


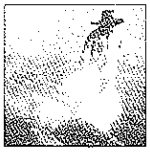


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A Cross-sector Priority Setting Method: Critical Gaps in Malaria Research in Tanzania

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This paper describes a new priority setting method for identifying critical information gaps in a multisector system. This method characterizes the information structure of the system using graph-theoretical concepts. Its application is illustrated in the context of malaria research in Tanzania. This illustration reveals two critical pathways, EVHA and EVHPA, which warrant better understanding. The first suggests that malaria research should generate information on the effects of environmental changes (E) on vector ecology (V) and then on the effects of V on human health (H) and then on the effects of H on agriculture (A). Interpreted likewise, the second pathway points to the additional need for information on the effects of socioeconomic conditions (P) on A.

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Introduction[1]

The literature on priority setting is rich and offers a wide range of methods (see Alston *et al.* (1995)). Most of the methods are applied to identifying the key theme(s) within a sector by either a single or multiple criteria, or optimization techniques. They deal with, for example, setting priorities in agricultural research or in health research in an isolated manner. But what about priorities that concern multiple sectors simultaneously, such as priorities in malaria, HIV/AIDS, biotechnology or food safety research? What about sources, intermediaries, and users of information concerning the prioritized areas? What about cause–effect information pathways between sources and users of this information? What about the links in a multisector system between organizations operating under different jurisdictions?

This paper introduces a new priority setting method that takes all of these concerns into consideration. It is a method for identifying critical information gaps[2] within a given theme, such as malaria control, which concern organizations from multiple sectors concurrently. It uses graph-theoretical concepts and principles of systems theory to characterize the underlying cause–effect information structure of the system under investigation.[3] Such a method will prove especially useful in addressing cross-cutting problems for which alternative solutions lie in the effective flow of information between the relevant organizations from different sectors. The key premise of the method is that identifying cause–effect information pathways between the organizations is essential for designing policy interventions.

The proposed method is in some ways different from and in other ways similar to priority setting methods in the literature. The key difference is that it has been developed in such a way as to identify priorities within a given theme that relate to organizations from multiple sectors. The cause–effect pathways that are established represent hypotheses to be tested for the design of policy interventions. It is similar to other methods, in that priorities reflect the subjective choices of people in the priority-setting exercise, which is the case in scoring methods. Once the priorities are set, conventional methods, such as cost–benefit, economic surplus, or mathematical programming can be applied to rank the pathways concerned.

The method is described by applying it to priority setting in malaria research in Tanzania. It is used in

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1 I would like to thank all the participants of the Dar es Salaam workshop, funded jointly by System-wide Initiative on Malaria and Agriculture (SIMA) and ISNAR, for providing insights into the dynamics of malaria in Tanzania. Thanks also go to Anna Wuyts, Ninatubu Lema, and Barnabas Kapange for the implementation of this workshop, to Michael Loevinsohn for his comments on the organization of the workshop, and to Kayo Narita for the preparation of the manuscript.

2 The term "gap" is used to refer to an area that warrants better understanding; the term "pathway", a chain of interactions between organizations; and the term "information pathway" is used to mean that the content of the interaction concerned is information.

3 See Von Bertalanffy (1968) and Murota (1987) for the principles of systems theory and Hudson (1992) and Freeman (2000) for the use of graph-theoretical concepts.

analyzing expert knowledge gathered by a workshop held in October 2003 in Dar es Salaam (Temel 2003). This is a relevant application because malaria is a cross-sectoral problem and solutions are strongly dependent on the presence and degree of information flow among the organizations in the malaria control system. Using a multi-voting scheme, the workshop determined five critical gaps, which have been reduced to two critical pathways that warrant better understanding.

The ISNAR project, *Building Capacity for Cross-sector Demands*, aims to strengthen the capacity of agricultural research organizations to respond effectively to new demands for knowledge arising from social, economic, and environmental changes, beyond those traditionally associated with agricultural production. With the new priority setting method described here, this paper contributes to the development of the capacity of agricultural research organizations in cross-sector planning.

