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Evaluation Scenarios for Water Supply Accessibility to the Urban Poor in Developing Countries: The Case of Dhaka, Bangladesh

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Abstract: This paper develops a robust methodology to aggregate indicators of water supply accessibility by the urban poor in developing countries. The methodology includes both linear and non-linear mathematical modelling. The results obtained are examined in terms of the variation of values from different scenarios and the factors responsible for good or poor performance of urban water supply. The methodology could be used by planners and managers for any type of urban service planning and management.

Key words: Urban poor, water supply, system evaluation, Dhaka, Bangladesh.

Introduction

Water covers a vast area of the world but fresh water is limited. Thus, the price of water in some places is higher than the price of oil. Moreover, oil as a fuel has many other alternatives but water does not. Water is a unique product of the natural system and is an essential requirement for the survival of human beings. At present, over six billion people live on this earth. Some people do not even have enough potable water for drinking and personal hygiene. The urban poor of developing countries are in this category. International agencies such as the World Bank, UNDP and UNCHS have in the past overestimated water supply accessibility by the urban poor because they defined accessibility by only one indicator i.e., quantity of water supply per capita (20 litres per capita per day) and ignored other indicators of a water supply system. Even their definition of water supply accessibility is inhuman, because a human being needs at least 30 litres water per day for drinking, cooking, bathing and personal hygiene. A recent study identified the indicators of potable water supply accessibility (Akbar, 2005). This paper aggregates these indicators using both linear and non-linear aggregation techniques in assessing water supply accessibility by the urban poor in developing countries. Here, evaluation scenarios refer to the mathematical techniques of aggregating the indicators in order to derive an index which will reveal the overall performance of the water supply systems in urban informal settlements. Case study data on water supply systems used by the urban poor in Dhaka City, Bangladesh, have been used to examine the overall performance of the indicators over different evaluation scenarios.

Aggregation of Indicators

Aggregation of the values of a number of indicators could be made by using either a weighted average (WA) or ordered weighted average (OWA) (Yager, 2004; Smith, 2000-2001; Nijkamp et al., 1997); the former is a linear aggregation operator and the latter is a non-linear aggregation operator. Here both the methods are used,

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though the OWA operator is developed as a more general aggregation. The OWA operator allows users to decide what type of aggregation operators will be used, implying a particular attitudinal character. Thus this method has recently emerged as a very flexible system of aggregation. To gain a complete understanding of both methods of aggregation, it is necessary to know what these are and how they are structured.

Responses to a household survey of the urban poor living in slums and squatter settlements against each indicator were standardized by a "fuzzyfication" procedure and then 'importance' weights for indicators were derived using the analytic hierarchy process (AHP). Standardized values of the indicators were multiplied by the weights in order to yield weighted values, and these weighted values were aggregated using the WA or OWA operator.

Key Indicator Selection

The term 'indicator' means something that gives information, or shows something, or points out something (Flood, 1997). Indicators can work as problem identifiers, as performance evaluators, as an empirical interpretation of reality, as a source of systematic knowledge, as a management tool and as a tool for policy analysis (Flood, 1997; Fiadzo, 2003; Stork et al., 1997). Thus indicators act as a symbol to describe the present situation of any phenomenon and at the same time indicate what improvements are needed in future.

Generally, an indicator is developed through an understanding of the fundamental principles and relevant criteria for any given phenomenon (Stork et al., 1997). One indicator may contain one or more verifiers depending on the purpose of the study and the local condition of a phenomenon. A verifier is the source of information for the indicator and also is the reference value of the indicator. Actual assessment of performance of a certain phenomenon should be based on the verifiers of the indicator. Indicators can be measured in the field as well as from behind a desk. Indicators should be in the form of derived figures, which could be simple statistical or mathematical measures such as averages, rates, ratios, proportions, percentages, quartiles or deciles.

The selection of indicators generally depends upon the objectives of their use and user priorities, timeliness, availability and accuracy of data, cost and feasibility, tools and techniques to analyze, completeness and comprehensibility (Rao, 1978). Indicators need to be easy to understand and simple to apply in order to gain effective acceptance at all levels i.e., global, regional, national and local (Stork et al., 1997). By following all requirements for indicator selection, a study (Akbar, 2005) identified indicators of potable water supply accessibility and information about these indicators through a sample survey (i.e., two-stage random sampling) in the slums and squatter settlements of Dhaka city. Based on this study, fourteen indicators are selected here, leading to twenty seven verifiers (see Box).

Indicators and *verifiers* for performance evaluation of UWS to the slums and squatter settlements in Dhaka city

Biophysical indicators: (i) sources of water (*1-3. sources of water for drinking/cooking/washing and bathing purposes*); (ii) physical accessibility of potable water (*4. distance between the home and the sources, 5. water consumption per capita, 6. queuing for collecting water*), (iii) water quality (*7. cleanliness of water*); (iv) sustainability of the source (*8. sign of damage in the source*).

Political indicators: (v) Political commitment (*9. given political commitment; 10. implemented political commitment*).

Institutional indicators: (vi) Legal practices (*11. legality of the access to the system; 12. corruption in the system management*), (vii) Organizational capacity (*13. efficiency in service delivery; 14. system monitoring at household level*).

Economic indicators: (viii) ability to pay (*15. ability to pay capital cost; 16. ability to pay user charge)*; (ix) willingness to pay (*17. willingness to pay capital cost; 18. willingness to pay user charge*).

Social indicators: (x) community participation and capacity (*19. community demands; 20. people's participation in maintenance; 21. Household (or social) awareness to pilfering water*); (xi) water is treated as social good (*22. satisfaction with the water supply system*).

Technical indicators: (xii) planning and design standard (*23. user-friendly repair and maintenance at household level*), (xiii) reliability of water supply (*24. satisfaction with the water pressure; 25. duration of water supply; 26. technical performance of the system*), (xiv) water conservation (*27. technical system loss*).

