Report

The Socio-Economic Benefits of the HIGHWAY project

Paul Watkiss, Robert Powell, Alistair Hunt, Federica Cimato

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Executive summary

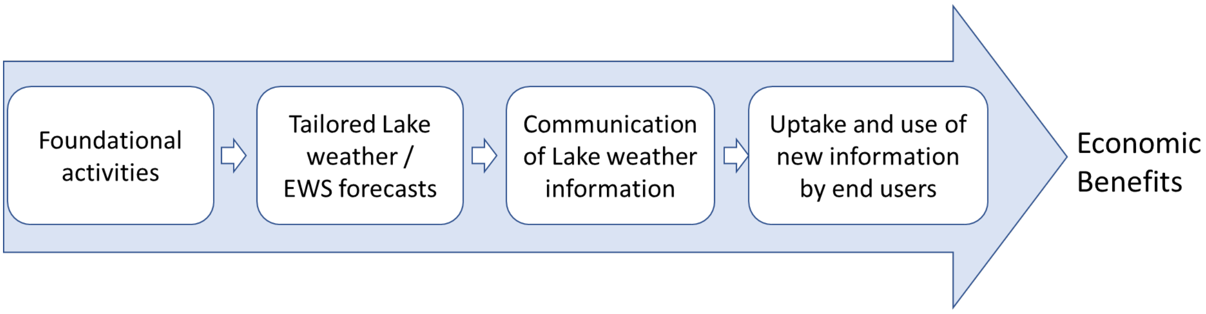
The HIGHWAY project (HIGH impact Weather lAke sYstem - a proposal framework for the Lake Victoria region) is integrating a regional Early Warning System (EWS) into strategies and plans on a regional, national and local scale. By doing so, it is increasing the use of weather information to improve resilience and reduce the loss of life and damage to property.

A key impact indicator of the HIGHWAY project is the 'value of avoided losses due to use of climate information'. To assess these benefits, this study has assessed the socio-economic benefits (SEB) of more accurate and timely early warnings, achieved by the project. This focuses on the benefits from users taking action and avoiding fatalities and losses, as well as possible benefits. This document presents the results of the socio-economic benefit analysis in HIGHWAY.

<u>Study method including weather chain analysis</u>

The HIGHWAY project is generating regular Lake Victoria weather forecasts and severe weather warnings. This investment in weather and climate services leads to improved information. In turn, this provides economic benefits to users, from the positive outcomes from the actions and decisions that users take. This is known as the value of the information. This study has developed a method to assess these economic benefits, using the WISER SEB guidance.

Previous studies have estimated between 3000 and 5000 people drown on Lake Victoria each year. The SEB study has assessed the benefits from HIGHWAY activities along the weather value chain, from foundational activities (e.g. new infrastructure), improved forecasts, enhanced communication and greater user uptake, and thus the benefits in reducing these fatalities, as well as other losses.



The study identified the potential socio-economic benefits from new weather forecasts and warnings for Lake Victoria, derived a baseline, and then assessed the change with the new weather and climate service in place (along the whole value chain). It then estimated the benefits of this change, valuing all market and non-market benefits, and comparing these to the costs of the project. It has also looked at how these benefits could be further enhanced in subsequent phases of HIGHWAY.

Socio-economic benefits of HIGHWAY

The study identified a large number of benefits (avoided losses or positive opportunities) from the new weather forecasts and severe weather warnings on the Lake, including for fisherfolk, small boat passengers and operators, large boats, fish traders, and tourism and recreational activities. These include tangible benefits, such as the reduced loss of boats, reduced weather-related losses (fish drying) and reduced costs from lower boat fuel use. It also includes intangible (non-market) benefits, including reduced fatalities. Alongside this, it has identified indirect benefits, including on the associated impact on dependants of fisherfolk, and wider economic benefits to other users around the Lake.

A baseline was compiled, drawing on the existing HIGHWAY baseline reports. These estimate that the number of users reached with relevant Lake weather information before HIGHWAY was below 5%. The analysis also found that national forecasts of all three countries contained very little information of relevance to small boat users in Lake Victoria and very few people in fishing communities paid attention to them. A new baseline analysis of weather-related impacts was also undertaken.

The study then analysed the benefits of HIGHWAY project activities. This used a combination of desk analysis, field research, interviews, telephone and WhatsApp discussions and focus groups, to assess the project's benefits across the value chain. Fifteen focus groups were held in Uganda and Kenya for the study, at different landing sites and Beach Management Units (BMUs) to gather information on the communication, perceived accuracy and uptake of the HIGHWAY regular weather forecasts and severe weather warnings. These have focused on Kenya and Uganda, where the marine information had been up and running for a year. Similar activities have now started in Tanzania, but as the weather information bulletins followed later, we have not been able to assess these benefits as yet. In the absence of other information, we assume similar benefits will be generated in Tanzania as found in the other two countries.

The findings are:

- The foundational activities, including the advances in the science and the investment in meteorological equipment (including the field campaign), as well as meteorological staff training and capacity building, have led to an improved forecasts, with much higher resolution and accuracy for the Lake. It is difficult to estimate the individual contribution of each element, but focus group discussions and interviews with users report a much higher level of forecast accuracy. A figure of around 70% accuracy has been used for the analysis.

- The introduction of new marine weather forecast bulletins that were co-designed by the national met agencies for small craft users on Lake Victoria, and radical improvements in the way weather information was communicated to lakeside and island communities, has dramatically improved the reach and impact of the weather information generated and disseminated with the assistance of HIGHWAY. The forecasts were targeted at selected local radio stations which serve lakeside and island communities, with training on how to translate the forecasts accurately into local languages, along with guidance on the times to broadcast forecast bulletins. HIGHWAY also piloted the use of WhatsApp to disseminate the forecasts to a wide range of key users, including radio journalists, fishermen's leaders, community intermediaries at landing sites and government officials. Based on the findings from focus groups, around 85% of potential users at landing sites were accessing the improved weather information.

- User uptake of information. The activities undertaken to increase use of weather information, including sensitisation at selected landing sites, including use of community intermediaries, weather flags and weather noticeboards (secondary local communication) has led to greater use of the information. The focus groups at these landing sites indicated that, 75% of those who receive weather information use it to inform their decision making.

The interviews and focus groups revealed a large number of actions are being taken by end-users in response to the weather forecasts and severe weather warnings.

- Fishermen and small passenger boat operators take life jackets, wet weather gear and extra fuel.
- If severe weather is forecast, they often postpone or cancel their trips or avoid going out too far in the lake. Passenger/cargo boat operators often respond to forecasts of bad weather by carrying a lighter load.
- Rescue services are alerted and put on standby to respond to any emergencies.
- Boat owners and skippers secure vessels at the landing site to prevent damage from high wind or large waves.
- Skippers use wind and wave information from the forecast to adjust their routing in order to reduce fuel consumption and save money.
- Silver fish dryers and traders cover fish to protect them from rain, and alter their fish purchasing strategy if rain is forecast.
- Travellers use the forecasts to avoid undertaking journeys in small boats at times when travel is likely to be uncomfortable or dangerous.
- Other stakeholders also use the marine forecasts to inform their decisions. They include farmers, tourism operators and a company that provides electricity and water supply services.

Overall, the weather information is leading to safer navigation on the lake, and also financial benefits, from fuel savings, and from avoided losses (damage to boats, lost nets, and lost boats). The bulletins are credited with bringing about behaviour change, and improved marine security and saved lives, both for fishermen and for small boat operators and passengers.

Looking at the overall value chain, the improvement (in % accuracy, reach, communication and use) at each stage is impressive. Nevertheless, there is still a large loss of efficiency across the weather chain. At each successive stage there is a fall-off, e.g. due to the % of people who hear the forecast, or the ability to accurate predict a storm, the trust that users have in the forecast and thus their willingness to take action. This means that the level of benefits in reducing weather related impacts on Lake Victoria for key target groups, as compared to perfect information and use, are 30%. This information has been used to estimate subsequent benefits. This information on the value chain – and the losses in efficiency along it - also provides key information on how the service can be enhanced in the future.

This analysis suggests that the HIGHWAY project is leading to approximately a 30% reduction in weather-related deaths on the Lake.

The study undertook new analysis to try and assess the numbers of fatalities each year on the lake, and to get information on potential reductions in fatalities from the use of HIGHWAY weather information. This indicates that the number of people who die on the lake annually is likely to be lower than previous estimates of 3000-500/year. This is due to more routine use of life jackets, the trend towards larger boats, and interventions to reduce boats going out in bad weather. It is also highlighted that not all of these deaths (drownings) will be due to weather related events, i.e. some may due to other reasons. For this SEB analysis, based on new data gathered, the baseline weather related deaths on the Lake was therefore estimated to be 1000/year. When the efficiency losses along the weather chain are accounted for (30%), we estimate that the marine information in HIGHWAY is avoiding 312 deaths/year.

Very positively, there was already an indication of reduced fatalities in some BMUs attributed to the stronger precautions taken by fishermen on the basis of the HIGHWAY forecasts. Based on interviews, indicative statistics indicate drownings have fallen by around one third to one half with the forecasts in place in both Uganda and Kenya. This level correlates well with the focus groups and efficiency analysis.

The study then estimated the economic value of the reduced impacts. The impacts on health are more difficult to value than other sectors, because there are no observed market prices. However, it is possible to derive monetary values by considering the total effect on society's welfare. For the valuation of fatalities, the focus is on valuing the change in the risk of mortality, and not, the valuation of life itself. While these values are often seen as controversial, they are widely used in economic appraisal by Governments. There are different approaches that can be used for valuing the change in the risks of mortality. For this study, we have used the value of statistical life, also known as the value of a prevented fatality, VPF, transferred to the relevant East Africa context. The impact on dependants is captured by applying an uplift to these values.

Alongside the human tragedy of these events, there are also more material losses associated with the loss of boats and gear, as well as the benefits from reduced fuel and reduced fish drying losses. The additional benefits of these were also estimated, based on survey work, focus groups and interviews. There was widespread agreement in the focus groups that the forecasts are reducing fuel costs for small boats, in terms of the fuel consumption of outboard motors. An analysis of these benefits, taking account of value chain efficiency, indicates the fuel savings could be up to $10 to $20 million year due to HIGHWAY.

A further group of user benefits were found to arise for fish driers and traders. Focus group discussion were held to understand and quantify these benefits. Indicative analysis indicates reduced losses to fish driers could be $1 to $3 million year due to the use of improved weather information. These benefits accrue almost entirely to women.

Adding all tangible and non-tangible benefits together, the study estimates that the economic benefits of HIGHWAY activities are $44 million/year (central value).

Based on the continued operation of the new HIGHWAY marine information over the next few years, the cumulative benefits of the project investments will be extremely large. When these benefits are compared to the project costs, of around $5M total, it is clear that HIGHWAY has an extremely large benefit:cost ratio. This has been analysed, assuming a fall-off in benefits without further investment. The analysis finds the net present value of HIGHWAY is $73 million, with a benefit to cost ratio of 16:1, at a 10% discount rate.

There are also indirect benefits that arise from the improved Lake weather and severe weather forecasts from HIGHWAY. These include benefits for the larger lake vessels (ferries and cargo ships), the agriculture sector and for Lake tourism, although these have not been quantified. It also includes wider benefits for weather related decisions for the 5.4 million people who live in fishing communities around the coastline of Lake Victoria and on islands in the lake, and from the improved severe weather forecasting capacity and training from Rwanda's involvement in the HIGHWAY project. While it has not been possible to quantify these, they would increase the benefits above further.

Future phases and business plan

Building on HIGHWAY, the National Meteorological and Hydrological Services (NMHSs) of the East African Community (EAC) have agreed to develop a more integrated and collaborative regional approach to the delivery of Early Warning Services (EWS) over the period 2020 - 2025. This EWS Vision 2025 enhances the existing marine weather information and expands the sectoral coverage (to other sectors impacted by severe weather).

The EWS vision includes four activities

1. Collection and calibration of quality data and its integration into national climate databases.

2. Training and working groups to enhance capacity in NWP and wave modelling and improve the accuracy of modelling.

3. The creation of impact-based forecasts and warnings which pertain to users' risk perception. The

4. Training, capacity building and sharing of best practice to enhance the capacity of intermediaries responsible for communication of forecasts to the public.

The SEB analysis has assessed the potential benefits of the EWS Vision 2025.

A regional EWS would enable countries to pool resources and benefit from economies of scale. This is particularly relevant since individual investment is costly and developing countries face budget constraints due to other development priorities. A literature review was undertaken to estimate these cost savings. This indicates regional cooperation could generate savings worth 30% of the sum of the investment costs incurred individually by countries (for equivalent systems).

The EWS Vision 2025 would also deliver major improvements in marine forecasts, i.e. improving the benefits realised in HIGHWAY. The SEB study has looked at how the interventions in this future phase would reduce the current efficiency losses along the weather chain, and thus deliver higher benefits. Based on the analysis, and supported by the upper estimates from individual focus groups of what is realistic, we estimate that 90% effectiveness is possible at each individual stage (for reach, accuracy, user uptake, and effectiveness of action taken) based on the activities in Vision 2025. This would significantly increase the final user benefits, more than doubling the levels of economic benefits in HIGHWAY.

With these updates, the efficiency losses in the weather chain would fall dramatically, reducing the total weather-related deaths by 66% (compared to pre-HIGHWAY baseline). When the efficiency losses along the weather chain are accounted for, we estimate that the marine information in EWS Vision 2025 could avoid 656 deaths/year.

