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Prevent, Prepare and Respond:
Economics of One Health to Confront Disease Threats
30 January – 2 February 2017

Workshop Report



**EcoHealth
Alliance**



**Network
for Evaluation
of One Health**

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The following report intends to be a reflection of the workshop and care has been taken in seeking to accurately capture contributions; however, Catherine Machalaba and Kristine Smith take final responsibility for its contents. The authors' views expressed in this publication do not necessarily reflect the views of the United States Agency for International Development, the United States Government or the World Bank.

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The following colors are used throughout the report to represent Human Health, Agriculture, Environment/Natural Resources and other sectors:

Environment/
Natural Resources

Agriculture

Human Health

Private Sector/
Other Sectors

Primary Sector

Executive Summary

Recent disease threats, such as Ebola virus disease in West Africa and Zika, demonstrate the importance of global health security for developing and developed countries alike. Despite near-global progress against infectious disease in recent decades, zoonoses still account for an estimated >2 billion human cases per year, with significant public and animal health burden and economic consequence, in particular to vulnerable populations. Notably, the rate of infectious disease emergence appears to be increasing as pressures on natural ecosystems intensify, production systems change without adequate biosecurity, and trade, travel and urbanization accelerate, each facilitating pathogen evolution, spillover and/or spread.

In light of the critical links between human, animal and environmental health, over the past decade international agencies have expressed strong support for a One Health approach. Global analyses have suggested high return on investment from pandemic prevention through human and animal health capacity, yet most public health systems employ largely reactive measures to epidemic and pandemic threats. Country decision support to guide investments may help operationalize One Health for both local and global good.

Experts in animal and human health, ecology, economics, data science and policy examined how existing efforts could be brought together to pragmatically align approaches, methods, metrics and data collection to assist decision making at country level. While each sector has meaningful metrics (e.g. Disability-Adjusted Life Years in human health, production gains in agriculture), *economic evaluation offers a shared measure of value across multiple sectors, and is relevant for ministries of finance seeking to optimally allocate resources*. A basic methodology suggests main steps for One Health Economic Evaluation: Question Framing, Costing of the Impact, Option Assessment, and Measuring Efficacy and Feedback. Qualitative and quantitative frameworks are presented that can be refined to more specifically or broadly capture impacts (positive or negative).

In addition to value metrics, system mapping tools can assist in identifying links between sectors, in terms of drivers, information flow, and consequences (emphasizing social and cultural context). Importantly, even partially capturing this information (prospectively for identified hazards, or retrospectively for past or ongoing epidemics) may help elucidate stakeholders of variable investment (e.g. tourism or food production industries and relevant government ministries) with interests in risk mitigation, potentially enhancing options and/or resources for multisectoral health security actions at country level. For any One Health topic, there will likely be some degree of uncertainty, including both known and unknown factors that affect risk. It is essential to include informed qualitative data from engaged stakeholders in such cases rather than exclude relevant sectors to ensure a comprehensive One Health approach.

Evaluation may be applied to One Health coordination mechanisms (e.g. to determine the value of a database shared between ministries) or prevention or control actions that may occur in response to disease threat(s). While here targeted to zoonotic diseases, these methods have potential application to other sustainable development topics, such as antimicrobial resistance, food safety and security, non-communicable diseases, and health-benefitting ecosystem services, and may help to balance possible trade-offs (e.g. disease control and possible impacts to nutrition, biodiversity, etc.)

Workshop recommendations included:

- Promotion of cross-sectoral understanding and cooperation through clear terminology;
- The importance of acknowledging and integrating social and cultural context, and involving local stakeholders;
- Leveraging specific disease priorities to create gains against impacts of multiple disease threats, optimizing collaboration opportunities and efficiencies (e.g., vector control, passenger travel screening);
- Recognizing that stakeholders/participants may have different priorities and levels of buy-in, but engagement is key to robust multi-sectoral impact assessments and engagement in decision making;
- Increase representation of environment sector. Where precise data is unavailable, direction and magnitude of impacts can be used as a starting point and qualitative data can be integrated;
- Promote integrated risk and impact assessments for human, animal, environmental and other (e.g., social) sectors to ensure complete understanding of risk drivers, impacts, and linkages;
- Reinforce the value and broaden the scope of prevention opportunities.

The scope of the proposed methodology from this workshop was limited to economic evaluation of One Health approaches. Epidemiological or system efficiency assessment, while related to cost-effectiveness, were not in themselves the main target. These other aspects of evaluating One Health effectiveness can also be highly meaningful and are being undertaken elsewhere (please see **Chapter 5** for further information).

Table 1: Overview of components for economic evaluation of One Health defined at the workshop (see **Chapter 2**).

Step	Broad Components	Examples
1) Question Framing	<ul style="list-style-type: none"> • Specific issue in question (whether a particular disease or coordination mechanism) • Geographic and temporal scope • Intended audience 	<ul style="list-style-type: none"> • What is the most cost-effective way to reduce impact of Rift Valley Fever in my country in a given year, for the Finance Minister to direct limited funds?
2) Costing of the Impact	<ul style="list-style-type: none"> • Impact costing flow diagram/ stakeholder mapping • Cost analysis for specific sectors 	<ul style="list-style-type: none"> • Relevant sectors identified, e.g. Agriculture and veterinary medicine, public health, environment, commerce ministries; private sector (agriculture, tourism) • Costs to sectors, e.g. international livestock trade ban, hospital treatment costs
3) Option Assessment	<ul style="list-style-type: none"> • Defining options • Defining parameters (e.g. cost saving vs. epidemiological effectiveness) • Stakeholder acceptability 	<ul style="list-style-type: none"> • No action taken, universal vaccination, targeted vaccination, aerial insecticide spraying, etc. • Farmer willingness to pay for vaccination, public perception of insecticide use • Consistency with provincial, national and international environmental, public health, food safety and other standards • Estimated outcomes from options (qualitative and/or quantitative)
4) Measuring Efficacy and Feedback	<ul style="list-style-type: none"> • Iterative assessment and refinement 	<ul style="list-style-type: none"> • Outcomes, e.g. RVF case incidence in animals and humans, livestock trade status, etc. • New findings or options informing risk assessment • Programmatic adjustments

What this report adds

Evaluation of costs and benefits is routine in designing disease control strategies. However, despite the high financial toll from recent emerging infectious disease outbreaks, management of epidemic and pandemic threats remains largely reactive. One Health Economic Evaluation emphasizes opportunities to expand stakeholders beyond the public health community toward proactive solutions. This is particularly relevant as the majority of human infectious pathogens are zoonotic (of animal origin); in addition to their public health impacts, zoonoses can have detrimental impacts on livelihoods, trade, biodiversity, and beyond. Rapidly changing practices in other sectors are contributing to the emergence of new diseases, but the wide-ranging economic impacts of zoonotic disease epidemics can incentivize other sectors (e.g. agriculture, tourism) to partner in risk mitigation. By improving understanding of the drivers of disease and where costs and benefits are accrued, One Health Economics may inform budget decisions (e.g. by Ministries of Finance and Parliaments) to optimize health, environmental and economic outcomes for sustainable development. The report provides guidance for a country to initiate One Health Economic Evaluation, for specific diseases or coordination mechanisms. In national health security action planning and other efforts to address pandemic and epidemic zoonotic threats, prevention of initial spillover through outbreak response and recovery should be considered in One Health Economic Evaluation.

Chapter 1 – Introduction

Recent emerging infectious disease outbreaks— including the West Africa Ebola virus crisis, Zika virus in Latin America, and Middle East Respiratory Syndrome— highlight the current resource-intensive, reactive approaches used to respond to disease threats and the resulting health and financial impact. At the same time, endemic infectious diseases continue to impose high health and economic burden in developing countries, in many cases also reducing agricultural production and diminishing gains for other development sectors. More than 60% of all human infectious pathogens originate from animals, and globally, at least 2.4 billion human cases and 2.2 million deaths per year are attributable to zoonotic diseases, plus additional disease burden from vector-borne infections (Taylor et al. 2001; Grace et al. 2012). Development in biodiversity-rich, public health infrastructure-poor regions as well as mobility via trade and travel is increasingly facilitating pathogen transmission between species and enabling rapid spread of infections around the world while also potentially threatening valuable ecosystem services and livelihoods (Jones et al. 2008; Karesh et al. 2012). A One Health approach that recognizes the connections between human, animal and environmental health is thus key to promoting global health security and minimizing the health and financial impact of infectious disease threats.

While global burden of infectious disease is decreasing through the success of public health campaigns and focused progress under the Millennium Development Goals, the rate of disease emergence events and related threats such as antimicrobial resistance appears to be increasing (Jones et al. 2008; WHO 2016). Limited capacity to prevent and prepare (including via detection) for disease threats has led to forced response with resource-intensive measures, in some cases overwhelming public health system capacity and redirecting development resources. Infectious disease emergencies have proven extremely costly; for example, the SARS epidemic in 2003, which spread to 29 countries, cost between US\$30-50 billion, the introduction of MERS (which emerged in 2012) into South Korea in 2015 totaled \$700 million in losses, and the 2014-2015 Ebola epidemic in Guinea, Liberia and Sierra Leone decreased gross domestic product (GDP) growth by 12% for the three heavily affected countries. Similarly, the trajectory of HIV/AIDS, which originally emerged from a non-human primate before becoming a global epidemic, reinforces the need for diligence in addressing future zoonoses. Unfortunately, most countries remain unprepared for the next epidemic and pandemic threat.