Source: Akbar, 2005

Standardizing Data by Fuzzy Membership Value

The notion of fuzzy sets was conceptualized by Lotfi Zadeh in 1965 in a seminal paper. He described a fuzzy set as a class of objects with a continuum of grades of membership in the interval [0, 1] (O'Hagan, 2003). This idea stands in contrast to the conventional set theory in which objects have only membership (characteristics function) values taken from doubleton set {0, 1} (Heikkila, 2003). Fuzzy sets allow one to model gradual transition from membership to non-membership and vice versa (O'Hagan, 2003). For instance, the result expresses a fuzzy membership grade (also called possibility) that ranges from 0.0 to 1.0, indicating a continuous increase from non-membership (e.g., no quality of life or worst state) to complete membership (e.g., full quality of life or ideal state), on the basis of the indicators being fuzzified (Mendes and Motizuki, 2001). Sometimes the lowest level of satisfaction or the performance cannot be zero because the person might have some satisfaction with the lowest level of services (O'Hagan, 2003). Thus this study uses fuzzy set theory to obtain degree of membership value (DMV) for elements of the indicators of potable water supply.

The membership value of the best quality or best performance of water supply services or high satisfaction with services under the given situation has been considered as equal to one (1) such as a household tap connection. This is considered as the safest and most accessible source for the informal dwellers. Unsafe sources such as river, pond or canal water are not regarded as zero, because those sources have a minimum level of importance to the informal dwellers. Therefore, worst performance is considered to be 0.10 rather than zero. None/no/completely negative or the clearly end point of a negative characteristic is considered as equal to zero (0), such as illegal access to the water supply and no monitoring by the water providers. The membership values between 0.0 and 1.0 or 0.10 and 1.0 are calculated with equal proportional intervals.

Weighting Indicators by Analytic Hierarchy Process

The main challenge of aggregating indicators to generate performance scenarios is in the choice of relative 'importance' weights. Although weighting variables/indicators is subjective and somewhat controversial in theoretical terms, the relative importance of variables is widely used in social sciences and planning disciplines. Amongst several methods available to determine relative weights, a convenient, reliable method is analytic hierarchy process (AHP) introduced by Saaty (1977).

AHP is also known as a pairwise comparison method in which each criterion is compared with each of the other criteria in terms of relative importance. Relative judgements are assumed to be more easily generated and to be more meaningful than absolute judgements (Smith, 1980). Pairwise comparisons are considered to be 'reciprocal' such that, for example, if the dominance of A relative to B for criterion C_1 is say '5', then the dominance of B relative to A for C_1 must be '1/5'. Numbers 1, 3, 5, 7 and 9 are associated with verbal expressions of dominance (respectively 'equal', 'weak', 'strong', 'very strong', 'absolute') and the numbers 2, 4, 6 and 8 represent intermediate values between adjacent scale values. AHP can be used to differentially weight the indicators in terms of importance in assessing water supply accessibility.

Thus, the indicators of potable water supply accessibility to the poor in Dhaka City vary in terms of relative importance. However, here the relative importance is assessed by subjective judgement based on a literature review and field level experiences. After completing the weighting of factors and indicators, a consistency test of the weights was derived by calculating the ratio of a 'consistency index' and 'random index' (Smith, 1980). This ratio should be less than 0.1 for acceptable consistency, and was for the indicator weights calculated.

Weighted Averaging and OWA Operators

Weighted Average Operator

The weighted averaging operator is the most commonly accepted composite index. The term 'composite index' can be defined as an aggregation of the indicators' values which collectively convey information about the quality of some complex aspects or components of a condition (Nijkamp et al., 1990). This may be expressed as

$$U = Y_1X_1 + Y_2X_2 + \dots\dots\dots + Y_nX_n$$

where X_n is the n^{th} indicator, and Y_n its corresponding weight. This is a linear aggregation.

Ordered Weighted Averaging (OWA) Operator

The OWA is primarily concerned with the problem of aggregating multicriteria to form an overall decision function. This is a comparatively new but flexible system of aggregation. It allows the users to decide on the types of aggregation depending on the purpose of their decision making (Yager, 2004; Smith, 2000-2001). The basic formula of OWA is given as:

$F = w_1 b_1 + w_2 b_2 +$ --------- $+ w_j b_j$

Here b_1, b_2, …, b_n are the positional values of the indicators and w_1, w_2, …, w_n are the weights of those positional values. Positional values of the indicators are arranged in descending order, and thus this is a non-linear aggregation. The value of the positional weights is between 0 and 1, and they sum to unity.

The OWA operator was introduced by Yager in 1988. It is an important tool in evaluating the performance of urban service delivery (Mendes and Motizuki, 2001). A primary concern in the determination of the structure of OWA is the relationship between the indicators involved. At one extreme is the situation in which we desire that all indicators be satisfied. At the other extreme is the case in which the satisfaction of one of the indicators is all we desire. These two extreme cases lead to the use of "and" and "or" operators to combine the indicator functions (Yager, 1988).

Formally, an OWA operator of dimension n is a mapping ¦ : R^n ® R, that has an associated weight vector $W = [w_1, w_2, w_3, \ldots w_n]^T$, such that $w_i \in [0,1]$, and $\sum_{i=1} w_i = 1$. The functional value ¦ $(a_1 \ldots a_n)$ determines the aggregated value of arguments $a_1, a_2 \ldots a_n$ in such a manner that ¦ $(a_1 \ldots a_n) = \sum_{j=1}^{n} w_j b_j$ (Aggregation equation) [14]; where b_j is the jth largest element of the collection of the n aggregated objects (here, indicators) $a_1, a_2 \ldots a_n$.

A fundamental aspect of the OWA operator involves ordering the indicators' values. If we consider the resulting indicator scores to be ranked from highest to lowest, the indicator with the highest score is given the first positional weight; the indicator with the next highest score is given the second positional weight, and so on. This has the effect of a weighting indicator based on their rank from maximum to minimum value. Thus argument a_i (a particular indicator value) is not associated with a particular weight w_i but rather a weight w_i is associated with a particular ordered position i of the arguments (Filev and Yager, 1998). A known property of the OWA operators is that they include the max, min, and arithmetic mean operators for the appropriate selection of the vector W:

1. For $W = [1, 0, 0, \ldots 0]$, $f(a_1 \ldots a_n) = \mathrm{Max}_i\, a_i$ [Optimistic OWA (OP-OWA)]
2. For $W = [0, 0, 0, \ldots 1]$, $f(a_1 \ldots a_n) = \mathrm{Min}_i\, a_i$ [Pessimistic OWA (PE-OWA)] and
3. For $W = [1/n, 1/n, \ldots 1/n]$, ¦ $(a_1 \ldots a_n) = \frac{1}{n}\sum_{i=1}^{n} a_i$ [Average OWA (AV-OWA)].