The economic benefits of the improvements from the EWS Vision 2025 has also been estimated. For the marine information, the SEB study estimates that the future direct economic benefits of future marine regional early warning for Lake Victoria – from EWS 2025 - could be $83.5million/year. This compares to the annual benefits from HIGHWAY of $44 M (central valuation), i.e. benefits are almost twice as large under the regional EWS. This can be compared to the estimated costs of delivering the EWS 2025, which is estimated in the region of USD 17 million for a five-year programme, and additional costs of weather radar, of approximately USD 8 million over the same five year period.

A cost-benefit analysis of EWS Vision 2025 has been undertaken. The analysis finds the net present value is $241 million, over and above the benefits already realised in HIGHWAY, with a benefit to cost ratio of 11:1, at a 10% discount rate, for the improvements seen on Lake Victoria. This increases at lower discount rate, and with the high valuation estimate. This compares extremely favourably to other W&CS investments.

However, EWS Vision 2025 would also generate much larger economic benefits to other user groups. It is anticipated that EWS Vision 2025 will generate marine weather information for other lakes in the region and these would increase the benefits above. Finally, EWS Vision 2025 extends beyond marine information and has activities that will benefit shore-based users. This could include severe weather warning for lakeside floods and storms, as part of multi-hazard Alert Systems. These additional services would increase the benefits above, reaching potentially millions of beneficiaries, and generating further large-scale economic benefits.

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List of acronyms

AWS - Automatic weather station

BMU - Beach Management Unit

EAT - East Africa Time

DFID - UK Department for International Development

EAC - East African Community

EWS – Early warning system

HNI - Human Networks International

INGO – International Non-Governmental Organisation

KMD - Kenya Meteorological Department

LVBC - Lake Victoria Basin Commission

LVFO - Lake Victoria Fisheries Organisation

MHEWS- Multi-Hazard Early Warning Service

SEB – Socio-Economic Benefits

SWAP – Severe Weather Alerts Project

TAHMO-Trans-Africa Hydro-Meteorological Observatory

TMA - Tanzania Meteorological Agency

UNMA – Uganda National Meteorological Authority

URN - Uganda Radio Network

WISER –Weather and Climate Information SERvices for Africa

WMO - World Meteorological Organization

The HIGHWAY project is being delivered by the World Meteorological Organization (WMO) working with partners including the UK Met Office, the National Meteorological and Hydrological Services (NMHSs) of Kenya, Rwanda, Tanzania and Uganda, the East African Community (EAC), the National Center for Atmospheric Research (NCAR) and the Lake Victoria Basin Commission.

To find out more about the project, please visit https://www.metoffice.gov.uk/about-us/what/working-with-other-organisations/international/projects/wiser/highway

The views expressed in this publication are the sole responsibility of the author(s) and do not necessarily reflect the views of WMO, the UK Met Office, the NMHS, EAC or NCAR.

Authors: Paul Watkiss, Robert Powell, Alistair Hunt, Federica Cimato

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Introduction

Background and objectives

The HIGHWAY project (HIGH impact Weather lAke sYstem - a proposal framework for the lake Victoria region) is a three year project, led by the World Meteorological Organization (WMO), to increase the use of weather information to improve resilience and reduce the loss of life and damage to property in the Lake Victoria Basin.

The aim of the project is to integrate the plans for a regional EWS into the strategies and plans on a regional, national and local scale, such that a regional Early Warning System (EWS) will be in place by the end of the project which is accessible, operational and sustainable. The expected impact of the project is an increased use of weather information to improve resilience and reduce the loss of life and damage to property, supporting sustainable economic development in the Lake Victoria Basin. The Impact Indicators for the project are:

- Number of people with improved resilience resulting from the use of EWS;
- Value of avoided losses due to use of climate information.

To assess this second indicator, the HIGHWAY project is assessing the socio-economic benefits of more accurate and timely early warnings. This SEB information is also being used in the business plan for HIGHWAY (to ensure sustainability) and to demonstrate the value for money of regional EWS on the lake. This report sets out the socio-economic benefits – and the value of avoided losses – from the activities in the HIGHWAY project.

Socio-economic benefits of weather and climate services

Weather and climate services (W&CS) are non-technical in nature and it is difficult to assess their benefits in quantitative terms. However, investing in these services leads to improved information, such as better forecasts, early warning and seasonal forecasts. In turn, these provide economic benefits to users, as they lead to positive outcomes from the actions and decisions that users subsequently take. This is often known as the value of the information.

There are several previous studies (ECONADAPT, 2015) that have assessed the socio-economic benefits from the use of information from early warning systems (EWS). These show large economic benefits, which arise from the anticipation and preparation for extreme events and the reduction in damage costs and fatalities that arise from preventative actions taken.

The WISER programme (Weather and Climate Information SERvices for Africa), which is funding HIGHWAY, is encouraging the quantification of these socio-economic benefits in all WISER projects. It has produced guidance on how to assess these benefits (WISER, 2016[1]). This document sets out the methodology for quantifying socio-economic benefits in the HIGHWAY project, drawing on this WISER guidance. As set out in the guidance, there are a number of reasons why it is beneficial to consider socio-economic benefits in the project:

- SEB studies can help to identify the 'impact' of the project, and what it is trying to achieve in terms of delivering benefits to users (this aligns to the HIGHWAY impact indicator above on value of avoided losses). This can also be communicated to end-users to incentivise further uptake and use of the information (e.g. to highlight the benefits of information for end-users in daily decision making, especially around potential loss of life).
- SEB studies can help to understand how to maximise user-benefits, looking at how benefits are delivered from initial services down through the user chain.
- SEB studies can provide information for policy makers on the economic benefits of W&CIS and thus help to justify current and future investment in these services.
- SEB studies can provide quantitative information on effectiveness and help demonstrate and report on the Value for Money[2].

For HIGHWAY, all of these are relevant, but the information will also provide inputs to the project 'business plan' to help ensure the sustainability of regional EWS after the project has finished. It is also important, however, that studies take account of the delivery of information and use by end-users. Estimates of the benefits of weather and climate services – including EWS - vary according to the assumptions about the uptake and use of information. For example, it is vital to know whether potential users of climate data services have the resources to act effectively on the information they receive (i.e. do they have access to financial resources, or the ability to change behaviour or respond to risks) and what their incentives to act are.

This is determined by the nature and form of information provision and its perceived reliability. These issues are important to capture in determining socio-economic benefits and it is useful to undertake a weather chain (or value chain) analysis. Previous analysis has identified the key steps in the chain as (Perrels, 2013):

- Forecast accuracy,
- Tailoring of information to user groups,
- Access to information,
- Comprehension of information by users,
- Ability to respond,
- Effectiveness of response, and
- Redistribution (leaks) of initial benefit.

[1] GUIDANCE NOTE ON IMPLEMENTATION OF WISER VALUE FOR MONEY AND SOCIO-ECONOMIC BENEFIT FRAMEWORK VERSION. APRIL 2017. Available at https://www.metoffice.gov.uk/binaries/content/assets/mohippo/pdf/international/wiser/wiser-guidance-on-value-for-money-and-socio-economic-benefits.pdf

[2] DFID guidance frames VfM at three levels which are clearly linked to the theory of change and logframe: Economy, Efficiency and Effectiveness (the 3Es).

This also leads to the analysis of information decay along the chain, which requires 'cost-loss' (CL) analysis, to identify the effects of changes in forecast accuracy in an otherwise fully informed world, combined with weather service chain analysis (WSCA). Taking account of these weather chain losses is important for two reasons.

- First, it is important to factor in these losses along the weather chain in estimating the socio-economic benefits of the HIGHWAY project, and a future regional EWS, to make sure the estimated benefits are realistic (and avoid over-estimation from the assumption of perfect uptake and use). This is particularly important given the information is targeting fishermen and small boat users.
- Second, the process of weather chain analysis can help to develop a better understanding (and better articulation) of a project and help to make more informed, evidence-based choices, i.e. to improve the design of subsequent scale-up. This can highlight if additional resources would be more effectively employed in improving forecasting accuracy, increasing communication, or providing training to users for appropriate response to reduce losses.

The weather chain analysis for HIGHWAY has considered the recent WISER pilot study, Multi Hazard Early Warning Service (MHEWS) in Tanzania, which has used the four main elements of effective early warning systems, as defined by the UN-International Strategy for Disaster Relief (UN-ISDR) in people centred early warning (UNISR, 2006)

Figure 1 Elements of Effective Early Warning Systems. *Source UN-ISDR.*

In HIGHWAY, the EWS value chain was also presented (by UK Met Office) at the launch meeting in Nairobi as below:

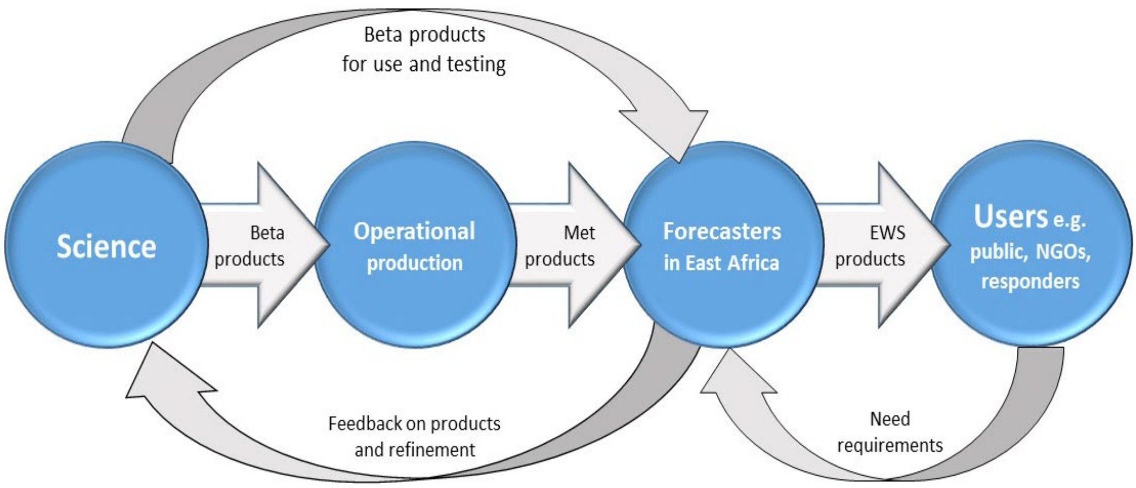

Figure 2 Weather Chain for HIGHWAY. Source UK Met Office, 2020.

Finally, it is particularly important to consider these weather chains to fully capture the benefits of the HIGHWAY project, as it is investing right across the weather chain (in outputs 2, 3 and 4). These investments include:

- Improved science;
- Rehabilitation and enhancement of observational data;
- Enhanced data sharing and capacity, improving the accuracy of warnings;
- Better communication and dissemination of warnings;
- New services and technologies to alert the public;
- Targeting warning service to relevant and specific users - right information to right people at right time and in the right way;
- Ensuring warning messages are understood and the action taken in response;
- Wider benefits from improvements to weather forecasting and services;
- Indirect benefits (global coverage and foundational activities).

The socio-economic benefit study has therefore aimed to capture the benefits of all these investments along the EWS value chain.

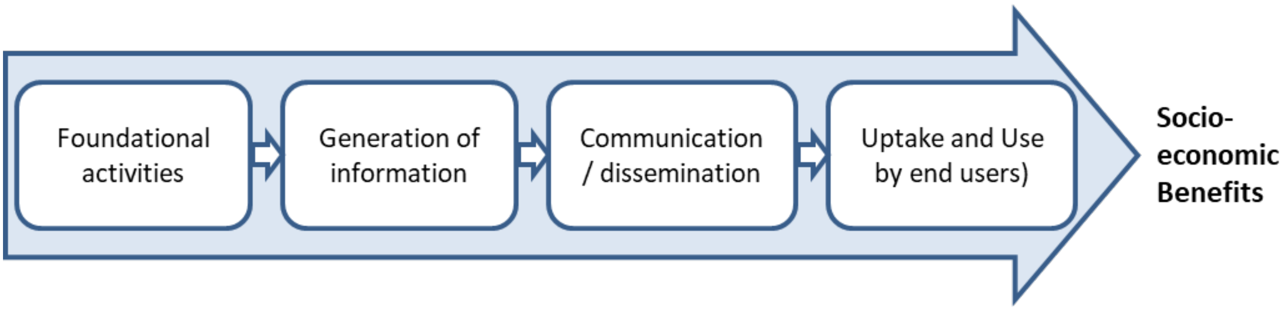

Figure 3 Weather Value Chain for HIGHWAY

Method

The overall method used to quantify SEB looks at the activities and outcomes from the use of enhanced weather and climate services, then compares this to a baseline without this additional information: the difference is the benefit. For EWS, this centres on the reduction in fatalities, injuries and losses that arise from taking precautionary action in advance of severe weather events. These benefits include avoided impacts (benefits) where there is an obvious financial return (or avoided financial loss), but it also includes benefits which are more difficult to value in monetary terms. They include:

- Tangible benefits, including the direct effects (reduced loss of marine assets, reduced damage to buildings and infrastructure, reduced lost time from transport disruption), as well as indirect effects (reduced traffic disruption affecting business supply, or reduced effects on wider economy).
- Intangible (non-market) benefits, including reduced loss of life and injuries, and the indirect effects of reduced impacts on dependants.

The combination of market and non-market benefits, that arise direct and indirectly, is illustrated in the following matrix. The direct tangible effects can usually be valued using market prices, but as the intangibles involve non-market effects, they require the use of additional economic methods to derive economic values.

