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Cost–utility analysis of schistosomiasis intervention strategies in Kenya

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ABSTRACT. When decisions to intervene in different schistosomiasis severity states are taken in isolation, inefficiencies are unavoidable due to failure to take account of the synergy between community and facility level options. To date no studies have been conducted of the sequential nature of decision-making processes in schistosomiasis. The main aim of this study is to develop a methodology that could be used to compute the costs and health benefits of alternative strategies for ameliorating the burden of illness from schistosomiasis, with a view to determine that strategy which would produce the greatest excess of benefits over cost. In other words, the goal is to develop a conceptual framework that could be used to map out the most efficient path of options for intervention across a spectrum of schistosomiasis states – asymptomatic, mild, moderate, severe, and very severe.

A cost–utility decision analysis (CUDA) model was developed and applied to the population living within the schistosomiasis endemic region of Kenya covered by the Mwea Irrigation Scheme. Both primary and secondary level options were included in the analysis.

The main findings are as follows. Strategies involving treatment at the community level were generally superior to non-treatment community strategies. The selective population *praziquantel* chemotherapy (SPCPS) was found to be the optimal strategy. Molluscicide strategies are the most cost-effective among the non-treatment strategies. The results of the sensitivity analyses were, however, mixed. The inconclusive nature of the results indicates that firm policy conclusions cannot be made on the basis of current epidemiological information, and more research is urgently required to establish both the validity and reliability of the health-related quality of life (HRQoL), and the Delphi technique (DT) measurements used in the study.

1. Introduction

The fundamental linkage between health, environment, and development have not been exhaustively explored; yet, ultimately the rationale for concern about environmental degradation rests heavily on the threat it poses to human health (Warford, 1995). For example, the reclamation of

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semi-arid and arid areas in Kenya through construction of large irrigation schemes has altered both the natural and epidemiological environments of those areas. One component of that environmental impact is the effect on human health (Daily and Ehrlich, 1996). Communicable diseases, such as *schistosomiasis* (bilharzia), are transmitted by vectors which depend on water. The development of an irrigation scheme, such as the Mwea in Kenya, increased both the number of aquatic snails (vectors) and the frequency of contacts between human communities and vectors. This change in the epidemiological environment led to a remarkable increase in the prevalence of *schistosoma mansoni* infections from 0 per cent in 1956 to over 70 per cent in mid-1980s (Muthami *et al*., 1992).

Schistosomiasis may produce a range of diverse consequences: from impairment of growth and development of children, to reducing the functioning of school children in educational institutions, and even their ability to attend school; from very low levels of impairment of the day-to-day function of adults to significant inhibition of productivity; from mild to severe acute morbidity (e.g., from anaemia) to death (e.g., from intestinal obstruction); from severe chronic disability to death (e.g., from bleeding oesophageal varices) (Warren *et al*., 1993: p. 134).

Various epidemiological studies have shown that provision of hygienic latrines, clean water within the homestead, health education, molluscicide, and chemotherapy, are effective in reducing schistosomiasis infections (Jordan *et al*., 1975; Jordan, 1977; Jordan *et al*., 1978; Jordan and Webb, 1982; Jordan, 1985; WHO, 1985, 1991; Berquist, 1993). Given the scarcity of resources, the Schistosomiasis Control Programme (SCP) cannot afford to implement all the above mentioned interventions simultaneously. Thus, the SCP managers may have to choose probably one intervention strategy. The application of economic evaluation (and other decision-analysis) methods, that weigh intervention costs and health benefits, can guide policy-makers to ensure that scarce resources are invested in those interventions which yield the maximum health gain per unit of expenditure (Mills, 1985; Culyer, 1992; Baumol, 1996; Brown and Layton, 1996; Kirigia, 1996).

A few cost-effectiveness analyses of chemotherapy, focal snail molluscicide, physical destruction of snail habitats, and water supply have been published (Rosenfield *et al*., 1977; Jordan, 1977; Polderman, 1984; Rosenfield *et al*., 1984; Jordan, 1985; Korte *et al*., 1986; Prescott, 1987; Guyatt and Evans, 1992; Swiss Tropical Institute, 1993). These studies did not use ultimate health outcome measures; and they seem to have ignored the fact that schistosomiasis intervention decisions are of a sequential nature.

This study will attempt to shed light on the following questions.

(a) From the social perspective, if the Status Quo (SQ) [or Household Piped Water Supply (HPWS), Household Health Education Visits (HHEV), Vented Improved Pit Latrines (VIPL), Focal-Molluscicide (FM), Mass Population Chemotherapy with Praziquantel (MPCP), Mass Population Chemotherapy with Oxamniquine (MPCO), Selective Population Chemotherapy with Praziquantel (SPCP), Selective Population Chemotherapy with Praziquantel (SPCO)] is implemented

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at the community level, would it be more efficient to provide either praziquantel care at the dispensary (PCD) or oxamniquine care at the dispensary (OCD), instead of the status quo at the dispensary (SQD) policy for those suffering mild schistosomiasis?

(b) From the social perspective, if the SQ (or HPWS, HHEV, VIPL, FM, MPCP, MPCO, SPCP, SPCO) is implemented at the community level, would it be more efficient to provide either praziquantel care at the health centre (PCHC) or oxamniquine care at the health centre (OCHC), instead of the health centre status quo (SQHC) policy for those suffering moderate schistosomiasis?

(c) From the social perspective, if the SQ (or HPWS, HHEV, VIPL, FM, MPCP, MPCO, SPCP, SPCO) is implemented at the community level, would it be more efficient to provide either praziquantel care at the district hospital (PCDH) or oxamniquine care at the district hospital (OCDH), instead of status quo at the district hospital (DHSQ) policy for those suffering severe schistosomiasis?

(d) From the social perspective, if the SQ (or HPWS, HHEV, VIPL, FM, MPCP, MPCO, SPCP, SPCO) is implemented at the community level, would it be more efficient to provide either the provincial general hospital drug management (PGHDM) or the provincial general hospital surgical operation (PGHSO), instead of the provincial general hospital status quo (PGHSQ) policy for those suffering very severe schistosomiasis?

The specific research objectives were to develop a cost–utility[1] decision analysis (CUDA) model that could be used to map out the most efficient path of intervention options across a spectrum of schistosomiasis states, i.e., asymptomatic (functionally normal), mild, moderate, severe, and very severe states; and to demonstrate the operational feasibility of the CUDA model.

2. Methods

2.1 Working Definitions

Primary interventions are defined as those aimed at attenuating the transmission of schistosomiasis (table 1 and appendix 1). In other words, they are policies whose goal is to reduce the number of new infections and/or lead to early diagnosis and treatment of those found infected. Such policies determine the distribution patterns of the population living in an endemic area across the five defined health states (i.e., normal, mild, moderate, severe, and very severe).

Secondary interventions are defined as those aimed at influencing outcome (recovery, moving to preceding (less serious) states, remaining in the state, advancing to the next more severe states and dying in the state) probabilities for those suffering various stages of schistosomiasis disease.

[1] Cost-utility analysis framework was chosen because health-related quality of life is THE important outcome; intervention(s) under evaluation affect both morbidity and mortality and I wished to have a common unit of outcome that combines both effects; and interventions being compared have a wide range of different kinds of outcomes (Drummond, Stoddart and Torrance, 1987).

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Table 1. *A list of primary and secondary schistosomiasis interventions*

Health state labels	*Selected set of options*
Primary options	1 Status quo (SQ) 2 Household piped water supply (HPWS) 3 Household health education visits (HHEV) 4 Focal mollusciciding (FM) 5 Household vented improved pit latrines (VIPL) 6 Mass population chemotherapy with praziquantel (MPCP) 7 Mass population chemotherapy with oxamniquine (MPCO) 8 Selective population chemotherapy with praziquantel (SPCP) 9 Selective population chemotherapy with oxamniquine (SPCO)
MILD S	1 Status quo at the dispensary (SQD) 2 Praziquantel care at the dispensary (PCD) 3 Oxamniquine care at the dispensary (OCD)
MODERATE K	1 Status quo at the health centre (SQHC) 2 Praziquantel care at the health centre (PCHC) 3 Oxamniquine care at the health centre (OCHC)
SEVERE Z	1 Status quo at the district hospital (SQDH) 2 Praziquantel care at the district hospital (PCDH) 3 Oxamniquine care at the district hospital (OCDH)
VERY SEVERE A	1 Provincial general hospital status quo (PGHSQ) 2 Provincial general hospital inpatient department drug management (PGHDM) 3 Provincial general hospital inpatient department surgical operation (PGHSO)

They encompass all possible treatment options available in health facilities for the patients in the five states.