The above aggregation scenarios can be performed by a particular value of the weighting vector. A measure called the 'orness' of aggregation is defined as

$$\text{Orness } (W) = \frac{1}{n-1}\sum_{i=1}^{n} (n-i)w_i$$

This equation characterizes the degree which the aggregation is like an "or" (max) operation. It can be shown that

Orness $([1, 0, \ldots, 0]^T) = 1$ (Optimistic OWA)
Orness $([0, 0, \ldots, 1]^T) = 0$, (Pessimistic OWA)
Orness $([1/n, 1/n, \ldots, 1/n]^T) = 0.5$ (Average OWA)

The "andness" of an aggregation is defined as *andness* = 1 – *orness*. A pure "or" operator is optimistic (i.e. reflects a degree of optimism in a probabilistic decision) but is a risk taking solution. The pure "and" operator is pessimistic (i.e. reflects a degree of pessimism in a probabilistic decision) and is a risk averse solution (Mendes and Motizuki, 2001). In the case of pure "or" operator order weights will be [1, …, 0, 0] and in the case of pure "and" operator, order weights will be [0, 0, …, 1]. Equal weights [1/n, 1/n, … 1/n] assigned to all the indicators produces a risk-neutral, intermediate solution. This is also known as "arithmetic mean" or "average" operator. This operation allows for full trade-off between indicators, so that poor indicator scores can be compensated for by higher score of another indicator (Mendes and Motizuki, 2001). OWA aggregation is a non-linear aggregation because it uses an ordering process to aggregate the indicators' values. All OWA operators satisfy the properties of commutativity, monotonicity and idempotency and are bounded by the Max and Min operators [$\mathrm{Min}_i\, a_i \leq f(a_1 \ldots a_n) \leq \mathrm{Max}_i\, a_i$] (Filev and Yager, 1998).

Recently other types of OWA operators (i.e., "maximum entropy OWA", "exponential OWA", and "weighted OWA") have been developed (Smith, 2000-2001; Filev and Yager, 1998).

Yager (1988) used the dispersion or entropy (evenness) associated with a weighting vector. He used this measure to develop a procedure to generate the OWA weights that have a predefined degree of orness α. That is, the weights will be as even as possible (maximizing entropy) subject to yielding a given level of orness. These are called as maximum entropy OWA (ME-OWA) weights.

This approach is based on the solution of the following constrained non-linear optimization problem (Smith, 2000-2001):

Maximize $E\,(W) = \sum_{i=1}^{n} w_i \ln w_i$ [Maximum Entropy OWA]

subject to $\mathrm{a} = \frac{1}{n-1} \sum_{\mathrm{i}=1}^{\mathrm{n}} (n-i) w_{\mathrm{i}}$ (a = orness)

$w_{\mathrm{i}} \in [0,1],\ i = 1, \ldots, n$

A somewhat simpler approach, which does not require the solution of a non-linear programming problem, is the exponential OWA (EX-OWA) operator (Filev and Yager, 1998). This method is an alternative solution to the constrained optimization problem. OWA weights can easily be generated according to either of the following equations:

$w_1 = \mathrm{q};\ w_2 = \mathrm{q}(1-\mathrm{q});\ w_3 = \mathrm{q}(1-\mathrm{q})^2;\ \ldots;\ w_{n-1} = \mathrm{q}(1-\mathrm{q})^{n-2};\ w_n = (1-\mathrm{q})^{n-1}$ [EX1-OWA]

$w_1 = \mathrm{q}^{n-1};\ w_2 = (1-\mathrm{q})\mathrm{q}^{n-2};\ w_3 = (1-\mathrm{q})\mathrm{q}^{n-3};\ \ldots;\ w_{n-1} = (1-\mathrm{q})\mathrm{q};\ w_n = (1-\mathrm{q})$ [EX2-OWA].

Here parameter q belongs to the unit interval, 0 £ q £ 1 and $\mathrm{S}w_j = 1$ for each of EX1-OWA and EX2-OWA.

The functional relationship between the *orness*, a, and the parameter q for different numbers of values (indicators) to be aggregated (n = 2, 3, …) can be identified for each of EX1-OWA and EX2-OWA. The exponential OWA operators have a useful property in that, given a value of n, one can simply obtain the associated parameter value of q for a given level of orness, a.

In EX1-OWA, *orness*, a, is a monotonically increasing function of q and the degree of *orness* is higher than the value of the parameter q (or equal to q for n = 2) and is different for different n (n = 2, 3, …). The OWA operator is called an *optimistic* EX-OWA operator (Figure 1a) (Filev and Yager, 1998). In particular, as the number of indicators increases this aggregation becomes more and more "orlike" (optimistic).

In EX2-OWA, *orness*, a, is also a monotonically increasing function of the parameter, q. However, the degrees of *orness* is lower than the value of parameter q (or equal to q for n = 2). The OWA operator is called a *pessimistic* EX-OWA operator of (Figure 1b) (Filev and Yager, 1998). In particular, as the number of indicators increases this aggregation becomes more and more "andlike" (pessimistic).

For these OWA weights given *orness*, a, the parameter q can be derived from either Figure 1(a) or Figure 1(b) as appropriate. The degree of orness assumed by the decision maker for a particular subdistrict determines the performance of urban water supply (from that decision maker's perspective).

It is important to recognize that each of these exponential weighting schemes can be either optimistic or pessimistic, irrespective of the terminology used by Filev and Yager (1998), depending on the value given to q. If q =1, then EX1-OWA = [1, 0, …, 0] (optimistic, MAX, orness = 1, andness = 0), and when q = 0, then EX1-OWA = [0, 0, …, 1] (pessimistic, MIN, orness = 0, andness = 1). If q =1, then EX2-OWA = [1, 0, …, 0] (optimistic, MAX, orness = 1, andness = 0), and when q = 0, then EX2-OWA = [0, 0, …, 1] (pessimistic, MIN, orness = 0, andness = 1).

To include importance weights associated with the indicators themselves, a weighted OWA (WOWA) may be used. This approach is natural when some linguistic quantifier is available to guide the aggregation factors (Smith, 2000-2001). A WOWA operator generalizes the OWA operator and is mathematically defined as WOWA $= \sum_{j=1,} \beta_j b_j$.