Table 1 Matrix of Possible Benefits from improved forecasts and early warning.

	Tangible (market)	**Intangible (non-market)**
Direct	Reduced losses or damage to assets from early warning / operational savings (benefits) from early warning and improved forecasting	Reduced loss of life or injury from early warning
Indirect	Reduced loss of production or effects on wider economy, from early warning and enhanced forecasts	Reduced impacts on dependants

Methodological steps in SEB analysis

The WISER SEB guidance (WISER, 2017) – which draws on WMO guidance (WMO, 2015) - presents a set of steps for SEB analysis.

- **Identify the potential socio-economic benefits** of the weather and climate service, in this case the benefits of the early warning systems. These primarily arise as a response to current impacts, but for HIGHWAY there are also additional spill-over benefits from the improvements in forecasting more generally, at local, regional and global scale. Note that in identifying potential benefits, it is also important to assess how these benefits will be delivered down the weather chain, i.e. from early warning information providers to users. The potential SEB of the project was collated in early work in the HIGHWAY project and presented at the HIGHWAY launch meeting.

- **Review and decide on the potential methods for assessing socio-economic benefits in the project**, taking account of resources and local context. This outlines the approach to quantify benefits and their valuation. This was set out in an earlier document (socio-economic benefits for the HIGHWAY project, 2018).
- **Derive the baseline** for the current situation without the new W&CS information provision. This should take place at the start of the project. To the extent possible, this should quantify the potential social, economic and environmental impacts, across sectors and actors (e.g. households, private and public sector) and the current provision of weather and climate services. Depending on the subsequent method chosen, it may also include survey work.
- **Assess the change with the new weather and climate service in place, i.e. the socio-economic benefits.** This should include analysis of all potential benefits, ideally in economic terms, from the project activity. It should ensure that the efficiency losses along the weather chain are considered.
- **Assess the costs of the project**, including investment in meteorological stations, system operation and information provision (capturing equipment and resource (labour) costs).
- **Compare benefits against costs** where possible in monetary terms.
- **Explore how benefits could be enhanced** through interventions along the weather chain, aligning to the learning component of WISER.

These steps have been used to estimate the socio-economic benefits of the project.

Input to the HIGHWAY Business Plan and VfM reporting

HIGHWAY is developing a 'business plan' under Output 1 of the project. The business plan will help to build the sustainability case for a regional EWS in the Lake Victoria Basin. It will also help inform project partners and wider stakeholder groups of the costs and benefits of investing in regional EWS and help frame the institutional relationships on EWS going forward. This business plan will link closely to the socio-economic benefits (SEB) study in HIGHWAY and it will use the results of this study to help justify future investment in enhanced regional EWS. The business case is also closely aligned with the wider objectives of the WISER programme to promote enhanced regional cooperation and collaboration, and the associated economic costs and benefits.

The information the socio-economic benefit analysis will be used to feed into the Value for Money reporting for the HIGHWAY project, notably on the effectiveness and efficiency components.

Potential Benefits

The first task in the method is to identify the potential socio-economic benefits of the project. The WISER SEB guidance sets out a series of questions to help frame this analysis.

What are the potential benefits of your programme to users? Are they likely to result in improved crop production or reduced losses from improved early warning? It is useful to identify the existing impact that you are trying to address, the list of beneficiaries and the benefits you expect.

Have you included a baseline assessment in your project proposal? It is useful to collate information on baseline conditions, e.g. on current conditions, or how large the potential current impacts of extreme events are. This could include gathering information on the current costs of disasters (of relevance for early warning). Once you have a better idea of the method for SEB, this can be used to draw up a formal step for deriving this baseline.

What are the steps in the weather chain, i.e. in the successful delivery of climate information through to end-users? It is useful to map out how your weather and climate service will flow down the chain to end users, and to identify what barriers and additional steps are needed to maximise uptake and use. It is also useful to consider the ability of users to respond and effectively use information.

What type of W&CS are you providing and which SEB methods might be applicable? There are a range of methods that can be used.

How does a SEB study feed into the VFM analysis? The results from a SEB analysis, when combined with the project cost information, generate the information for the effectiveness components of VfM. Further work can be undertaken to show how the costs and benefits of the project compare to other alternative choices.

How can you use SEB information to summarise and disseminate the benefits of your project? It is worth thinking about how to use the results of an SEB study. This could include the production of relevant policy briefs and news items, that would enhance the impact of you project.

These questions were used to build the SEB analysis for HIGHWAY, as below.

Background Context

Lake Victoria is the world's second largest body of fresh water by surface area. It is located between the eastern and western branches of the East Africa Rift System more than 1100m above sea level. The Lake is relatively shallow (maximum depth is just over 80 m and the average depth is about 40 m) and it has a long shore line of about 3500 km, which crosses Tanzania, Uganda and Kenya. There is a large lake region population, reported (in 2007 based on census data) at about 35 million, but which is probably closer to 45 million today (Powell, 2016). Many of the local population are extremely poor and live under $1.25 per day, using the lake as a source of food, energy, drinking and irrigation water, and transport.

Lake Victoria supports Africa's largest inland fishery and produces about one million tons of fish annually, employing about 220,000 fishers (Frame Survey 2016). Total fish landings from the lake for the period of 2011 to 2014 have been about 1 million tons with a beach value increasing from about US$ 550 million in 2011 to about US$ 840 million in 2014 (Kayanga, 2017), though the sustainable catch is estimated (Abila et al. 2009) to be just over US$ 800 million annually.

Tanzania, Uganda and Kenya control respectively 49%, 45% and 6% of the lake surface (Chamberlain at al. 2014), though there is a much higher population density in the lakeside Kenyan communities. The direct and indirect contribution of fisheries to the economic growth of these countries arise both at macro and micro (household) level through contribution to GDP of riparian states, employment, foreign exchange earnings, contribution to diet, employment and consumption. In 2009, it was estimated that the lake contribution to GDP was 1.8% for Tanzania, 1.5% for Uganda and 0.5% for Kenya (Abila et al. 2009). At a micro level, fisheries generate employment and income for fishermen, but also directly benefits their dependents, and lead to positive multiplier effects on the local economy.

The large population around the lake, and on lake islands, also leads to large boat passenger transport volumes. There are an estimated 610,000 people living on lake islands (Powell, 2016[3]). Marine transport is used by island inhabitants, but also by many of the more remote onshore lakeside communities due to the poor transport links. Many of these people use smaller and informal passenger boats. In many of these communities, marine transport also acts as an affordable means of transport for the poor and local small businesses, and thus there is also cargo transport by these smaller boats.

There are also larger marine freight transport vehicles operating on the lake, including ferries. Transport on the lake includes vehicles, cement, fertilizer, petroleum products and daily consumption goods, such as cottonseed, wheat flour, fish and coffee. Lake Victoria is a potentially important section of the Central Corridor and provides a link between the Northern Corridor (Kigali–Kampala–Mombasa) and the Central Corridor (Dar es Salaam–Tabora– Mwanza), enlarging the economic impact zone of the respective corridors.

Average freight tariff on Lake Victoria is about 7-8 U.S. cents per ton-km, which in theory makes it competitive against road transport on roads circling the lake. However, there has been a decline of commercial shipping operations over the years, and lack of maintenance and limited investments have resulted in the decay of most ports in Lake Victoria. In addition, the spread of water hyacinth has also affected the navigability of the lake. The Nile Basin Initiative (NBI) (2016) reports that there are multiple factors constraining the use of the Lake for commercial navigation. As a consequence, road transport has increased at the expense of lake transport.

[3] Ukerewe District in Tanzania, which consists of the islands of Ukerewe and Ukora, has a population of about 350,000. In Uganda, Kalangala District in Uganda, which encompasses the Ssese Islands, has an estimated population of about 70,000 and Buvuma District, which consists of Buvuma island, has 55,000. Mfangano Island, the largest island in the Kenyan sector of Lake Victoria which is not connected to the mainland by a causeway, has a population of 26,000.

However, there are major plans to invest in lake port infrastructure and help build the role of the lake as a marine transport corridor, notably with a planned (pipeline) World Bank Lake Victoria Transport Program (Phase 3[4]), a very large investment project of $205 million[5]. Improved navigation on the lake, as a result of investment, has the potential to strengthen inter-regional transport connections and economic integration, benefitting particularly landlocked countries such as Burundi, DRC, Rwanda, and Uganda.

The seasonal climate of East Africa is determined largely by the Inter-Tropical Convergence Zone (ITCZ). However, Lake Victoria generates its own micro-climate and it is one of the most convectively active regions on Earth. It generates severe thunderstorms, which constitute an important weather hazard (Thiery et al, 2017: Chamberlain et al, 2014) with intense and often heavy rainfall, high and often gusty winds, high waves on the lake, lightning and hailstorms. Tanzania and Uganda are also adversely affected by the strong southerly winds which blow across most of the lake between May and September (and especially in June and July): these dry season winds from northern Tanzania cause high waves and make navigation in small craft extremely hazardous (Powell, 2016). They are often associated with the fatalities on the lake.

This combination of hazards poses a major threat to fishermen, as well as passengers on small boats, and there are a large number of drownings on the lake each year. A series of reports cite that 3000 to 5000 people die each year (CCN, 2013: IFRC, 2014) though there is little substantive evidence for these figures.

Some early survey work was undertaken in the EAC/Semazzi (2011) report with lake inhabitants. This found that when asked whether they knew anyone who died or whose boat capsized in the past three months, a majority of respondents, 61.7%, indicated that they did. More detailed survey work was undertaken in four Ugandan lakeside districts (Kobusingye et al, 2016). This survey found very high levels of drowning in lakeside communities, with a drowning fatality rate of 502 deaths per 100,000 population, which is extremely high. The majority of drowning events occurred during transportation (51.7%) or fishing (39.0%) due to capsizing or sinking. The most frequently mentioned factors were stormy weather and overloading. Further survey work by Tushemereirwe et al. (2017) in Uganda found that over 50% of the respondents (113/215) were aware about at least one community member who had been injured due to lightning on the lake in the past year and 32.6% knew at least one community member who had died on the lake due to lightning. Atieno et al (2017) provide some additional survey work on Lake fatalities,

These losses also affect the dependents of those who drown, which have been estimated to be 8 people per fisherman (Semazzi et al, 2011).

[4] http://projects.worldbank.org/P160955?lang=en
[5] The project includes (i) Improving the physical infrastructure by investing in port infrastructure at Mwanza South, Mwanza North, Bukoba, Kemondo Bay and Musoma and in port access roads and associated infrastructure; and (ii) Improving the institutional framework and implementation assistance by supporting TANROADS and Tanzania Ports Authority (TPA) with the preparation and implementation of the project as well as providing technical assistance for the improvement of port management and shipping operations.

These storms also disrupt transport by larger vessels on the lake, though there is little information available on the level of this disruption, though there are periodic groundings or loss of larger boats. The MV Bukoba, (96) capsized while on its way to Mwanza in Tanzania killing about 800 people. The MV Kabelega sank on 8 May 2005 and though losing no lives, lost consumer produce of about 800 tons. Grounding of the MV Thor at Ghana Island on 24 March 2006 lost 300,000 liters of petroleum products. On 21 April 2006, the MV Nyamageni capsized and sank, resulting in 28 deaths (source Kiwanuka-Tondo et al).

Furthermore, when severe thunderstorms come ashore, or severe storms form over nearby land regions, they can cause impacts up to 100 km inland (Powell, 2016). These storms can lead to floods in low-lying areas, gully erosion and flash floods, as well as damage to farming communities and agriculture. In southern Uganda, especially in urban areas of Kampala (including informal settlements) these floods frequently cause damage to roads, bridges, buildings and other infrastructure, as well as disrupting transport (congestion).

Water spouts are a less common but also a potentially lethal weather-related hazard on the Lake itself. Their formation is associated with high water surface temperatures during the rainy season (Powell, 2016). Fishermen consider water spouts to be especially dangerous, as they capsize or sink small boats and are almost guaranteed to cause fatalities in such incidents.

Thunderstorms also cause death and injury from lightning strikes and occasionally from hail stones. Indeed, Uganda has one of the highest reported rate of lightning strikes in the world 158 - 218 per square km (see Powell, 2016). Mary and Gomes (2014) provide data on lighting strikes (mortality and injuries) in Uganda.

In terms of urban flood and severe weather risk, there are some data on the impacts of severe weather in Kampala (Barrow et al, 2016). From literature and economic assessment in Kampala, households incur an average $13.6 per month (US) on costs associated with flooding, and with an average income of $62.8 the expenditure is just under a quarter of the income, although impacts are concentrated in informal settlements. At the neighbourhood scale, estimated household expenditure on flood-related costs is $17.4 million annually. Costs at the city-wide scale were assessed for loss of life, affected people, infrastructure destruction, infrastructure damage and disaster relief that are calculated as a ratio of the GDP. Studies indicate that in Kampala flood-related deaths of 2.7 per year from 1993-2014 were estimated to cost between 0.22 to $5.7 million USD in life years lost while effects on people was estimated to be between $0.17 to $0.57 million per year. Destruction and damage to buildings due to floods was estimated to cost between $0.16 to $0.88 million per year. There is less data for Mwanza and Kisumu available, though the latter is frequently affected by flooding.