The remainder of the paper is organized as follows: first the method is presented by applying it to the information gathered at the workshop; then follows a discussion of how to construct testable hypotheses using the method; finally, conclusions are presented.

A cross-sector priority setting method

This section describes the proposed method and illustrates its application in the context of a cross-sector workshop on malaria control in Tanzania.

Rationale

Malaria is multi-factorial in its cause and cross-sectoral in its solution. Conventionally, the epidemiology of malaria concerns factors relating to the nature and spread of the *Plasmodium* parasite and its vectors, mosquitoes, the human host, and their interaction within the natural environment (Krier and Baker 1980; Clyde 1987). More recently, however, close association of malaria prevalence with poverty has led to research on the effect of economic, social, and political factors on the epidemiological triad – agent, host, and environment (Gallup and Sachs 2001; Panvisavas 2001; Sharma et al. 2001; Sachs and Malaney 2002). Another critical association, documented in the literature, is with agriculture (Temel 2004a). These factors originate from different sectors, and hence controlling them simultaneously requires cross-sector collaboration. The following definition of a malaria control system describes the structure of this collaboration.

Malaria control system S

S is a set of organizations that jointly and/or individually contribute to the generation, dissemination, and use of existing or new information that directly and/or indirectly improves living conditions through reduced malaria (Temel 2004b). In **S**, information flow is highly variable and context-sensitive, the meaning and the value of this information depends on the competencies of the interacting organizations (Wolf et al. 2001).

Components of S

S is described as a system with five components, {H, V, E, A, P}, which are placed in the diagonal cells; and binary causal relations between the components are placed in the off-diagonal cells.

$$\mathbf{S} = \begin{bmatrix} H & HV & HE & HA & HP \\ VH & V & VE & VA & VP \\ EH & EV & E & EA & EP \\ AH & AV & AE & A & AP \\ PH & PV & PE & PA & P \end{bmatrix}$$

The "human health" component, H, regards human beings as hosts to malaria mosquitoes. It should ideally comprise all of the health organizations fighting malaria, such as ministries of health, hospitals, research and diagnostic laboratories, health information centers, health research institutes, medical supply firms, NGOs, and donors.

The "vector" component, V, regards *Plasmodium* species as causal agents; and mosquitoes, as vectors that bridge the gap between malaria and human beings. It includes organizations dealing with parasite and vector ecology, such as changes in vector density, distribution, feeding habits, and prevalence. These include research and diagnostic labs, research institutes, NGOs, and donors.

The "environment", E, represents the physical surroundings of human beings and mosquitoes. Thus, all organizations aimed at improving the quality of environmental resources should be included in this component. Examples include ministries of environment, meteorology centers, environmental research institutes, land cadastral units, water associations, NGOs, and donors.

The "agriculture" component, A, represents agricultural systems, agricultural technologies, and resource development, and should include such organizations as ministries of agriculture, extension and information units, agricultural research institutes, farms, agro-industries, input quality control bodies, NGOs, and donors.

Finally, the "socioeconomic" component, P, represents the social and economic dimensions of malaria. It includes economic and social organizations that directly or indirectly affect malaria through monetary and nonmonetary resource allocation. Such organizations are ministries of economy, finance and/or cultural affairs, grass root organizations, NGOs, international organizations such as the World Bank, and municipalities.

Causal relations between the components

Causal relations between the five components are placed in the off-diagonal cells of **S**. Following the clockwise convention, each off-diagonal cell represents a relation between two components. Matrix 1 shows an example of how to construct **S**.