Here, b_j is the j^{th} largest element (indicator value) for a particular subdistrict and b_j is the j^{th} largest indicator value for a particular subdistrict. OWA weights can be parameterized by a linguistic quantifier Q: [0,1] → [0,1] having the properties: (1) $Q(0) = 0$; (2) $Q(1) = 1$; and (3) $Q(x) \geq Q(y)$ if $x > y$. The classical quantifier, "all", is $Q(j/n) = 0$ for

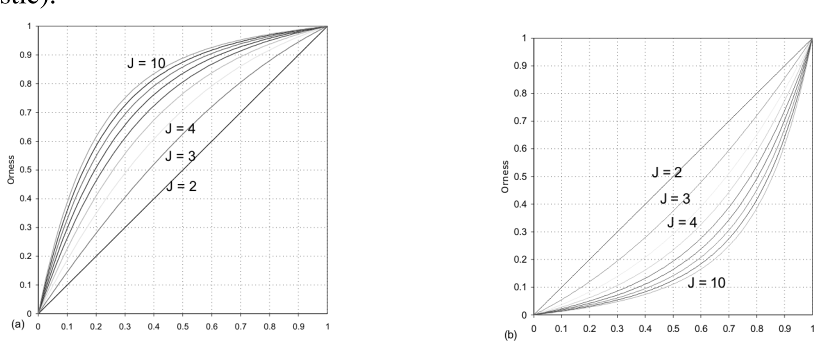

Figure 1: (a) Optimistic EX-OWA (when orness, a > q). (b) Pessimistic EX-OWA (when orness, a < q)
Source: Smith, 2000-2001; Filev and Yager, 1998.

$j < n$ and $Q(n/n) = Q(1) = 1$, in which case OWA weights are [0, 0, …, 1] (yielding the MIN operator). The classical quantifier, "at least one", is $Q(j/n) = 1$ for $j \geq 1$ in which case a = [1, 0, …, 0] (yielding the MAX operator). We can obtain OWA weights as $w_j = Q(j/n) - Q((j-1)/n)$. It can be shown that these weights satisfy the conditions $w_j \varepsilon [0,1]$ and $\Sigma_{j=1,n} w_j = 1$. The orness of the quantifier weights is given as orness (a) = $[1/(n-1)]\Sigma_{j=1,n-1} Q(j/n)$. The quantifier "most" might be defined as $Q(r) = r^2$.

The WOWA operator weights are given as $\beta_j = Q(\Sigma_{k=1,j} u_k) - Q(\Sigma_{k=1,j-1} u_k)$ where u_j is the importance weight associated with b_j. Here u_j is the indicator importance weight associated with b_j (the j^{th} largest indicator value for a particular subdistrict). Here we use the linguistic quantifier "most", that is we require "most" of the indicators to be satisfied. An undesirable feature associated with the WOWA operator is that the "orness" will be different for different subdistricts as the WOWA weights depend on the indicator weights which are associated with the indicator values.

Evaluation Scenarios

Indicators for the six different factors have been aggregated by WA and OWA operators to find out the performance of water supply to the informal settlements in 16 sub-districts of Dhaka City (Appendix). Thus, the performance of every factor has been measured. Indicator aggregations by WA and OWA operators were implemented using Visual Basic for Application (VBA) in MS Excel and MathCAD. Based on these operators, three evaluation scenarios were determined to evaluate the performance of UWS to the informal settlements in Dhaka City. These are known as:

(a) Scenario one: Weighted Average (WA);
(b) Scenario two: Ordered Weighted Average (OWA); and
(c) Scenario three: Weighted OWA (WOWA).

The values of WA and OWA operators vary on a scale between 1 (one) and 0 (zero). Here 1 (one) means 100% or the ideal condition of the indicators existed, and 0 (zero) means that the indicators revealed no performance. WA and OWA operators' values can be interpreted using three main methods. Firstly, the values (i.e., mainly the highest, lowest and average values) will be interpreted by comparing them with the ideal condition. This will indicate the absolute performance of water supply within the informal settlements. Secondly, the value of each subdistrict will be interpreted by how well the urban water supply condition is compared to the mean (average) value, i.e., identifying the position of the sub-districts by counting the number of standard deviations from the mean (NSM) (Figure 2). Thirdly, the values for each factor have been shown in a summary table to find out the critical factors in urban water supply accessibility to the informal settlements.

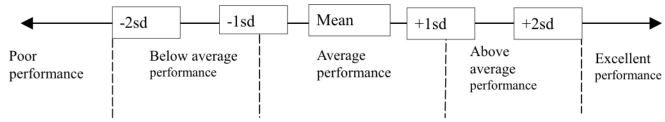

Figure 2: Categorical scale for the interpretation of WA and OWA values using mean and standard deviation (sd) [Adapted from Gunewardena 2000].

Case Study Findings

First, under the weighted average (WA) scenario, while considering the absolute values of the indicators and linear arithmetic aggregation, the average condition of urban water supply systems to the informal settlements is about 28% of the ideal condition and the gap between the highest and lowest performance is about 32% (Table 1).

Table 1: Performance of water supply to the informal settlements in Dhaka City: by WA values and NSM

Sub-district	*Slums*		*Squatter settlements*	
	Value	*NSM*	*Value*	*NSM*
Cantonment	0.287	0.6	0.217	-0.8
Demra	0.244	-0.2	0.361	0.6
Dhanmondi	0.312	1.0	0.290	-0.1
Gulshan	0.214	-0.8	0.303	0.0
Kotwali	0.153	-1.9	0.580	2.8
Lalbagh	0.218	-0.7	0.417	1.2
Mirpur	0.257	0.0	0.287	-0.1
Mohammadpur	0.275	0.3	0.200	-1.0
Motijheel	0.394	2.5	0.352	0.5
Narayanganj	0.261	0.1	0.184	-1.2
Pallabi	0.201	-1.0	0.294	-0.1
Ramna	0.253	-0.1	0.212	-0.9
Sabujbagh	0.200	-1.0	0.238	-0.6
Sutrapur	0.270	0.2	0.245	-0.6
Tejgoan	0.301	0.8	0.348	0.5
Uttara	0.258	0.0	0.269	-0.3
Mean	*0.256*		*0.300*	
Standard deviation	*0.055*		*0.099*	

Source: Akbar, 2005

Second, under the ordered weighted average (OWA) scenario, while considering the positional values of the indicators and nonlinear arithmetic and/or exponential aggregation, performance of water supply to the informal settlements varies between 0.35% and 82% of the ideal condition depending on the model that is considered. For instance, under the OP-OWA operator, the average condition of water supply systems is about 94% of the ideal condition (Table 2), and in contrast, under the PE-OWA operator, the average condition of water supply systems is 0.35% of the ideal condition (Table 3). AV-OWA reveals the trade-off among the indicators and the average water supply condition is about 41% of the ideal condition (Table 4). The ME-OWA operator considers some constraints of the indicators which means considering the desired degree of orness to maximize the evenness among the indicators, and under this operator the water supply condition is about 22% of the ideal condition (while 'orness' is low) and that situation is about 62% (while 'orness' is high) (Table 5). Under the EX-OWA operator, which is based on the functional relationship between the 'orness' and 'parameter' of the indicators, on average, the water supply situation is 0.7% of the ideal condition (while considering the low level of 'orness') and this is 82% of the ideal condition (while considering the high level of 'orness') (Table 6).