Finally, it is worth highlighting that these severe events will also be affected by future climate change, though these changes are complex. Thiery et al. (2016) investigated the impacts of future climate change on Lake Victoria's mean precipitation and extremes. They report that model projections for the end-of-the-century indicate that Lake Victoria amplifies the future intensification of extreme precipitation seen over the surrounding land. Under a high-emission scenario (RCP8.5), the 1% most extreme over-lake precipitation may intensify up to four times faster compared to surrounding land. Interestingly, the change in extremes contrasts to the change in average over-lake precipitation, which is projected to decrease by 6% for the same period, i.e. although mean rainfall will decrease, intense storms will become more frequent. This difference is because the response of extremes is essentially thermodynamic. These impacts will also depend on what happens on Lake water levels, and on whether these levels fall or rise with climate change (as well as with other socio-economic factors).

Potential Users of EWS information

Powell (2016) documents the potential users of a Lake EWS in detail. He identifies.

- **Fisherman**. The largest and most at risk community exposed to severe weather conditions on Lake Victoria are fishermen, especially those in smaller boats (6-8m) without outboard motors. The majority of these do not travel extensively and therefore remain within mobile network coverage. However, Powell notes that there are differences in fishing practice between the three countries, and differences on user needs (type of forecast, variables etc). He also notes that communication needs to be produced in terms that fisherman can relate to and act upon. There is also a set of additional users, with the beach management units (BMUs), who represent the interests of all those who contribute to each fishing community. They are used by the Fisheries Department as frontline agents to regulate the fishing industry.

- **Smaller unlicensed and unregulated marine transport crafts (and their passengers).** These groups are not usually subject to any form of government control or supervision. These constitute the most widely used form of passenger transport between the inhabited islands in Lake Victoria and nearby ferry points on the lake shore. They typically transport between 20 and 80 passengers at a time and small volumes of cargo. The weather information needs of these marine transporters are similar to those of the fishermen in terms of forecasts but also the need for appropriate communication. There is also the potential to provide forecasts to passengers.

- **Larger marine freight and passenger vessels** which are licenced and regulated by the government. There are relatively few vessels of this type and most of them are quite old, due to the shift to road transport (see earlier) and the decline in cargo and passenger traffic. However, there are plans to reinvigorate lake transport, with major investments, which would increase current volumes and numbers of vessels. These ships have different needs, and captains of these larger vessels are normally educated and trained in marine navigation and have no problem in understanding marine weather forecasts and severe weather warnings in conventional meteorological language. They are also interested in different information, given their vessels can cope with rougher weather conditions. In the case of transport development, as a result of new investment, transport logistics companies would be a new group interested in lake forecasts.

- **Fish value chain and Tourism.** This category includes the ladies who dry small fish in the open air and suffer heavy losses if rain falls on the fish while it is drying. It also includes the impact on recreational navigation and tourism (sailing, game fishing and boat safaris).
- **Farmers.** While storm risk is an issue, farmers are more interested in seasonal forecasts and specific weather forecasts for key parts of the agricultural cycle (e.g. planting). Nonetheless, thunderstorms and hail represent a risk to people and livestock. The early warning information needs of farmers can be adequately met by accurate and reliable downscaled daily weather forecasts for the general public, which carry hazard warnings embedded in them when appropriate, with perhaps additional short-term forecasting for hail.
- **Urban communities.** The three cities on the shore of Lake Victoria with large urban populations are Kampala, Mwanza and Kisumu. The main impact of severe weather in all three cities is flooding caused by heavy rainfall. This is a particular issue for informal settlements. These heavy events also lead to major problems of traffic congestion (for Kampala). There is therefore an additional set of potential urban users of severe weather information.

The potential benefits of improved EWS for the user groups are set out below.

Table 2 Possible socio-economic benefits from HIGHWAY

User Group	Potential Benefits
Fishermen	Avoided loss of life Reduced loss of assets (boats, nets, etc.) Reduced damage to boats colliding while at anchor Improved efficiency of operations and benefits (fuel savings) Reduced lost income and economic stream (fish landings) Reduced impacts from loss of life on dependants (indirect)
Small transport boat operators and their passengers	Avoided loss of life Reduced loss of assets (boats) Reduced loss of cargo Improved efficiency of operations and benefits (fuel savings) Reduced impacts from loss of life on dependants (indirect)
Large boat transport	Improved marine safety Avoided loss of life Reduced loss of assets (boats) Reduced loss of cargo Improved travel time (better routing information) Indirect economic benefits (improved transport corridors, leading to modal shift, improved regional transport, avoided road transport)
Fish traders	Reduced losses in fish drying (avoiding heavy rain)
Tourism / recreational	Reduced impacts (avoiding storms, strong winds and large waves) and reduced losses for tourism and recreational use (avoided loss of life, assets, etc.)
Urban areas	Reduced loss of life and injuries Reduced building damage and infrastructure damage Reduced traffic disruption (and congestion), and indirect economic impacts Improved information for water-borne disease (flood information) Reduced impacts from loss of life on dependants (indirect)
Famers	Reduced loss of life or injury (farmers) Reduced loss of life or injury to livestock Reduced damage to crops

Other benefits including regional benefits

In addition to the direct benefits of the EWS for the user groups above, the improvements in weather forecasting and equipment introduced as part of the HIGHWAY project will lead to wider benefits for weather and climate services in the Lake Victoria Basin and in individual country NHMS. Many of these benefits arise above and beyond the national level investment, i.e. they are the additional benefits of a regional EWS. These are shown in the table below.

Table 3 Possible other (national and regional) economic benefits from HIGHWAY

Benefit area	Potential Benefits
National Forecasts	Enhanced weather forecasts (forecast accuracy) from additional infrastructure and training from HIGHWAY within the country itself. Improved sharing of information, e.g. use of TMA wave forecasting model, ECMWF information, etc., Enhanced weather forecasts (forecast accuracy) from exchange of information between NHMS and improved accuracy of forecasts. Reciprocal data shared both ways across borders can improve the analyses and information available for each participating country and thereby enhance the accuracy of forecasts. This can also lead to improved short-term and weather and seasonal forecasts, more generally, with potential benefits to agricultural production, reduced disaster impacts, use of information for other sectors (e.g. health, energy, water). Improved communication and dissemination may provide additional channels to reach other users.
Regional Forecasts	A regional EWS forecast covering the whole lake would provide great coverage (more users). It would also help harmonisation, minimize confusion, and improve confidence, uptake and use of information and warning. Enhanced regional (lake wide) forecasts would be of particular use for major shipping transport across the lake, where it would have the potential to reduce delays and improve safety on the lake. A regional EWS would contribute to improving the reliability of lake transport, with positive impact on trade and spill-over effects benefiting all neighbouring countries, particularly land-locked.
Global Forecasts	Enhanced global observations and improved NWP from greater observational reporting, improving global, regional and national information and forecasts.

Step 2: Method for HIGHWAY socio-economic benefits

There are a variety of potential methods for assessing socio-economic benefits. The WISER SEB guidance sets out the potential options for assessing SEB:

- It is possible to model the potential benefits from the use of weather information. This can be done with the use of hydrological and disaster risk models that use historical events as their basis. This is particularly relevant for early warning systems, to assess the losses associated with previous disasters or events of defined return periods (i.e. probabilistic events) and then to assess how EWS will avoid or reduce these. This has the advantage of using observed (ex post) data on losses but still involves many assumptions regarding the modelling approach.
- A simpler form of this approach is to use analogues of previous events to scope out the potential benefits of reduced losses. This involves looking at information on damages recorded (e.g. in national or international databases on events) or humanitarian spending.
- It is also possible to look at observed improvements following the implementation of better weather and climate services and assess the benefits. This can be done using different levels of detail, including econometric analysis (regression). These studies have the advantage of using direct observations and thus address efficiency and cost-loss assumptions. However, they are complex and time consuming to undertake, and in many cases, it is difficult to separate out (attribute) the role of weather information from other factors. A further approach to look at observed improvements is to directly survey users to explore potential benefits.
- To derive monetary values for potential services, a further approach is to survey user's willingness to pay for weather services. This can use measures of *revealed preference*, i.e. recorded observations of how people change their behaviour, including their decision-making, in instances where new climate information has been introduced. An alternative (or a further complementary validation) is for *stated preference* methods, which use interviews with identified user communities to estimate their willingness to pay for weather and climate services directly.

Methods for HIGHWAY

The choice of method depends on the availability of representative models and data, but also on the resources, noting modelling, econometric and survey methods are all time and resource intensive.

For the Lake Victoria EWS in HIGHWAY, the most obvious way to assess the benefits of an EWS would be to assess statistically reported fatalities (drownings) and reduced losses, before and after the implementation of the EWS. This would involve a combination of statistical analysis and surveys.

However, for drownings, previous studies (Kobusingyea et al, 2017; Powell, 2016) have highlighted that the existing reported data are extremely poor. Many drownings are not reported or recorded, and this makes the baseline and EWS analysis very difficult. Indeed, there are question marks over the reliability of the baseline data, i.e. on current reported numbers of deaths per year.

There are no existing cost loss models for the Lake, and therefore a modelling approach is not possible.

As a result, the primary method for estimating SEB was to derive a baseline of fatalities and reduced losses/enhanced gains from existing literature, surveys and information, coupled with new surveys in the areas of the pilot EWS. This provides indicative estimates of the forecast reduction in fatalities and other losses/benefits on the lake for the populations that receive EWS. This analysis is complemented with consideration of the additional benefits along the weather chain based on the existing survey work detailed earlier, i.e. the effectiveness of the forecasts in reaching people (numbers), their perception of the forecasts (accuracy), and the response rates (numbers taking action on the basis of the forecasts).

The study also includes analysis of the improvement in EWS forecasting. Previous studies have looked at the forecast accuracy for Lake thunderstorms (Chamberlain et al, 2014). The HIGHWAY project will improve forecast accuracy, through a combination of infrastructure, information sharing, improved models, etc. but extending to wind and wave, and not just thunderstorm activity. Ideally an analysis would therefore undertake a similar analysis (to Chamberlain) looking at the modelled versus observed improvement. However, such an activity is not being undertaken in the project. The SEB analysis will therefore consider the likely improvements based on the available information (many of the potential benefits of investment on the science and EWS forecasts – and their potential costs – were set out in the EAC (2011) analysis) and through direct discussions with the modelling teams.

Alongside these EWS benefits, HIGHWAY is investing in science and forecasting, that will have wider benefits for national and regional forecasting. These are more complex to assess, thus will be primarily assessed in qualitative terms.

Finally, there are two further areas of socio-economic benefits that will be assessed. First, to assess the potential additional benefits to larger lake transport, i.e. to larger ships and passenger and freight logistics, taking into account the planned investment in lake transport infrastructure. Second, the HIGHWAY project could, if extended, provide benefits for other weather services around the Lake, e.g., Severe Weather Alerts in Kampala. This has the potential to reach a very large population (3-5 million people living within 50 km of central Kampala).

Based on the analysis above, the SEB method undertook the following:

- Estimated the baseline population and therefore the potential number of users.
- Derived a baseline of lake fatality rates, based on the estimated lakeside and lake island population and the rates from recent surveys. This covered both fishermen and small boat passengers.

- Derived a baseline for the potential lost landings and indirect impacts on dependants from these losses.
- Derived a baseline of associated losses of assets (small boats and motors) and cargo associated with small boat transportation, as well as potential benefits, e.g. fuel savings, from the use of information.
- Estimated the potential losses associated with major boat incidents (noting the much lower frequency) and potential improvement from reduced travel time disruption (note that baseline data on marine transport of passenger and goods is difficult to find).
- Estimated the likely improvement in forecast accuracy from 1) information sharing 2) infrastructure modernisation and investment and 3) training for NHMS for EWS from a) HIGHWAY and b) a regional EWS. This considered the estimates of how investment could improve forecasts (EAC, 2011) and the associated costs. This took into account lessons and insights from the improvement from the field campaigns, the refurbishment of radar.
- Estimated the potential numbers of users, in each of the groups above, who might have access to improved forecasts and EWS, as a) a result of HIGHWAY pilots and b) as a result of a fully functioning regional EWS.
- Estimated the potential action (user response) and the maximum potential reduction in losses, across all of the above areas and user groups, through the identification of possible actions to reduce or avoid losses (i.e. included estimates of the number of users receive information and act on the basis of this).
- Estimated the likely level of uptake of the EWS, i.e. the number of users who receive information, and then who subsequently trust and thus act on the information, based on previous survey work and information from the pilot EWS studies. This information will then be used to estimate the likely reduction in fatalities. This will be complemented with focus group discussions and surveys with EWS pilot areas are the end of the project.
- Estimated the potential spill over benefits in terms of general weather forecasting (and even seasonal forecasts) from the improvements above, e.g. in relation to daily weather forecasts, etc. from a) HIGHWAY and b) a regional EWS building on HIGHWAY.
- Estimated the potential spill over benefits for Global reporting (WIGOS) and modelling Global Numerical Weather Prediction (NWP) from the greater reporting of automated stations and the other investments made in a) HIGHWAY and b) a regional EWS building on HIGHWAY.
- Estimated the potential benefits for larger marine transport vessels and lake transport from enhanced regional EWS and more general marine weather products.

- Estimated the potential benefits in reducing urban severe weather impacts, and current damages (analogues) associated with major floods in the three major lake cities, including fatalities and injuries, building and infrastructure damage, transport disruption, etc.
- Estimated wider economic benefits from improved weather and climate services associated with the Lake and the regional economy

Monetary valuation of benefits

The benefits of early warning systems are primarily associated with avoided losses. This includes the avoided loss and damage to infrastructure, assets, etc., but also the reduction in fatalities and injuries. The various approaches for the monetisation of avoided impacts from the EWS are outlined below.

