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Article

Fuzzy Logic Analysis of the Build, Capacity Build and Transfer (B-CB-T) Modality for Urban Water Supply Service Delivery in Ethiopia

Samuel Godfrey [1], Getachew Asmare [2], Tamene Gossa [2,*] and Michele Paba [3]

[1] Water Supply and Sanitation Regional Adviser, East and Southern Africa, UNICEF, UNON, Nairobi P.O. Box 44145-00100, Kenya; sgodfrey@unicef.org
[2] Water Supply and Sanitation Section, Addis Ababa P.O. Box 1169, Ethiopia; gasmare@unicef.org
[3] Water Supply and Sanitation Section, Lilongwe P.O. Box 30375, Malawi; mpaba@unicef.org
* Correspondence: tgossa@unicef.org; Tel.: +251-115-184179

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Abstract: Rapid urbanization in Ethiopia is resulting in the need for alternative sustainable service models for urban water supply. Contractual arrangements to improve the functionality of urban water services in Ethiopia have included build, operate and transfer (BOT), design, build and operate (DBO), performance-based contracts (PBC) and utility development. UNICEF undertook a review of these modalities and concluded that a modified version of the BOT modality was required to both incentivize private sector engagement in urban water supply and to enhance public sector utilities. This paper describes the contractual modality developed to achieve this aim, namely an Ethiopian build, capacity build and transfer (B-CB-T) modality. This paper tests the applicability of the B-CB-T model using fuzzy logic statistical analysis and concludes that of the four tested variables (internal accountability, external accountability, operation and maintenance and financial management), the most statistically significant was the clear mandate to address complaints and maintain a positive relationship with the clients (users). This paper concludes that the B-CB-T is an effective contracting modality that should be accompanied by appropriate behavior change and social mobilization outreach to maximize tariff, billing, extension and performance of the infrastructure that is administered within the B-CB-T arrangement.

Keywords: build, capacity build and transfer (B-CB-T); BOT; risk factors; fuzzy logic approach; urban water supply; civil engineering contract; procurement; sustainability

1. Introduction

The global obtainment of the Sustainable Development Goals (6.1 and 6.2) requires innovative approaches to improve the engagement of the private sector in both construction and operation of urban water supply systems [1]. Given the global trend towards mass urbanization, in which the urban population of the world has risen from 30% in 1950 to 54% in 2014 [2–6], there is a need to ensure the optimum functionality of urban water supply systems to achieve the SDG targets. Civil engineering contractual methods that have been applied in the literature include the use of concession contracts such as the BOT (build, operate and transfer) modality. The BOT is a private sector participation model in which a project company is established to finance, design, construct and operate a facility for a concession period before it is transferred to the government [7,8]. The BOT entity undertakes financing, design and construction as well as operation and the client takes no direct cost risk other than the possibility that the facility does not meet its needs, or that the concession agreement is unsatisfactory [9].

Other concession methods include the build-own-operate-transfer (BOOT), the design-build-finance-operate (DBFO) and the build-own-operate (BOO) [10–12]. A review of the literature reveals limitations in the application of these models and the need to explore new and additional modalities [13,14]. The World Bank, Millennium Challenge Cooperation and UNICEF were engaged in establishing a delegated management model in Southern Africa. The delegated management model adapted the BOOT and encountered some challenges in secondary cities where government or local level utility capacity was low. Learning from the authors' experience in BOOT implementation in Mozambique, UNICEF in Ethiopia undertook a desk assessment of the existing BOT, BOOT and DBFO arrangements and devised a new management model termed the build, capacity build and transfer (B-CB-T) model [15]. The B-CB-T, more than any other procurement option, offers the possibility of packaging different contractual components into a single legal agreement, and transferring the liability for the infrastructure development and operations to the private sector with expected benefits in terms of a more effective and efficient service delivery. UNICEF Ethiopia has revised the BOT concept to be consistent with the Ethiopian public sector context, without compromising the basic principles of public ownership of assets.