A *strategy* is defined as a comprehensive ameliorative course of action composed of one primary preventive intervention and all the secondary intervention options at each of the five schistosomiasis health states (appendix 2).

An *optimal strategy* is defined as a comprehensive ameliorative course of action, composed of one primary preventive intervention and the most cost-effective secondary intervention option at each of the five schistosomiasis health states.

A *combination* is a single secondary (facility level) intervention preceded by a single primary (community level) intervention (appendix 2).

2.2 Strategies and policy combinations

The *strategies* evaluated were: status quo (SQS); focal mollusciciding (FMS); household piped water supply (HPWSS); house-to-house health education visits (HHEVS); household vented improved pit latrine (VIPLS); mass population chemotherapy with praziquantel (MPCPS); mass popu-

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lation chemotherapy with oxamniquine (MPCOS); selective population chemotherapy with praziquantel (SPCPS); and selective population chemotherapy with oxamniquine (SPCOS). Each strategy is made up of twelve *policy combinations* (appendix 2).

When a single primary intervention is combined with options available for the mild, moderate, severe, and very severe cases, we get twelve *policy combinations*. For example, combining the focal molluscicide (FM) policy with relevant secondary options yields one strategy consisting of the following combinations: FM + SQD, FM + PCD, FM + OCD, FM + SQHC, FM + PCHC, FM + OCHC, FM + SQDH, FM + PCDH, FM + OCDH, FM + PGHSQ, FM + PGHDM, and FM + PGHSO. The positive sign (+) implies that the effect of the primary intervention is reflected in the secondary option with which it is combined. It does not imply the two are combined in a simple additive manner. The abbreviation FM + SQD involves implementing focal molluscicide at the primary level and status quo at the dispensary for the mild schistosomiasis state (S) cases. The full meanings of all the abbreviations are as defined in table 1.

Thus, there are 108 combinations (i.e., twelve secondary interventions times nine primary options) for which expected costs and quality-adjusted-life-years (QALYs) need to be calculated to facilitate estimation of the CUDA model developed below (see appendix II).

2.3 The cost–utility decision analysis model

The conceptual framework for the analysis is shown in table 2.

2.3.1 The decision tree model

Figure 1 is a graphical representation of the various courses of action available to schistosomiasis decision-makers (represented by decision nodes) and the various actions available to nature (depicted by chance nodes), arranged in their natural sequence. The decision tree model has 37 square decision nodes [(4 secondary nodes × 9 strategies) + 1 primary node] and 117 circular chance nodes [(12 secondary nodes × 9 strategies) + 9 primary nodes)]. At each chance node (health state) there is a finite set of mutually exclusive uncertain outcomes $\{O_\Phi\}$, $\Phi = o_1, o_2, o_3, o_4$, and o_5, where o_1 is full recovery, o_2 is moving to the immediately preceding state, o_3 is remaining in that state, o_4 is dying in the health state, and o_5 is advancing to the next, more severe health state.

2.3.2 The expected quality adjusted life years (EQALYs)

A number of assumptions were made:

1. If an epidemiological cross-sectional survey were done in the Mwea Irrigation Scheme settlement at any point in time, the population would be distributed across the following health states: normal (Y), mild (S), moderate (K), severe (Z), and very severe (A); with some probability P_{ij} ($i = 1,2,...,5$; $j = 1,2,...,m$) associated with the ith health state and the jth intervention policy.

2. The likelihood that an individual drawn at random from the Mwea population would be in health state Y, S, K, Z, or A, depends upon the

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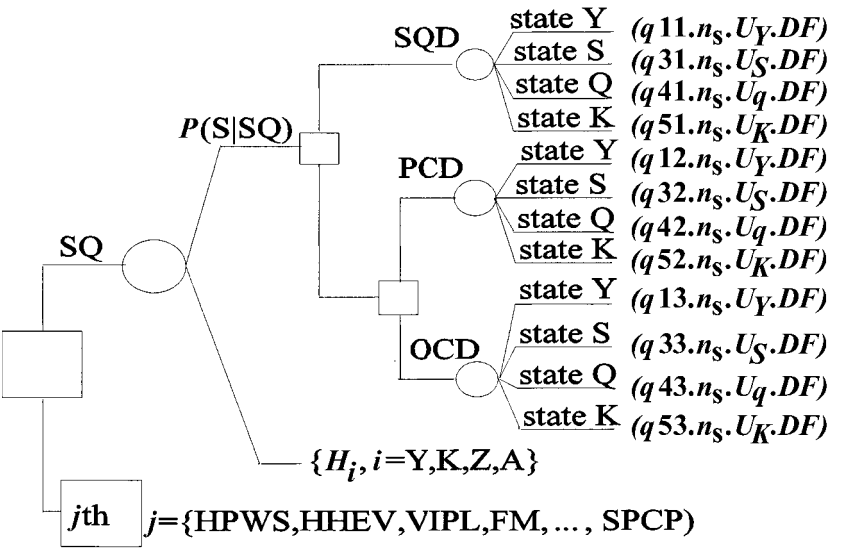

Figure 1 *Cost-utility decision analysis model*

*j*th = SQ, HPWS, HHEV, VIPL, FM, MPCP, MPCO, SPCP, or SPCO).
Hi = decision tree branches for the other health states Y, K, Z and A.
$q_{11} = q$(Y | S,SQ,SQD) – is the probability that a patient in state S will experience outcome 'o_1' (i.e., full recovery) given that SQ and SQD options have been adopted at the community level and dispensary respectively.
$q_{31} = q$(S | S,SQ,SQD) – is the probability that a patient in state S will experience outcome 'o_3' (i.e., remaining in health state S) given that SQ and SQD options have been adopted at the community level and dispensary respectively.
$q_{41} = q$(Q | S,SQ,SQD) – is the probability that a patient in state S will experience outcome 'o_4' (i.e., die in state S) given that SQ and SQD options have been adopted at the community level and dispensary respectively.
$q_{51} = q$(K | S,SQ,SQD) – is the probability that a patient in state S will experience outcome 'o_5' (i.e., advance to the next state) given that SQ and SQD options have been adopted at the community level and dispensary respectively.
$q_{12} = q$(Y | S,SQ,PCD) – is the probability that a patient in state S will experience outcome 'o_1' (i.e., full recovery) given that SQ and PCD options have been adopted at the community level and dispensary respectively.
$q_{32} = q$(S | S,SQ,PCD) – is the probability that a patient in state S will experience outcome 'o_3' (i.e., remaining in health state S) given that SQ and PCD options have been adopted at the community level and dispensary respectively.
$q_{42} = q$(Q | S,SQ,PCD) – is the probability that a patient in state S will experience outcome 'o_4' (i.e., die in the state S) given that SQ and PCD options have been adopted at the community level and dispensary respectively.
$q_{52} = q$(K | S,SQ,PCD) – is the probability that a patient in state S will experience outcome 'o_5' (i.e., advance to the next state) given that SQ and PCD options have been adopted at the community level and dispensary respectively.
$q_{13} = q$(Y | S,SQ,OCD) – is the probability that a patient in state S will experience outcome 'o_1' (i.e., full recovery) given that SQ and OCD options have been adopted at the community level and dispensary respectively.
$q_{33} = q$(S | S,SQ,OCD) – is the probability that a patient in state S will experience outcome 'o_3' (i.e., remaining in health state S) given that SQ and OCD options have been adopted at the community level and dispensary respectively.
$q_{43} = q$(Q | S,SQ,OCD) – is the probability that a patient in state S will experience outcome 'o_4' (i.e., die in state S) given that SQ and OCD options have been adopted at the community level and dispensary respectively.
$q_{53} = q$(K | S,SQ,OCD) – is the probability that a patient in state S will experience outcome 'o_5' (i.e., advance to the next state) given that SQ and OCD options have been adopted at the community level and dispensary respectively.
n_S – is the number of persons expected to experience state S given that *j*th (*j* = SQ, HPWS, HHEV, VIPL, FM, MPCP, MPCO, SPCP, or SPCO) primary intervention has been implemented.
U_Y – is the utility of outcome (o_1); U_K is the utility of outcome o_3; U_q is the utility of outcome o_4; U_K is the utility of outcome o_5.
DF_t – is the discount factor for year '*t*'.