Matrix 1. An Example Information Flow in S

H Public health interventions	INFO on effects of health intervention on mosquito density **HV**	INFO on effects of health intervention on water and forest use **HE**	INFO on effects of health intervention on farm productivity **HA**	INFO on effects of health intervention on economic growth **HP**
INFO on effects of mosquito density on health interventions **VH**	**V** Mosquito density and distribution	INFO on effects of mosquito distribution on water & forest use **VE**	INFO on effects of mosquito distribution on cropping pattern **VA**	INFO on effects of mosquito density on health seeking behavior **HP**
INFO on effects of water & forest use on health interventions **EH**	INFO on effects of climate change on mosquito distribution **EV**	**E** Climate, forest, water	INFO on effects of water availability on farming system **EA**	INFO on effects of climate change on economic growth **EP**
INFO on effects of cropping pattern on health intervention **AH**	INFO on effects of cropping pattern on mosquito density **AV**	INFO on effects of cropping pattern on climate change **AE**	**A** Agricultural systems	INFO on effects of productivity of farm on health seeking behavior **AP**
INFO on effects of health-seeking on health intervention **PH**	INFO on effects of growth on malaria prevalence **PV**	INFO on effects of growth on climate change **PE**	INFO on effects of health-seeking on farm productivity **PA**	**P** Health-seeking, economic growth

Note: INFO stands for information on the effect of one variable on another.

For illustrative purposes, a small set of factors is considered. HV in **S** denotes "H causes V." This corresponds in Matrix 1 to the HV cell indicating "information on effects of health interventions on mosquito density". Similarly, VH denotes "V causes H", which corresponds to the VH cell in Matrix 1 indicating "information on effects of mosquito density on health interventions". Binary causal relations in the 1st row of **S**, therefore, indicate how H (i.e., human health-related organizations) is assumed to affect organizations in the rest of the system by either generating or disseminating the information concerned; and those in the 1st column indicate how organizations in the rest of the system are assumed to affect H by generating or disseminating the respective information.

S is further characterized by pathways of binary causal relations. For example, a 3-edged pathway, EVHA, is one from E to V and then from V to H and then from H to A. This pathway will be realized only if the relevant organizations collaborate during the process of generating, disseminating, and using the information concerned. The cell corresponding to EV in Matrix 1, for example, indicates that E is to generate and disseminate information on the specificities of climate change expected, while V is to use this information to study expected changes in the distribution and types of mosquitoes. The cell corresponding to VH similarly shows that V is to generate and disseminate information on the specificities of mosquito density predicted, while H is to use this information in the design of proper health interventions. Finally, the cell HA indicates that H is to generate and disseminate information on the specificities of the designed health interventions, while A is to use this information to study expected changes in farm productivity. Needless to say, an effective flow of information can only be realized if the organizations concerned have formal and/or informal linkages between them.

The total number of k-edged pathways in **S** is calculated by $[n!/(n-k-1)!]$, where n and k represent the number of components and the number of edges concerned, respectively. The (!) sign denotes factorial in statistical terms. Applying this formula, one can calculate, for instance, the number of two-edged pathways in **S** by

$$[n!/(n-k-1)!] = [5!/(5-2-1)!] = 60.$$

Information collection

A workshop was used to gather information for identifying top priority causal relations in **S**. For illustrative purposes, analysis in the rest of this study draws on the findings of this workshop, held in Dar es Salaam on 27–28 October 2003, on malaria information needs, sources, and use in Tanzania (Temel 2003). The workshop gathered policymakers, research managers, scientists, and field experts from the health, ecology, environment, agriculture, NGO, socioeconomic, and political sectors to identify (i) critical areas in malaria research that warrant better understanding and (ii) the capacities necessary for addressing these critical areas.

The workshop was organized into three working groups, each with 6 participants from different sectors. Each participant could vote on the importance of various causal relations using a "strong" vote worth 3 points, a "mediocre" vote worth 2 points, or a "weak" vote worth 1 point. This multi-voting scheme allowed the participants to rank their preferences over binary causal relations. By using Matrix 1, each working group prepared a map of causal relations that the group thought to be critical. The resulting three maps were then consolidated, and the participants voted over the individual causal relations in the consolidated map. The top three causal relations were then discussed in the working groups to identify the capacities required to address the top three relations.