Why Zoonoses Matter for Development:

- Account for 2.4 billion human cases/year, the majority of which are from endemic diseases;
- Affect food production and security (accounting for an estimated ~20% of livestock production losses);
- Often have environmental determinants and/or impacts (e.g. weather predictors of Rift Valley Fever virus in East Africa; Ebola virus and Great Ape declines);
- Can become pandemic/global epidemics (e.g. HIV/AIDS);
- Impose private sector losses (e.g. worker health and productivity, business continuity, public image, consumer confidence);
- Have wider development impacts (e.g. impacts to school attendance, routine & other high-priority health services such as vaccination campaigns, malaria treatment);
- Global change is driving an increase in number and cost of emerging infectious diseases.

Global analyses by the World Bank suggest that a total investment of \$1.8-3.4 billion annually in human and animal public health systems would raise standards up to global levels in low to middle income countries. This minimal investment would permit pandemic prevention benefits of upwards of \$34 billion per year and net positive return on investment even if only a portion of potential pandemics are prevented over a century (World Bank 2012). Once this foundation is established, investing in research and development and contingency planning nearly doubles anticipated benefits (National Academy of Medicine 2016). These investments are modest compared to the high cost of outbreaks; for example, just six disease events (e.g., novel disease outbreaks) were estimated to cost upwards of \$6.7 billion per year between 1997-2009 (World Bank 2012). Strengthening One Health capacity is expected to provide benefits in addressing both emerging and endemic disease problems, as well as driving benefits to society, economies, and safeguarding natural resources and the environment. Despite compelling potential benefits and high-level endorsement of the need and value for a One Health approach to benefit global public good (e.g. by the FAO-OIE-WHO Tripartite and the United Nations Convention on Biological Diversity), investment in a One Health approach for prevention or preparedness capacity and overall resilience at a national level remains limited. Greater emphasis on concrete and actionable country-level analyses and investment decisions may help move forward its implementation on the ground.

Existing global programs along the prevent, prepare and respond spectrum

Several key initiatives are in development by the World Bank and its partners that address various points along the prevention, preparedness and response spectrum for emerging infectious disease outbreaks. These include the World Bank's Pandemic Emergency Financing Facility, an innovative contingency financing mechanism to rapidly deploy funds to countries to help contain the international spread of an outbreak. Current efforts are also being undertaken by the World Health Organization (WHO) and Global Health Security Agenda (an initiative led by ~50 countries) to assess implementation of the International Health Regulations, promote integration with the World Organisation for Animal Health (OIE) Performance of Veterinary Services evaluation (via the Joint External Evaluation for the IHR Monitoring and Evaluation Framework), and develop country health security plans. These programs will greatly advance preparedness and response infrastructure to reduce the impact of emerging and priority diseases, and will provide strengthened human and veterinary public health systems that can better anticipate and mitigate zoonotic disease risks.

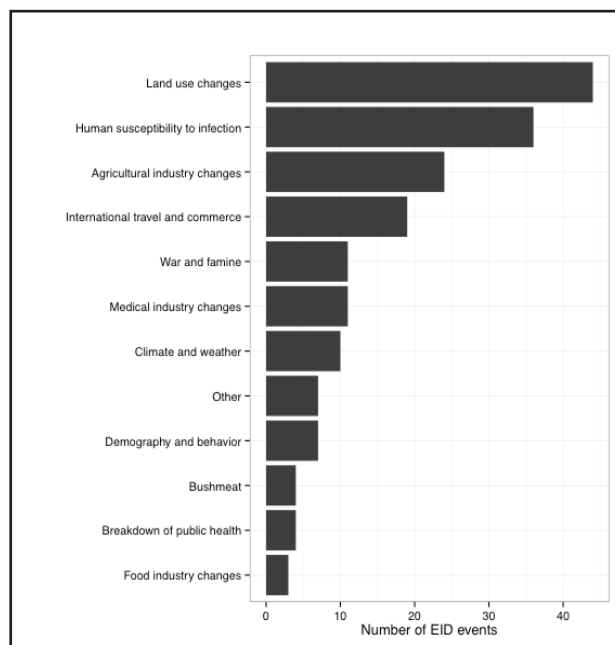
Working Definition of One Health (World Bank, 2017):

*A collaborative approach for strengthening systems to prevent, prepare, detect and respond primarily to infectious diseases and related issues such as antimicrobial resistance that threaten human health, animal health, and environmental health, collectively, using tools such as surveillance and reporting with an endpoint of improving global health security and achieving gains in development. While using infectious disease as a starting point, this definition and approach is expandable for wider scope (e.g. water or soil pollution with animal and environmental connections).**

**We also note the merit of expanded definitions of One Health, including those emphasizing participatory process and their role in defining stakeholders and system delineation.*

To date, efforts to outright prevent future disease emergence events are limited, most likely given the challenges in addressing their root causes (or “drivers”, which are in large part shared with the leading drivers of biodiversity loss -e.g., land use/habitat change such as deforestation, extractive industries, conversion; agricultural practice changes; wildlife trade and hunting; climate change; and international trade and travel- see Fig 1). These drivers typically lie outside of direct understanding and control of the health sector and require multi-sectoral stakeholder engagement to facilitate comprehensive assessments and strategies that are ideally mutually beneficial. Strengthened capacity for surveillance systems in human and animal health is being developed through the World Bank's Regional Disease Surveillance Systems Enhancement (REDISSE) program in West Africa, which will help countries meet IHR and OIE standards and establish a functional One Health Network. Similarly, the USAID Emerging Pandemic Threats-2 (EPT-2) program, through its PREDICT-2 project and in coordination with FAO, is conducting novel pathogen surveillance along high-risk interfaces in “hotspot” countries where infectious disease may be most likely to emerge. Findings from such surveillance initiatives are progressively informing risk assessment for future disease emergence, allowing governments to take preventative action through risk mitigation measures. One Health platforms facilitated or supported through REDISSE, the EPT-2 Preparedness and Response project, and via other initiatives are instrumental

Figure 1: Drivers of emerging infectious diseases from wildlife (Loh et al. 2015)



in determining the decision course for addressing complex disease threats. However, aside from these investments, prevention of emerging disease threats overall remains under-valued and under-explored as a global public good.

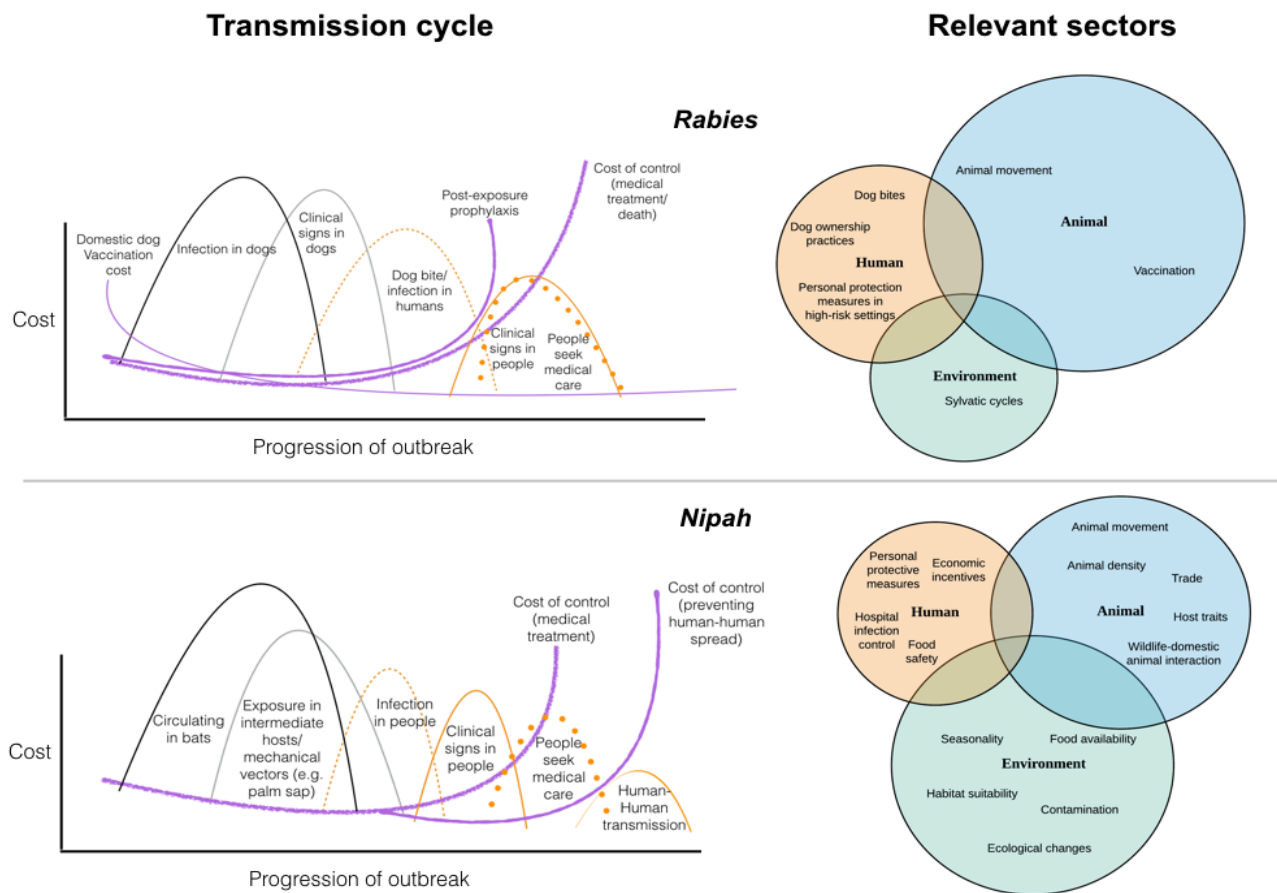
There is inherent benefit to a One Health approach in prevention, preparedness and response to infectious diseases given their multidimensional nature, complex behavioral and environmental drivers, and multisectoral impacts. Not all interventions or mitigation actions will require One Health integration on the ground; however, having a One Health “intention” at the outset to ascertain opportunities for cross-sectoral communication essential for informed planning and decision making, full understanding of scope of cross-sectoral health challenge impacts, occasions for cross-sectoral capacity building or sharing, and knowledgeable cost-benefit analyses of different options will inform the assessment process and delineate most efficient and cost-effective targeted actions. Ultimately, before anything else, interventions and their coordination must ensure effectiveness to warrant resource allocation. Given that One Health considerations are not routinely built into planning and economic costing processes, economic analysis may help clarify existing incentives for cross-sectoral action and shared gains by bringing additional sectors into the dialogue to more optimally face disease threats.