Valuation of health and fatality risk

The impacts on human health are more difficult to value than other sectors, because there are no observed market prices. However, it is possible to derive monetary values for this non-market sector, by considering the total effect on society's welfare. This requires analysis of three components which each capture different parts of the total effect:

- The resource costs i.e. medical treatment costs;
- The opportunity costs, in terms of lost productivity; and
- Dis-utility i.e. pain or suffering, concern and inconvenience to family and others.

The first two components can be captured relatively easily. Techniques are also available to capture the third component, by assessing the 'willingness to pay' or the 'willingness to accept compensation' for a particular health outcome. In the OECD, these are derived using survey-based "stated" preference methods and/or "revealed" preferences methods that are based on observed expenditures such as on consumer safety. These can then be transferred to the developing country context.

However, a particular issue is the valuation of fatalities, in which case the focus is on the valuation of the change in the risk of mortality, and not, the valuation of life itself. These values are often seen as controversial, but they are widely used in economic appraisal, for example in transport appraisal (for the risks of transport accidents).

There are different approaches that can be used for valuing the change in the risks of mortality. In the OECD, these impacts are often valued using a long-established metric, the value of statistical life (VSL - also known as the value of a prevented fatality, VPF) (OECD, 2011). These values can be transferred to developing countries using appropriate adjustments (Cropper and Sahin, 2009).

Other methods exist, such as the human-capital approach – also known as the Foregone Output – method of valuing mortality risks is based on estimation of the loss of income resulting from an individual's premature death. This assumes that the value to society of a human life corresponds to the production potential calculated as the present discounted value of expected labour earnings (using GDP or GNI per capita, PPP[6])[7]. However, this method is controversial because it attaches no value to non-labour earnings and to non-market activities (though it is also possible to add a sum or a % uplift for pain and suffering alongside the basic human capital calculation). Further, the choice of an appropriate social discount rate is controversial, as well as income growth rate. These assumptions need to be documented and tested. However, despite all these issues, this approach is straightforward and easy to derive.

Note that it is also possible to report these events just as fatalities or convert alongside injuries into a commonly used health metric, the Quality Adjusted Life Year.

For HIGHWAY, a number of different approaches were used to explore the potential range of socio-economic benefits.

The annual income, and thus potential annual loss, of fishermen on Lake Victoria is approximately $1000- 2000. Summed over the average length of life lost, this would lead to human capital estimates of $16,000 and $42,000 (for $1000), rising to $32,000 and $84,000 ($2000), depending on whether a discount rate of 10% or 3% is used, respectively. However, recent World Bank documentation, (Narain and Sall, 2016), suggests that whilst the Human Capital approach is appropriate for financial analysis and accounting, the alternative approach – based on individual's willingness to pay (WTP) to avoid or reduce the risk of premature mortality – is more appropriate for economic analysis. In theory, the present value of lifetime earnings should be less than the VSL, since the VSL also captures the utility derived from intangibles such as being alive and spending time with loved ones in addition to consumption (Hammitt and Robinson 2011). Thus, the question is: which values of WTP could be used in the Lake Victoria context?

Ideally, we would like to use WTP measures of VSL that have been derived directly from the population that would be affected by a given policy or project intervention since we are interested in their preferences regarding resource allocation. However, based on a search of the mortality risk valuation literature, we have been unable to identify any relevant studies that have been undertaken in the sub-Saharan Africa context. Consequently, a second-best approach is to adopt values that have been derived elsewhere – known as value transfer or benefit transfer. Whilst there are a large number of factors that potentially affect the reliability of making these types of transfer, evidence to date suggests that income level has the most consistent relationship with VSL. As a result, value transfer exercises tend to explicitly factor in differences in income levels. However, recent evidence suggests that this relationship is non-linear; income elasticities applied to VSL are found to be greater than 1 for low- and middle-income countries, and < than 1 for high-income countries.

[6] https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD

[7] As an example, Hallegatte (2012) - Using the Copenhagen Consensus value of a human life (i.e., $1,000 and $5,000 DALY) and the average life expectancy in the African region of 60 years, estimates the value of a life saved at mid-life is between US$30,000 and US$150,000. Current data for the region could use an average GNP PPP/GDP PPP per capita for the three countries, although their figures differ by country. The fishermen who drown are primarily young, thus the period of life lost will be large.

The most relevant transfer function that we have identified was derived by Milligan et al. (2014). The authors derive a function for low and middle-income countries that is specific to the transport safety; it therefore has relevance to the Lake Victoria context. The value function is:

VSL = 1.3732 * 10^{-4} *GDP/capita$^{2.478}$

If we apply a GDP/capita value of $3,183 (2019, PPP) – the average per capita income over the three countries – to this formula, we derive a VSL of just over $65,200.

One way to benchmark this value is to compare it with a rule of thumb GDP per capita multiplier. The International Road Assessment Programme and World Bank apply a factor of 70 to GDP per capita to derive a VSL. Using the GDP per capita figure of $3,183, we find a VSL of just over $223,000.

On the basis of this data, we suggest a central value of $65,000. This value represents a central WTP-based estimate and is also within the range of human capital derived values. A high value for sensitivity testing is recommended as the upper WTP-derived value of $223,000.

Catch value and fuel savings

There are an estimated 1 million tonnes of fish per annum with a landed value of approximately US$ 800 million to 1 billion. This value is generated by ~ 220,000 fishers.

Based on Powell (2018: 2020), in March 2018, the price of fish in Kalangala, the main town in the Ssese Islands, was (dollar equivalent values correspond to the exchange rate at the time):

- Nile perch 10,000-15,000 shillings (US$ 2.75 to $4.10 / kg (larger fish over 5kg fetch higher prices)
- Tilapia 5,000-7,000 shillings (US$ 1.40 to $1.90) / kg
- Mukene (Silver Fish) dried for human consumption 5,000 shillings ($1.40) / kg
- Mukene (Silver Fish) dried for animal consumption 3,000 shillings (85 US cents) / kg

Fishermen on Bufimira island said in March 2018 that the average size of fish catch per two-man boat per night was either:

- 10 kg of Nile Perch – 125,000 shillings - using the mid-price of 12,500 shillings / kg ($34.30)
- 15 kg of tilapia - 90,000 shillings – using the mid-price of 6,000 shillings / kg ($24.70)

In 2018, fish catches of this size would have resulted in gross earnings of $7.40 to $12 per trip for each of the two crew members and for the boat owner (i.e. when shared three ways). However, net earnings for both owner and crew would probably be lower once the net costs of the trip had been deducted.

For motor-powered boats, the biggest operational cost of each fishing trip is the cost of fuel. Labour is important, although fishermen are typically paid a share of the fish they catch. The amount of fuel consumed per hour by a fishing boat depends on several factors.

Outboard motors are heavy fuel consumers. They burn a mixture of petrol and lubricating oil. Fuel is usually purchased from dealers at the landing site and costs between $1.00 and $1.30 per litre. The more remote the landing site, the higher the fuel cost is likely to be. In April 2020, a time of low international crude oil prices, fuel mix for outboard motors was selling for 4,500 to 4,900 shillings (95 US cents to $1.03 per litre in the Ssese islands.

A broad rule of thumb is that outboard motors consume 0.5 litres of fuel per horsepower per hour. On this basis, a 10 to 15-horsepower engine of the type widely used by (Ugandan) fishermen would normally consume five to 7.5 litres per hour. Fishermen in the Ssese Islands reported in April 2020 that they actually use six to seven litres per hour, which is consistent with this.

The length of the trip will dictate fuel costs. For short trips, fuel costs may be low. For a long trip such as for Nile perch, e.g. an eight to 10-hour fishing trip could involve a one to two-hour journey to the fishing ground and similar return journey to the landing site, fuel consumption would be high (e.g. 10 to 25 litres of fuel possibly).

However, the engine consumes more fuel if the boat has to sail into a moderate wind or through large waves. Therefore, forecast-informed route planning can potentially save several dollars-worth of fuel on each trip.

Since fishermen are poor, they tend to judge the amount of fuel they need to buy for each trip very precisely, without allowing for much of a reserve. When bad weather strikes unexpectedly, this may result in the boat running out of fuel and having to be towed back to the landing site by another vessel. One of the key advice messages to small boats setting sail in potentially rough weather is to carry extra fuel to ensure the can get back to land safely.

Value of lost assets

Powell (2018: 2020) provides information on potential costs of lost assets. In Uganda, a typical 28-foot fishing boat cost four to eight million Ugandan shillings (840 to 1,700 US dollars) to build in April 2020. The price varied according to the quality of the wood used. The boat has a working life of three to five years. If the boat is well made from good quality wood and is painted and well cared for, it may last eight or 10 years.

Based on the EWS survey, it was found that most fishermen in the Ssese Islands used outboard motors of 10 to 15 horsepower. Depending on its power rating, a brand-new outboard motor of this size cost 7.5 to 8.5 million shillings (1,580 to 1,790 dollars) in April 2020 – up to twice as much as the boat itself.

The high cost of outboard motors means that there is now a trade in importing cheaper second-hand outboard motors from overseas, particularly small low-powered units which have low fuel consumption. These cost as little as 3.0 to 3.5 million shillings (630 to 740 dollars) in April 2020,

Fishing boats powered by a 10-15 horsepower outboard motor usually travel at a cruising speed of about 15 km per hour in good weather and water conditions. They usually travel more slowly than their top speed in order to conserve fuel.

The gill nets used in to catch Nile Perch and Tilapia are 45 to 90 metres long and hang 2.0 to 2.5 metres down from the surface of the water. They are set in a straight line and are kept vertical in the water by floats at the top and weights at the bottom. Gill nets catch fish by the gills as they try to swim through them. The finer mesh seine nets used to catch silver fish also hang vertically in the water, but these are drawn in a circle to trap the fish caught inside.

In April 2020, a new 90-metre gill net for Nile Perch fishing cost 125,000 to 135,000 shillings (26 to 28 dollars) in the Ssese Islands. A seine net of similar size for Silver Fish fishing cost 125,000 to 130,000 shillings (26 to 27 dollars).

If a fishing boat capsizes, the hull of the boat may be recovered, but the following valuable items are often lost:

- The fishing gear, including nets, lines, hooks, floats and floating lamps etc;
- The outboard motor, fuel tanks and fuel, if the boat is engine powered;
- The anchor;
- The fish catch;
- The emergency mobile phone.

However, if the boat sinks, the hull too is lost.

Impact on dependants

The direct loss of life will lead to major impacts on the dependents of those affected. This will translate through into decreased levels of health and education, though these are very challenging to measure. There is some literature, albeit from car crashes in Asia, that estimate the indirect impact of fatalities on dependants (TRL, 2003). This found over 70% of poor households reported their household income, food consumption and food production decreased after a death. Among non-poor households, 57% reported household income to have decreased. Three quarters of all poor households affected by a death reported a decrease in their living standard, compared to 59% of non-poor households. Furthermore some 61% of poor households were forced to arrange a loan after a death, while only 34% of non-poor had to do so. A larger proportion (35%) of poor bereaved households sold an asset, compared to 21% of non-poor. Few households reported having to give up work or take on extra work after a death, but again poor families were more likely to report these effects. In earlier work, TRL (1995) suggested that human capital values should add sums to reflect pain grief and suffering from fatalities, suggesting a value of 28% of total costs for a fatality. This includes an amount to reflect pain grief and suffering. It is possible to use this as a proxy for the adverse effect upon dependants.

Equity

Equity is now formally incorporated in DFID's value for money framework (DFID smart guide[8]) as the fourth E.

- Equity (*spending fairly*). How fairly are the benefits distributed? To what extent does the project reach marginalised groups?

In line with this, it is therefore important to consider whether the HIGHWAY project is reaching marginalised groups, including women, the disabled, and the poorest, and to include this in the socio-economic benefit analysis. Indeed, these aspects are now included in the overall WISER framework, including the co-production guidance (Vincent et al., 2017). Reaching marginalised groups often involves some additional activities (and resources) and it may not lead to benefits that are as large as compared to those users who have larger assets to protect, or can generate more economic value from enhanced W&CS. There are different ways of assessing the potential equity aspects for HIGHWAY.

The first is just to identify the different socio-economic groups that stand to benefit from the project (i.e. EWS), assessing the numbers of marginalised users who benefit. The second is to use distributional weights to adjust explicitly for distributional impacts in the benefit analysis and cost-benefit analysis. Benefits to lower income household are weighted more heavily than those in higher income households. However, the use of distributional weights is controversial and is not routinely adopted (e.g. by development partners and IFIs, such as the World Bank and DFID). For HIGHWAY, we propose that information on the users that will benefit from the project, and subsequently from the regional EWS, are collected, and the numbers of users in different income groups and marginalised groups. This would include tracking by income level and gender.

For this analysis, a distributional and gender analysis has not been undertaken. However, there are specific groups that are targeted that are relevant. For example, there are a large number of females employed in fish drying and processing, as well female boat owners.

There will also be the benefits to small boat travellers, i.e. the lake island population, which will include men and women, and will also include lower income groups (than the mainland)

[8] DFID Smart Guide (2017). DFID's Approach to Value for Money.

Step 3 Baseline / 4 Benefits of EWS

This section reports on the baseline and the 'with EWS' scenarios. These are presented together, to allow a sequential analysis of each individual benefit, then aggregated together. The two steps in the methodology are:

Step 3. This is the baseline for the current situation without the new W&CS information provision. This aims to quantify the potential social, economic and environmental impacts, across sectors and actors (e.g. households, private and public sector) and the current provision of weather and climate services. Depending on the subsequent method chosen, it may also include survey work.