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Table 2. *Conceptual framework for the cost–utility analysis of schistosomiasis intervention strategies*

Costs

1 Costs to the government of organizing and operating community-based schistosomiasis control interventions, e.g., health personnel time, inservice training, per diem, transport, lunch allowance (while in the field), materials, drugs (antischistosomes and chlorpheniramine), administration, utilities (i.e., electricity, water, telephone, and postage), maintenance (of vehicles, equipment, and buildings), capital costs (i.e., vehicles, equipment, and buildings).

2 Costs to the government of organizing and operating health facility-based schistosomiasis control interventions, e.g., health personnel time, in-service training, transport, materials, drugs (antischistosomes and chlorpheniramine), administration, utilities (i.e., electricity, water, telephone, and postage), maintenance (of vehicles, equipment, and buildings), capital costs (i.e., vehicles, equipment, and buildings).

3 Costs borne by households under community-based interventions

3(a) Selective population chemotherapy options

Community resource input into specimen collection phase: information dissemination time (for village heads and household heads) and transport cost, specimen extraction and packaging time (by adults and children), specimen delivery time (household head travel time, waiting time, instruction time), and transport costs.

Community resource input into therapy phase: information dispatch time (for village heads and household heads) and transport costs, treatment input (adults and children travel time and waiting time) and transport costs, negative side-effects monitoring time (adults and children time), negative side-effects treatment time (for adults and children). Only the community inputs into therapy phase are relevant under the mass population chemotherapy options. Time for adults was valued at local market wage rate of Ksh. 5 per hour; and Ksh. 2.5 per hour for children.

3(b) Community resource input into HHEV option

Time spent by communities with public health technicians, family health educators, and village health workers

Value of lunch provided by communities to health personnel during their field visits

Value of community space (used during health education sessions)

3(c) Community resource input into VIPL option

Community labour (in days) used to maintain cleanliness of latrines; materials (litres of water, brooms, drying rugs, pairs of hand gloves, water pails); land occupied by latrines; transport (including travel time, shopping time, and bus fare).

4 Costs borne by patients, their households and community members under health facility-based intervention options

Payment for treatment, transport (for patients, accompanying persons, and visitors if hospitalized), x-ray and laboratory fees, mortuary fees (for patients who die during treatment), mortuary bribes (for patients who die during treatment).

Opportunity cost of the time invested (by patients, accompanying persons and visitors) in treatment, including travel time, waiting time, x-ray time, treatment time, externality monitoring time, externality treatment time

Consequences

Changes in health (i.e., quantity and quality of life) of the Mwea irrigation scheme residents (measured in quality-adjusted-life-years).

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primary course of action taken collectively at the community level. On the other hand, the probability of a person who is already in any one of the health states experiencing the Φth outcome will depend upon the effectiveness of the policy undertaken at the secondary level.

3. The schistosomiasis Delphi panel experts hold prior beliefs (p) about how the Mwea population would be distributed across the five health states, assuming that the jth primary policy had been undertaken. That is $P = \{P_i\}$, $i = P_Y,P_S,P_K,P_Z$, and P_A, where P_Y is the probability that the ith individual is in a normal state (Y), etc. (Kirigia, 1997).

4. At each health state (chance node) there is a finite set of uncertain health outcomes $\{O_\Phi\}$, $\Phi = o_1,o_2,o_3,o_4$, and o_5, where o_1 is full recovery; o_2 is to move to the immediately preceding state; o_3 is to remain in that health state; o_4 is to die in the health state; and o_5 is to advance to the next state.

5. The panel of experts hold prior beliefs (q) about the likelihoods of a person in the ith health state experiencing a specific outcome, assuming the jth primary and secondary policies have been undertaken. That is $q = \{q_K\}$, $K = q_1,q_2,q_3,q_4,q_5$, where q_1 is the probability of full recovery; q_2 is the probability of moving to the immediately preceding state; q_3 is the probability of remaining that health state; q_4 is the probability of dying in the health state; and q_5 is the probability of advancing to the next state.

6. The listing of health states and outcomes is assumed to be exhaustive (i.e., includes all the possibilities) and mutually exclusive (implying that any inhabitant of the Mwea scheme can never be in more than one health state at any point in time or experience more than one outcome simultaneously).

7. The panel of experts can estimate the remaining life expectancy (L) (to the nearest whole year) for each health state (assuming a five year base age and a general Kenyan life expectancy of 57 years) in the absence of the intervention policy. That is $L = \{L_\beta\}$, $\beta = L_Y,L_S,L_K,L_Z$, and L_A, where L_1 is the remaining life for a person in state Y, etc. (Kirigia, 1997).

8. Mwea Scheme residents (farmers, teachers, and health professionals) are the appropriate judges of their welfare, and their mean health state valuations (U) should count in the decision analysis. That is $U = \{U_\alpha\}$, $\alpha = U_Y,U_S,U_K;U_Z$ and U_A, where U_Y is the average utility of health state Y, etc.

9. By multiplying respective health state probabilities (P_{ij}) by the projected annual population (N), the distribution (n) of the Mwea population across health states can be derived. That is $n = \{n_\lambda\}$, $\lambda = n_Y,n_S,n_K;n_Z$, and n_A, where n_Y is the number of persons in state Y under the jth policy combination for those in Y, etc. Thus, the number of persons in a given health state during any one year will depend upon the effectiveness of the intervention policy adopted at the primary/community level.

10. The rate of return on Kenya Government bonds is assumed to reflect the social opportunity cost of capital. All health benefits and costs were discounted at a discount rate (r) equal to the real rate of return on bonds (i.e., 10 per cent) (Brent, 1990). Thus, the present value of benefits and costs for year t will be a product of the relevant discount factor (DF_t) and expected benefits and costs.

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11. The Delphi panel of experts will be able to propose a reasonable project life (T) for the schistosomiasis projects, beyond which the flow of costs and benefits would either cease or would be insignificant.

12. The appropriate physical measure of intervention effectiveness is its expected quality adjusted life years (EQALY) index, where $EQALY_j$ is the sum of the values of each health outcome (O_Φ), with each outcome utility being multiplied by its probability of occurrence, the specific year under consideration (= 1), the discount factor, and the number of people who are likely to experience the Φth state by the end of the year in question.

The EQALYs are calculated within the decision analysis framework (figure 1) in two steps. In the first, each jth strategy's EQALYs for year 0 to 14 are calculated using equation (1).

$$\sum_{t=0}^{t=14} EQALY_{ij} = (q_{1J} \times n_t \times U_Y \times 1 \times DF_t) + (q_{2J} \times n_t \times U_S \times 1 \times DF_t) + (q_{3J} \times n_t \times U_K \times 1 \times DF_t) + (q_{4J} \times n_t \times U_Z \times 1 \times DF_t) + (q_{5J} \times n_t \times U_A \times 1 \times DF_t) \quad (1)$$

In the second step, each option's EQALYs for year 15 and above are estimated using equation (2).

$$\sum_{t=15}^{t=15} EQALY_{ij} = (q_{1J} \times n_t \times U_Y \times L_1 \times ADF_Y) + (q_{2J} \times n_t \times U_S \times L_2 \times ADF_S) + (q_{3J} \times n_t \times U_K \times L_3 \times ADF_K) + (q_{4J} \times n_t \times U_Z \times L_4 \times ADF_Z) + (q_{5J} \times n_t \times U_A \times L_5 \times ADF_A) \quad (2)$$

This means that in year 15 the remaining life expectancy would be used instead of just the single year under consideration. The EQALYs for year 15 will have to be discounted using average discount factors (ADF_i) over the remaining life expectancies for the relevant outcomes (i = Y,S,K,Z,A). Summation of the present values of QALYs expected from the optimal option for each of the five health states yields the total health benefits of the jth strategy. That result, which is the sum of equations (1) and (2), is algebraically expressed in equation (3) below.

$$\sum_{i=1}^{5} \sum_{t=0}^{T=15} EQALY_{ij} \quad (3)$$

In the above equation, $EQALY_{ij}$ refers to the present value of QALYs which the ith health state patients expect if the jth strategy is undertaken for a period of 15 years. The symbols in equation (1) and (2) are described in the 'notation'. In the context of the measurement of health impact of schistosomiasis intervention, effectiveness is to be seen as the difference over a period of time between EQALYs with and without the intervention.