Application

$\mathbf{S}_S$ indicates the causal relations that received strong votes. For instance, HA (in the 1st row–4th column of $\mathbf{S}_S$) received 12 points; that is, 4 strong votes each with 3 points. In the 3rd row–2nd column, EV received 5 strong votes amounting to 15 points. With 15 points, EV is the top priority causal relation to be investigated, followed by HA and PA with 12 points each.

$$\mathbf{S}_S = \begin{bmatrix} H & 3 & 3 & 12 & 3 \\ 9 & V & 0 & 0 & 0 \\ 0 & 15 & E & 0 & 0 \\ 3 & 6 & 0 & A & 0 \\ 3 & 0 & 0 & 12 & P \end{bmatrix}$$

$\mathbf{S}_M$ indicates the causal relations that received mediocre votes. With 6 points (3 mediocre votes each with 2 points) in the 1st row–5th column of $\mathbf{S}_M$, HP is the strongest causal relation, followed by HV, VH, EV, and AH with 4 points each.

$$\mathbf{S}_M = \begin{bmatrix} H & 4 & 2 & 2 & 6 \\ 4 & V & 0 & 0 & 0 \\ 0 & 4 & E & 2 & 0 \\ 4 & 0 & 0 & A & 2 \\ 0 & 0 & 0 & 2 & P \end{bmatrix}$$

$\mathbf{S}_W$ indicates the causal relations that received weak votes. With 4 points (4 weak votes each with 1 point), VH is the strongest relation, followed by HP and AE with 3 points each.

$$\mathbf{S}_W = \begin{bmatrix} H & 2 & 1 & 0 & 3 \\ 4 & V & 0 & 0 & 0 \\ 0 & 0 & E & 0 & 0 \\ 0 & 0 & 3 & A & 1 \\ 2 & 0 & 0 & 1 & P \end{bmatrix}$$

Finally, $\mathbf{S}_T$, defined as $(\mathbf{S}_s+\mathbf{S}_M+\mathbf{S}_W)$, indicates the total number of points for each binary relation.[4] With 19 points, EV stands out as the top priority relation, followed by VH with 17, PA with 15, HA with 14, and HP with 12 points.

$$\mathbf{S}_T = \begin{bmatrix} H & 9 & 6 & 14 & 12 \\ 17 & V & 0 & 0 & 0 \\ 0 & 19 & E & 2 & 0 \\ 7 & 6 & 3 & A & 3 \\ 5 & 0 & 0 & 15 & P \end{bmatrix}$$

By construction, **S** has a structure in which the *Cause* (C) of a component is defined as the sum of the points in the corresponding row; and the *Effect* (E), as the sum of the points in the corresponding column (see Table 1).

We will analyze $\mathbf{S}_T$ only. Figure 1 maps the causal relations in $\mathbf{S}_T$ as a directed graph, which indicates three critical regions. Region 1 is the locus of the 45-degree line, where C=E. A component on this line is said to be highly interactive with the rest of the system if its coordinate falls in the top-right corner of the figure; and minimally interactive if its coordinate is close by the (0, 0) coordinate. Region 2 is the area below the

Table 1. Cause –Effect (C–E) Coordinates

	$\mathbf{S}_S$	$\mathbf{S}_M$	$\mathbf{S}_W$	$\mathbf{S}_T$
H	(21, 15)	(14, 8)	(6, 6)	(41, 29)
V	(9, 24)	(4, 8)	(4, 2)	(17, 34)
E	(15, 3)	(6, 2)	(0, 4)	(21, 9)
A	(9, 24)	(6, 6)	(4, 1)	(19, 31)
P	(15, 3)	(2, 8)	(3, 4)	(20, 15)

4 Murota (1987) studies the features of square systems represented in matrix formats.

45-degree line, where C>E. A component with a very high C and a very low E, denoted by C>>E, suggests that it strongly dominates the others in the system. Region 3 is the area above the 45-degree line, where C<E. A component with a very low C and a very high E, denoted by C<<E, suggests that it is strongly subordinate to the others in the system.