Third, under the weighted ordered weighted (WOWA) scenario, while considering the importance weighting with the positional values of the indicators, the average condition of water supply systems is about 25% of the ideal condition (Table 7). When considering all scenarios,

Table 2: Performance of water supply to the informal settlements in Dhaka City: by OP-OWA values and NSM

Sub-district	*Slum*		*Squatter settlements*	
	Value	*NSM*	*Value*	*NSM*
Cantonment	1.000	0.9	0.958	0.3
Demra	1.000	0.9	0.914	-0.3
Dhanmondi	1.000	0.9	1.000	0.9
Gulshan	0.918	-0.4	0.872	-0.9
Kotwali	1.000	0.9	1.000	0.9
Lalbagh	0.854	-1.4	0.857	-1.2
Mirpur	0.848	-1.4	0.941	0.1
Mohammadpur	0.953	0.2	0.903	-0.5
Motijheel	1.000	0.9	0.833	-1.5
Narayanganj	0.833	-1.7	1.000	0.9
Pallabi	0.944	0.1	0.799	-2.0
Ramna	1.000	0.9	1.000	0.9
Sabujbagh	0.900	-0.6	0.909	-0.4
Sutrapur	0.950	0.1	1.000	0.9
Tejgoan	1.000	0.9	1.000	0.9
Uttara	0.856	-1.3	1.000	0.9
Orness	*1.000*		*1.000*	
Mean	*0.941*		*0.937*	
Standard deviation	*0.064*		*0.069*	

Source: Akbar, 2005

Table 3: Performance of water supply to the informal settlements in Dhaka city: by PE-OWA values and NSM

Sub-district	*Slum*		*Squatter settlements*	
	Value	*NSM*	*Value*	*NSM*
Cantonment	0.000	-0.4	0.000	-0.3
Demra	0.000	-0.4	0.000	0.0
Dhanmondi	0.000	-0.4	0.000	-0.6
Gulshan	0.000	-0.4	0.019	-0.4
Kotwali	0.000	-0.4	0.000	2.8
Lalbagh	0.012	1.0	0.000	1.3
Mirpur	0.032	3.3	0.000	-0.6
Mohammadpur	0.013	1.1	0.000	-0.6
Motijheel	0.000	-0.4	0.000	1.6
Narayanganj	0.000	-0.4	0.000	-0.6
Pallabi	0.000	-0.4	0.025	-0.3
Ramna	0.000	-0.4	0.000	-0.6
Sabujbagh	0.000	-0.4	0.000	-0.6
Sutrapur	0.000	-0.4	0.000	-0.6
Tejgoan	0.000	-0.4	0.000	-0.6
Uttara	0.000	-0.4	0.000	-0.2
Orness	*0.000*		*0.000*	
Mean	*0.004*		*0.003*	
Standard deviation	*0.009*		*0.008*	

Source: Akbar, 2005

Table 4: Performance of water supply to the informal settlements in Dhaka City: by AV-OWA values and NSM

Sub-district	*Slum*		*Squatter settlements*	
	Value	*NSM*	*Value*	*NSM*
Cantonment	0.479	1.1	0.435	0.4
Demra	0.432	0.2	0.456	0.8
Dhanmondi	0.472	0.9	0.336	-1.4
Gulshan	0.398	-0.3	0.399	-0.2
Kotwali	0.304	-2.0	0.482	1.3
Lalbagh	0.377	-0.7	0.427	0.3
Mirpur	0.376	-0.7	0.414	0.0
Mohammadpur	0.421	0.1	0.402	-0.2
Motijheel	0.486	1.2	0.422	0.2
Narayanganj	0.346	-1.2	0.366	-0.9
Pallabi	0.421	0.0	0.382	-0.6
Ramna	0.505	1.5	0.427	0.3
Sabujbagh	0.414	-0.1	0.396	-0.3
Sutrapur	0.435	0.3	0.481	1.3
Tejgoan	0.477	1.0	0.477	1.2
Uttara	0.345	-1.3	0.287	-2.4
Orness	*0.500*		*0.500*	
Mean	*0.418*		*0.412*	
Standard deviation	*0.058*		*0.053*	

Source: Akbar, 2005

Table 5: Performance of water supply to the informal settlements in Dhaka City: by ME-OWA values and NSM

Sub-district	*ME-OWA (low 'orness')*				*ME-OWA (high 'orness')*			
	Slums		*Squatter Settlements*		*Slums*		*Squatter Settlements*	
	Value	*NSM*	*Value*	*NSM*	*Value*	*NSM*	*Value*	*NSM*
Cantonment	0.277	1.1	0.240	0.4	0.697	1.0	0.637	0.4
Demra	0.219	-0.1	0.260	0.9	0.665	0.5	0.648	0.6
Dhanmondi	0.248	0.5	0.140	-1.9	0.705	1.1	0.568	-0.6
Gulshan	0.214	-0.2	0.236	0.3	0.601	-0.4	0.570	-0.6
Kotwali	0.109	-2.4	0.234	0.2	0.561	-1.0	0.736	1.9
Lalbagh	0.201	-0.4	0.235	0.3	0.566	-0.9	0.611	0.0
Mirpur	0.223	0.0	0.231	0.2	0.546	-1.2	0.610	0.0
Mohammadpur	0.244	0.4	0.216	-0.2	0.608	-0.3	0.590	-0.3
Motijheel	0.298	1.6	0.273	1.2	0.671	0.6	0.572	-0.6
Narayanganj	0.188	-0.7	0.167	-1.3	0.508	-1.7	0.581	-0.4
Pallabi	0.228	0.1	0.232	0.2	0.625	0.0	0.536	-1.1
Ramna	0.297	1.6	0.230	0.2	0.716	1.3	0.633	0.3
Sabujbagh	0.209	-0.3	0.211	-0.3	0.624	0.0	0.594	-0.2
Sutrapur	0.221	0.0	0.241	0.4	0.662	0.5	0.726	1.8
Tejgoan	0.221	0.0	0.291	1.5	0.734	1.5	0.674	1.0
Uttara	0.160	-1.3	0.131	-2.1	0.545	-1.2	0.479	-2.0
Orness	*0.300*		*0.300*		*0.700*		*0.700*	
Mean	*0.222*		*0.223*		*0.627*		*0.610*	
Standard deviation	*0.048*		*0.044*		*0.069*		*0.066*	

