. The lower community awareness, the less effectively water is used and as a result, lower benefit gained than perceived. The nearer the water is available, the less time needed to fetch the water and the more time will be saved, more time will be available for other income generating activities giving higher income level. Higher income level leads to higher capacity to pay and demand for better service level. The saved time has to be used for the productive activities to increase the income level; needing knowledge to be productive and use time and available resources within the community productively, otherwise the perceived benefit of time saving will be counter-productive. Effective supply of knowledge or capacity building in the form of external drive for awareness building to enhance productivity is perceived to be playing a vital role for sustainability of the system.

System Conceptualization

System conceptualization or cause and effect representation of a system is the second step in SD approach. The system may be conceptualized with causal-loop diagrams, plots of variables against time and computer flow diagrams or combination of these three tools, depending upon availability of information. In the paper, system of RWSS problem is conceptualized in the form of causal-loop diagram. The causal-loop diagram includes major feed back relationship that represents the problem raised as well as few external influences that affect the problem. [The external influences in the case of RWSS problem under study are an introduction of the new RWSS schemes and capacity building initiatives.]

The feedback loop (causal loop) system behaves in two ways, while moving around the factors in the loop, the behavior may be termed as positive and negative feedback system. If the feedback system continuously increases or decreases while moving around the loop, it is called positive feedback loop, on the other hand, negative feedback loop is always tending towards the stabilizing situation. The first type of feedback system is reinforcing in nature while the other is goal seeking. The nature of the feedback loop system could further be clarified from the following generic case of RWSS.

Feed Back of Demand and External Drive System

Variation on WTP/P is dependent on benefit gained and perceived to be stabilizing at enhanced economic level by increased time saving and reduced IOD. Refer Figure 1, representing the simplified feedback system of demand. The nature of the feed back loop is goal seeking (conventionally negative), which means the economic level will be stabilizing at certain level of benefit gained through the availability of water, causing reduced IOD and increased time saving. Ultimately the WTP/P will be stabilizing when the equilibrium economic level of the community is reached.

The external drive system in the community is the intervention for awareness, education, training and ultimately capacity building while developing RWSS. The perceived enhancement on the economic level is being reinforced by the capacity and productivity cycle generated by commu-