Figure 1 reveals: (i) H is the most dominant component in the system, with a cause of 41 points, followed by E with 21 points; (ii) P is the most interactive component; and (iii) V and A are both subordinate components. Observation (i) and the three key relations HA, HP, and EV in $\mathbf{S}_T$ combined suggest that research is needed to determine the mechanisms through which H influences both A and P; and E influences V. Furthermore, observation (ii) and the key relation PA in $\mathbf{S}_T$ together suggest that research is needed to determine the mechanisms through which P influences A. Finally, the fact that H is also influenced strongly by the rest of the system points to the need for research as to how V influences H. It should be noted that these three observations further imply the following reduced form of $\mathbf{S}_T$:

$$\text{Reduced } \mathbf{S}_T = \begin{bmatrix} H & & & 14 & 12 \\ 17 & V & & & \\ & 19 & E & & \\ & & & A & \\ & & & 15 & P \end{bmatrix}$$

The reduced form maps only the significant relations. E is the only truly exogenous component, in the sense that there is no component influencing E (that is, the 3rd column in $\mathbf{S}_T$ has no points); while A is the only truly endogenous component, in the sense that it is influenced by others but exerts no influence on others (that is, the 4th column in $\mathbf{S}_T$ has positive points, while the 4th row has no points). One implication of this feature is that pathways of interest in the reduced $\mathbf{S}_T$ should always start with E and end at A. This yields two pathways: EVHA shown in Figure 2 and EVHPA shown in Figure 3. ($\mathbf{S}_S$, $\mathbf{S}_M$, and $\mathbf{S}_W$ should also be interpreted similarly.)

Testable hypotheses

Three concepts, critical information gaps, critical cause–effect information pathways, and critical hypotheses, are used to analyze the findings. The voting scheme yielded five critical gaps that warrant better understanding (see reduced $\mathbf{S}_T$). These gaps are as follows (expanded upon in Table 2): the effects of environmental changes (E) on vector ecology (V); the effects of changing vector ecology (V) on human health (H); the effects of changing human health (H) on agricultural systems (A); the effects of changing human health (H) on socioeconomic conditions (P); and the effects of changing socioeconomic conditions (P) on agricultural systems (A). Each one of these gaps represents a hypothesis to be tested.