One Health: three key sectors, but context matters

Conceptually, One Health is typically depicted as a Venn diagram with the human, animal and environment circles equally sized. Yet this inherently presents challenges for implementation, given factors including differing priorities, relevance of the problem, information access (e.g. key information gaps about environmental costs, as highlighted by workshop participants) and resources available for each of the three sectors. There may also be other key sectors that are affected by or directly play a role in shaping risk (see Figure 1 for examples of drivers of disease). The role played by different sectors in risk management may therefore vary greatly by disease.

For Rabies virus, for example, the majority (i.e. 99%) of human cases are transmitted from domestic/feral dogs (“animal” sector); thus, canine vaccination is the primary route of prevention. In regions with sylvatic cycles, emphasis may also be placed on preventing exposure from other animal species. In contrast, flying fox bats serve as the natural reservoir for Nipah virus and have a direct role in recurring spillover events in Bangladesh; therefore emphasis on reducing environmental contamination is key. Hospital-acquired human-human spread has been documented, but limited (though Nipah is designated as high potential for generating significant epidemics given its pathogenicity) (Figure 2; visuals are for illustrative purposes and are not to scale).

Figure 2: Examples of the variability of transmission cycles and relevance of the three sectors in disease management.



Chapter 2 – Methods

Measuring the efficacy of a One Health approach has been the goal of recent efforts to move theory and qualitative evidence of beneficial impact into objective evidence and best practices (Häsler et al., 2014; Baum et al. 2016). Recognizing that many developing nations still do not independently put in place One Health approaches and interventions, it is important to have proven evidence of economic benefit of a One Health approach to encourage and optimize future investments.

Thus, a critical need of both national governments and international funding agencies is a framework for evaluating economic efficacy of proposed One Health approaches to address local and global public health challenges (e.g., infectious diseases, environmental toxins, etc.). This is envisioned to closely complement (and ideally integrate with) capacity assessments and costing and planning exercises carried out through the OIE's Performance of Veterinary Services and the WHO Joint External Evaluation for Monitoring and Evaluation of the International Health Regulations, helping to reinforce opportunities for operationalization of One Health where it can offer added value, and potentially informing disease-specific or foundational capacity investments at country level. Because of the inherent complexity in One Health topics and their broad-reaching, variable impacts, a think-tank process was deemed appropriate to tackle this goal. Leading health economists, medical doctors, veterinarians, modelers and ecologists from the public health, agricultural and environmental sectors and development agencies working came together in an intensive 4-day workshop at the World Bank in Washington, D.C. The workshop informed the development of the following methods framework, which is intended to serve as a basic guide for One Health economic analysis.

Figure 3: Distinction between One Health coordination mechanism and disease approach options; the two often inform one another.

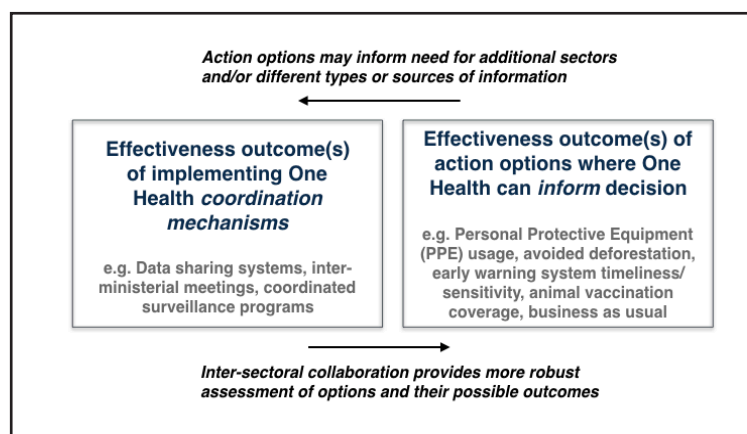
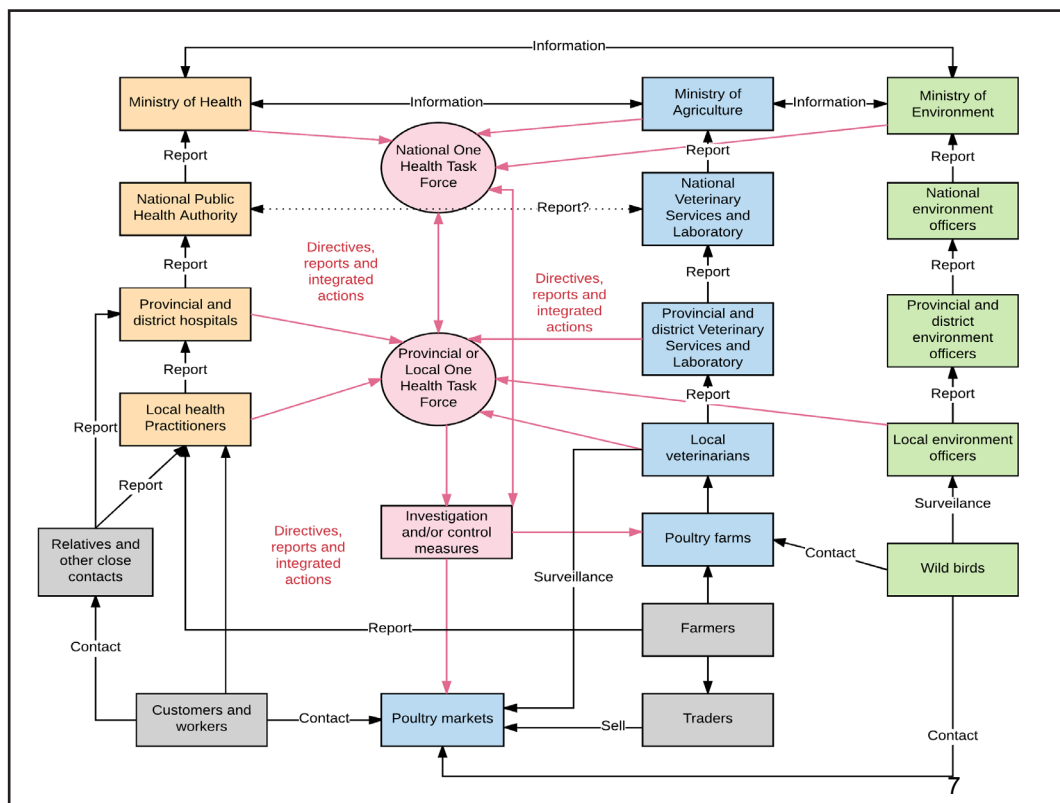


Figure 4: Illustration of One Health coordination mechanisms (pink) serving traditional disease prevention, preparedness and response systems (e.g. avian influenza).



One Health Coordination Mechanisms

In some cases, coordination mechanisms may be implemented to operationalize One Health multi-disciplinary collaboration, such as through routine or emergency inter-ministerial meetings to review information and inform decision making, shared databases, and coordinated field surveillance activities. These may be disease-specific or broader (e.g. a database for reporting unusual morbidity and mortality in humans, domestic animals, and wildlife, or decision support for optimizing design of surveillance programs). They may require upfront investment and/or recurrent costs, and may require additional resources for actionable follow-up (though not all situations may require action), including what might be considered a One Health response. For example, a database alert system could prompt investigation of an animal mortality event that could inform sentinel detection and deploy targeted vaccination or other measures to prevent spillover in humans. In theory, these coordination mechanisms may have long-term value in 'norming' One Health and facilitating ongoing platforms for collaboration, though they may rely on factors including awareness of their existence, perceived value (and actual cost-effectiveness), and use in practice. Ideally, these would be designed to promote health systems strengthening, e.g. providing a platform for use for multiple diseases and/or health threats. The effectiveness of One Health coordination mechanisms could be assessed by intermediate indicators (e.g. number of meetings held), or distinct outcomes (disease incidence before and after a mechanism is implemented, and the costs and benefits associated with any change).