Step 4. This assesses the improvements in reducing the baseline impacts above with the new weather and climate service in place, i.e. the socio-economic benefits. This should include analysis of all potential benefits, ideally in economic terms, from the project activity. It should ensure that the efficiency losses along the weather chain are considered.

Information and surveys used for the SEB analysis

The baseline analysis and assessment of benefits drew on a number of existing studies from HIGHWAY. These included:

- The baseline reports of Powell (2018) and information summarised for socio-economic baseline (2020).
- The baseline WISER/HIGHWAY Climate Resilience Pilot Study in Busia, Siaya and Homa Bay (WMO, 2019). This undertook interviews in 3 counties in Kenya, interviewing 315 fishermen.

The SEB work also commissioned a series of surveys to try and source better baseline and 'with HIGHWAY' benefits. These were undertaken during the summer of 2020, and thus took place during the COVID-19 period. These were focused on Kenya and Uganda, as the Tanzania HIGHWAY forecasts were not operational at the time. The survey work was led by Robert Powell, working with local consultants and included:

- Deaths from drowning and other accidental causes in the Kenyan sector of Lake Victoria 2017-2020: Statistics from BMU County Chairmen (David Agangu).
- Report on focus group discussions conducted with Kenyan fishing communities in Lake Victoria regarding the awareness and use of KMD's daily forecast for fishermen (Robert Powell and David Agangu).
- Telephone and WhatsApp survey of fishermen's leaders in the Ugandan sector of Lake Victoria on drownings and use of the UNMA marine forecast (Robert Bakaaki and Robert Powell).
- Report on focus group discussions conducted with fishing communities in the Ssese Islands May-June 2020 (Henry Kizito).
- The influence of the UNMA marine weather forecast on drownings in the Ssese Islands (Robert Powell and Henry Kizito).

HIGHWAY figures – use of consistent estimates

It is highlighted that there are a number of key figures that should be reported consistently across the HIGHWAY project, not just in the SEB study. These include:

- The number of potential beneficiaries (potential users). This is the total number of fishermen and local transport users who travel on the lake and could, in theory, be potential beneficiaries.
- The current number of users of weather information. This involves the number of users who currently receive weather information.
- The baseline use of information. This considers the number of actual users who currently act on current information. This is a combination of the trust in the forecast, itself determined by forecast accuracy, and thus the number who use the information.
- The number of HIGHWAY users who have received the new weather and climate information from the project. This is determined by the effectiveness of communication. This includes the direct beneficiaries (who directly receive the information) and the indirect beneficiaries.
- The change in use of information with HIGHWAY. This considers the number of users of HIGHWAY who act on the improved information. This is a combination of the improved trust in the forecast, itself determined by the improvement in forecast accuracy, the number who use the new information, and the additional action that they take (and thus the benefits they derive).
- The extrapolation of information from pilots and surveys. Most of the information on HIGHWAY has come from a small number of individual surveys and focus groups. There is an issue of how to accurately upscale these numbers to the total number of potential users.

Baseline population and thus potential users

The starting point is to establish the Lake side population. The data is drawn together from coastal ward data collected by Powell (2018: 2020).

In Uganda, data are available on the population of coastal and island areas in Lake Victoria by district and sub-county according to the 2014 National Census[9]. The total population of coastal and island sub-counties is reported at 1,574,442. This includes over 150 000 on the islands.

In Tanzania, the population of coastal and island areas in Lake Victoria by administrative region and electoral ward was taken from the 2012 census[10]. The total was 2,601,250.

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[9] Census results by sub-county can be found on the following web pages: Eastern Region: http://www.ubos.org/onlinefiles/uploads/ubos/census_2014_regional_reports/revised/NPHC_2014_Subcounty_Indicators_Report_Eastern_Region_25th_March_2017.pdf Central Region: http://www.ubos.org/onlinefiles/uploads/ubos/census_2014_regional_reports/Census_2014_Report_Central_Region.pdf

[10] The following web-page web-page contains a map showing each of these wards and their population registered for each one in the 2012 census https://www.citypopulation.de/php/tanzania-lake-admin.php

In Kenya, the population was sourced from the Government of Kenya's official gazette, published in 2016 ahead of the 2017 general elections[11].The population was 1,220,423.

While these data are not consistent 2020 figures, they indicate a population of 5,396,115. This represents the potential total number of (direct and indirect) beneficiaries from current and future projects. For the current period (2020), these estimates would be likely to be much higher given rising populations.

Powell (2018, 2018b: 2020) highlights the following key baseline aspects.

- About 5.4 million people – approximately 1.2 million households - live in fishing communities around the coastline of Lake Victoria and on islands in the lake. This is the key user group for enhanced weather and climate information.
- Fishermen. Approximately 220,000 fishermen go out on the lake in small boats every day. (109,000 in Tanzania, 67,000 in Uganda 41,000 in Kenya). These form a key end-user group, because of the high occupational risks from extreme weather on the lake. They operate from about 75,000 small wooden boats which are based at nearly 1,500 officially recognised landing sites. Only a third of the fishing boats have a motor. The majority rely on paddles for propulsion. Most fishing trips last 10 to 18 hours. In Tanzania, and Uganda, the majority of fishermen go out at night, but some also fish by day. In Kenya most communities fish both at day and night.
- Fisheries support workers. Tens of thousands of fish traders, transporters and processors rely on the daily arrival of freshly caught fish from Lake Victoria for their livelihoods. Their exact number is difficult to quantify. The size and price of the daily catch is often weather dependent. Many fisheries support workers are based on islands and travel regularly by boat on the lake.
- Marine transporters. About 50 roll-on roll-off (ro-ro) cargo vessels and car ferries built of steel carry thousands of passengers and hundreds of tonnes of cargo across the lake every day. Nearly all passenger and cargo transport voyages take place in daylight hours.
- More than 2,800 small transport vessels operate on the lake, carrying passengers and cargo to and from islands. These wooden boats are between 10 and 15 metres long and are propelled by outboard motors. They typically carry a mixture of cargo and paying passengers. Most of these boats carry up to 30 passengers, but some are able to carry more. A large percentage of the people who drown every year are passengers on small transport craft that break up, capsize or sink in rough weather.
- Data from Powell, primarily from the FRAME surveys in Uganda (2017), Tanzania (2016) (Sobo et al., 2017) and Kenya (2016), identify the number of fishermen, boats and landing sites.
- Island residents. More than 600,000 people live on islands in Lake Victoria (although based on recent data, the number may be closer to 700,000). They rely

11 file:///C:/Users/rober/Dropbox/Met%20Office/Highway/2018%20Highway%20research/Kenya/Kenya%20government%20list%20of%20electoral%20wards%20and%20their%20population%202016.pdf

exclusively on boat transport for all communication with the outside world. (More than 400,000 live on islands in the Tanzanian sector of the lake, and there is a sizeable Ugandan lake population as well[12]. This is another key end-user group, as they rely on marine transport, and often use smaller informal transport.

Country	Island(s)	Population
Tanzania	Ukerewe	345,000
	Kome	47,000
	Maisome	16,000
	Bumbire	13,000
Kenya	Mfangano [10]	26,000
Uganda	Buvuma	90,000
	Ssese Islands (63 inhabited islands)	54,000
	Koome	19,000
Total		**610,000**

- The WMO resilience baseline report (2019) reports that for Kenya only, the Kenya Meteorological Department (KMD) works with an estimate of 90,600 direct beneficiaries and 543,600 indirect beneficiaries in the HIGHWAY project. This estimate is based on the number of Beach Management Units (302 in Kenya, updated from the estimate from the 2016 survey), assuming each BMU has an average of 300 members[13]. This leads to an estimate of 302*300 = 90,600 direct beneficiaries. It is further assumed that each of these direct beneficiaries represents a household of 6 members (as per the average number of family members per household), thus the value is scaled up (by 6) to give the total number of beneficiaries (indirect) of 543,600.
- The Uganda FRAME survey (DiFR, 2017) reports on the number of Ugandan BMU. The number has varied considerably over time. Following the reorganisation of landing sites into Beach Management Units (BMUs), the number of landing sites decreased from 597 in 2000 to 435 in 2008. The survey in 2010 showed an increase to 503 landing sites, 2012 showed 555 with a slight increase to 567 in 2014 and a slight decrease to 556 in 2016 frame survey. Of these, 306 were on islands. The 2016 survey reports 29398 boats. The fisheries in the Ugandan waters were previously predominantly near shore with 59% of all fishing crafts using paddles (and 10,996 outboards). However, the number of fishing crafts using outboard engines increased by 10.4% between 2014 and 2016, targeting Nile Perch. Further increases since this time are likely, because of the 2018 requirement for fishing boats to be 28 feet long (and at this length, boats require motor power). There were 66869 fishers, of which 342 were women.

[12] The 54,000 population figure for the Ssese Islands is taken from the 2014 census. The actual population is about 70,000, including fishermen who are temporarily resident in the archipelago on a seasonal basis. Uganda also has several other inhabited islands in Lake Victoria with large populations which mainly depend on fishing that are not included on this chart. The largest are Sigulu (18,000) and Lolui (10,000).

[13] This was based on report by the Indian Ocean commission (2014) states that Kenyan BMUs at the coast had a BMU assembly members ranged from 54 to 500, with 9 to 15 for executive members.

- Earlier studies have estimated the number of dependants at 8 (WMO, 2018) while more recent studies put the number at 6 (WMO, 2019). However, these are based on typical family numbers, rather that the vulnerable groups (note fishermen tend to be young).

Table 4 Potential users of Lake Victoria Weather and Climate Services.

	Kenya	Tanzania	Uganda	TOTAL
Fishermen	41,000	109,000	67,000	217,000
N° Fishing boats	13,500	31,800	29,400	74,700
Island populations* (small boat users)	26,000	421,000	163,000	610,000
N° small transport boats	Not available	1115	1725	2840
Beach management Units (BMUs)	302	642	556	1500
BMU population (estimated)**	90,600[1]	192,600	166,800	450,000
Fish traders	Not available	Not available	Not available	Not available
Total Lake population# (direct and indirect beneficiaries)	1,220,423	2,601,250	1,574,442	5,396,115

Sources FRAME surveys, Powell, 2018: 2020, WMO, 2019.
*note island populations will include large numbers of fishermen. Recent analysis by Powell indicates that the population of the islands is higher, at probably closer to 700,000.
[1] Assumes 300 people per BMU.
Note this includes island populations.

Therefore, the numbers used in the study for calculations are as follows:

- There are approximately 217 thousand fishermen who are highly vulnerable and are the key target beneficiaries of the project.
- There are also at least 610 thousand lake island inhabitants – though recent estimates suggest closer to 700,000 – most of which will use small boat transport (albeit less frequently than fisherman) and also have a very high vulnerability. Note the island population will include fishermen.
- There are approximately 1500 Beach management Units, though numbers vary from year to year. While it is very approximate, this might equate to a total relevant BMU population of 450,000. This indicates that in approximate terms, there are likely to be just under half a million direct potential beneficiaries of weather services and early warning services across the three countries.
- The value of 450,000 direct beneficiaries has been used in this SEB study.
- It is difficult to estimate the number of dependants. We assume here that for every direct beneficiary, there are 5 additional dependents (thus forming a household of 6 on average). This would lead to approximately 2.25 million dependents (indirect beneficiaries).
- There are approximately 5.4 million people in coastal locations around and in Lake Victoria area in the three countries (Kenya, Tanzania, Uganda). There could be some benefits for this wider groups in terms of indirect benefits, i.e. in

addition to the core beneficiaries, a functioning Lake EWS might have some benefits for an additional 5 million people.

For the wider regional project, including going forward with a regional EWS.

- The relevant population (indirect beneficiaries) will include the coastal populations as above (5.4 million) but would also extend to the entire Lake Victoria Basin, which includes more inward areas of Tanzania, Uganda and Kenya, as well as Rwanda and Burundi. This covers an area of approximately 183,000 km^2. The LVB has an estimated population of 45 million (World Bank, 2018).

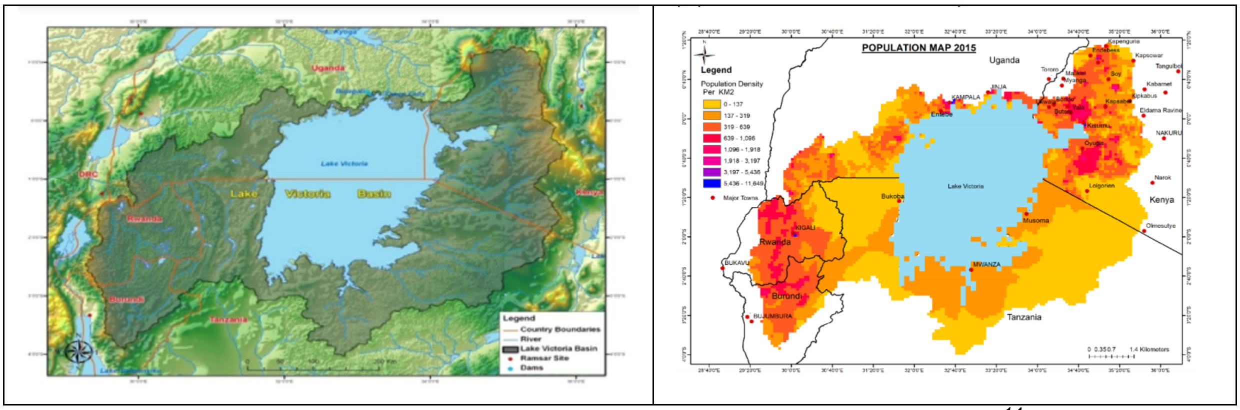


Figure 4 Lake Victoria Basin. Source Lake Victoria Basin Commission[14].and right, Population (World Bank, 2018).

