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Research article

Capacity factor analysis for evaluating water and sanitation infrastructure choices for developing communities

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ABSTRACT

40% of the world's population lacks access to adequate supplies of water and sanitation services to sustain human health. In fact, more than 780 million people lack access to safe water supplies and about 2.5 billion people lack access to basic sanitation. Appropriate technology for water supply and sanitation (Watsan) systems is critical for sustained access to these services. Current approaches for the selection of Watsan technologies in developing communities have a high failure rate. It is estimated that 30%–60% of Watsan installed infrastructures in developing countries are not operating. Inappropriate technology is a common explanation for the high rate of failure of Watsan infrastructure, particularly in lower-income communities (Palaniappan et al., 2008). This paper presents the capacity factor analysis (CFA) model, for the assessment of a community's capacity to manage and sustain access to water supply and sanitation services. The CFA model is used for the assessment of a community's capacity to operate, and maintain a municipal sanitation service (MSS) such as, drinking water supply, wastewater and sewage treatment, and management of solid waste. The assessment of the community's capacity is based on seven capacity factors that have been identified as playing a key role in the sustainability of municipal sanitation services in developing communities (Louis, 2002). These capacity factors and their constituents are defined for each municipal sanitation service. Benchmarks and international standards for the constituents of the CFs are used to assess the capacity factors. The assessment of the community's capacity factors leads to determine the overall community capacity level (CCL) to manage a MSS. The CCL can then be used to assist the community in the selection of appropriate Watsan technologies for their MSS needs. The selection is done from Watsan technologies that require a capacity level to operate them that matches the assessed CCL of the community.

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1. Introduction

The World Health Organization (WHO) reports that there are 780 million people worldwide without access to safe drinking water supply and 2.5 billion people without access to improved sanitation service (WHO-UNICEF, 2005). The report does not provide comparable statistics for solid waste service. The consequences of these deficiencies are higher rates of morbidity and mortality from sanitation-related diseases like cholera and diarrhea, and a vicious cycle of poverty, in which the inaccessibility of basic services constrains economic growth, which in turn limits the resources available for investment in basic sanitation services. More than two decades after the end of the United Nations International Drinking Water Supply and Sanitation Decade (IDWSSD: 1981–1990), its objectives are still not met. Between 1980 and 1990, the percentage of the population in low-income countries (LIC) that were not served by improved water and sanitation services declined from 56 % to 31%, and 54%–44%, respectively. From 1990 to 2006, the percentage of the world population not served by improved water service declined from 31% to 13%. However, in the case of access to improved sanitation services, the percentage of the world population without access to improved sanitation only

List of Acronyms: CF, Capacity Factor; CFA, Capacity Factor Analysis; CCL, Community Capacity Level; DC, Developing Community; DWS, Drinking Water Supply; LIC, Low-Income Countries; MDG, Millennium Development Goals; ML, Machine Learning; MSS, Municipal Sanitation Services; MSW, Management of Solid Waste; ODA, Official Development Assistance; TRL, Technology Requirement Level; UNICEF, United Nations Children's Fund; WB, World Bank; WHO, World Health Organization; Watsan, Water and Sanitation; WST, Wastewater and Sewage Treatment.

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decreased from 44% to 38% (UNICEF-WHO, 2012). In its most recent Joint Monitoring Program report, the WHO states that the world met the Millennium Development Goals (MDG) drinking water target in 2010, but warns that the world will not achieve even half of the MDG sanitation target by 2015 for access to improved sanitation (UNICEF-WHO, 2012).

Since the 1970s, Official Development Assistance (ODA) was largely based on technology cooperation, and institutional capacity building (WRI, 1996). From the analysis of the experience of the IDWSSD at the Dublin Conference in January 1992, the international community called for a new fundamental approach to ODA based on the four principles of; holistic management, participatory approaches, women as key players, and water as an economic and social good (ICWE, 1992). Following that, the United Nations Agenda 21 set goals for the international community. The standard basic water requirement for drinking, cooking, cleaning and sanitation was set as 40 L per person per day, a standard that was not precisely defined during the IDWSSD (Gleick, 1996). Furthermore, WHO and the United Nations Children's Fund (UNICEF) implemented a Joint Monitoring Program (JMP) to support countries in monitoring their water and sanitation sector in order to improve planning and management for these services. One important aspect of the JMP is that the users of the services should be involved in all aspects and activities of development of sanitation programs (UNICEF, 1995). This suggests looking beyond technology and institutions in order to increase the effectiveness of interventions to increase access to improved water and sanitation services. This has led water and sanitation ODA to base their strategies on integrated water resources management, in which market solutions, technical solutions, policy reforms, and regulatory solutions are to be implemented in concert, and should complement each other (Guttierrez, 1999). The strategies also require that program objectives include gender equity, social development, health and environmental protection, as well as sensitivity to local financial, institutional, and technical conditions. The World Bank uses the Demand Responsive Approach (DRA) and the Methodology for Participatory Assessment (MPA) as its two main frameworks for the assessment and design of water supply and sanitation services (Dayal et al., 2000).