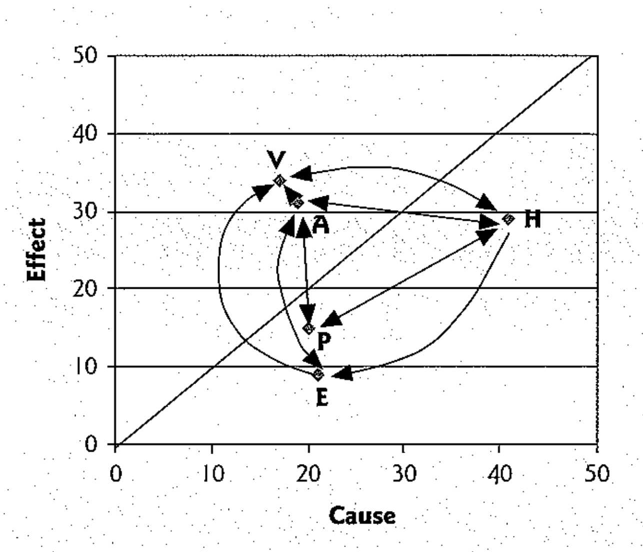

Figure 1. Cause–effect pathways in $\mathbf{S}_T$

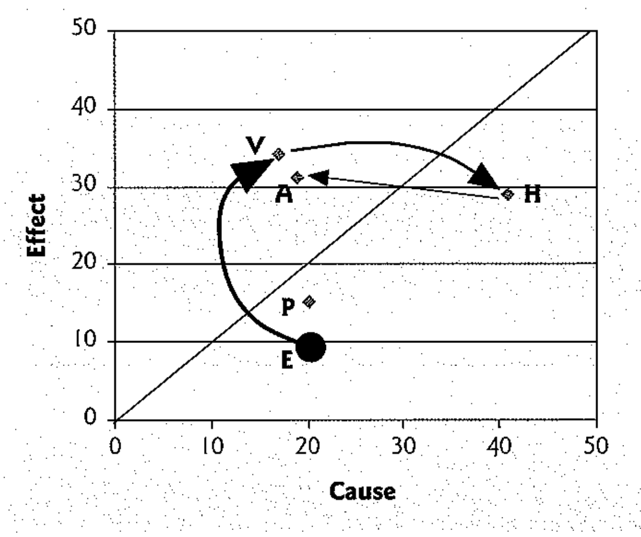

Figure 2. A priority pathway: EVHA

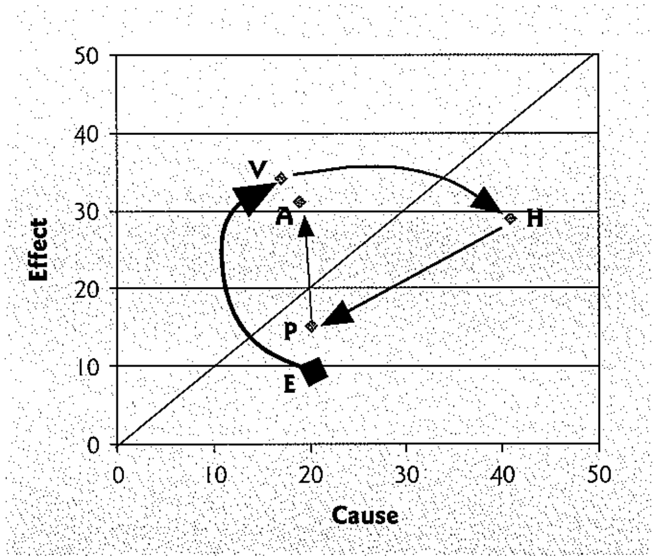

Figure 3. A priority pathway: EVHPA

Table 2. Critical Gaps that Warrant Better Understanding

EV	◆ Effects of climate change, deforestation, water use, and environmental management practices on malaria.
VH	◆ Effects of the malaria situation on the design of health interventions. ◆ Embodying malaria information in a Demographic Surveillance System would facilitate cross-sector health research.
PA	◆ Bottom up approach as a means to empower rural communities. ◆ Role of grass root organizations in supporting agricultural development. ◆ Effects of treatment-seeking behaviour on agricultural productivity.
HA	◆ Effects of health interventions on agricultural productivity. ◆ Health information systems incorporating malaria information should support agricultural policy making processes.
HP	◆ Effects of malaria control interventions and policies on economic growth, societal and economic changes, and poverty.

Source: Temel (2003).

The gaps further imply that reduced $\mathbf{S}_T$ has a total of two cause–effect information pathways, EVHA and EVHPA, to be examined. EVHA suggests that the "environment" organizations should generate information on the effects of climate change, deforestation, water use, and environmental management practices on the malaria situation, and this information should be communicated to the "vector" organizations. The "vector" organizations would then use this information in its research or field activities and pass it onto the "human health" organizations for expected use in the design of public health interventions. Finally, the "health" organizations should communicate the possible effects of health interventions on agricultural productivity. Interpreted likewise, EVHPA additionally indicates the need for information on the effects of changing health status on socioeconomic conditions and on the effects of changing socioeconomic conditions on agricultural systems. The sequence of interactions in these pathways is crucial and remains to be tested.

The *directed* causal relations in Figure 1 show that H is the *dominant source* of information, followed by E and P, and that V and A are the subordinate users of information. Each one of these observations represents an area to be studied. Regarding H being the dominant source, one can formulate a hypothesis of whether or not public health interventions significantly influence agricultural productivity or malaria. Likewise, the influence on A and V of the 2nd degree sources (E and P) can also be tested.