Source: Akbar, 2005

Table 6: Performance of water supply to the informal settlements in Dhaka City: by EX-OWA values and NSM

Sub-district	*EX1-OWA*				*EX2-OWA*			
	Slums		*Squatter Settlements*		*Slums*		*Squatter Settlements*	
	Value	*NSM*	*Value*	*NSM*	*Value*	*NSM*	*Value*	*NSM*
Cantonment	0.015	0.6	0.006	0.1	0.907	1.0	0.835	0.4
Demra	0.001	-0.6	0.003	-0.2	0.896	0.8	0.821	0.2
Dhanmondi	0.000	-0.7	0.000	-0.6	0.919	1.1	0.818	0.2
Gulshan	0.012	0.3	0.025	2.2	0.805	-0.3	0.741	-0.8
Kotwali	0.000	-0.7	0.000	-0.6	0.863	0.4	0.948	2.0
Lalbagh	0.013	0.4	0.001	-0.5	0.753	-0.9	0.764	-0.5
Mirpur	0.042	2.7	0.001	-0.5	0.720	-1.4	0.809	0.1
Mohammadpur	0.027	1.5	0.002	-0.4	0.788	-0.5	0.770	-0.4
Motijheel	0.020	0.9	0.007	0.2	0.838	0.1	0.722	-1.1
Narayanganj	0.000	-0.7	0.000	-0.6	0.669	-2.0	0.791	-0.2
Pallabi	0.001	-0.6	0.028	2.6	0.830	0.0	0.685	-1.6
Ramna	0.002	-0.5	0.000	-0.6	0.913	1.1	0.826	0.3
Sabujbagh	0.000	-0.7	0.002	-0.4	0.811	-0.2	0.791	-0.2
Sutrapur	0.000	-0.6	0.000	-0.6	0.865	0.5	0.935	1.8
Tejgoan	0.000	-0.7	0.009	0.5	0.943	1.4	0.874	1.0
Uttara	0.000	-0.7	0.000	-0.6	0.735	-1.2	0.717	-1.2
Orness	*0.013*		*0.013*		*0.885*		*0.885*	
Mean	*0.008*		*0.005*		*0.828*		*0.803*	
Standard deviation	*0.013*		*0.009*		*0.080*		*0.073*	

Source: Akbar, 2005

the average condition of water supply systems to the informal settlements in Dhaka City is about 36% of the ideal condition. This is the core finding by the method of absolute ideal condition analysis. Most scenarios (i.e., WA, AV-OWA, ME-OWA and WOWA) showed that there is a similar gap (i.e., about 22%) between the highest and lowest performance of water in the informal settlements. This suggests that 22% of existing improvements are necessary to improve the situation from the poor condition to the existing good condition. This gap mainly depends on political and economic factors and a detailed description of this matter is given later in this sub-section.

According to the relative condition (obtained through NSM counting) analysis method, urban water supply condition to the informal settlements in Dhaka City is summarized in Table 8.

Under all the scenarios, in case of slums, 2%, 11%, 74%, 12% and 1% of the sub-districts have excellent, above average, average, below average and poor condition of water supply respectively. In case of squatter settlements, 3%, 8%, 76%, 10% and 1% of the sub-districts have excellent, above average, average, below average and poor condition of water supply respectively (Table 8). So in terms of NSM, about 75% of the subdistricts have average condition of water supply; in absolute terms, this average condition of water supply is equivalent to about 36% of the ideal condition of the water supply system. Here, the most important finding is that the water supply condition of both types of informal settlement is similar. Slums are informal settlements where the housing is rented or subrented from legitimate

Table 7: Performance of water supply to the informal settlements in Dhaka City: by WOWA values and NSM NSM

Sub-district	*Slum*		*Squatter settlements*	
	Value	*NSM*	*Value*	*NSM*
Cantonment	0.160	0.3	0.081	-1.5
Demra	0.270	1.0	0.302	0.6
Dhanmondi	0.347	-1.2	0.073	-1.6
Gulshan	0.131	-1.5	0.204	-0.4
Kotwali	0.092	0.7	0.414	1.7
Lalbagh	0.318	0.7	0.303	0.6
Mirpur	0.319	1.4	0.242	0.0
Mohammadpur	0.387	0.8	0.223	-0.2
Motijheel	0.320	-1.4	0.305	0.6
Narayanganj	0.106	-0.2	0.056	-1.8
Pallabi	0.228	0.3	0.306	0.6
Ramna	0.272	-0.6	0.371	1.3
Sabujbagh	0.185	-0.9	0.239	0.0
Sutrapur	0.156	1.6	0.203	-0.4
Tejgoan	0.401	-0.2	0.317	0.7
Uttara	0.225		0.211	-0.3
Orness	*0.395*		*0.384*	
Mean	*0.245*		*0.241*	
Standard deviation	*0.099*		*0.104*	

Source: Akbar, 2005

Table 8: Overall condition of water supply to the informal settlements in Dhaka city

Aggregation scenarios	*Water supply condition by number of subdistricts*									
	Excellent		*Above average*		*Average*		*Below average*		*Poor*	
	Slums	*SS*	*Slums*	*SS*	*Slums*	*SS*	*Slums*	*SS*	*Slums*	*SS*
WA	1	1	0	1	14	13	1	1	0	0
OP-OWA	0	0	0	0	12	13	4	3	0	0
PE-OWA	1	2	1	0	14	14	0	0	0	0
AV- OWA	0	0	3	3	10	11	2	1	1	1
ME-OWA (low orness)	0	0	3	2	11	11	1	2	1	1
ME-OWA (high orness)	0	0	3	2	10	12	3	2	0	0
EX-OWA (low orness)	1	2	1	0	14	14	0	0	0	0
EX-OWA (high orness)	0	0	3	2	10	11	3	3	0	0
WOWA	0	0	2	2	11	11	3	3	0	0
Average	0.25	0.50	2.00	1.38	11.50	12.13	2.00	1.75	0.25	0.25
Percentage	2%	3%	11%	8%	74%	76%	12%	10%	1%	1%

Source: Akbar, 2005 [Note: SS = Squatter settlements] owners, while squatter settlements are on illegally occupied land. So legality or illegality of the settlement does not make any significant difference in accessibility of water supply to poor. The reasons follow.