Workshop purpose

While some recent studies have advanced the field significantly (e.g., World Bank 2012; Häslar et al. 2015; Kimani et al. 2016.; Pike et al. 2014), economic evaluation of One Health, as well as public health programs in general, remains limited. The workshop was shaped around the premise that existing tools could be brought together into a new framework to better align approach, methods, metrics and data collection. It sought to build upon previous global estimates of the value of a One Health approach, to target concrete applications at country and ministry-level in order to: reduce assumptions, clarify implications, improve accuracy through context-specific data analyses, promote a standardized, methodological framework for consistency and comparability, and generate more directly actionable findings at the national level. To account for variation in transmission routes, control options, and differing levels of information on epidemiological risks that may affect the ability to evaluate One Health approaches, a range of emerging and endemic zoonotic diseases were considered (see **Chapter 3** for examples).

The overall workshop objectives were to:

- 1) Advance the approach and methodology for comprehensive analysis of economic impact and One Health management or intervention options to address emerging and endemic diseases relevant to One Health;
- 2) Identify key data gaps across or within public, agricultural, environmental health and other relevant sectors;
- 3) Recommend methods for assessing the costs and benefits of intervention options for pandemic and epidemic risk.

The workshop scope focused on a proposed methodology for economic evaluation in relation to infectious disease (epidemiological or system efficiency assessment, while related to cost-effectiveness, were not in themselves the main target). These and other aspects of evaluating One Health effectiveness (including for non-communicable diseases) can be highly meaningful and are being undertaken elsewhere (please see **Chapter 5** for further information).

A methodology for economic assessment of One Health approaches

The methods and tools put forward in this section are mainly targeted for use by the public sector given that they can inform resource allocation across multiple sectors, though they may have application/relevance and value for the private sector. The framework contains four steps: 1) Question Framing, 2) Costing of the Impact, 3) Option Assessment, 4) Measuring Efficacy and Feedback. The order and methodology of each phase are described in the following section (though individual components may still have use or be applied out of sequence). When conducting evaluation, it is important to make the distinction of whether it is the coordination mechanism itself that will be evaluated for effectiveness, or the options for intervention that a One Health approach may inform (though the two are not mutually distinct and may feed into one another; see Figures 3 and 4). Effectiveness may be measured in economic outcomes, disease management, or qualitative indicators (e.g. perceived success of coordination),

though this report primarily focuses on economic effectiveness.

This economic assessment framework can inform broad disease risk assessments (DRA) for a wide range of disease threats. Specifically, this economic assessment methodology enhances the consequence assessment component of DRA frameworks, such as that established by the OIE Import Risk Analysis standards (OIE, 2016), where risk level is determined by the product of the probability of an event occurring and the consequences (i.e., impact) of that event (we recognize that alternate approaches to risk analysis may involve different inputs and yield different findings). Thus, knowing the economic impact or consequence of an infectious disease event is an important component of assessing its risk to a country.

Similar steps are taken in this framework leading up to the consequence assessment (impact costing) that are parallel to the OIE Risk Assessment approach, so that the methodologies may be applied concurrently, sequentially or independently. First, similar to the OIE framework Release Assessment step, the users of this framework identify the known or potential likely introduction pathway for the disease. Second, the users consider the known or potential likely exposure of animals or humans (Exposure Assessment). The users then define the stakeholders and estimate direct and indirect economic impacts (Consequence Assessment; e.g., health care costs, personal livelihood losses, livestock production losses, tourism impacts, surveillance costs, trade bans, etc.) resultant to the disease event.

Once the economic impact of a disease event is estimated, the users may consider how various coordination efforts and intervention options are likely to alter the consequences, thereby decreasing overall risk. Similar cost data that was used to assess initial economic impact can be used to evaluate whether the interventions imposed (or changes in One Health coordination efforts) actually resulted in the predicted economic benefit. Therefore, this is an iterative process which ideally improves financial decisions over time (rather than only for single diseases), increasingly benefits society and various sectors, and increasingly mitigates risk due to disease events while building overall resilience.

Phase I: Question Framing

Before any assessment, one must ensure the question or issue at hand is adequately identified and framed so to be clear what the goal is and is not regarding the assessment to be carried out. As many One Health issues are complex, framing the question will prevent the users from becoming lost in the assessment process.

Questions to be answered in the Framing phase include, 1) What is the health challenge and/or One Health coordination mechanism being evaluated?; 2) What is the geographical scope (national, regional) and time scale of this assessment?; 3) Who will be the audience of this assessment (e.g., Finance Minister, Ministry of Agriculture, One Health inter-ministerial working group, external donor, etc.)?

An example result of the Question Framing phase may appear as follows: “What is the most economically cost-effective One Health approach to reducing Brucellosis infection in humans in South Africa, for the Finance Minister to direct limited funds?” Another example might be, “What is the most economically efficient of the epidemiologically effective intervention options to protect people from Nipah virus infections in Bangladesh, to inform the Minister of Health?”

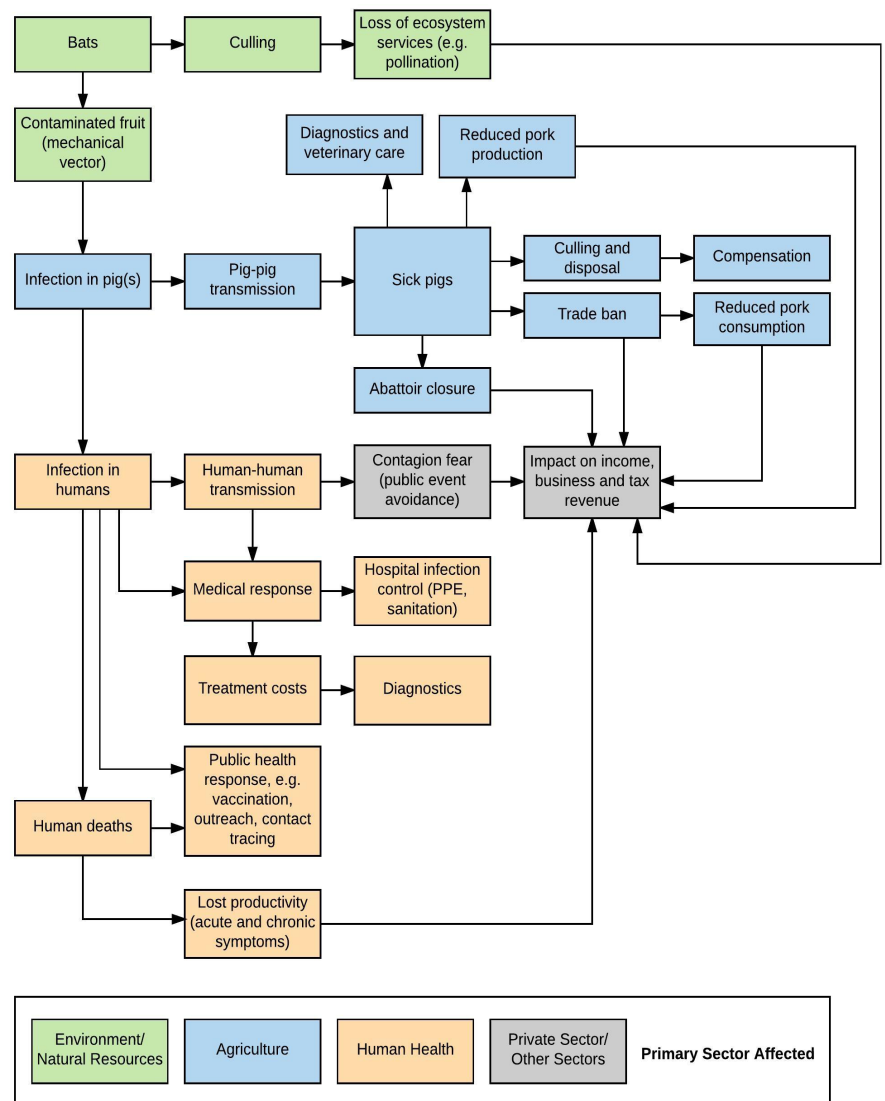
The Question Framing scope may be broad or specific depending on goal of assessment, but it should be comprehensive in inclusion of relevant stakeholders. It should be kept in mind that the broader the scope of the question, the more uncertainty that may be introduced if respective stakeholders cannot provide all required quantitative data during the assessment phase (in such cases stakeholders may provide expert-knowledge based qualitative data). As issues where One Health may be applied are often complex and do often inherently involve at least initial unknowns and uncertainty, assumptions made must be stated with transparency and always considered when evaluating outcomes.