The above analysis indicates that some components have distinct characteristics that remain to be tested. The first characteristic is that E is exogenous, generating information without input from other components. This immediately follows from Reduced $\mathbf{S}_T$, where the column associated with E is empty. The second is that A is endogenous, absorbing information but not letting it go. This follows from Reduced $\mathbf{S}_T$, where the row associated with A is empty.

The voting scheme was applied to classify binary relations into three groups: high, mediocre, and weak. A comparison of the implied information structures points to two regularities for further investigation. First, no matter which group is considered, H remains the most crucial source of information. Second, A experiences the highest variability within the spectrum; it moves from the subordinate (i.e., above the 45-degree line) to the dominant state (i.e., below the 45-degree line).

Concluding remarks

This paper proposes a new priority setting method for identifying critical information gaps in a multisector system. This method uses graph-theoretical concepts and principles of systems theory to characterize the underlying cause–effect information structure of the system under investigation. The application of the method is illustrated in the context of malaria research in Tanzania, drawing on the findings of a workshop held in October 2003 in Dar es Salaam

The workshop identified five critical information gaps (EV, VH, HA, HP, PA) and two cause–effect information pathways (EVHA and EVHPA) that warrant better understanding. These pathways imply that the time has come to go beyond the epidemiological triad (EVH) and investigate the roles that A and P are likely to play in the transmission of malaria in Tanzania (and elsewhere). Furthermore, a comparison of the three implied information structures points to two regularities to be investigated further. First, H remains the most crucial source of information; second, A shows the highest variability in the system. All of these results remain to be tested empirically.

The proposed method can be developed further. The system under examination is represented by **S**, in which the flow of information is presented in an input–output matrix format.[5] **S** does not allow loops between those organizations that belong to the same component and hence does not give full account of information flowing in the system.

The information flowing in the system must be standardized for comparability of the effects of pathways identified. A common unit must be used for measurement; however, this is difficult because the value of information depends on the specific situation of the parties involved (see Arrow 1986). The organizations interact with each other during the process of the generation, exchange, and use of the relevant information. The sole content of this interaction is information that directly and/or indirectly concerns malaria control. The value of the information would determine the speed and extent of information flow in the malaria control system. The systems approach adopted by the current study implicitly assumes that there is a benevolent decision-making body whose only goal is to improve living conditions by reducing malaria incidence, given the system constraints.

Developing an information accounting system requires a clear-cut distinction between formal and informal information. As Wolf et al. (2001) argued, "the distinction lies in the communication medium and the intentions underlying specific interpersonal contact. Formal information is defined as being derived through structured channels generally in the form of text, but also including conferences, phone calls and other forms organized for the explicit purpose of information exchange. Conversations and social interactions among family, friends, and business associates, including colleagues, customers, suppliers, and competitors constitute informal information. Of course, the distinction between social interaction and explicit information exchange is not clear-cut as personal, family, community, and economic spheres overlap."

On the empirical account, several weaknesses exist that relate to the quality of the findings of the workshop and hence the quality of the findings reported in this study. First, to check for consistency, the mapping of the gaps identified in the workshop should be compared with that implied by a literature survey on malaria in Tanzania. Literature mapping is left for future research, as the main objective of this study is to introduce a priority setting method. A second weakness, which is related to the first one, is that at this moment one cannot assess whether the participants made a distinction between critical gaps that warrant better understanding and critical areas in which they are aware that enough research has been carried out so far. This weakness could have been avoided by conducting two mapping exercises: one for critical gaps for which the participants are aware that enough research has been conducted and another for critical gaps that warrant further research. A third weakness is that some important gaps, for example effects of agricultural activities on malaria prevalence and effects of endogenous environmental deterioration on malaria, were simply not recognized. This can partly be attributed to limitations in the knowledge of the participants and partly to the composition of working groups in which some sectors were under or over-represented during the workshop.

[5] Leontief's input–output matrix is widely used in economic modelling, which shows the flow of resources and final outputs among economic actors. **S** has been constructed in the same spirit as in Leontief's.

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