Slum owners own the land legally. Some of them do not have the ability to spend a large amount of money to connect to the formal water supply system or to install a hand pump. Most of them are landlords. They either rent the land to the poor or just build some temporary houses to rent to the poor to earn money from the tenants and to keep the land secured from the local "godfather" or gangsters. If the slum owner is a politician, then he uses the tenants for political purposes. Some of them do not even allow the tenants to establish water points or to install hand pumps. Thus the system cannot develop for the tenants. In contrast, residents in squatter settlements occupy the land illegally. Although the squatters are controlled by local politicians and gangsters, they are more united than the slum tenants (often with the help of non-governmental organizations (NGOs) and even the politicians) in order to have potable water supply. Thus some factors work uniquely for each group and some factors work similarly. Together they lead to there being no significant difference in urban water supply accessibility to the poor because of the legality or otherwise of the settlements.

Second, it has been observed that no single subdistrict has a similar condition of water supply under all the evaluation scenarios (Akbar, 2005). But, a few subdistricts have a similar condition of water supply in the WA, AV-OWA, ME-OWA and WOWA scenarios. In these scenarios, in the case of the slums, it has been found that one subdistrict (i.e., Mirpur) has a good condition of water supply, because most slums in Mirpur were developed through government schemes and World Bank Projects, and these are well supplied with potable water when compared to the others. Despite these governmental and international initiatives, some NGOs such as Dushtha Shasthya Kendra (DSK), Phulki and Roads and Highways Co-operatives are working continuously in those slums, because these are the most stable slums and are mostly owned by the residents. For example, DSK have established 26 water points in Mirpur out of their total of 74 water points since June 2001 (DSK, 2001). On the other hand, Kotwali has a poor condition of water supply, because the slums in Kotwali are very old, dilapidated and overcrowded. Formal piped sources of water supply in these slums are limited. The majority of the slums dwellers buy water from the informal sources or water vendors. Most landlords do not live there and they do not care about the water supply to the renters.

Squatters in Gulshan and Pallabi are well served with potable water supply because the NGOs such as DSK, Association for Realization of Basic Needs (URBAN), Bangladesh Agricultural Working Peoples Association (BAOPA) and Population Services and Training Centre (PSTC) are working mainly in those squatter settlements because they are old, large settlements. Just before the national election in 2001, under pressure from its political leaders, Dhaka Water Supply and Sewerage Authority (DWASA) was forced to install a high capacity deep tube well in Sattala *Bastee*[1] , which is the home of about twenty seven thousand squatters. This *Bastee* is situated in Gulshan. Pallabi is also served well by the NGOs. Despite the NGOs' efforts, squatter settlements have developed on vacant land owned by industries or housing companies. Large numbers of squatters occupy those areas, and they have developed their own water supply system by themselves. They have also taken many illegal connections from the DWASA pipelines. Politicians representing these sub-districts are comparatively more aware of the needs of the poor for water supply because a large proportion of the voters are squatters. The squatters are politically conscious and comparatively more united, and more likely to speak out to the political leaders and the water supply providers. In contrast, squatters of Uttara are the worst-served with potable water, because most squatter settlements there are newly developed and small in size. NGOs seldom work there, and also there are fewer illegal connections because the settlements are comparatively further from the DWASA distribution pipelines. So the size of the settlements and the nature of permanency are the key parameters for attracting the NGOs, and also for mobilizing the people themselves for water supply development.

The performance of each individual factor varies over the evaluation scenarios (Table 9). Table 9 demonstrates that on average, the political factor has the lowest values compared to the other factors i.e., 13.2% to 18.5% of the ideal condition; and biophysical factors have the highest performance i.e., 53.6% to 56.4% of the ideal condition. Institutional, economic and technical factors vary between 20% and 40% of the ideal condition. So, the political factor is the least satisfactory and the biophysical factor is the most satisfactory factor in terms of urban water supply accessibility to the informal settlements in Dhaka City.

So, the performance of urban water supply accessibility to the informal settlements in Dhaka City varies by the type of settlement in the same location, and also

[1]Slum or squatter settlement

Table 9: Mean values of WA and OWA operators: all factors

Aggregation scenarios	*Factors*											
	Biophysical		*Political*		*Institutional*		*Economic*		*Social*		*Technical*	
	Slums	*SS*	*Slums*	*SS*	*Slums*	*SS*	*Slums*	*SS*	*SS*	*SS*	*Slums*	*SS*
WA	0.036	0.037	0.065	0.099	0.041	0.038	0.012	0.012	0.043	0.052	0.060	0.060
OP-OWA	0.920	0.879	0.241	0.330	0.886	0.763	0.403	0.378	0.877	0.826	0.765	0.773
PE-OWA	0.291	0.292	0.043	0.064	0.026	0.023	0.103	0.078	0.121	0.186	0.042	0.044
AV-OWA	0.665	0.625	0.142	0.197	0.300	0.267	0.225	0.201	0.389	0.467	0.394	0.390
ME-OWA (low orness)	0.531	0.497	0.058	0.085	0.466	0.093	0.070	0.123	0.121	0.290	0.079	0.227
ME-OWA (high orness)	0.783	0.741	0.226	0.309	0.579	0.507	0.316	0.294	0.627	0.664	0.572	0.560
EX-OWA (low orness)	0.443	0.416	0.142	0.197	0.170	0.151	0.173	0.147	0.267	0.342	0.184	0.191
EX-OWA (high orness)	0.842	0.800	0.142	0.197	0.509	0.446	0.291	0.269	0.565	0.612	0.612	0.601
Average	0.564	0.536	0.132	0.185	0.372	0.286	0.199	0.188	0.376	0.430	0.325	0.356

Source: Akbar, 2005 [Note: SS = Squatter settlements]

varies over the locations. The advantage of using the above three evaluation scenarios is that planners or managers can assess the present water supply situation from different points of view. Thus water providers could make decisions about the nature of investment and the type of water supply system development. The above scenarios could determine the performance of urban water supply at micro (e.g., community) and macro (e.g., mega-city) level, and have a role in determining priorities and making decisions for water supply development. The providers could make decisions by analyzing the individual factors. For example, private providers are unlikely to invest money if they find there is no chance of at least a return of the investment with a marginal profit; and initially they will decide whether to invest by the values of the economic factor in the various scenarios.