2.3.3 The expected costs of the jth strategy

The total cost of the jth strategy is given by equation (4) below.

$$\sum_{i=1}^{5} \sum_{t=0}^{T=15} C_{ij} \quad (4)$$

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In this equation (4), C_{ij} refers to the present value of cost that would be incurred if the *j*th strategy were made available to patients in the *i*th health state, for a period of 15 years.

2.3.4 The cost–utility criteria

The expected benefits to patients are defined as $EQALY_{ij}$; and the expected cost as C_{ij}; where *i* denotes the health state and *j* the policy combination being evaluated. The following three policy combinations, SQ + SQD, SQ + PCD and SQ + OCD, for those in state S will be used to illustrate how the cost–utility analysis model works. Thus $EQALY_{SQ+SQD}$ are the total QALYs expected from the status quo policies at primary level and the dispensary for those in state S; $EQALY_{SQ+PCD}$ are the total QALYs expected from the status quo policy at the primary level and the praziquantel treatment at the dispensary for those in state S; $EQALY_{SQ+OCD}$ are the total QALYs expected from the status quo policy at the primary level and the oxamniquine treatment at the dispensary for those in state S.

In parallel notation, the associated costs are C_{SQ+SQD} which is the total expected cost of status quo policies at the primary level and the dispensary for those in state S; C_{SQ+PCD} is the total expected cost of status quo policy at the primary level and the praziquantel treatment at the dispensary for those in state S; and C_{SQ+OCD} is the total expected cost of status quo policy at primary level and the oxamniquine treatment at the dispensary for those in state S.

With partial differentials of the expected QALYs and costs of the SQ + PCD and SQ + OCD with respect to those of the status quo (SQ + SQD), the incremental EQALYs and incremental costs can be obtained. Thus $\partial EQALY_1 = EQALY_{SQ+PCD} - EQALY_{SQ+SQD}$; $\partial EQALY_2 = EQALY_{SQ+OCD} - EQALY_{SQ+SQD}$; $\partial C_1 = C_{SQ+PCD} - C_{SQ+SQD}$; and $\partial C_2 = C_{SQ+OCD} - C_{SQ+SQD}$, where $\partial EQALY_1$ and $\partial EQALY_2$ depict EQALY gains from SQ + PCD and SQ + OCD over SQ + SQD; while ∂C_1 and ∂C_2 represent the change in cost by doing SQ + PCD and SQ + OCD over SQ + SQD.

The incremental cost–utility ratio (CUR) criteria indicates that, if $\partial C_1 / \partial EQALY_1 < \partial C_2 / \partial EQALY_2$, SQ + PCD option is the preferred option (assuming there are only two combinations). If $\partial C_1 / \partial EQALY_1 = \partial C_2 / \partial EQALY_2$, the decision-maker would be expected to be indifferent between them. Where there is more than one mutually exclusive alternative under evaluation, the strategy (or combination) with the least incremental CUR should be preferred.

2.4 Data sources

2.4.1 Effectiveness data

The following information was used in the calculations of expected QALY gains: utility values for each of the health states; age of disease onset; remaining life expectancy at each health state; outcome/transition probability estimates; annual health state probability estimates assuming each of the primary policies is undertaken singly over the relevant project period; annual population projections for the Mwea Scheme over the project period; and a discount rate.

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Health states values

A schistosomiasis epidemiologist delineated the seven main severity stages in Schistosoma Mansoni and accompanying clinical symptoms: the 'asymptomatic' stage, where the victim feels quite healthy (functionally normal); the 'mild' stage characterized by cercarial dermatitis, mild fever, and pulmonary symptoms (mild cough); the 'moderate' stage characterized by gastro-intestinal symptoms, dysentery (plus increased frequency of stools), and microscopic haematemesis; the 'severe' stage characterized by hepatosplenomegaly, oesophageal varices (not bleeding), and ascites (mild to moderate); the 'very severe' stage characterized by gross ascites, bleeding oesophageal varices, and portal hypertension; the 'comatose' stage; and finally the seventh, the absorbing stage of 'death'.

The schistosomiasis epidemiologist was requested to explain briefly in layman's language the impact of each of the severity stages on victims six functional dimensions, i.e., mobility, self-care, livelihood, energy, pain, and social participation. This process produced a health related quality of life (HRQoL) instrument consisting of seven health states (table 3) and a visual analogue scale. The HRQoL instrument was administered to random samples of rice farmers ($N = 417$), teachers ($N = 89$), and health personnel ($N = 37$) living in the Mwea Irrigation Scheme. Table 4 presents the health states utility valuations used in this study. Invariably, the utility valuations increase with the decrease in the perceived severity of health states.

Delphi effectiveness estimates

The relevant randomized controlled trials probabilistic effectiveness information needed in decision analysis was unavailable in the published epidemiological literature. Thus, a modified Delphi approach was used to elicit expert subjective judgements on the remaining life expectancy at

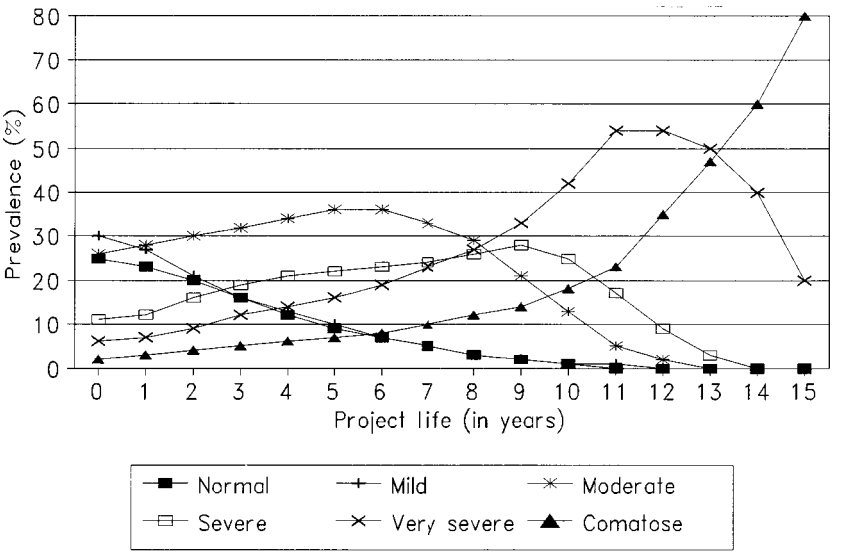

Figure 2a *State prevalence with SQ: local experts judgements*

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Table 3. *English translation of kikuyu version of health states used in the field*

STATE Y Your normal state of health
STATE S You have bilharzia germs, but your mobility, livelihood activities, self-care, social participation and energy are normal, except for occasional mild bladder and stomach pain. you will proceed to the next more severe state, in three years, without intervention.
STATE K You have bilharzia germs, but your mobility, self-care, and social participation are normal, except for: frequent moderate bladder and stomach pains slight reduction in energy causing moderate reduction in capacity for livelihood activities, but no absence from livelihood activities – work, school, etc. you will proceed to the next more severe state in three years, without intervention.
STATE Z You have bilharzia germs, but you have no difficulty with self-care, except for: slightly impaired mobility, can only walk for more than 1 mile with difficulty persistent moderate bladder and stomach pains moderate reduction in energy causing frequent absence from livelihood activities – school, work, etc. frequent absence from social community activities – church, peer get-together meetings, public 'baraza', etc. you will proceed to the next more severe state in three years, without intervention.
STATE A Due to bilharzia germs, you have: severely impaired mobility, bed-ridden most of the time moderate lack of control of urination and defecation severe reduction in energy causing total absence from livelihood activities – work, school total absence from social activities – church, public 'baraza', peer get-together meetings, etc. severe body pain you will proceed to the next more severe state in three years, without health intervention.
STATE R You are unconscious because of bilharzia germs you will proceed to the next more severe state in three years, without health intervention.
STATE Q Death

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Table 4. *Health state utility values for various states*

Health states	*Mean*
Normal (Y)	1
Mild (S)	0.81
Moderate (K)	0.65
Severe (Z)	0.49
Very severe (A)	0.33
Comatose (R)	0.17
Dead (Q)	0
Sample size	526

each health state, health state probability estimates, and outcome/transition probability estimates assuming each of the policies is undertaken singly over the relevant project period. The probabilities were elicited from three schistosomiasis experts.