Baseline communication and use of weather information

Powell (2018) undertook an analysis of the baseline, prior to the HIGHWAY study.

In Kenya, coastal communities were able to receive some marine weather information by radio at the start of the HIGHWAY Project. In March 2018 Kenya Meteorological Department (KMD) resumed publication of a daily weather forecast for fishermen in the Kenyan sector of Lake Victoria after an eight-month interruption. The revived forecast for fishermen was broadcast by two popular radio stations in Kisumu – Nam Lolwe FM and Lake Victoria FM. However, field research among fishermen based over 100 km from Kisumu in Siaya and Homa Bay counties in May 2018 found that none were receiving any weather information by radio. Most said they mainly listened to the Nairobi-based Dholuo language station Ramogi FM, which did not carry the KMD forecasts.

In Tanzania, in May 2018 lake shore and island communities were able to receive some marine weather information for Lake Victoria by radio and television. However, the information provided to broadcasters by Tanzania Meteorological Agency (TMA) was very limited. Most fishermen said they did not regard it as accurate or useful and had difficulty understanding it. The overwhelming majority said they ignored weather forecasts on radio and TV completely. However, a handful of fishermen in Sengerema District (fewer than 15) who received severe weather warnings from

[14] https://www.lvbcom.org/Who%20we%20are

TMA by SMS through a small pilot project, said the messages were useful and they shared them with neighbours.

In Uganda, the Uganda National Meteorological Authority (UNMA) did not publish any marine weather information for Lake Victoria at the start of the WISER HIGHWAY Project. Coastal and island communities did not receive any marine weather information at all.

Powell (2018) summarises the baseline as below.

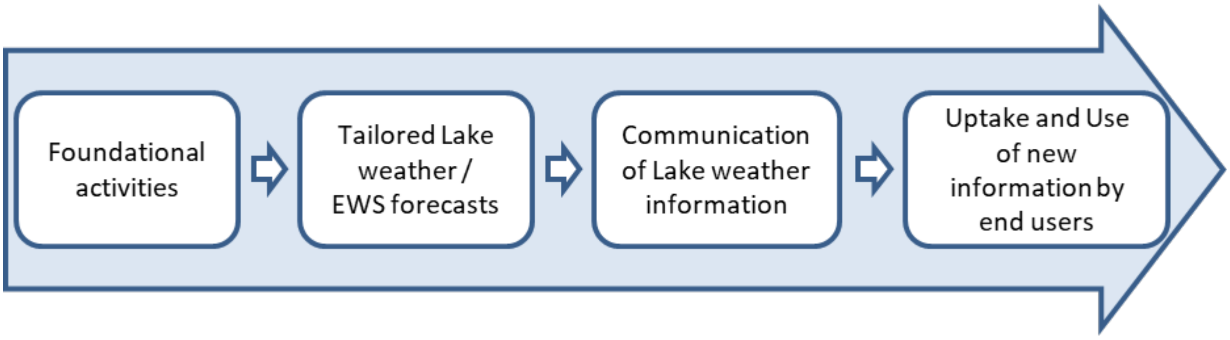
Table 5 Proposed baseline for marine weather information reach and use. May 2018. Source Powell (2018).

Country	Target Population	Current Reach	Population Reached	Households Reached	Estimated % use of households reached
Tanzania	2,600,000	10%	260,000	54,000	5%
Kenya	1,200,000	5%	60,000	14,000	5%
Uganda	1,600,000	1%	16,000	3,000	1%
Total	5,400,000	-	336,000	71,000	-

These baseline estimates for each region use slightly differing methodologies, based on the information available during the baseline study, and were agreed for use by the project. The Kenyan figures refer exclusively to the number of people reached by the embryonic KMD forecast for fishermen. They do not include people who saw the national weather forecast on TV or heard it on the radio. If those were taken into consideration, the reach level in Kenya might be higher. The Ugandan figures represent estimates of those receiving UNMA national forecasts on radio or TV (the dissemination of mobile weather alerts for fishermen stopped in 2013 or 2014). The estimate that 5% of targeted Tanzanian households in lakeside and island communities received weather information refers to the TMA national forecast picked up on radio or TV and the local daily forecast for Sengerema district, which was supposed to be broadcast by one local radio station. Feedback from the target users also suggested that the national forecasts of all three countries were considered to have little relevance to small boat users in Lake Victoria and very few people in fishing communities paid attention to them, even if they did see or hear them in passing.

HIGHWAY Improved forecasts, communication and use figures

It is possible to estimate benefits from EWS by looking along the weather value chain, and looking at the improvement in forecasts, the increase in communication of forecasts, as well as the uptake and use of these forecasts, including how this use leads to alternative decisions that reduce fatalities, losses or enhancing gains. This is captured through the weather chain analysis.



Improved foundational activities

HIGHWAY has invested in improved science, which has led to improvements in forecast accuracy. This is reported in output 3 (Met Office, 2020).

The work centred around the development of products and the verification of the new products. These included new high-resolution model data, lightning data, Nearcast data (a blend of satellite and model for nowcasting to forecasting timescales) and other satellite nowcasting products (NWC SAF).

Output 3 is also linked to the HIGHWAY field campaign (Output 2) and the ongoing enhancement and collection of atmospheric data over East Africa.

This will have long lasting impacts on the quality of operational forecast data over the region, as well as playing an essential role in monitoring climate and climate change.

HIGHWAY has also part-funded the HyVicpilot flight campaign, which has produced the first meteorological observations of the diurnal circulation over Lake Victoria and the confirmation of many of the dynamical and convective processes that had only previously been hypothesised by model experiments.

The approach for visualisation has been developed – with reliance on existing technology to visualise new products individually and a progression towards cloud technology.

While all of these will have benefits in improving lake forecasts and severe weather warnings, there is no empirical evidence to estimate the level of improvements. Instead the study has looked at the reported improvement in accuracy from survey data (see later section). Further work to look at the improvement in foundational science, i.e. before and after investments (such as in Chamberlain et al, 2014) would be useful, and should be included in any future phases of HIGHWAY.

User communication, confidence, uptake and use

Previous projects have been implemented on Lake Victoria with the support of international development partners. This includes Mobile Weather Alerts in pilot areas of Uganda's fishing grounds. These pilots provide information on the likely uptake of EWS, which are critical in estimating the weather chain losses and likely responses. Empirical research was conducted in 2015 in Uganda (Tushemereirwe et al.) to gather fishermen's feedback on these pilots. This study conducted research targeting a sample of fishermen who had previously benefitted from Severe Weather Early Warning Systems (SWEWS) in the Lake. An assessment was conducted between March and May 2015 to determine the participants' opinions about the EWS, as well as their willingness to pay. A total of 215 respondents were sampled from the 1000 participants who had participated in the earlier pilot of Mobile Weather Alerts supported by World Meteorological Organization that started in early 2011. The findings showed that all respondents used mobile phones. Ninety-two percent (198/215) mentioned the mobile phone as their most useful tool for obtaining information, while 8 % mentioned the radio. The majority of the respondents 85% (183/215) paid for their own mobile usage fees. On average, the respondents reported that they spend USD 8 per month for mobile phone services. It was reported that 30.7% (66/215) of the respondents were currently receiving mobile phone weather alerts. When these respondents were asked how the mobile phone alerts were helping them, 80.3% (53/66) said that the alerts were helping them in planning while 2.8% (6/66) said that the alerts informed them about the weather conditions. However, 70.2% (151/215) of the respondents were not receiving any mobile phone weather alerts. Most respondents preferred an alarm as a warning system over colour codes or text. This may be due to the low literacy levels among fishermen. They also agreed that timeliness was the most important factor and thus preferred the use of local language for EWS. Interesting, when asked about whether they trusted the EW, only 3% said they did all the time, 43% said most of the time, and 52% said sometimes. The respondents also reported that authorities such as the police should be the responsible body for issuing the alerts. These values still show a large drop off in efficiency along the value chain.

In terms of the impact of HIGHWAY, a combination of previous work (Powell, 2019) and commissioned focus groups for the socio-economic benefit work (see earlier) have been used.

Kenya

In Kenya, the resilience study (WMO, 2019) assessed the potential impact of HIGHWAY, based on a number of interviews (315 structured questionnaires were administered to the program beneficiaries in three project counties Busia, Siaya and Homa Bay). In summary, this found:

- Most of those interviewed (96.44%) have regular access to some weather information services for all hazards from both Highway project or other initiatives. 38% considered they received a lot of information on weather. 89% of these received from KMD. This means that 85% (96%*89%) receive more targeted weather information from KMD (including from HIGHWAY).
- The beneficiaries received weather information from many sources at the same time, including radio (42%), but also SMS, WhatsApp, and BMU communication.
- About 72% of the beneficiaries indicated that the information was accurate for some specific events and hazards, while 23% stated that the information was accurate for all events and hazards. 52% replied that they fully understood the information, and 47% said they moderately understood the information. Furthermore, 50% of the respondents stated that most of the weather information was delivered on time (with the other half saying it was moderately delivered on

time). Close to a half of the respondents stated that they shared the information with other users (BMU group, other transport users, family and friends).

- The survey reports that of the respondents who receive weather information from KMD, about 63% used a lot of the information on all severe weather alerts. About 28% used these alerts only half the time and about 8%, did not use the weather information at all. Of those that used the weather information, 99% prepared themselves for the hazards. However, this needs to be considered in light of the number of respondents who fully understand the information given (only about half) and the timeliness (see above). 96% reported they made timely decisions to cope with the hazards and 3% did not make timely decisions to cope with the hazards.

The report also presents the responses taken. 31% and 21% prepared themselves to respond to hazards from heavy rainfall and high waves respectively. 14% reported they prepare themselves on for both severe storms and poor visibility, 8% prepared themselves to respond to wind relate hazards such as wind direction and speed.

The study found that the respondents undertook various actions to prepare for a hazard after receiving the weather and climate information. Depending on the type of hazard they take life jackets, polythene bag and rain capes to protect themselves from heavy rains. They also take lamps and torches to help with visibility. In severe weather they do not go fishing until the hazard is over. Rescue services are also alerted and ready to respond to any emergencies. However, there is no information on the proportion of respondents who took each option, and also, on how effective these actions were in reducing risks.

However, 58% of respondents felt that the information allowed them to protect their business and, or assets during most or all weather and climate related hazard events, and 39 % of the respondents, to moderately protect. Only 2% reported the information could not protect their business, and or assets at all. Of those respondents who did not take action, most did not trust the weather information provided, 7% replied they did not have the resources needed to respond to the weather hazard and 7% replied they did not due to late sharing of information.

The focus group discussions conducted with Kenyan fishing communities in Lake Victoria regarding the awareness and use of KMD's daily forecast for fishermen (Powell and Agangu, 2020) complement these findings. This research initiative conducted 10 focus group discussions with a total of 149 participants at 10 different beach management units (BMUs) at 10 landing sites, in two different counties. The findings showed high levels of awareness and use of the KMD forecast right across the Kenyan sector of Lake Victoria. In summary:

- In Homa Bay County, 5 of the 10 pilot landing sites that were equipped with weather warning flags and weather information boards were chosen. The theory being tested was that the flags and noticeboards would help the intermediaries to communicate the KMD forecasts to local people more effectively.
- The overwhelming majority (96%) of the 81 participants in the five focus groups in Homa Bay County were already aware of the twice-daily KMD forecasts for fishermen in Lake Victoria. 54% of participants in Homa Bay said they had

received the KMD forecast earlier on the same day. A further 30% said they had received at least one forecast in the previous week. 93% of the focus group participants said they also paid attention to the weather flag at their landing site.

- The KMD forecasts are widely used to inform decision making in lakeside and island communities because they contain relevant information that is trusted as being largely accurate. The focus groups in Homa Bay thought the KMD forecasts for fishermen were accurate most of the time. 50% thought the forecasts were accurate on at least five days of the week (71% accurate). A further 44% reckoned they were accurate on at least four days of the week (57% accurate). Anecdotal evidence from KMD forecasters and forecast users in 2019, had taken indicated accuracy levels of 70 to 80%.
- Nearly all the focus group members (98%) said the KMD forecasts for fishermen influenced their own personal behaviour. However, some said they also used indigenous knowledge to assess local weather conditions. 93% estimated that the KMD forecasts influenced the decision making of at least three quarters of the people in their local community. 7% thought only half the population was influenced by them.
- At the landing sites in Siaya County, there were 69 participants in the five focus groups. Nearly everyone was aware of the KMD forecasts for fishermen in Lake Victoria broadcast by local radio stations. 12% said they had received a KMD forecast earlier the same day. The remaining 88% said they had received a forecast within the past week. 98% said they listened to the KMD forecasts for fishermen on local radio stations that broadcast mainly in the Dholuo language. 70% of the focus group participants said nearly everyone in the wider community heard the KMD forecasts for fishermen regularly on local FM radio stations. The remaining 30% thought about three quarters of the population of lakeside communities listened to the forecasts regularly.
- The focus groups in Siaya thought the KMD forecasts for fishermen were accurate most of the time, although there were errors. Around half of participants thought the forecasts were accurate on at least five days of the week (71% accurate). The other half reported the forecasts were accurate on at least four days of the week (57% accurate).
- Further, in Siaya, 48% said the forecasts influenced the behaviour of about three quarters of all fishermen and marine transporters. 23% said the forecasts informed the decisions of about half of them. Only 17% thought the forecasts influenced a quarter or less.
- In both counties, people primarily received the KMD forecasts through bulletins broadcast in local languages on local and regional radio stations. The focus groups said that between half and three quarters of the lakeside population listened to KMD forecasts for fishermen regularly on the radio.
- The BMUs where focus groups took place on the west coast of Homa Bay County each had two community intermediaries who were trained by the HIGHWAY Project. These volunteers received the KMD forecasts for fishermen by WhatsApp twice a day on their smartphones and were supposed to communicate relevant weather information from these bulletins to local people. 10 pilot BMUs had been equipped with flags and noticeboards to help the

intermediaries communicate weather information more effectively. The extent to which the flags and noticeboards were used varied greatly from one landing site to another.