The emergence of public–private sector initiatives, such as build-operate-transfer (BOT), build-own-operate-transfer (BOOT), design-build-finance-operate (DBFO), build-own-operate (BOO) and build, capacity build and transfer (B-CB-T) for procuring infrastructure facilities provides governments with the option of satisfying their infrastructure needs and demands by alternative means. Generally, such means involve a user-pays concept, which invariably can be implemented by governments, yet many governments have preferred to execute the concept through the private sector so as to minimize their financial liability [16]. The procurement of infrastructure projects using these methods requires both the public and the private sector to change their existing approaches, skills, roles, responsibilities and risks so that all the phases of a project's life-cycle can be managed effectively.

The assessment of the efficiency of these models is context specific and there is limited evidence in the academic literature. One tool that can be applied to assess the effectiveness of the contracts is the statistical method termed fuzzy logic [17–28]. These include the application by Kangari in managing the risks during the construction cycle, and by Choi and Carr in identifying the principle risks in construction management [29,30].

The fuzzy logic theory can be implemented as a part of a construction project risk management system which consists of five steps:

1. risk identification,
2. policy definition,
3. risk sharing and allocation,
4. risk analysis, and
5. risk minimization and response planning.

This paper builds on the use of the fuzzy logic technique as a means of assessing the appropriateness of a solution to a specific challenge. This approach has been most recently applied to the regulation component of water resources [31]. The fuzzy logic has also been combined with the analytic hierarchy process (AHP) and other methodologies in selected papers to review the effectiveness of different water supply options [32,33]. This paper describes the application of the fuzzy logic technique to the B-CB-T to determine the statistical significance of specific variables.

2. Materials and Methods

The objective of this research was to identify a statistical tool that could be used to test the validity of the B-CB-T for application in eight small towns in Ethiopia. Using performance data from the eight towns, selected statistical tools were reviewed including logistic regression, analytic hierarchy process (AHP) and fuzzy logic. Based on outputs from the initial trials, this paper focused on the use of fuzzy logic to assess the applicability of the tool. Fuzzy logic is a concept in project risk assessment which is used to decrease errors of risk factors in risk management decision making.

2.1. Build, Capacity Build and Transfer (B-CB-T)

The concept of the B-CB-T, developed by UNICEF Ethiopia in 2013, reflects the principles of the widely known BOT—build, operate and transfer, and is designed to be a more applicable tool for the specific institutional framework of the water supply, sanitation and hygiene (WASH) sector in Ethiopia. Outlined in Table 1 are the key differences and rationale behind the BOT and the B-CB-T which are essential for the understanding of the applicability of the tool.

Table 1. Comparison of the build, capacity build and transfer (B-CB-T) and the build, operate and transfer (BOT).

A	BOT	BCBT
CAPEX and OPEX Financing	Responsibility of the private entity to secure CAPEX (usually through commercial debt) and recover OPEX (through water revenue streams). Profit margins regulate the commercial strategy of the private entity in providing services.	CAPEX is channeled through a national water revolving fund and lent to the Town Water Utilities (TWU) on soft concessional rates. OPEX are generated by water sales by the water utility. There is no interference by the private sector in the utility's commercial strategy.
Asset Ownership	Concession from (public) administration to the private sector entity. The assets are transferred to the public administration at the end of the concession agreement, without any additional remuneration of the private entity involved. The risk associated in the concessional arrangement is related to possible overexploitation of infrastructure to maximize the private sector entity's profit.	Ownership remains with the public sector (water utility). The private sector supports the utility to maximize its efficiency and to properly maintain the assets.
Water Revenue Stream	Within the concessional arrangement, a service charge is usually applied to the water utility (for the private sector to recover the investment and operation costs). Alternative user fees are directly collected by the private operator. In the absence of a strong regulatory framework and stable market, there is a significant risk of overcharging water costs.	Water fees are directly collected by the utility from users without any interference from the private sector. The private sector is supporting the utility to revise and improve existing business plans towards cost-effectiveness and credit-worthiness.
Skills Transfer from Private to Public Operators	Limited unless properly stipulated in the concessional agreement.	On-the-job process, starting during the construction phase, whereby the private sector provides systematic support to the utility in developing required competencies.
Performance of the Private Sector Entity	Main risk associated with the BOT. The performance of the private sector operator is strongly driven by its commitment to recover the investment.	Regulated by a performance-based contract against KPIs and assessed over a 12 month period.