The MPA provides a complete framework for assessing the sustainability of a project by using a participatory approach of the local community (World Bank, 2000). The subjects of investigation are service systems that are already in existence, with a focus on systems operating steadily for at least one year, in order to gauge the effectiveness of MPA in creating long-lived service systems. The MPA could also be applied to non-functioning systems. The analysis of non-functioning systems is an important source of information about why systems fail and the mistakes to avoid in implementing new systems. These approaches to infrastructure development in lower-income communities recognize the importance of the community's capacity to manage the systems they acquire, i.e. “appropriate technology”. Louis has identified seven capacity factors of a developing community that are key to the success of sustainable municipal sanitation services (Louis, 2002). These capacity factors are Institutional, Human Resources, Technical, Economic and Financial, Environmental and Natural Resources, Energy, and Social and Cultural. However, none of the existing approaches assesses all of these key capacity factors that determine the sustainability of a Watsan infrastructure in a developing community.

A lower income country by classification of the WB includes all countries in the low or middle-income group. Limited access to improved municipal sanitation services (MSS) is primarily a problem of the world's lower income countries, particularly in Asia, and in Africa (WHO-UNICEF, 2005). However, it is important to identify clearly the problem of lower-income communities, which are those most afflicted by the lack of services. This paper defines a lower-income community to be one in which the median household income is within one standard deviation or less of the defined poverty level for the country (Louis and Magpili, 2002). This distinction is necessary to account for the wide variations in income and accessibility to services in lower income countries, where households with median household income that would qualify as low income in industrialized or higher-income countries, enjoy local purchasing power parity and access to infrastructure services that are comparable to those of middle and upper income households in industrialized countries. Conversely, many lower-income households in industrialized countries have incomes that are comparable to the wealthy in low income countries, but face a lack of improved MSS comparable to their counterparts in low income countries. The use of purchasing power parity adjusted for market value of similar baskets of goods, would permit more objective analysis of relative access to water and sanitation services in lower income and higher income countries. Unfortunately such comparative statistics are not routinely available. Thus, it is the poorest communities in any country that tend to be most affected by inadequate access to improved MSS, regardless of the income level designation of the country. Effective ODA intervention should recognize this nuance, and include strategies to reach *lower income communities*, where the need is often greatest (Louis, 2003a, 2003b).

In order to avoid this potentially misleading association with income, the term developing community will be used instead of lower-income community. A developing community (DC) is defined as one which lacks the capacity to provide sustained access to adequate levels of one or more basic human services to its residents with its own resources.

The basic human services are defined as; air, water, food, shelter, sanitation, household energy and personal security. Air refers primarily to clean indoor air. Sustained access is uninterrupted access to scheduled levels of service over the planning horizon of the system that provides the service.

For the purpose of this paper, a community is defined as a group of people that occupy a single defined geographic area, and are supposed to receive public services like water supply and sanitation from a common jurisdiction.

The current approaches for the selection of Watsan technologies in developing communities have a high rate of failure. Indeed it is estimated that 30%–60% of Watsan infrastructures installed in developing countries are not operating. Inappropriate technology is a common explanation for this high rate of failure, particularly in developing communities (Palaniappan et al., 2008). In a recent study published by the Woodrow Wilson Center and the Pacific Institute, Palaniappan et al. (2008) reviewed 120 existing support resources for the selection of Watsan technologies for developing communities. Five types of support tools were identified: evaluation tools, process guides, technical briefs, technical references, and policy papers. After reviewing these 120 decision support resources, Palaniappan et al. selected 18 that provide the most comprehensive decision-making supports to water and sanitation practitioners. However, the conclusion of this comprehensive review was that there exists a need for a decision-making support tool to assist Watsan practitioners in identifying, evaluating, and choosing a technology option that best suits the conditions and needs of a community (Palaniappan et al., 2008).

This paper presents the capacity factor analysis (CFA) model, which is part the decision support framework presented in Fig. 1, and proposed to address this need. The CFA model is used for the assessment of a community's capacity to manage and sustain access to water supply and sanitation services. The result of the assessment can then be used to assist a developing community in

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