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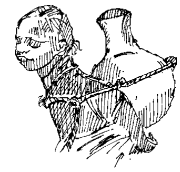
INTEGRATED DEVELOPMENT FOR WATER SUPPLY AND SANITATION



Estimating the financial costs of sanitation systems

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ANYONE WHO EVER tried to find information on the cost of sanitation systems, particularly on on-site facilities, knows how scarce and scattered these data are, and how difficult their interpretation is. In the course of his work, the authors found that on the other hand there is a widespread interest in information that allows at least an approximate estimate of the costs incurred by sanitation projects. This paper discusses the development of around 50 costing functions for a wide variety of alternatives ranging from simple pit latrines to sewerage and centralised treatment works such as the activated sludge process. Basically, these functions were established using relative cost estimates from a variety of sources and cost-capacity relationships. They allow estimates of the capital and the recurrent costs of sanitation alternatives. Not surprisingly, the reader will find that many assumptions underlie this work. It is recognised that while most of them are underpinned by evidence from literature or other sources, some might be questionable. It is thus hoped that this contribution will receive scrutiny from its readers and stimulate discussion.

A = Land cost, US$/m²
C_c= Capital cost, US$ (1995).
C_r= Recurrent cost, US$ (1995).
D = Population density, persons/ha.
F_e = Frequency of pit emptying, years.
F_s = Frequency of desludging, years.
F_n = Frequency of nightsoil collection, days.
G = Factor to account for increased costs due to construction difficulties because of rocky ground.
H = Number of households.
I = Soil infiltration rate, L/m² /d.
M = Average number of persons per household.
N = Average number of households served by one unit.
P = Total population served.
Q = Hydraulic loading, L/person/d.
S = Size of process units.
T = Factor to account for increased costs due to traffic. impediments during construction.
V = Sludge accumulation, m³/person/year.
X = Factor to account for the type of sewage system.

Introduction

The work presented in this paper was carried out for the development of the expert system SANEX© for the evaluation of sanitation alternatives in developing countries. SANEX© uses around 50 technical, sociocultural and financial criteria in order to assess more than 80 sanitation systems, ranging from simple latrines to sewerage, with respect to the indicators ‘Implementability’ and ‘Sustainability’.

One of the software’s main features is its capability to estimate the costs of these systems based on costing functions. These functions can be expected to yield estimates with an order-of-magnitude accuracy, which, by definition, is within +/- 30 per cent of the actual costs (Bauman, 1964). Although the validity of absolute estimates might sometimes be questionable, the relative cost ranking of alternatives is usually of good accuracy. The results generated by the functions represent financial costs, indicating whether beneficiaries can afford certain sanitation systems. They do not tell us about their economic merits. A more detailed comparison of financial versus economic costs is provided in a technical note from WASH (1992).

Methodology

All costing equations yield estimates for the United States, from where the most abundant and reliable absolute cost information was available. However, the author developed a simple method for converting the US figures to account for regional construction costs in any project locale. The publication of this method, which is based on the local residential building cost and which was implemented in SANEX©, is planned.

Capital costs

Since factors such as the locality, base year and exchange rates only influence relative costs to a limited extent, relative figures from various sources and locations can be directly compared. Thus, in a first step, information on the relative cost of sanitation systems was collected mostly from literature (e.g. Kalbermatten et al., 1982). Subsequently, fixed (default) community conditions (10,000 persons, 5 persons per household, etc.) were used to establish the capital costs of all sanitation technologies relative to the two-compartment septic tank, the cost of which was assumed to be 100 per cent (= 1). These relative figures were pegged to the absolute cost of a septic tank in default conditions, which, based on various sources, was determined to be $570 (1995). Table 1 shows an excerpt from the results.

Table 1. Relative costs per household of some sanitation systems (example)

	Relative Cost	$ (1995)
Pit Latrine	0.28	160
Septic Tank	1	570
Conventional Sewerage	5.3	3021

Once relative costs were established for all technologies, the next step was to allow community parameters to vary. Since costs are mainly a function of process capacity, costing functions must express the effect of varying community parameters on the volume of process units (e.g. pits and tanks). To achieve this, different methods were used for on- and off-site systems.

For on-site systems, the cost-capacity relationship described by North (1976) was used:

1. $C = C_1 (S / S_1)^m$

where C_1 = Known cost of system of size S_1
C = Desired cost of system of size S.
m = Empirical system-specific exponent (usually approximately m = 0.6).

Relationships to determine S were readily available from literature (e.g. Franceys et al., 1992).

For sewerage and off-site treatment works, costing functions were derived through power regression of data available from various sources. The following example shows the result for an activated sludge plant (cost of land not included):

2. $C = 29080. \left[\frac{PQ}{1000}\right]^{0.56}$

Additionally, for off-site treatment works, a land cost component was included based on estimated area requirements.