Figure 1 illustrates how the B-CB-T approach adapts to a typical timeframe of a construction contract. The capacity building component starts during the "implementation of works" phase and is finalized within the defect liability period. Through its implementation, the capacity building component is paid off against an agreed work schedule and if the capacity building key performance indicators (KPIs) are met, the final retention payment is released. The performance of the private company supporting the utility is then measured after one year of operation (coinciding with the duration of the defect liability period (DLP)) through KPIs such as non-revenue water, number of new metered and functioning connections and quality of water supplied. Such indicators are then measured at the end of the DLP and if the minimum service level benchmarks (SLBs), set in line with the business plan provisions, are met, then the 10% retention money is released to the private company. If this is not the case, the retention is held until such indicators are met at no additional costs for the client or UNICEF.

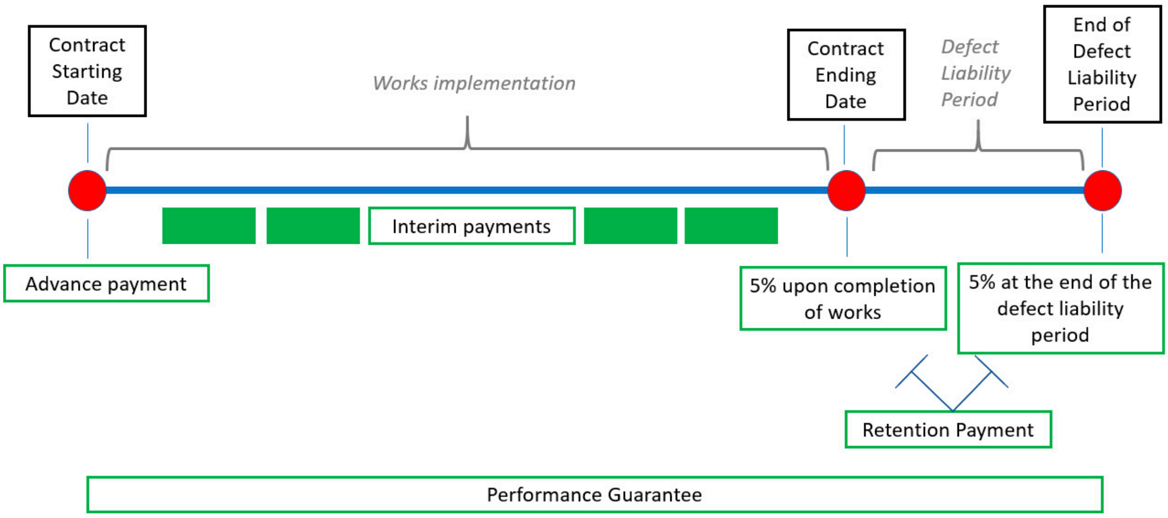

Figure 1. B-CB-T schematic.

To make the B-CB-T effective, the main contractor is required, as part of the tender document provisions, to bid either through a joint venture or a sub-contracting association with consultancy firms with relevant experience in WASH (besides qualified suppliers and drilling company for the "build" component). The consultant for capacity building is part of the main contract and a part of the overall team of the contractor. The principle areas of support provided to utilities cover the establishment of external accountability, internal accountability, operation and maintenance, and financial management.