The lesson from this discussion is that political, economic and institutional factors are consistently the least satisfactory, and biophysical and technical factors are consistently the most satisfactory in almost all the analyses. So, biophysical and technical factors are not the main barriers to water supply. The critical factors are political, institutional and economic. A good illustration of this is the way that the work of DSK—as an institutional factor, and as a political factor, with respect to political pressure during the last election to build water supply systems in some large squatter settlements—contributed to a better performance of water supply systems in the informal settlements of Mirpur, Pallabi and Gulshan subdistricts. This means the solution to improving urban water supply lies in improving political and institutional factors rather than technical and biophysical changes. Economic and social factors are driven by the former factors.

Conclusion

Weighted average (known as a composite index), ordered weighted average (OWA) operators and weighted OWA have been used to aggregate the values of all indicators of the factors of urban water supply accessibility to the poor. All types of aggregation show that the average water supply performance to the informal settlements in Dhaka City is about 36% of the ideal condition of water supply systems. Analysis of the factors of urban water supply accessibility also reveals that biophysical and technical factors are not the main factors limiting the water supply to the informal dwellers. The critical factors are political, institutional and economic.

Therefore, it can be specifically concluded that people living in the informal settlements of Dhaka City are neglected in terms of formal potable water supply. Throughout this study it is evident that there is almost no problem with actual water availability at local source. The research on which this paper is based showed that even a social mediator system has emerged to overcome the problem of property rights. What are lacking, however, are political willingness and an institutional framework to ensure reliable water supply to the informal settlements. The existing biophysical and technical indicators of urban water supply to the poor can be easily improved if the political and institutional indicators are working properly. The evaluation methods described here have been shown to be effective in assessing the impact of critical factors that affect the availability of potable water to the urban poor. Potentially the approach could be used for in the planning and management of other services utilized by the urban poor.

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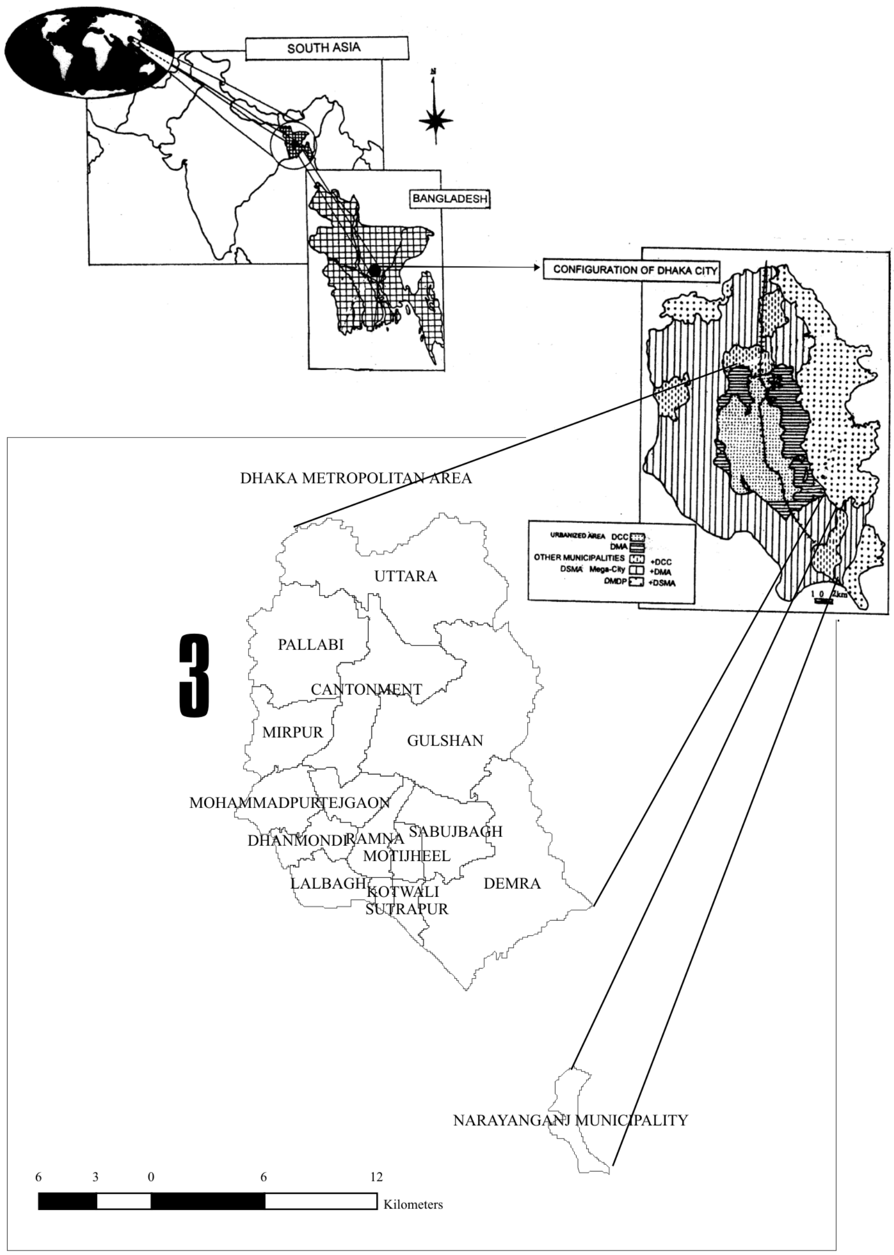
Appendix

Map of the study area (Dhaka Metropolitan Area and Narayanganj Municipality)



Source: Asaduzzaman and Rob, 1997