Phase 2: Costing of Impact

In any health challenge there is a flow of impact that affects various systems, sectors, stakeholders and groups in various ways. This phase is intended to create an impact costing flow diagram to understand the chain of impact of a particular health challenge on any relevant/affected sectors/groups.

In any given nation there exists a framework of systems between which are connections of information and responsibilities (governmental ministries, nongovernmental organizations, private/business sectors, individuals/communities, etc). The WHO defines health systems as “all organizations, people and actions whose primary intent is to promote, restore, or maintain health” (2007). It is essential in impact costing to consider the roles, responsibilities, and flow of information of the three main health sectors typically encompassed in One Health (Ministry of Health, Ministry of Agriculture, and Ministry of Environment/Forestry and/or Wildlife) of most national governments. The users should begin with a minimum of these three pillar systems to ensure a One Health assessment approach, and then invite other private or public sectors (e.g., Ministry of Tourism, pharmaceutical companies, etc.) to engage in the review process as deemed prudent during the impact costing process. However, other private or public systems may be included from the outset to help determine flow of impact if desired by the user. The users are encouraged to include all systems/sectors significantly affected by health challenges in order to have a more accurate understanding of overall economic impact.

Figure 5: Illustrative example of a impact costing flow diagram; different sectors may have different roles (e.g. in disease prevention or response).



The impact costing flow diagram should illustrate the flow of impact through various sectors and stakeholders upon introduction of an infectious disease event (Figure 5). This may be reflective upon a previous or current outbreak or endemic disease situation, or potential scenarios of risk based upon application and outputs of informed risk assessment.

If based on several risk assessment scenarios, there may be multiple different impact costing flow diagram scenarios with various economic outcomes. In other words, if one scenario takes place, the downstream epidemiological and economic impacts may be very different from another scenario. Under this framework, a consequence assessment (economic impact estimation) can be made to give the users an idea of economic risk under various scenarios (i.e., potential economic impacts of an outbreak event). It is important to be broad-minded in the approach in thinking of impacts related to animal and human illness, economic burden of disease on families, culling of livestock, and damage to natural resources, especially when constructing the

impact costing flow diagram of a near full chain of events (e.g., affecting livestock farming operations, public hospitals, trade pathways, all the way to the individual farmer/consumer/patient, etc.).

Once an impact costing flow diagram has been made, the next step is to obtain quantitative economic information where available, to calculate the extent of those costs. The users can work with the various sectors/stakeholders in their country to identify which impacts can be economically estimated with confidence, and obtain that data, which impacts require further data collection (i.e., significant financial impact presumed by quantitative data is currently unavailable and needs to be gathered), and which impacts cannot be measured but perhaps rather only qualitatively or directionally (i.e., positive or negative impact). For financial impacts that require data collection, the users should attempt to adhere to a relatively standardized set of cost items, as shown in Table 2. Items included may vary slightly according to disease event and its presumed impacts. (Note that cost items listed in Table 2 may also include intervention assessment costs).

Further, while constructing and collecting data for the impact costing flow diagram, the users should notate: 1) what sector/entity bears each cost, 2) what sector/entity bears responsibility/regulation over impacted groups/individuals, 3) the flow of responsibilities, information, communication, and decision-making, and 4) how these impact costs may incite positive or negative financial feedback loops (e.g., nosocomial infections due to financially strained hospital practices will lead to more human cases that will further strain hospitals financially).

Once Phase 2 is complete the users will be able to estimate, with varying levels of uncertainty based on knowns and unknowns, what the cost of a particular health challenge is and who (which sectors, industries, stakeholders, individuals) bears that cost.

Consideration of the total economic impact of a disease event is not limited to a single value at the national scale. There may be times when international economic impacts are far greater, or when an economic impact is devastating at the local village level, even though minimal at the national level. Likewise, a disease event may prove particularly devastating to a particular sector or industry (e.g., dairy cow industry), but have minimal impact on others. Thus not only the amount, but context of the economic impact must be considered when weighing the value in mitigation investment.

Further, it is recognized that certain impacts on “value” cannot be reflected in economic terms but through alternate currency such as human wellbeing, cultural or religious meaning, or historical relevance. Inclusion of relevant qualitative data via stakeholders (and their willingness to pay based on their valuation) is thus essential to ensure the three pillars of sustainability (economy, society and environment) are considered in decision making.

Table 2: General impact costing template (example). Its use will typically capture information in a partial (vs. general) equilibrium model, operating on the assumption that affected industries likely have an incentive to mitigate losses.

Timeline (DD-MM-YYYY through DD-MM-YYY) for economic cost(s) of outbreak:					
Pathogen/Outbreak Name:					
	Breakdown of pathogen/disease-related economic costs				
Sector/ Industry	Item	Description of item(s)	Cost (local currency)	US\$	Sector paying cost
Human Health	Surveillance/Investigation				
	Diagnostics				
	Biosecurity measures				
	Control/Vaccination				
	Medical costs/Treatment				
Environment/ Wildlife	Surveillance/Investigation				
	Diagnostics				
	Biosecurity measures/Culling				
	Control/Vaccination				
	Medical costs/Treatment				
	Trade				
Animal/ Agriculture (Livestock and other domestic animals)	Surveillance/Investigation				
	Diagnostics				
	Biosecurity measures/Culling				
	Control/Vaccination				
	Medical costs/Treatment				
	Animal Trade				
Other Sectors	Tourism/Travel				
	Other Production and/or Trade/Consumerism				
	Household Income				
	Other (please specify)				

Phase 3: Option Assessment

Another benefit of the impact costing process is to aid in discerning where in a system the most relevant intervention options (which, depending on the situation, may include no action at all) might be for addressing a given disease or risk. Risk mitigation, either via One Health coordination approaches or intervention actions, involves decisions or acts made to decrease, minimize, or prevent current and future epidemiological and/or economic impact of disease on humans, animals, and the environment. Under this economic framework, the users would want to ask themselves if they are looking to find the most cost-effective approach/intervention, or to ascertain the cost of the most epidemiologically effective approach, or simply to minimize economic impacts of the disease across multiple sectors, regardless of epidemiological impact. Often, epidemiological assessments of the disease and disease risk exercises will already have determined several intervention options and their epidemiological outcomes, such as improving information flow via improved One Health platform

communications, smarter surveillance activities, animal vaccination, public hospital capacity building, public education campaigns, etc. It is important to know the likely epidemiological effectiveness of each intervention strategy in order to accurately weigh the economic benefits (and epidemiological outcomes) along with the economic cost of implementation, particularly given the frequently multi-sector nature and potential trade-offs.

The users introduce the impact scenarios into the impact cost flow diagram in order to assess how it will change the predicted/current economic impacts (i.e., an investment of \$X into intervention A will result in a savings of \$Y to the livestock private sector and \$Z to the Ministry of Health). The users may then assess where funds to support the action effort should be derived, considering factors including the group expected to benefit (other relevant factors may include sectoral mandates and institutional capacities).

The goal of a One Health approach is to understand the full scope of economic impact of a given health challenge (e.g., infectious disease outbreak) when all relevant sectors are considered. The other benefit is that this approach will allow clearer visualization of One Health collaboration opportunities (e.g., surveillance cooperation, resource pooling, cross-capacity building, etc.) and assessment of their cost-effectiveness. Through this process it may be deemed, under certain scenarios, unproductive to have a collaborative effort on the ground for a specific intervention (e.g., vaccination of cattle for brucellosis). However, the benefit to the other sectors will have been recognized through the decision making process and a One Health approach will have been taken to come to the informed conclusion.

The users may then also ask: ‘How might relevant resources be optimized through existing or additional feedback loops?’ The system framework should give the users an idea of connection, interdependency, and interrelatedness between systems/sectors to identify any areas for improvement such as responsibility or capacity gaps and opportunities for resource pooling. This is the procedure normally undertaken for health systems strengthening, however if focusing on economics, the users should look for these gaps and opportunities also through the lens of financing and cost.

Table 3: Abbreviated example of a qualitative “stoplight” approach to assessing economic impact of a disease and/or intervention option on various sectors. The expected direction of association is captured as positive (+) or negative (–). The number of signs and density of color reflect estimated magnitude of cost. Where available, quantitative data may be included for more precise assessment.

Economic impact	Sectors	Ministry of Health	Ministry of Agriculture	Ministry of Environment	Livestock Industry	Food Industry	Tourism Industry	Other Retail	The Public	Other
Human Health										
Outbreak investigation/surveillance	---	---			---		---	---		
Diagnostics/Medical treatment	---				---				---	
Other...										
Agriculture										
Outbreak investigation/surveillance	--	---			---	---	---			
Diagnostics/Medical treatment		---			---	---				
Production and trade losses		---			---	---				
Other...										
Environment/Wildlife										
Outbreak Investigation/surveillance		---	---	---	---		---			
Natural Resources		---	---	---	---		---		---	
Other...										
Other										
Tourism/travel impacts						---	---	---	---	
School attendance									---	
Other...										
Overall Qualitative Impact	---	---	---	---	---	---	---	---	---	

*Enhancements or damages to natural resources may include impacts on biodiversity (species richness and/ or abundance), provisioning of ecosystem services (water supply, pollination, carbon sinks, etc.), ecosystem functions, species composition (e.g. via invasive species introduction and establishment), etc.