2.2. Fuzzy Logic

To assess the effectiveness of the B-CB-T, the fuzzy logic concept was applied. The fundamental base of fuzzy logic is that a real number is assigned to each statement written in a language, within a range from 0 to 1, where 1 means that the statement is completely true, and 0 means that the statement is completely false, while values less than 1 but greater than 0 represent that the statements are "partly true", to a given, quantifiable extent. Eight small–medium sized urban water supply system studies have been employed in this sample to demonstrate the application of the proposed model. The synoid function was applied to calculate the statistical relevance of a relationship between the variables using the standard logistic function of:

$$S(x) = \frac{1}{1 + e^{-x}} \tag{1}$$

$$(x) + S(-x) = 1 \tag{2}$$

$$(S(x) + S(-x)) \times (S(y) + S(-y)) \; etc. \tag{3}$$

The primary input variables for the model are outlined in Table 2 below and described in detail in Figure 2.

Variable:

V: external accounability
X: Internal accountability

Y: Operation and maintenance
Z: Financial management

To assess the final project risk, i.e., the level of risk associated with the B-CB-T model, the input variables were assessed using the risk hierarchy outlined below.

Table 2. Risk hierarchy model at company and project levels.

	Company Risk	Project Risk
LEVEL 1	External Accountability	Relationship with users and board Capacity of addressing users' complaints Roles and Mandates
	Internal Accountability	Organizational structure Trained human resources Clear division of roles
LEVEL 2	Operation and Maintenance	Water balance (unaccounted for water/non-revenue water) Assets Management and new connections Continuity of service
	Financial Management	Setting service standards Maximizing the efficiency of service delivery Maximizing the source of revenues

Risks are categorized considering the main functional areas of a town water utility: external accountability, internal accountability, operation and maintenance, and financial management.

3. Results

This paper selected the two variables of external accountability and operation and maintenance for the full application of the fuzzy logic technique. Initial analysis of the four variables revealed that the variables of internal accountability and financial management were not considered to be of high risk. Due to the scope of the paper, no further analysis of these two variables is presented. Outlined below is the risk analysis of external accountability as an example.

Risk Analysis of External Accountability

Three independent variables were analyzed, namely,

1. relationships with users and the board,
2. addressing complaints,
3. a clear mandate

These three risks were entered into the risk inference matrix outlined in Table 3 and were applied in the eight small–medium sized water supply systems.

The results indicate that the ability of a water utility under a B-CB-T contracting arrangement to respond to user complaints and its ability to establish a relationship with its users were considered as the medium to high-risk factors for the success of the B-CB-T. The management of user complaints was more statistically significant than the definition of the mandate of the utility.

A similar analysis was also done for the risks associated with the operation and maintenance of the water supplies. Three independent variables were analyzed:

1. Water balance–unaccounted-for water (UAW),
2. Asset management and new connections,
3. Continuity of service.

The fuzzy logic analysis was applied and it concluded that the operation and maintenance component indicated a lower risk than the external accountability.

Table 3. Risk inference for external accountability.

Fuzzy Logic	Variable	and	Variable	and	Variable	External Accountability
IF	Addressing complaint is LOW		Clear mandate is HIGH		Relationship with users and board is LOW	
THEN						External accountability is HIGH
IF	Addressing complaint is HIGH		Relationship with users and board is LOW		Clear mandate is HIGH	
THEN						External accountability is MEDIUM
IF	Addressing complaint is MEDIUM		Clear mandate is MEDIUM		Relationship with users and board is MEDIUM	
THEN						External accountability is LOW