Expert judgements of health states prevalence rates with various primary policies were elicited through the following question:

> Suppose each of the following primary schistosomiasis interventions: SQ, HPWS, VIPL, HHED, FM, MPCP, MPCO, SPCP, and SPCO, were implemented separately in Mwea Scheme (where the prevalence rate is currently 75 per cent) at the beginning of the year and allowed to run for 15 years. Suppose towards the end of each of the years 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, random samples of 100 persons are drawn from the Mwea Scheme, what percentages would you expect to be in normal (Y), mild (S), moderate (K), severe (Z), very severe (A), and comatose (R) health states, with each of the primary policies mentioned above.

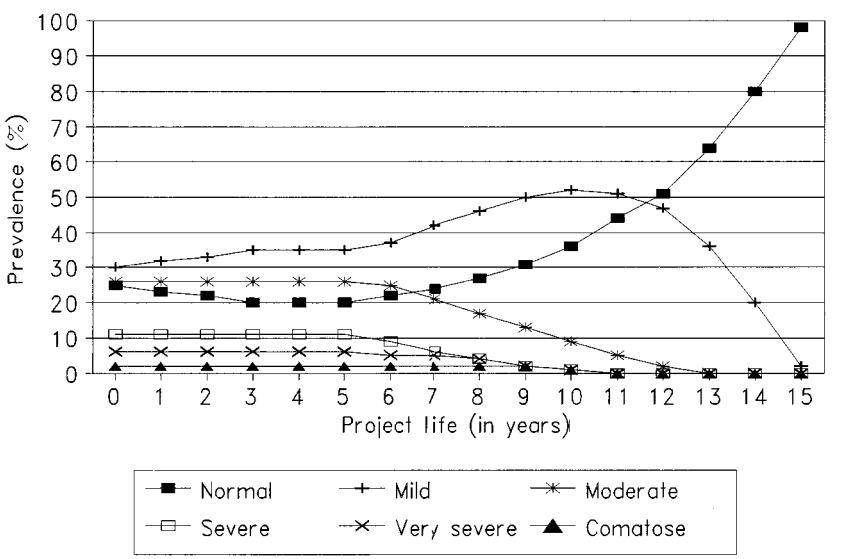

Figure 2b *State prevalence with HPWS: local experts judgements*

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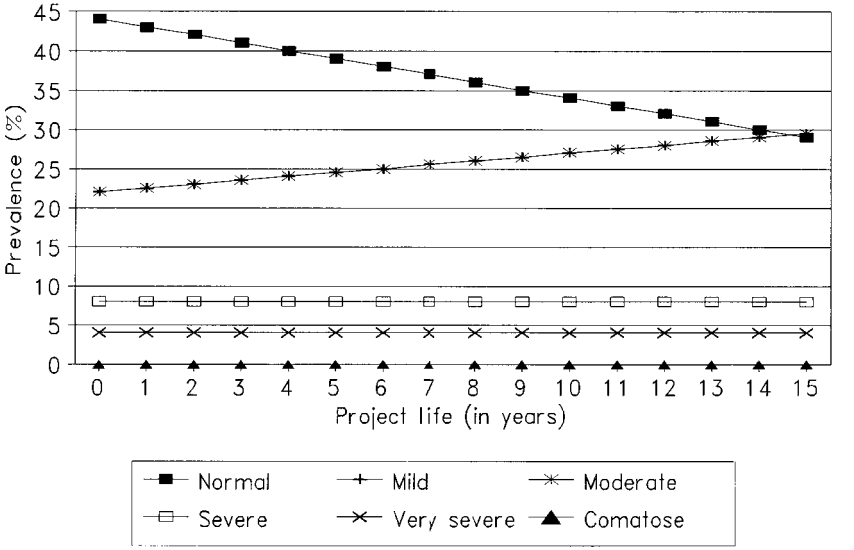

Figure 2c *State prevalence with SQ: foreign experts judgements*

Their health states probability estimates with SQ and HPWS are shown in figures 2(a), 2(b), 2(c) and 2(d) for illustration. The projections for other interventions can be obtained from the author.

The impacts of secondary interventions on probabilities for the five consequences mentioned in sub-section 2.3.1 were elicited via the following question: 'Suppose at the *n*th chance node (in figure 1) you are given 100 persons randomly selected from Mwea Scheme, what

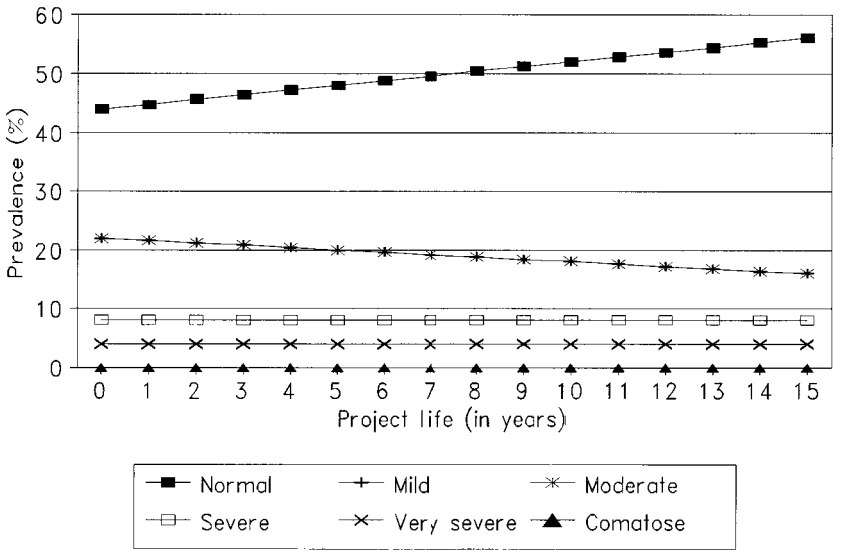

Figure 2d *State prevalence with HPWS: foreign experts judgements*

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percentage would you expect to: have spontaneous recovery, recede to the preceding health state, remain in *n*th state, die in *n*th state, and advance to the next state.' The experts' outcome/transition probability estimates are presented in appendix 3. The detailed procedures, the short-comings of the Delphi technique and the practical problems encountered during the elicitation process are discussed elsewhere (Kirigia, 1997).

2.4.2 Cost data

The costing process involved identification, quantification, and valuation of key inputs, such as health professionals' time, in-service training, administration, pharmaceuticals, chemicals, materials, utilities (telephone, electricity, and postage), travel, transport, maintenance (of equipment, vehicles, and buildings), capital commodities (vehicles, equipment, and buildings), and community inputs (time for those not in severe and very severe states and visitors, money, and materials) into the various interventions. Apart from the cost of SQ (which is based on 1992 expenditure data), the estimates of quantities of inputs that would be needed under alternative options (over the next 15 years) were estimated prospectively. The quantified inputs were valued in 1992 constant market prices. The recurrent costs were discounted at a rate of 10 per cent (Scott *et al.*, 1976; MacArthur, 1978; Brent, 1990; Curry and Weiss, 1993). The annual equivalent costs of vehicles, equipment, and buildings were calculated assuming useful lives of 10 years, 10 years and 30 years, respectively. A standard conversion factor (SCF), derived and used in past Kenyan studies (Scott *et al.*, 1976; MacArthur, 1978; Brent, 1990; Curry and Weiss, 1993) was used to revalue resources for interventions from their constant market price values to their shadow price values. In short, the shadow price = SCF $\times$ market price value. The ratios of expected numbers of the mild (moderate, severe, and very severe) schistosomiasis cases to the total number of cases expected at the dispensary (health centre, district hospital, provincial general hospital) annually, were used as the basis of apportioning various cost components to the relevant policy combinations.

The direct and indirect costs for each of the policy combinations listed in appendix 2 were estimated for every year in the estimated project life. The cost in each case was for the number of patients expected to use that specific secondary option assuming the primary option it is combined with is already in place.