Phase 4: Measuring Efficacy and Feedback

Building One Health into the approach may improve outcomes through expanded knowledge and participation of multiple sectors to inform decision-making, and allows for iterative refinement of the most efficient One Health platforms and actions. To facilitate assessment, users must be clear on the objective, i.e. as to whether they are looking to support decision-making on key elements of a One Health platform, the most cost-effective interventions in a health challenge, the most epidemiologically effective options regardless of cost, or whether they are merely attempting to ascertain extent of cost of a health challenge and/or options and which sectors bear that cost. This will allow for measurement of cost against the desired goal, such as a certain percent risk reduction of disease spillover, cost-benefit of One Health organizational infrastructure and planning, etc. This method may also be used to assess avoided costs from outbreak prevention or reduction in disease burden/efficient disease control.

Once the users are clear on their question/goal at hand, have illustrated the impact costing flow diagram, and have evaluated cost-benefit and effectiveness of intervention opportunities, they may more easily take a systematic One Health approach to monitoring efficacy of the coordination/interventions put in place. Using the impact costing and option assessment as an iterative tool to assess estimated outcomes of chosen interventions may inform improvement of the process and interventions, as well as establishment of best practices and lessons learned. Users should continue to collect data on impact costs of disease events after implementation of chosen coordination and/or intervention actions in order to assess the economic and epidemiological efficacy of these approaches and to compare to predictions (Table 1) .

As mentioned, costing may be completely quantitative, semi-quantitative, or completely qualitative. Quantitative data can be calculated directly, or assessed through economic models (Figure 6), while semi-quantitative or qualitative data may be assessed through a combination of techniques (e.g. Tables 3-4).

In the below equation (Figure 6), the human health sector (HH) variable is dependent on human morbidity and mortality and the extent externalities of a trade ban. The livestock sector (LS) variable depends on animal morbidity and mortality, and the extent of the trade ban, and the environmental health (EH) variable depends on the ecosystem services provided by the area of study. All of these health measurements are linked through variables that depend on the economy and the targeted disease dynamics.

Figure 6: For example, a quantitative model approach like dynamic optimization models allow us to estimate the optimal amount of resources to invest in policies in each period through measuring the changes in social welfare in monetary terms. In the case of Rift Valley Fever (RVF), we could think of a model that maximizes social welfare as the present value of the sum of human health (HH), animal health (LS), and environmental health (EH) choosing the amount of prevention investment that would reduce trade bans imposed as control measures. (NB)= net benefits. Each of these measurements are exchangeable and depend in turn on economic and health parameters.

$$\text{Max} \int_{t=0}^{\infty} [HH + LS + EH - \text{policy investment}] e^{-\rho t} dt$$

$$HH = NB^{HH} \text{ (human morbidity and mortality, trade ban)}$$

$$LS = NB^{LS} \text{ (morbidity and mortality of animals, trade ban)}$$

$$EH = NB^{EH} \text{ (ecosystem services)}$$

Table 4: Hypothetical impacts (which may have positive or negative values) to different sectors from different actions that could be implemented in response to a given disease threat.

Action(s)	Possible Outcome (hypothetical examples)			
	Livestock	Public health	Environment	Socio-economic
Disease and disease control impact	Prevented animal production losses	Prevented human losses (e.g. DALYs)	Effects (protective or detrimental) on non-target species	Prevented tax losses
				Prevented producers'/other stakeholders' livelihood losses
				Level of public satisfaction
				Prevented tourism losses
Illegal trade (due to imposed measures)	Increased animal production losses	Increased human losses (DALYs)		Increased tax losses
Value chain restructuring	Losses or gains		Impact on wild animal harvest (changes in hunting pressure)	Impact on income distribution (changes in value chain equity)
International trade ban	Prevented international market access			Impact on food security

Considerations

The four broad phases of the One Health Economic Evaluation, while standard in systematic approach, may vary considerably in content by geographical area, specific health challenge, and goal of the evaluation. In fact, the purpose of the evaluation may be to assess the cost of the process itself and its value. Similarly, building One Health coordination platforms or components thereof may also be costly, although typically the cost of maintenance of such collaboration is less than the initial start-up costs.

The broader the One Health approach, the more likely for encountering challenges in acquiring economic data. However, in some cases economic data is readily available with a little bit of research and/or collaboration. Data precision is often possible at a country or local level, with greater opportunities for validating data directly from domestic information sources. Conversely, when economic measurement is not available, either due to epidemiological impact or indirect cost uncertainties, qualitative factors may be introduced. In some of these cases a spotlight approach can be taken (i.e., assigning a positive, negative, or neutral/insignificant impact to qualitatively indicate expected direction and magnitude) to those components and add their consideration as a narrative to accompany the quantitative or semi-quantitative model.

For any One Health topic, there will likely be some degree of uncertainty, including both known and unknown factors that affect risk; risk analysis frameworks may have limitations when facing ambiguity on probability and consequences of occurrence, as well as appropriate interventions (see Pfeiffer 2014 for examination of different tool utility under various knowledge constraints: ambiguity, ignorance, risk and uncertainty). In some cases, where there is a high level of uncertainty, users may decide to transparently make decisions (ideally identifying exactly where those uncertainties lie so that data may be collected in the future or so that all collaborators understand), or may find value in waiting to make a decision until more is known (Pike et al. 2014). Regardless, the users must recognize the limitations of the assessment outputs and applicability based on the level of uncertainty in variables considered.

While taking a comprehensive One Health approach to disease threats is ideal, it is recognized that in many cases economic data supporting certain impacts (such as decreases in consumerism attributable to fear of disease exposure) might be lacking. The working group acknowledged that analyses of complex problems with many unknowns often requires simple decision making in the face of uncertainty (Kochenderfer, 2015).

Justifications and applications for this are a field of study in themselves, but relevant points here include:

- 1) Collection of all relevant data is time consuming and costly, and may not be necessary when a qualitative attribution can be made (e.g., understanding that consumerism is negatively affected by the disease threat); whereas absence of decision-making until all unknowns are known will lead to permanent inaction;
- 2) Entering imperfect data into mathematical models will add uncertainty and potentially bias to the model and decrease its accuracy and credibility (i.e., in certain cases a qualitative or semi-quantitative assessment will be more accurate than a quantitative model with imperfect or incomplete data);
- 3) Too many uncertain factors to consider can paralyze decision making, or lead to attempts at management of various impacts versus focusing on prevention or intervention upstream. Under uncertainty, the user must consider the sources and extent of uncertainty and weight those against the objective of the assessment and decision. However, where information (quantitative or qualitative) available is significant and accessible through cross-sectoral collaboration, it should be included for informed decision making purposes. Testing options in different scenarios (e.g., 'stress testing') may also help improve confidence in a given option.



Experts acknowledged that there are limitations to a broad-brush approach when it comes to even similar health challenges faced by individual countries given the variability in cultural, economic, social, professional (e.g., medical, laboratory, ecological, biosecurity knowledge) infrastructural and environmental capacities. However, it was understood that a general, relatively consistent framework that may be adapted to specific situations is needed in order to objectively evaluate the economic considerations of One Health approaches. Such consistency would also better allow for comparison of effectiveness across different geographical and topical situations and identification of lessons learned that may be transferrable.

Likewise, the group acknowledged that governments and industries are often making decisions in the face of multiple uncertainties (e.g., absence of economic or epidemiologic data, variability of how various impacts on diverse sectors may be valued differently). In such cases, a semi-quantitative or qualitative approach must be taken, and often decisions are then made or not made, but ideally with comprehension and transparency regarding information that is lacking).

Lastly, it was recognized that the scope of the proposed methodology from this workshop was limited to economic evaluation of One Health approaches, and epidemiological or system efficiency assessment, while related to cost-effectiveness, were not in themselves the main target. These other aspects of evaluating One Health effectiveness can be highly meaningful and are being undertaken elsewhere (please see **Chapter 5** for further information).

Chapter 3 – Illustrative example

To assist in considering concrete examples in the workshop, an initial list of diseases (a mix of emerging and endemic pathogens) were examined at the start of the workshop in terms of their transmission cycle, impact, and the role of the human health, animal/agriculture and environment sector, noting that involvement of each sector may vary widely by disease and context. These included Echinococcus, Nipah virus, MERS, Rabies, Q fever, Highly Pathogenic Avian Influenzas, and Brucellosis.

The following example is intended to be briefly illustrative for how methods may be applied and is not intended to be complete. Participants recognized that other endemic diseases of high human and animal health burden would also be ideal for a One Health approach (e.g. Leptospirosis, Cysticercosis, zoonotic Tuberculosis; please see Grace et al. 2012 for additional examples).

One Health Economic Assessment of Nipah virus emergence

Evidence of henipavirus has been detected in fruit bats in several countries in Africa (Hayman et al. 2008). There has also been serological evidence of exposure in humans in Cameroon (Pernet et al. 2014). Some workshop members worked through the One Health Economic Assessment Framework to conduct a prospective assessment of a potential Nipah virus outbreak in humans and animals in a given country (for the purpose of the exercise, a nation in Western Africa noted as “country X” was selected).