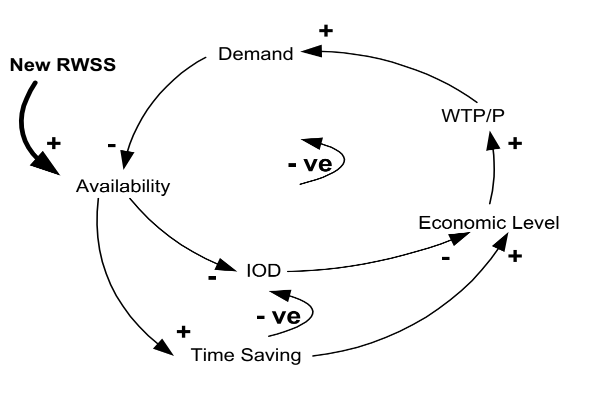

Figure 1: Feed Back of Demand System

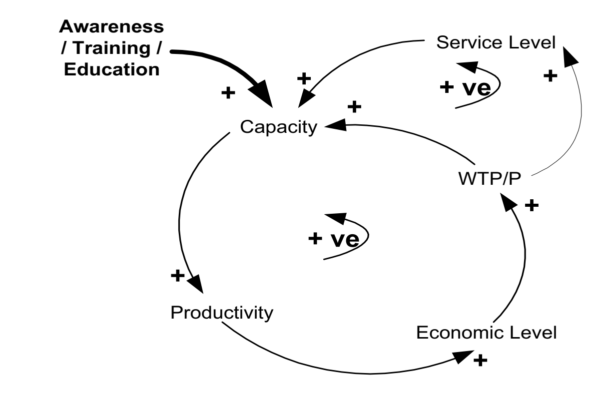

Figure 2: Feed Back of External Drive System

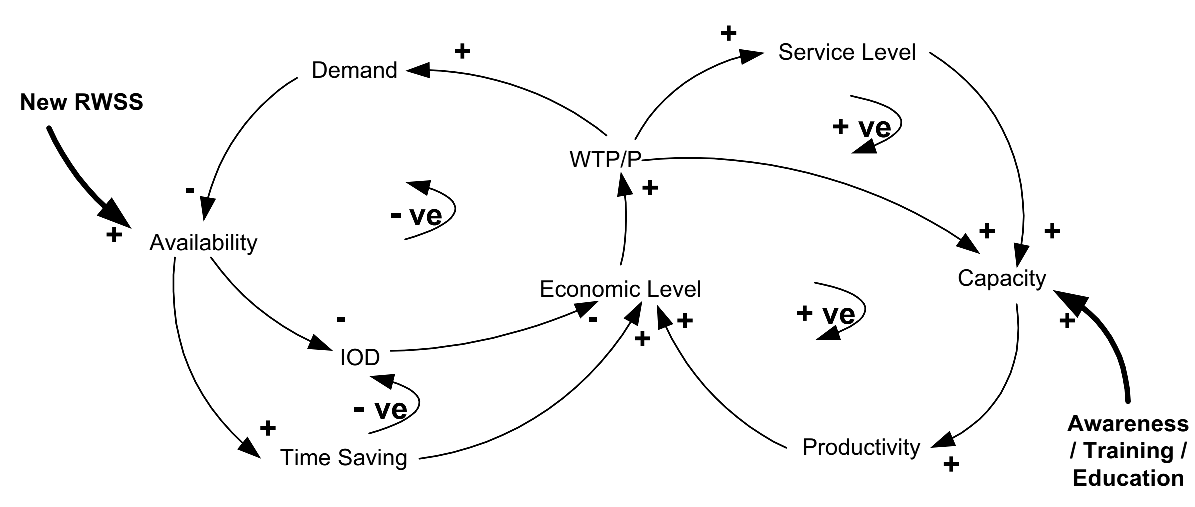

Figure 3: Combined Feed Back of Demand and External Drive System

nity capacity building process, which is driving to increase continuously the economic level, Refer Figure 2. The nature of this feed back system is opposite than that of a demand system, increased capacity of community is always reinforcing to the economic level of the community and ultimately to WTP/P and desired service level. The increased capacity is increasing productivity, economic level, WTP/P and service level. The nature of the external drive feed back system is positive (reinforcing or always forcing to continuously increase or decrease).

Response of Combined Feedback System

Interesting phenomenon occurs when the demand and the external drive feedback systems are combined. The increase in economic level and WTP/P of the second feed back system is reinforcing to become higher/lower demand level in the first feedback system. The net result of demand is dependant on the economic level. The stabilizing nature of demand feed back system has to be positively reinforced from the external drive of capacity with the productively using the gained benefit (decreased IOD and increased time saving) to make the system sustainable in case of lower economic level. The combined feed back of demand and external drive system is shown in Figure 3.

DDAS Finding and The System Behavior

DDAS objective was to develop robust, reliable and cost effective methodologies for estimating demand for rural WATSAN facilities. Which can be used in carrying out pre-feasibility, feasibility and monitoring and evaluation works. The DDAS was made with the agreement on output of i) tools to tentatively determine the willingness to pay for various service levels during the pre-feasibility and development phase ii) improved technique to measure the benefits, taking into account the opportunity cost of time, health benefits as well as productive use of water. The tools proposed by the DDAS included village data sheet, sociometry & wealth ranking; willingness to contribute, bidding games for (basic & enhanced) service level; time savings; medical cost (healthy home survey to monitor health benefit); productive use of water.

The DDAS demonstrated that the increase in WTP/P leads to increase in Service Level, which is true for both the initial investment as well as O&M, leading to demand. In the benefit side, only limited amount of saved time is used in a productive way. The DDAS shows men use only 33% of the time saved productively, which is lesser (25%) in the case of women. IOD is reduced by 50% in case of Cholera and 25% in case of Diarrhoea, with the increase in water supply. While linking demand to benefits, the DDAS concludes, "Benefit of improved water supply does not automatically translate into demand", variation on demand is dependent on quality (test & look) of available water, number of cattle and household's highest education level. In other words, DDAS stated, demand or WTP/P is a product of some un-identified function, perceived benefit and socio-economic variables. Similarly, perceived benefit is product of some other function, expected service level and perceived need (availability). Opportunity cost of time used for fetching water or productive use of saved time is critical in translating improved water supply into economic upliftment of community. While focusing on poverty and sustainability of the RWSS system, initial Economic Level of community and Capacity Building initiative are the critical factors to break the vicious circle of Poverty and Sustainability. Examining these critical issues, DDAS recommended the ways for productive use of time saved and available water with monitored benefit.

Concluding Recommendations

Recommended tools in DDAS are improved version of information collection in isolation and could not fully articulate the behavior in the system as discussed above on response of combined feedback of demand and external drive system. Observation on behavior of the system over time is critical aspect for monitoring and evaluation. The DDAS scope was beyond the research to explore the applicability of the state of the art tool like SD. The author initiated the independent research with the SD approach, covering only two steps, out of six in the approach. The following remaining steps in SD approach for WATSAN analysis is recommended further as a pilot scale research utilizing the tools from DDAS.

Model Representation: Development of model on available SD analysis computer software for representation of feed back system into model, which can be simulated against time with the factors of interest to examine.

Model Behavior: the behavior of model to analyze the represented system with the data / information collected from recommended tools of DDAS. On top of the objective data, the SD model is capable of utilizing mental data (historical behavior observed by key informant or time series information observed in relation to one factor with the other) and should also be explored to put to effective use.

Model Evaluation, Policy Analysis & Model Use: The model running with the data is further to be evaluated for validation of the system behavior. The validated model is expected to be ready to use for rural WATSAN pre-feasibility, feasibility and monitoring and evaluation works. The simulation run of the model with time is perceived to demonstrate the sustainability and poverty focus of the WATSAN schemes under review.

Realizing the complexity in assessment of RWSS interventions for sustainability and poverty alleviation issue, SD is perceived to be an innovative tool with its optimum application to simulate the given RWSS system with the following benefit:

- representation of all major factors associated with RWSS issue in a single system which could be simulated over time.
- simple computer literate support organizations (SO) and support agencies (SA) staff could use the model at various stage of RWSS project utilizing scheme specific information received as recommended by DDAS.
- input information could be cumulative of each house hold (hh), SD model could be analyzed for sensitivity for hh specific information to the cumulative community condition for sustainability and poverty focus.
- capability to use mental database in case of unavailable historical field data (representation of socio-cultural behavior change over time).
- easy to accommodate seasonal variation of availability and variation of factors over time depending upon local condition.
- perceived to be process focused method to forecast and monitor change supported by project.

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