3. Result

3.1 Intervention strategies' cost–utility results

The cost–utility ratios for the nine alternative strategies are presented in tables 5 and 6. The main findings are as follows. (1) except for the vented improved pit latrine strategy (VIPLS), all the other alternative strategies are more cost-effective than the status quo strategy (SQS). (2) the selective population chemotherapy with praziquantel (SPCPS) was found to be the optimal strategy, i.e., had the lowest cost–utility ratio. (3) the strategies which involve treatment at the community level (except FMS) were more cost-effective than those with non-treatment community level policies. (4)

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Table 5. *A cost–utility analysis of schistosomiasis strategies using foreign expert probabilistic effectiveness estimates*

Strategies	*Total EQALYs*	*Total cost (Ksh)*	*Average cost per QALY*	*Incremental cost per QALY*
SQS	335,132	347,548,217	1,037	—
HPWSS	377,990	361,521,325	956	326
HHEVS	387,689	291,750,508	753	−1,062
VIPLS	387,575	810,363,736	2,091	8,825
FMS	402,779	244,151,321	606	−1,529
MPCPS	425,365	212,735,211	500	−1,494
MPCOS	425,365	251,626,046	592	−1,063
SPCPS	420,134	151,998,743	361	−2,301
SPCOS	420,134	174,154,033	415	−2,040

the incremental cost–utility ratios calculated using the foreign expert subjective judgements could be expressed as follows: $SPCPS_{CUR} < SPCOS_{CUR} < FMS_{CUR} < MPCPS_{CUR} < MPCOS_{CUR} < HHEVS_{CUR} < HPWSS_{CUR} < VIPLS_{CUR}$. (5) the strategies could be ranked in terms of their incremental cost–utility ratios estimated using local experts' subjective probabilities: $SPCPS_{CUR} < SPCOS_{CUR} < FMS_{CUR} = MPCPS_{CUR} < MPCOS_{CUR} < HPWSS_{CUR} < HHEDS_{CUR} < VIPLS_{CUR}$. (6) the local experts were more optimistic in their assessment of the effectiveness of all alternative intervention strategies than was the foreign expert. (7) there was a consensus that among the non-treatment interventions, Molluscicide strategy (FMS) would be the most cost-effective.

3.2 Optimal strategy's cost–utility results

The optimal strategy's policy combinations' EQALYs, expected costs, and cost–utility ratios are given in tables 7 and 8. It is important to note that all the secondary level options under the optimal strategy will have been preceded by SPCP treatment at the primary level. The three sub-options available for mild schistosomiasis patients are: status quo at the dispensary (SPCP + SQD); praziquantel care at the dispensary (SPCP + PCD); and oxamniquine care at the dispensary (SPCP + OCD). The incremental CUR relationships were as follows: $CUR_{SPCP+PCD} < CUR_{SPCP+OCD}$.

Table 6. *A cost–utility analysis of schistosomiasis strategies using local expert probabilistic effectiveness estimates*

Strategies	*Total EQALYs*	*Total cost (Ksh)*	*Average cost per QALY*	*Incremental cost per QALY*
SQS	2,504,365	569,055,519	227	
HPWSS	11,998,780	424,271,493	35	−15
HHEVS	11,887,600	452,153,928	38	−12
VIPLS	12,138,675	946,857,458	78	39
FMS	12,037,874	290,643,818	24	−29
MPCPS	14,013,933	236,390,603	17	−29
MPCOS	13,489,119	274,496,299	20	−26
SPCPS	14,013,933	162,723,615	12	−35
SPCOS	13,489,119	198,435,423	15	−33

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Table 7. *Cost–utility of secondary options under the optimal schistosomiasis intervention strategy – SPCPS (estimated using foreign experts' subjective probabilities)*

Health state	*Secondary options*	*Total EQALYs*	*Total costs (Ksh)*	*Average cost/QALY*	*Incremental QALY*
Y	SPCP + Y	324,767	33,747,846	104	—
S	SPCP + SQD	37,245	7,837,846	210	—
	SPCP + PCD	45,644	13,722,318	301	701
	SPCP + OCD	45,644	14,340,835	314	774
K	SPCP + SQHC	32,133	10,043,772	313	—
	SPCP + PCHC	42,312	33,496,384	792	2,304
	SPCP + OCHC	42,312	33,972,015	803	2,351
Z	SPCP + SQDH	5,437	13,914,145	2,559	—
	SPCP + PCDH	6,077	49,359,576	8,123	55,437
	SPCP + OCDH	6,077	49,533,819	8,151	55,710
A	SPCP + PGHSQ	1,017	21,480,970	21,130	—
	SPCP + PGHDM	1,335	22,033,356	16,506	1,735
	SPCP + PGHSO	1,335	21,672,620	16,235	602

The incremental CUR criteria indicate that the SPCP + PCD treatment is preferred for mild schistosomiasis patients.

The three sub-options available for moderate schistosomiasis patients are: status quo at the health centre (SPCP + SQHC); praziquantel care at the health centre (SPCP + PCHC); and oxamniquine care at the health centre (SPCP + OCHC). The incremental CUR relationships were as follows: $CUR_{SPCP+PCHC} < CUR_{SPCP+OCHC}$. Thus, according to the incremental CUR criteria the SPCP + PCHC treatment is the preferred one for the moderate schistosomiasis patients.

The three options available for severe schistosomiasis state patients are: status quo at the district hospital (SPCP + SQDH); praziquantel care at the district hospital (SPCP + PCDH); and oxamniquine care at the district hos-

Table 8. *Cost–utility of secondary options under the optimal schistosomiasis intervention strategy – SPCPS (estimated using local experts' subjective probabilities)*

Health state	*Secondary options*	*Total EQALYs*	*Total costs (Ksh)*	*Average cost/QALY*	*Incremental QALY*
Y	SPCP + Y	12,049,801	27,659,785	2	—
S	SPCP + SQD	459,452	7,248,949	16	—
	SPCP + PCD	1,134,955	13,180,776	12	9
	SPCP + OCD	1,126,481	13,804,571	12	10
K	SPCP + SQHC	206,152	5,784,911	28	—
	SPCP + PCHC	714,841	23,347,547	33	35
	SPCP + OCHC	690,165	23,779,334	34	37
Z	SPCP + SQDH	10,672	12,237,637	1,147	—
	SPCP + PCDH	114,083	43,650,796	383	304
	SPCP + OCDH	109,126	43,819,672	402	321
A	SPCP + PGHSQ	63	22,146,050	351,525	—
	SPCP + PGHDM	101	22,706,684	224,819	14,754
	SPCP + PGHSO	253	22,339,988	88,300	1,021

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pital (SPCP + OCDH). The three rank as follows: $CUR_{SPCP+PCDH} < CUR_{SPCP+OCDH}$. Since SPCP + PCDH dominates SPCP + OCDH, the praziquantel care at the district hospital (SPCP + PCDH) is preferred for severe schistosomiasis cases.

The three options available for the very severe schistosomiasis patients are: provincial general hospital status quo (SPCP + PGHSQ); provincial general hospital inpatient department palliative drug management (SPCP + PGHDM); and provincial general hospital surgical operation (SPCP + PGHSO). The three rank as follows: $CUR_{SPCP+PGHSO} < CUR_{SPCP+PGHDM}$. Since SPCP + PGHSO dominates SPCP + PGHDM, the preferred option for the very severe schistosomiasis cases is that they be operated on at the provincial general hospital surgical department.

3.3 Sensitivity analysis

When the CUDA model was run with a foreign expert's and local experts' estimated subjective probabilities, on both cases SPCPS turned out to be the optimal strategy, even though there were remarkable differences in the magnitudes of probabilistic effectiveness estimates elicited from the two sets of experts.

Analysis of the impacts of systematic changes in EQALYs on the choice of optimal strategy was conducted, holding the expected cost constant. When the expected QALYs are varied 'across-the-board' by over 80 per cent, the choice of the SPCPS as the optimal strategy remained invariant. However, the choice of SPCPS as the optimal strategy was found to be sensitive to minor variations (1 per cent change) in its effectiveness with the effectiveness of other strategies held constant.

4. Discussion

This study developed a cost–utility decision analysis (CUDA) model for determining the optimal path of interventions across various schistosomiasis states. To test the operational efficiency of the CUDA model the following data were used: expected costs of both primary and facility level options; health states (outcomes) utility values; expected life years for each of the health states (outcomes); health state probabilities and transition probabilities; population forecasts for the Mwea Scheme; and discount factors for each year. The CUDA model was estimated separately using both local and foreign experts' subjective probabilities.