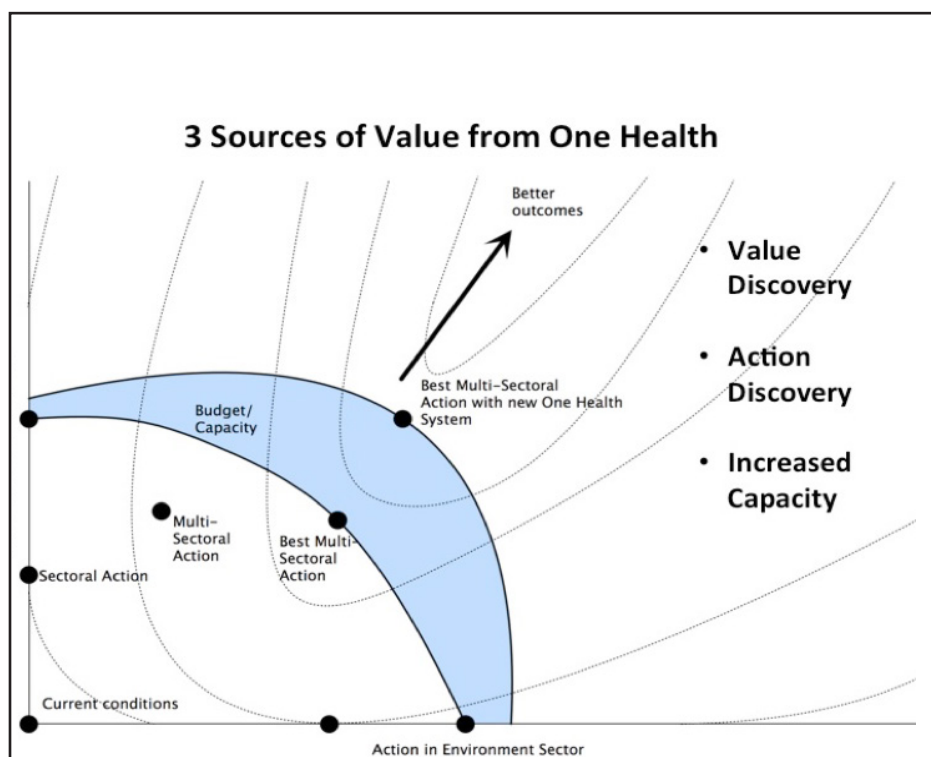
Phase 1 Question Framing

For the purposes of this exercise, the workshop attendees posed the question: “What would be the cost-effectiveness of key interventions for a potential Nipah virus outbreak causing significant morbidity and mortality (comparable to that seen in Bangladesh and Malaysia) in pigs and humans in country X?”

Phase 2 Costing of the Impact

The working group assessed a hazard identification scenario under which a virulent Nipah virus spilled over from free-ranging fruit bats to domesticated pig farms, and subsequently spread from infected pigs to humans. Although the virulence of Henipavirus strains found to date in Africa are unknown, the working group conducted a One Health Economic Assessment with presumed morbidity and mortality in humans and pigs similar to those found in previous Bangladesh and Malaysia outbreaks. Impact costing flow and values were

Figure 7: Conceptual model of potential One Health ‘frontiers’



estimated in the context of the given nation's health systems, livestock production and bushmeat extraction practices, and economies (this example may not be comprehensive and would require national stakeholders' participation to complete and validate sector impacts.)

Phase 3 Option Assessment

Once the economic impact of the disease outbreak scenario was mapped via the impact costing flow diagram, the working group considered various intervention scenarios individually and in combinations to assess the potential change in economic impact under One Health approaches. Figure 5 illustrates some of the general potential interventions (multiple intervention scenarios are shown in a

single impact costing flow diagram due to limited space for illustrations in this report). The economic data examined in this example were largely quantitative, taken from scientific and grey literature, sector professionals and researchers, and educated cost estimations based on similar countries under similar challenges. However, further involvement of national and pathogen-specific experts would be required to complete full analysis.

Phase 4 Measuring Efficacy and Feedback

Based upon the impact costing flow diagram, standardized cost items as illustrated in Table 1 can be collected if a similar scenario as was proposed in this example occurs, and compared with our estimations. Further, the country's government could use the impact costing exercise to consider additional options for prevention, such as increased surveillance in bats, biosecurity of pig farms, public education campaigns – their costs and potential benefits.

Chapter 4 – Conclusions and Recommendations

The proposed four basic steps largely bring together existing tools in a framework to help consistently assess and reinforce the connections between and relative impacts of infectious diseases to various sectors (at a minimum, human health, animal health, and environment) for a given objective. While the One Health concept is typically presented as a Venn diagram with all circles equal weight, in reality the role of (and effect on) each of the three sectors varies widely based on the particular context of the situation (which may be dependent on the specific disease, transmission pathway, risk factors, etc. [see Figure 2 for examples]). Such mapping and impact assessment exercises may help identify opportunities for One Health information to flow that otherwise would not have been identified by individual sectors due to differing data access and understanding (thereby expanding capacity and knowledge ‘frontiers’, as shown in Figure 7).

The four steps represent a basic process for economic evaluation of One Health, intended for (but not exclusive to) ministerial use without sophisticated processing software (though portions assume some level of technical expertise, or at least access to inputs, on specific human health, animal health and environmental aspects that would be expected from the respective ministries). As with other processes (e.g. epidemiological risk assessment), the methods can be refined and widely expanded based on availability of data and technical skill inputs, with many applications for more sophisticated methods (e.g. real-options analysis for time-horizon decision making about disease risk mitigation versus adaptation [see, for example, Pike et al. 2014] weighted cost-effectiveness to adjust the varying relevance of multiple criteria, etc.). It is intentionally non-theoretical, oriented to directly informing actionable options around a particular disease or foundation capacity.

Given the paucity of existing quantitative evaluation of One Health in general, especially at a country level (Häsler et al. 2014; Baum et al. 2016), the application of this methodology is expected to considerably add to the evidence base to assess situations in which One Health approaches do or do not add value. This can be helpful on a national or local level (e.g. determining resource allocation to address a specific disease), and may potentially be aggregated to discern overall best practices for One Health globally.

Lastly, it should be noted that the *process* of conducting One Health Economic Evaluation itself may potentially have inherent value in advancing One Health capacity. Even if no specific action is taken following the findings of the evaluation, it may still yield overall strengthened connections between sectors (including, but not limited to, human health, animal health, and environment), greater appreciation of shared priorities/concerns, and more direct contact points between ministries that in the future could be mobilized for future cross-sectoral collaboration. If undertaken by finance ministers, for example, he or she may too be more apt to consider broader connections in health emergencies – be they infectious diseases in humans, wildlife or livestock mortality events, water contamination, ecotoxicology, food safety and security, or other topics that may benefit from multisectoral coordination.

Potential applications could also explore wider development impacts of health disasters that were beyond the scope of the workshop but may be highly relevant for development goals (e.g., educational gaps, nutritional stunting, wellbeing impacts that may result).

Workshop Recommendations:

- **Promote cross-sectoral understanding through clear terminology:** Given the unique expertise that each sector brings, there is potential for misunderstanding or disagreement around the different meaning of terms among human health, animal health, and environment sectors (as well as other potential participants such as economists, behaviorists, etc.). Wherever possible, developing working definitions understandable and acceptable to participants may assist in collaboration. Developing a platform for ongoing dialogue on terminology (e.g., via a Wiki) may help in compiling and refining a set of terms. Existing resources may provide a strong starting point (e.g., see description of RISKSUR and OECD glossaries in **Chapter 5**).
- **Work within country context:** The importance of context (e.g., socially and culturally-acceptable

parameters, values, and practices) was emphasized to ensure approaches considered in the One Health Economic Evaluation process are pragmatic and could have successful uptake. Furthermore, using follow-up to ensure approaches are followed and sustainable allows for identification of failed mitigation strategies and opportunity for substitution with more effective measures. Thus, while international experts may have an interest and role in supporting development of this field, it is essential to involve in-country researchers and partners in the refinement of methods and integration into country planning that works for them. World Bank Country Economists may be an excellent resource for collaboration and information sharing.