Recurrent costs

Recurrent costs consist of costs for operation, maintenance and renewal. It was attempted to express annual recurrent costs as a percentage of capital costs for the construction of the process units (i.e. excluding the cost of land). Since only relative costs were involved, it was possible to rely on figures from a variety of locales cited in literature.

Results

Table 2 outlines the costing functions for sanitation systems frequently encountered in developing countries. Equations were also formulated for the following systems: aquaprivy, biogas digester, bucket latrine, cistern-flush toilet, communal septic tank, Imhoff tank, nightsoil treatment, pour-flush pan, pour-flush toilet with vault, primary treatment, public overhung latrine on fish pond, public toilet block, septic tank for excreta reuse.

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Table 2. Financial costs per household in dollars (1995) as they would occur in the United States.

On-Site Systems	
Pit Latrine (including superstructure)	$C_c = \frac{1}{N} \cdot \left[96 + 50 \cdot U \cdot (MNVF_e)^{0.6}\right]$ $C_r = 0.051C_c$ U = 0.25 in normal soil = 1 in unstable soil V = 0.06 if anal cleansing with water or soft paper = 0.09 if anal cleansing with bulky materials
Ventilated Improved Pit (VIP) Latrine (including superstructure)	$C_c = \frac{1}{N} \cdot \left[188 + 99 \cdot U \cdot (MNVF_e)^{0.6}\right]$ $C_r = 0.026C_c$ U = 0.5 in normal soil = 1 in unstable soil V = 0.06 if anal cleansing with water or soft paper = 0.09 if anal cleansing with bulky materials
Double-Vault Composting (DVC) Latrine (including superstructure)	$C_c = \frac{1}{N} \cdot \left[188 + 745 \cdot U \cdot (MNV)^{0.6}\right]$ U = 0.5 in normal soil = 1 in unstable soil V = 0.04 if anal cleansing with water or soft paper = 0.06 if anal cleansing with bulky materials
Pour-Flush Latrine (including superstructure)	$C_c = \frac{1}{N} \cdot \left[181 + 17.4 \cdot U \cdot (MNF_e)^{0.6}\right]$ $C_r = 0.027C_c$ U = 0.5 in normal soil = 1 in unstable soil
Septic Tank (two compartments)	$C_c = 376 \cdot S^{0.6}$ $C_r = 0.089 \cdot C_c$ $S = 1.25M \cdot \left(\frac{Q}{1000} + VF_s\right)$ AND $S \geq 1\,\mathrm{m}^3$ V = 0.04 if septic tank receives greywater = 0.025 if septic tank does not receive greywater
Seepage Pit	$C_c = \frac{28.7}{N} \cdot \left[\frac{MNQ}{I}\right]^{0.9}$
Drain Field	$C_c = 28.4 \cdot \left[\frac{MQ}{I}\right]$
Latrine with Vault	$C_c = \frac{1}{N} \cdot \left[96 + 6.65 \cdot (MNQF_n)^{0.6}\right]$ $C_r = \frac{1.54}{N} \cdot (MNQF_n)^{0.6}$

Table 2 continued

Sewerage / Off-site Treatment	
Sewerage (excluding treatment) *	$C_c = XGT \cdot (5610 \cdot (H-10)^{-0.46} + 1800) \cdot (5.04 \cdot D^{-0.35})$ $C_r = \mathrm{f}C_c$ f = 0.05 for conventional and settled sewerage = 0.16 for stormwater drains and simplified sewerage G = 1 if normal ground, G = 1.6 if excavation impediments e.g. due to rocky ground (> 25% rock) H > 10 households T = 1 if sewer construction causes no traffic impediments = 1.33 if sewer construction causes traffic impediments X = 1 for conventional sewerage = 0.41 for simplified sewerage = 0.26 for covered stormwater drains = 0.21 for settled sewerage
Waste Stabilization Ponds (anaerobic, facultative and maturation ponds)	$C_c = \frac{1}{H} \cdot \left[3038 \cdot \left(\frac{PQ}{1000} \right)^{0.74} + 46A \cdot \left(\frac{PQ}{1000} \right)^{0.95} \right]$ $C_r = \frac{82}{H} \cdot \left(\frac{PQ}{1000} \right)^{0.73}$
Activated Sludge Treatment (incl. preliminary and primary treatment, chlorination, sludge digestion and dewatering, but excl. nutrient removal)	$C_c = \frac{1}{H} \cdot \left[29080 \cdot \left(\frac{PQ}{1000} \right)^{0.56} + 34A \cdot \left(\frac{PQ}{1000} \right)^{0.67} \right]$ $C_r = \frac{1989}{H} \cdot \left(\frac{PQ}{1000} \right)^{0.56}$

*In most cases, a community's population is not evenly distributed over the project area. Houses form clusters with unpopulated areas inbetween. This equation uses the average population density within these clusters, without taking into account the unpopulated areas.