4.1 Multiple primary interventions

This study assumes that primary options (like secondary options) are mutually exclusive. While the assumption is definitely plausible for the latter, in reality it may not hold for the former. However, that problem in principle could easily be dealt with in the CUDA model, by evaluating a combination of two or more primary options as a single option. For example, if SPCP were combined with FM, we would have SPCP/FM primary option plus associated secondary options (SPCP/FM + SQD, SPCP/FM + PCD, SPCP/FM + OCD, and so on). Kirigia (1997) attempted to elicit subjective probabilistic effectiveness of combinations of primary options, but experts found combinations extremely difficult to evaluate.

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The reason is possibly that while their costs could just be 'summed up', the same could not be done with effectiveness (mainly because it is not linear).

4.2 Effectiveness

One of the key findings of the study is that the strategies which involve treatment at the community level (except FMS) are more cost-effective than those with non-treatment community level policies. However, this finding needs to be tempered by the fact that HPWSS, HHEVS, and VIPL may have enormous positive externalities which were not quantified in the current study. For example, the provision of a safe and reliable water supply within the homestead would reduce the prevalence of diarrhoeal diseases and other water-borne diseases (in addition to schistosomiasis).

4.3 Validity and reliability

Given that the validity and reliability of the quality of life and the Delphi measurements were not established, it follows that the reliability and validity of results from the cost–utility model remain uncertain. It follows that the findings generated in this study may not be able to be generalized. The EQALYs estimated in this study are tentative and they should only be used with caution to aid decision making.

The disadvantages of effectiveness assessments from a Delphi panel must be weighed against the advantages that can be achieved through the use of subjective probabilities. The fact remains that in many instances these technological methods are the only systematic approaches available. More empirical work needs to be done on the contributions to accuracy of the four key aspects of Delphi, i.e., number of experts, expertise, iterative procedure, and feedback (Kirigia, 1997).

At the same time however and despite these qualifications this study does represent a major step forward in terms of both the methodology adapted and the basis on which current decision making takes place. Problems remain as indicated but the analysis here and the results used with caution can help to improve the efficiency in use of schistosomiasis control resources.

4.4 Dilemma regarding measurement of impacts of epidemiological environment change on health

There has been singular ignorance of the epidemiological environment (EE) of schistosomiasis in Kenya's economic policy; and it is reflected in the lack of national policy to combat this EE hazard. The alleged ignorance by policy-makers might be a manifestation of the inherent failure by economists to conduct substantive research into the fundamental (but complex) links between human health, EE, and various interventions. This gap could be attributed to the difficulty in quantifying the impact of EE change on health (defined in terms of life expectancy and health-related quality of life). There are a number of dilemmas in this regard. Should economists do nothing about measurement of EE change intervention policies costs and health consequences until epidemiologists come up with the 'hard' data (preferably from randomized controlled trials) required in decision analyses? Do epidemiologists know the kind of infor-

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mation required by economists? Given the scarcity of research resources in Kenya, is randomized controlled trial data likely to be forthcoming in the near future? Will the policy-makers in Kenya wait until the 'hard' data required in decision analyses are made available by epidemiological environmentalists for economists to undertake efficiency evaluations? Given that the Delphi technique has been fruitfully used in industry, commerce, and academia in developed countries, can health policy-makers in Kenya do worse (than the current practice where decisions to commit resources are based on 'what we did last time' tempered with 'gut feelings') by using systematic decision analysis based on data from such a technique? Our answer to all the questions is: NO! Since the political and ethical cost of inaction may be enormous, the Schistosomiasis Control Programme (SCP) policy-makers will have to take decisions with or without guidance from economists. Thus, in this paper, we advocate the use of subjective EE expert judgements regarding health consequences of policies meant to attenuate negative externalities of developmental projects (like the MIS).

5. Conclusion

The proven operational feasibility of the CUDA model indicates that the decision analysis conceptual framework provides a useful adjunct to cost–utility analysis. It also provides a cohesive framework for dealing with both uncertainty and difficult value judgements, as well as the complex sequencing of decisions based on the current level of information and long-range probabilistic effectiveness forecasts.

The choice of SPCPS (using both local and foreign expert judgements) as the optimal strategy in the CUDA model was invariant to changes in expected effectiveness values across the board. However, the choice of SPCPS as the optimal strategy proved to be very sensitive when its effectiveness was decreased when the effectiveness of the other strategies was held constant. Such sensitivity could be attributed to the closeness of the probabilistic effectiveness values of various strategies as assessed by experts.

In summary, there is no more than a limited basis for drawing any policy conclusions from this study. There is a need for a greater degree of consensus among the schistosomiasis intervention(s) experts. In addition, a change is necessary in the way randomized controlled effectiveness trials are currently conducted to enable them to produce the relevant epidemiological information needed in economic evaluations.

Finally, readers are cautioned that the main purpose of this study was not to produce a policy paper for adoption or implementation by the Ministry of Health. Instead its purpose was primarily to develop a decision analytic framework which could be used to determine the optimal path of interventions across various schistosomiasis states, when reliable and valid empirical data do become available. Nonetheless, while the results are tentative, they do represent a better basis than has previously existed for decision making in this field. It would be appropriate however for yet firmer basis and better data to be developed before action is taken to alter the current strategies for schistosomiasis interventions.

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Appendix 1

Description of primary intervention options

The following nine primary options were chosen for study:

(a) *Status quo (SQ)*, which implies continuing current schistosomiasis control activities at the community level. Currently there are haphazardly implemented canal weeding, unhygienic household built latrines, sporadic drip-molluscicide, experimental water bore-holes (which are non-functional most of the time) and *ad hoc* experimental targeted-selective chemotherapy activities in the Mwea Irrigation Scheme.

(b) *Focal molluscicide (FM)*, which entails treating with niclosamide the specific spots inhabited by vector snails (intermediate schistosome parasite host) using hand operated or automated pressure pump sprayers. Niclosamide (BAYLUSCIDE) is the WHO recommended chemical molluscicide and is the only chemical molluscicide currently available in the market (WHO, 1989; WHO, 1973).

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(c) *Household piped water supply (HPWS)*, which involves provision of clean piped water to every household at risk. Its effectiveness has been demonstrated in St. Lucia (Jordan, 1985). The intermediate goal is to reduce the frequency of human contact with the schistosome parasite (cercariae) contaminated water.
(d) *House to house health education visits (HHEV)*, is a programme aimed at imparting knowledge to the individuals at risk concerning the life cycle of the schistosome parasite, symptoms of infection and methods of avoiding infection and transmission of the disease.
(e) *Vented improved pit latrines (VIPL)*, is an on-site disposal system where human excreta fall into a pit in the ground, and a new pit is dug when the pit is about two-thirds full. The pits are covered by squatting slabs. Ventilated improved pit latrines in general are familiar to rural folk and will have higher usage/compliance. Since VIP latrines are fitted with a fly-screen, vent pipe odours are virtually eliminated (Feachen *et al*., 1983).
(f) *Mass population chemotherapy with praziquantel (MPCP)*, which involves praziquantel treatment of the entire population without prior diagnosis.
(g) *Selective population chemotherapy with praziquantel (SPCP)*, which entails screening stool samples from the entire population and treating only persons excreting schistosome eggs with praziquantel.
(h) *Mass population chemotherapy with oxamniquine (MPCO)*, which involves oxamniquine treatment of the entire population without prior diagnosis.
(i) *Selective population chemotherapy with oxamniquine (SPCO)*, which entails screening stool samples from the entire population and treating only persons excreting schistosome eggs with oxaminiquine.

Description of secondary options

On the advice of schistosomiasis epidemiologists, the consensus is that the technically appropriate place to treat patients in mild state is the dispensary, in moderate state is the health centre, in severe schistosomiasis is the district hospital, and in very severe state is the provincial general hospital inpatient department.

Mild health state (S) options

There are three options for those suffering mild schistosomiasis:

(a) *Status quo at the dispensary (SQD)*, entails continuing the current practice, which is characterized by rampant shortages of schistosomiasis treatment drugs (REACH, 1989; Forgey *et al*., 1990; Musau *et al*., 1995). The dispensary is the lowest level facility within the Kenyan public health care system, and they do not have laboratories.
(b) *Praziquantel care at the dispensary (PCD)*, would entail diagnosis by exclusion, followed by full dose of praziquantel.
(c) *Oxamniquine care at the dispensary (OCD)*, would entail diagnosis by exclusion, followed by full dose of oxamniquine. Under options (b) and (c) there would be no shortages of the relevant inputs.