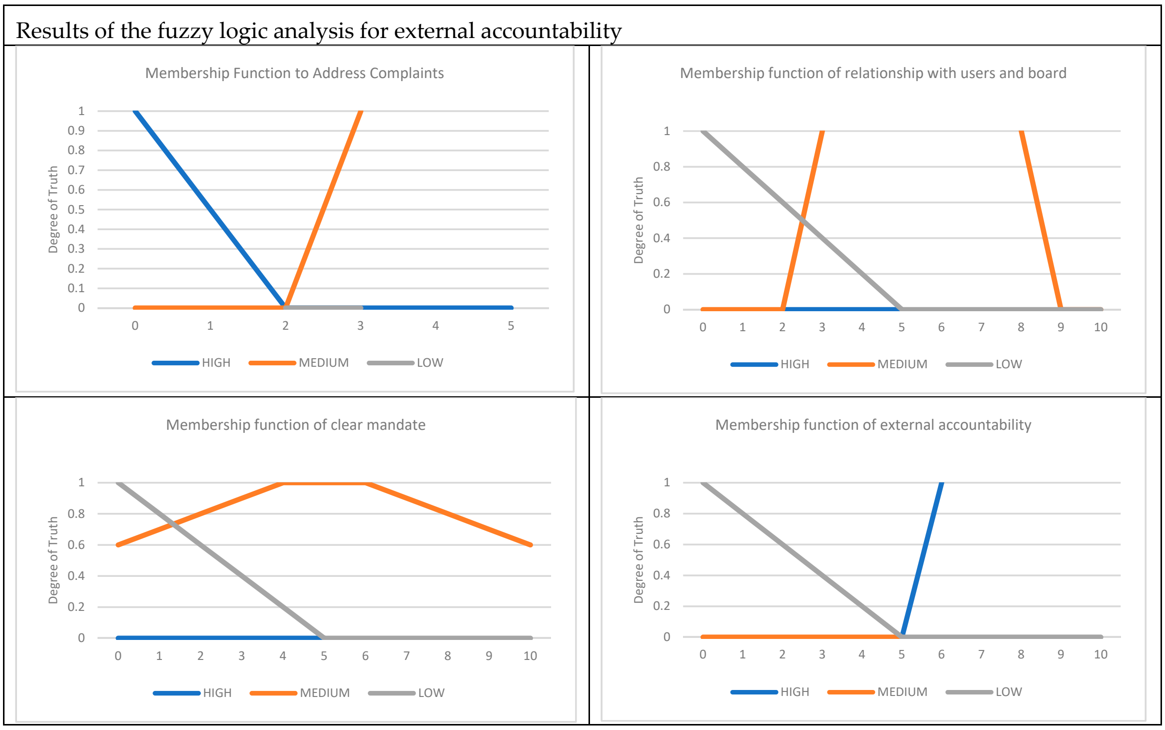

Figure 2. Application of the fuzzy logic analysis.

4. Conclusions

Designing, implementing and monitoring small–medium sized urban water supply systems requires innovative approaches to deal with contract administration. The B-CB-T approach provided the opportunity to address selected risks in administrating both the contract and management of the system. The fuzzy logic technique was applied to select the specific variables that are most statistically significant in the B-CB-T method. The application of the fuzzy logic method proved to be an effective tool to assess the risks involved in applying the B-CB-T approach and it predetermined the thresholds which will help to design the minimum capacity building package for future B-CB-T interventions.

This study has shown that the specific risks analysis and evaluation using fuzzy logic identified the external accountability of the water utility as the biggest risk to success in providing equitable water services through a B-CB-T modality. The paper concludes that of the four tested variables (internal accountability, external accountability, operation and maintenance and financial management), the most statistically significant was the clear mandate to address complaints and maintain a positive relationship with the clients (users). This paper concludes that the B-CB-T is an effective contracting modality that should be accompanied by appropriate behavior change and social mobilization outreach to maximize the tariff, billing, extension and performance of the infrastructure that is administered within the B-CB-T arrangement.

Author Contributions: The research was led by S.G. who provided both the conceptual framework for the research as well as the access to the UNICEF project sites and data. Field data collection was undertaken by M.P. and T.G. Application of the fuzzy logic technique was led by G.A. Authors include 2 Ethiopian experts from the field locations.

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