- **Work toward multiple gains, but recognize that specific disease priorities may provide a platform for initial engagement:** Experts noted the importance of working toward multiple gains to optimize efficiency, rather than considering options for addressing single diseases alone. While striving for this, opportunities and interest in One Health application may vary, and may be initiated and tested via dialogue on specific single-disease issues (e.g. rabies control).
- **Recognize that participants may have different priorities and levels of buy-in:** Sectors may have varying degrees of initial interest, and varying goals for their participation in the assessment process. Certain metrics may have high relevance and priority to some sectors and not to others (e.g., Disability-Adjusted Life Years are highly relevant to the human health sector). Therefore, it may be useful to showcase a range of evaluation metrics (e.g. economic and epidemiological data). Goals should be transparent and discussed throughout the process to ensure all participants are motivated to collaborate where needed.
- **Increase representation of environment sector:** While environment is one of three main sectors in the concept of One Health, in practice it is systematically underrepresented. The chronic lack of economic, and even ecological data available on impacts to the environment sector was a recurring discussion point. Participants suggested that in the absence of concrete data, initial qualitative assessments that demonstrate the known or expected direction (and where available, magnitude) of an impact be used. This approach may also help identify priority data gaps (which then could potentially be addressed by relevant initiatives that aim at valuation, such as ecosystem service assessments undertaken by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services and The Economics of Ecosystems and Biodiversity). Furthermore, understanding that the breadth of economic costs related to environmental impacts often affect human and animal health and other sectors (e.g., contamination of natural water sources can lead to public health problems (drinking water), livestock disease spread, and required clean-up or alternative planning interventions by government, sectors using irrigation, tourism industries, etc.), beyond the inherent value of the ecosystem itself, warrants greater efforts toward costing environmental impacts.
- **Promote integrated risk and impact assessment:** Assessing risks and impacts to human, animal, environmental and other (e.g., social) sectors provides a more complete understanding of their potential links. This may yield a broader understanding of potential outcomes of disease control options, or could be applied to other contexts (e.g., potentially facilitating future iterations of safeguard frameworks to help promote the health of people and the environment associated with nationally-funded, development, or private investment projects). A common set of indicators (e.g., as proposed in **Chapter 2** and for further refinement) may help provide a starting point for integration.
- **Reinforce the value of prevention:** As understanding of the drivers and mechanisms for pathogen spillover increases, more can be done to mitigate risk and work toward prevention (e.g., via integrated risk assessment to anticipate possible externalities that could affect public health, whether positive or negative). In some cases, individual behavior change may drive prevention, but may be aided by a public sector investment (e.g., via education campaigns); in other cases, broader-scale public and private sector policies may be needed (e.g., redirecting land conversion sites to avoid high risk of disease emergence).

Next Steps

The workshop outcomes help inform a forthcoming World Bank Operational Framework on One Health, intended as a pragmatic resource to assist staff and client country implementation of One Health strategies. The methodology is planned for use through the USAID Emerging Pandemic Threats PREDICT-2 project to test frameworks developed and generate additional analyses. Other researchers and evaluators are encouraged to use and build on the methodology, viewing it as an iterative process to be improved on, in particular strengthening environmental components. Ideally, findings will help inform future investment options under programs such as the REDISSE Phase III countries and guide multisectoral collaboration (including in the public sector, as well as potentially with private industry) for epidemic and pandemic risk mitigation, preparedness, and response (e.g., as part of the guidance currently under development by the World Health Organization to assist countries in action plans for health security). Ultimately, systematic documentation of impacts of emerging and endemic diseases, as well as the costs and benefits of different options to address them, can improve understanding of where value can be added from a One Health approach to better confront local and global health threats.



Chapter 5 – Informational Resources

The following resources showcase examples of active One Health projects and/or may be helpful in implementing One Health Economics or other types of One Health evaluations:

Emerging Pandemic Threats-2 (<https://www.usaid.gov/what-we-do/global-health/pandemic-influenza-and-other-emerging-threats/programs>): A program of USAID. Projects include PREDICT-2, to assist focus countries in monitoring viruses with pandemic potential as well as behaviors, practices, and conditions associated with viral evolution, spillover, amplification, and spread; Preparedness and Response, to enable national governments to establish and strengthen systems, policies, and practices for prevention, detection, response, and control of emerging disease threats – especially zoonotic diseases; and One Health Workforce to train the current and future workforce across sectors (e.g., human health, animal health, and environmental health) and disciplines (e.g., medicine, public health, epidemiology, agriculture, and ecology). FAO is also a partner under the EPT-2 program, managing dimensions of livestock disease along the livestock value chain.

European Union COST Action Network for Evaluation of One Health (<http://neoh.onehealthglobal.net>): An open network bringing together experts interested in One Health from across Europe. The initiative is developing a One Health Index and associated handbook that will cover various dimensions of One Health evaluation.

Regional Disease Surveillance Systems Enhancement Project for Africa, or REDISSE (<http://projects.worldbank.org/P154807?lang=en>): A program of the World Bank, it is planned for three phases covering 15 eligible countries, with an objective to strengthen national and regional cross-sectoral capacity for collaborative disease surveillance and epidemic preparedness in West Africa, thereby addressing systematic weaknesses within the animal and human health systems that hinder effective disease surveillance and response; and in the event of an Eligible Emergency to provide immediate and effective response.

RISKSUR (<http://www.fp7-risksur.eu>): An EU FP7 funded project aimed to develop decision support tools for cost-effective risk-based surveillance systems that integrate the most recent advances in epidemiological methodologies, based on an interdisciplinary approach and tailored to the needs of individual EU Members States. This was achieved by the development of evaluation frameworks for animal health surveillance system designs for livestock diseases. A glossary is available at: <http://www.fp7-risksur.eu/terminology/glossary>.

The Economics of Ecosystem and Biodiversity (TEEB) (<http://www.teebweb.org/>): a global initiative involving a structured approach to value the benefits of ecosystems and biodiversity to inform decision making.

The Pandemic Emergency Financing facility (<http://www.worldbank.org/en/topic/pandemics/brief/pandemic-emergency-facility-frequently-asked-questions>): a program of the World Bank, it offers an innovative insurance-based mechanism which provides the needed surge funding to the world's poorest countries to help prevent disease outbreaks from becoming pandemics, thereby saving lives and money, and protecting economies. PEF funding under the insurance window is provided by resources from the reinsurance market and the proceeds of catastrophe bonds issued by IBRD [International Bank for Reconstruction and Development]. The PEF also includes a cash window to complement the insurance window.

WHO Joint External Evaluation (JEE) (http://apps.who.int/iris/bitstream/10665/204368/1/9789241510172_eng.pdf): The JEE- International Health Regulations (2005) is intended to assess country capacity to prevent, detect, and rapidly respond to public health threats. The purpose of the external evaluation process is to measure country specific status (capacity and capabilities) and progress in achieving IHR targets. The external evaluation allows countries to identify the most urgent needs within their health security system, to prioritize opportunities for enhanced preparedness, response and action, and to engage with current and prospective donors and partners to target resources effectively.

WHO OneHealth Costing Tool (<http://www.who.int/choice/onehealthtool/en/>): The OneHealth Tool is a software tool designed to inform national strategic health planning in low- and middle-income countries (the name refers to the array of diseases and health system components that it intends to cover, not the One Health

concept specifically). It seeks to align disease control objectives and targets with needed investments, providing a framework for scenario analysis, costing, health impact analysis, budgeting and financing of a country's health sector.

Examples of web tools/efforts to assist in online open workspaces and sharing of data:

Zenodo (<https://zenodo.org>): Commissioned by the EC to support their Open Data policy, Zenodo provides a platform for depositing or identifying available data and models (access to the files themselves is controlled by the owner's choice of access rights options). The European Food Safety has a robust 'Knowledge Junction' open repository for evidence and models sharing on Zenodo (<https://zenodo.org/communities/efsa-kj?page=1&size=20>).

Wiki space (<https://www.wikispaces.com>): A collaborative platform for projects. Permissions can be set to restrict or invite users.

Glossary

The OECD Glossary of Key Terms in Evaluation and Results Based Management (<https://www.oecd.org/dac/evaluation/2754804.pdf>) also provides definitions that may be useful.

Adaptation: response (e.g. to pathogen spillover and/or a disease event).

Benefit: Direct and indirect advantages produced by the surveillance system. This does not need to be limited to financial savings and better use of resources but can also include any losses avoided due to the existence of the system and the information it provides. These avoided losses may include improved animal production; maintenance of a structured network of actors able to react appropriately against a future threat; improved public health; increased understanding about a disease; maintained or increased trade; or improved ability to react in case of an outbreak of disease (RISKSUR project).

Cost: The evaluation should list and quantify each of the resources required to operate the surveillance system and identify who provides each resource. These resources could include: time, personnel, financial input and equipment (RISKSUR project).

Cost-effectiveness: the extent to which the program has achieved or is expected to achieve its results at a lower cost compared with alternatives (World Bank).

Emerging disease: A new infection resulting from the evolution or change of an existing pathogenic agent, a known infection spreading to a new geographic area or population, or a previously unrecognized pathogenic agent or disease diagnosed for the first time and that has a significant impact on animal or public health (OIE 2011).

Endemic disease: A disease that is constantly present to a greater or lesser degree in people of a certain class or in people living in a particular location (World Bank 2012).

Mitigation: reduced risk and/or prevention (e.g. of pathogen spillover and/or a disease event).

One Health (working definition): A collaborative approach for strengthening systems to prevent, prepare, detect and respond primarily to infectious diseases and related issues such as antimicrobial resistance that threaten human health, animal health, and environmental health, collectively, using tools such as surveillance and reporting with an endpoint of improving global health security and achieving gains in development. While using infectious disease as a starting point, this definition and approach is expandable for wider scope (e.g. water or soil pollution with animal and environmental connections).

Prevent, Prepare and Respond: The terms are used throughout to capture the spectrum of disease trajectory, all the way from initial prevention of pathogen spillover (whether through addressing broad drivers or reducing individual exposures), to preparedness for its potential spillover (e.g. via detection capacity), to response to an outbreak, epidemic or pandemic.

Zoonosis: Any disease or infection that is naturally transmissible between animals and humans (IOM 2009).

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