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Moderate health state (K) options
There are three options for the moderate cases:

(a) *Status quo at the health centre (SQHC)*, entails continuing the current practice, which is characterized by chronic shortage of schistosomiasis treatment drugs (REACH, 1989; Forgey *et al*., 1990; Musau *et al*., 1995). The health centre (HC) is the second lowest level facility within the hierarchy of the Kenyan public health care system, and has laboratories where parasitological screening can be done.
(b) *Praziquantel care at the health centre (PCHC)*, would involve parasitological screening of all patients visiting the Health Centre, and treatment with praziquantel of all those who test positive.
(c) *Oxamniquine care at the health centre (OCHC)*, would involve parasitological screening of all patients visiting the health centre, and treatment with oxamniquine of all those who test positive. There would be no shortage of inputs needed to treat the moderate schistosomiasis cases under options (b) and (c).

Severe health state (Z) options
There are three options for the severe cases:

(a) *Status quo at the District Hospital (SQDH)*, is the current practice at the district hospital outpatient department (DHOD) which is characterized by chronic shortages of the recurrent diagnostic and therapeutic inputs needed in the treatment of severe schistosomiasis cases (REACH, 1989; Forgey *et al*., 1990; Musau *et al*., 1995). The district hospital (DH) has radiology departments where x-ray screening could be done.
(b) *Praziquantel care at the district hospital (PCDH)*, would entail x-ray screening of all the patients presenting themselves to the DHOD from the Mwea Division, followed by praziquantel treatment of all those found suffering from severe schistosomiasis.
(c) *Oxamniquine care at the district hospital (OCDH)*, would entail x-ray screening of all the patients presenting themselves to the DHOD from Mwea Division, followed by oxamniquine treatment to all those found manifesting severe schistosomiasis state. There would be no shortages of inputs needed to treat the severe schistosomiasis cases under options (b) and (c).

Very severe health state (A) options
There are three options for the very severe cases:

(a) *Provincial general hospital status quo policy (PGHSQ)*, is the current practice at the PGH, which is characterized by shortages of diagnostic and therapeutic inputs needed in treatment of the very severe schistosomiasis cases (REACH, 1989; Forgey *et al*., 1990; Musau *et al*., 1995). The PGHs are 'supposed' to have adequately equipped and manned surgical departments.
(b) *Provincial general hospital drug management (PGHDM)*, would require barium swallow x- ray for all the patients visiting the PGH from Mwea Division, followed by inpatient drug (vasopressin or sclerosant) treat-

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ment to reduce haematemesis (bleeding) and other relevant drugs to attenuate pain and anxiety.

(c) *Provincial general hospital surgical operation (PGHSO)*, would require investigation of oesophageal disorders by barium swallow and endoscopy of all the patients from Mwea Division, followed by balloon catheter treatment and surgical operation to lower the pressure in the blood supply to the liver.

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Appendix 2: Health states intervention combinations

Health states	*Intervention combinations*
S	SQ + SQD, SQ + PCD, SQ + OCD, HPWS + SQD, HPWS + PCD, HPWS + OCD, HHEV + SQD, HHEV + PCD, HHEV + OCD, VIPL + SQD, VIPL + PCD, VIPL + OCD, FM + SQD, FM + PCD, FM + OCD, MPCP + SQD, MPCP + PCD, MPCP + OCD, MPCO + SQD, MPCO + PCD, MPCO + OCD, SPCP + SQD, SPCP + PCD, SPCP + OCD, SPCO + SQD, SPCO + PCD, SPCO + OCD
K	SQ + SQHC, SQ + PCHC, SQ + OCHC, HPWS + SQHC, HPWS + PCHC, HPWS + OCHC, HHEV + SQHC, HHEV + PCHC, HHEV + OCHC, VIPL + SQHC, VIPL + PCHC, VIPL + OCHC, FM + SQHC, FM + PCHC, FM + OCHC, MPCP + SQHC, MPCP + PCHC, MPCP + OCHC, MPCO + SQHC, MPCO + PCHC, MPCO + OCHC, SPCP + SQHC, SPCP + PCHC, SPCP + OCHC, SPCO + SQHC, SPCO + PCHC, SPCO + OCHC
Z	SQ + SQDH, SQ + PCDH, SQ + OCDH, HPWS + SQDH, HPWS + PCDH, HPWS + OCDH, HHEV + SQDH, HHEV + PCDH, HHEV + OCDH, VIPL + SQDH, VIPL + PCDH, VIPL + OCDH, FM + SQDH, FM + PCDH, FM + OCDH, MPCP + SQDH, MPCP + PCDH, MPCP + OCDH, MPCO + SQDH, MPCO + PCDH, MPCO + OCDH, SPCP + SQDH, SPCP + PCDH, SPCP + OCDH, SPCO + SQDH, SPCO + PCDH, SPCO + OCDH
A	SQ + PGHSQ, SQ + PGHDM, SQ + PGHSO, HPWS + PGHSQ, HPWS + PGHDM, HPWS + PGHSO, HHEV + PGHSQ, HHEV + PGHDM, HHEV + PGHSO, VIPL + PGHSQ, VIPL + PGHDM, VIPL + PGHSO, FM + PGHSQ, FM + PGHDM, FM + PGHSO, MPCP + PGHSQ, MPCP + PGHDM, MPCP + PGHSO, MPCO + PGHSQ, MPCO + PGHDM, MPCO + PGHSO, SPCP + PGHSQ, SPCP + PGHDM, SPCP + PGHSO, SPCO + PGHSQ, SPCO + PGHDM, SPCO + PGHSO

Appendix 3: Expert estimates of health states transition probabilities with various secondary interventions

Health states	*Expected outcomes*	*Secondary intervention labels*		
		SQD	PCD	OCD
S	Y	0.03	0.9	0.87
	S	0.62	0.08	0.1
	Q	0	0	0
	K	0.35	0.02	0.03
	Outcomes	SQHC	PCHC	OCHC
K	Y	0	0.8	0.7
	S	0.05	0.1	0.15
	K	0.8	0.06	0.1
	Q	0	0	0
	Z	0.15	0.04	0.05
	Outcomes	SQDH	PCDH	OCDH
Z	Y	0	0	0
	K	0	0.49	0.46
	Z	0.68	0.38	0.4
	Q	0.24	0.1	0.1
	A	0.08	0.03	0.04
	Outcomes	PGHSQ	PGHDM	PGHSO
A	Y	0	0	0
	Z	0	0	0
	A	0.05	0.08	0.1
	Q	0.93	0.9	0.85
	R	0.02	0.02	0.05
	Outcomes	PGHSQR	PGHIUC	
R	Y	0	0	
	A	0	0	
	R	0	0	
	Q	1	1	

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Appendix 4: Percentage Distribution of the costs of primary schistosomiasis interventions

Recurrent Costs	*MPCO*	*MPCP*	*SPCO*	*SPCP*	*FM*	*HPWS*	*HHEV*	*VIPL*	*SQ*
Personnel	1.77	1.88	2.04	2.14	53.11	47.27	45.39	10.89	56.8
Materials and supplies	3.35	3.74	17.39	18.25	13.99	2.73	24.49	15.37	1.42
Drugs	87.08	86.30	73.50	72.19	0.00	0.00	0.00	0.00	1.61
Utilities	0.06	0.06	0.16	0.17	0.00	0.00	0.13	0.00	0.19
Lunch allowance	0.24	0.26	0.32	0.33	0.00	0.00	0.00	0.00	0.00
Per Diem	0.11	0.11	0.10	0.11	0.26	3.36	0.22	0.01	0.00
Transport	0.17	0.18	0.16	0.17	1.63	5.27	2.80	0.28	1.68
Maintenance	0.14	0.15	0.36	0.38	13.88	5.64	1.83	0.39	0.13
Community resource	6.41	6.79	4.14	4.35	0.00	0.00	13.00	71.73	0.00
Recurrent Subtotal	99.50	99.47	98.17	98.08	82.87	64.26	87.86	98.66	61.83
Capital Costs									
Building	0.08	0.08	0.23	0.24	2.22	0.08	0.86	0.08	1.12
Equipment	0.03	0.03	0.48	0.51	2.79	26.99	0.61	0.04	24.20
Vehicles	0.39	0.41	1.12	1.18	12.12	8.67	10.68	1.22	12.85
Capital sub-total	0.50	0.53	1.83	1.92	17.13	35.74	12.14	1.34	38.17
TOTAL COSTS	100	100	100	100	100	100	100	100	100