- Evidence from these focus groups indicates that the system of using unpaid volunteer intermediaries to communicate weather information to the local community will only be sustainable if the landing site itself is prepared to support their activities. This must include a willingness to pay for the maintenance and renewal of the flags and noticeboards from community resources.
- The KMD forecasts are communicated directly to individuals by FM radio and WhatsApp. Access to daily forecasts on radio is universal. However, access to the forecasts on WhatsApp is limited (<10%).
- Across all areas above, the areas with greater HIGHWAY outreach (Homa Bay) delivered higher levels of awareness, and greater user response. This highlights the % communication is influenced by activities, which in turn dictates the number of potential beneficiaries (users).

In Homa Bay, the forecasts were thought to influence the behaviour of about three quarters of the lakeside population. In Siaya the forecasts were reckoned to influence more than half the inhabitants of fishing communities. In both counties the bulletins were credited with helping to improve marine safety and reduce the number of deaths from drowning. 92% of the participants in the four mixed focus groups at Homa Bay said the number of drownings in Lake Victoria had decreased since KMD began publishing the forecast for fishermen in its current form and distributing it widely to radio stations in May 2019. (This question was not put to the fifth women-only focus group in Homa Bay). 88% of focus group members at Siaya thought the number of drownings in Lake Victoria had decreased since KMD began publishing the forecast in its current form and distributing it widely to radio stations.

People who use the forecasts to help plan fishing trips, passenger journeys and cargo transport voyages say they are less likely to venture out onto the lake if the weather forecast is poor. If they do decide to set sail, many will take the precaution of wearing a life jacket and carrying extra fuel for the engine. Focus group members said the most common behaviours that they personally adopted in response to KMD forecasts of rough weather on the lake were:

- Postpone the boat trip (cited by 58% of participants in Homa bay and Siaya)
- Avoid going far out into the lake (35%)
- Carry a lighter load (35% in Homa Bay; 58% in Siaya)
- Carry extra fuel (28%)
- Wear a life jacket when you go out in a boat (8% in Homa Bay [but low due to a shortage of life jackets in community]; 84% in Siaya)

The focus groups reported fishing communities had also used the KMD forecast to make decisions which enhanced their livelihoods. The main benefits highlighted were:

- Avoidance of financial losses caused by net damage and lost nets (mentioned by 97% of Homa Bay: 88% in Siaya)

- Savings in the consumption of outboard motor fuel (75% Homa Bay: 68% in Siaya)
- Increase in the fish catch (64% at both locations)

These people are saving money through avoided losses and increasing income by:

- reducing the fuel consumption of boats powered by outboard motors by 12 to 24 litres a week (2-4 litres per trip). This equates to 624 to 1248 litres per year, and a broadly equivalent $ saving (fuel varies typically between $1.00 and $1.30 per litre).
- reducing the loss of nets and other fishing gear in bad weather;
- reducing weather damage to boats moored at the landing site;
- Catching more fish. Although most fishermen said they had been able to achieve larger catches with the help of weather information from the forecast, this was disputed by others who said the size of the catch depended more on seasonal factors. Estimates of the additional income received from improved fish catches varied between the four landing sites at Homa Bay from 14,000 to 21,000 Kenya shillings (US$130 to $195 per boat per week) [although this may refer to the total catch, rather than the benefit alone].

For fish traders, reducing the amount of dried silver fish (omena) that goes rotten when rain falls on fish spread out to dry on the ground on large mats. Buy and sell fish at more advantageous prices.

The main economic benefits for transporters who used the KMD forecasts were:

- Saving money on outboard motor fuel (cited by 61% of focus group participants)
- Limiting cargo weight and passenger numbers if bad weather is expected (56%)

Uganda

In Uganda, Powell (2019) assessed the HIGHWAY project success, including production, dissemination and use of UNMA's weather forecast for small boat users in Lake Victoria. This focused on the HIGHWAY Project special community outreach initiative in the Ssese Islands (which have a population of approximately 70000). The findings are summarised below.

- The Uganda National Meteorological Authority (UNMA) publicly launched a twice-daily weather forecast for fishermen and other small boat users in the Ugandan sector of Lake Victoria in July 2019.
- This first evaluation of its impact, conducted five months later in November 2019, found that users considered the forecast to be at least 80% accurate, useful and easy to understand.
- Forecasters at UNMA's National Meteorological Centre (NMC) estimated that the marine forecast for Lake Victoria was more than 80% accurate. This assessment is based on the feedback received daily from WhatsApp monitors in each of the

four forecasting zones of Lake Victoria and from other individuals who receive the forecast by WhatsApp and comment on its accuracy.

- The degree of accuracy estimated by UNMA forecasters was supported by fishermen consulted independently in Kiyiindi and the Ssese Islands and by journalists on 10 radio stations that broadcast the bulletins daily. Nearly all sources reported an accuracy rate of 80% to 90%.
- Radio journalists, fishermen and other users commented that the specially designed weather icons in the forecast tables make the bulletins very easy to understand. Field research found widespread public awareness of the forecast in lakeside and island communities. At least 10 popular radio stations and possibly as many as 15, broadcast the bulletins daily.
- Field research on 10 of the 64 inhabited islands of the Ssese archipelago found the HIGHWAY Project's community outreach initiative in the archipelago to be largely successful. In September 2019, HIGHWAY partner ActionAid Uganda trained 122 community intermediaries at 60 landing sites throughout the Ssese Islands to receive the UNMA marine forecasts by WhatsApp and share them with their neighbours. Two intermediaries were trained at each landing site.
- Within each island community, the intermediaries share the forecasts through a number of different channels. These include local WhatsApp groups with up to 80 members, village loudspeaker systems, regular meetings with fishermen and ad hoc verbal communication with their neighbours. Although the level of public awareness of the UNMA forecasts is high, the number of people who regularly receive the bulletins regularly and use them to inform their decision-making is much smaller.

This indicates an 80 – 90% forecast accuracy. However, the UNMA bulletins do not capture the probability of water spouts occurring, which are often associated with boat sinkings. This is important as it highlights that the improved forecasts will reduce many, but not all, fatalities.

The uptake of radio (by multiple stations) does imply a good level of communication. There has also been targeted communication through WhatsApp. However, widespread awareness of the UNMA marine forecasts does not necessarily imply that most people use them regularly. Powell (2019) reports wide variation in the level of received communication, although a high user desire for information.

This background work also provides information on the action taken in response to the forecasts, which influences the benefits derived. There is also strong anecdotal evidence that the forecasts are leading to positive behaviour change by fishermen and other small boat users in the Ugandan sector of Lake Victoria. In Uganda, (Powell, 2019) the frequently cited responses to forecasts of severe weather include the following:

- Delay departure until the weather has improved;
- Only go to the lake in large boats that are completely seaworthy;
- Wear life jackets while on the water (whereas normally the individual would not do so automatically);

- Carry extra fuel for the outboard motor in case the journey takes longer than anticipated;
- Take an umbrella if rain is forecast;
- Buy smaller quantities of mukene (silver fish) for drying if rain is forecast since the rain could spoil the fish while it is spread out on mats or racks to dry in the sun.

The actions above should reduce the number of weather-related boat accidents and deaths from drowning.

Field research In the Ssese Islands found that many people also use the UNMA marine forecasts to inform their decisions about farming, tourism activities and the operation of electricity and water services. Many fishermen are also farmers. Several of those interviewed (Powell, 2019) said they were also using the forecasts to decide when to cultivate or harvest. Two hotels on at Kalangala use the marine forecasts to help plan tourist activities. Kalangala Infrastructure Services circulates the forecasts to all its employees by WhatsApp because the weather affects its water and electricity supply activities. The company is particularly concerned about the potential impact of lightning on its power lines.

The telephone and WhatsApp discussions conducted with local leaders of Ugandan fishing communities in all 13 administrative districts that have a coastline on Lake Victoria (Powell and Bakaaki, 2020). This found:

- On average fishermen regarded the forecast as being 75% accurate. It was therefore widely used to inform decision making.
- The survey highlighted four main types of behaviour change in response to the weather information received:
    - Crew and passengers wear life jackets if bad weather is forecast (cited by 85% of districts).
    - Boats adjust their route to avoid sailing into wind or through large waves (62%).
    - Boats do not go out if bad weather is forecast (38%).
    - Transport craft carry lighter loads if bad weather is forecast (7%)
- The respondents highlighted two main benefits from using the forecast:
    - Safer navigation on the lake (cited by 92% of districts).
    - Lower fuel consumption and consequent financial savings for boats propelled by outboard motors – they use the forecast to adjust course to avoid sailing into wind or through large waves (62%).

There was also more detailed work (Kizito, 2020) using focus group discussions conducted with fishing communities in the Ssese Islands. A total of 89 people took part in the discussions from five landing sites. They represented fishing communities with a combined population of around 10,400 people. This found:

- At least half the population of the Ssese Islands were aware of the UNMA marine forecasts. But the number of people who followed the forecasts regularly and used them to inform decision making varied considerably. 36% said they had listened to the forecasts on radio that day. 56% said they had received weather information from an intermediary within the past week. Awareness and use of the forecasts were highest at landing sites where local community intermediaries used secondary channels to actively disseminate the forecasts. At the first four landing sites, 90% said they had received an UNMA forecast earlier the same day or within the past week. But at final one, only 24% said they had done so. 22% of focus group participants said that they personally received the UNMA marine forecast by WhatsApp.

- For the UNMA marine forecasts, among those who paid attention to them, 71% of all focus group participants said they were accurate on at least five days out of seven. Nearly half the focus group participants (49%) said the forecast was accurate on at least six days out of seven.
- The forecasts were seen as influencing the decisions taken by a large number of boat owners, fishermen, transporters and fish traders and processors. 76% said the forecasts influenced their own personal decision making. In the wider community, they thought the forecasts influenced the behaviour of most people who received them regularly, but by no means all. Many passengers undertaking long journeys across the lake in small boats also consulted the latest UNMA bulletin before travel.
- The bulletins were credited with bringing about behaviour changes, and improved marine security and saved lives. Boats are now more cautious about going out whenever rough weather has been forecast and crews and passengers wear life jackets more often when travelling in predicted difficult weather conditions.

Focus group participants said the most common behaviours they personally adopted when the UNMA bulletin forecast rough weather were:

- Wear a life jacket when you go out in a boat (71% of focus group members)
- Carry extra fuel for the outboard motor to avoid running short (65%)
- Postpone the boat trip (48%)
- Carry lighter loads (39%)
- Avoid going far out into the lake (36%)
- Secure boats at the landing site to prevent damage from high wind or large waves, either by hauling them onto the beach or anchoring them away from shore at a safe distance from each other (29%)

Silver fish (mukene) dryers and traders said they used the forecast to decide when to cover fish spread out to dry in the sun to protect them from rain.

60% of all focus group participants said the forecasts had contributed to an improvement in marine safety. 90% thought that the overall number of drownings had decreased in the 11 months since UNMA launched the bulletins in July 2019.

Fishermen, transporters and boat owners reported substantial savings in outboard motor fuel from not having to battle their boats through severe weather. These savings ranged from 15 to 30 litres of fuel per boat per week. With outboard motor fuel costing roughly US$1 per litre, the forecasts could potentially save individual boats between $750 and $1,500 over the course of a year.

The focus groups reported benefits of:

- Safer navigation (60% of focus group)
- Save money on nets (31%)
- Save money on fuel (52%)

Many fishermen said the forecasts help them to reduce damage to their nets and the complete loss of their nets in severe weather. They did not quantify this saving in financial terms.

Silver fish (mukene) dryers said the forecasts helped them to reduce the amount of drying fish that they lost from rotting in the rain by up to 25%. The forecasts enabled each one to save between 30,000 and 100,000 shillings (US$8 and $27) per week.

Tanzania

There is currently no information for Tanzania, as at the time of the SEB analysis, the targeted Lake forecasts were only just starting, and thus it was not possible to capture ex post data. Due to this, we have not been able to assess the benefits of HIGHWAY in Tanzania, but we assume similar benefits to the survey and evidence from the other two countries in estimating overall benefits.

Summary

The estimates above are brought together in the Table below. Not surprisingly, the numbers vary with location, and also depending on the group interviewed. There are important differences in the action taken by some highly vulnerable groups (e.g. fishermen) versus others who use the lake.

It is stressed that the final column on effectiveness of the action taken, and thus how much it reduced risks, does not involve a single % (but is shown here for completeness).

Table 6 Summary Table of Project Improvements from surveys and interviews. See text above for caveats.

	% who receive information	**% who consider accurate**	**% use (act) on information**	**Effectiveness of action taken**
Baseline Kenya (Powell, 2018)	5%		5%	
Kenya (WMO, 2019)	85% [1]	72% [2]	63% / 92% [3]	See text
Kenya (Powell, 2020)	75% / 96% [4]	64% [5]	54% / 73% [6]	See text
Baseline Uganda (Powell, 2018)	1%		1%	
Uganda (Powell, 2019)		80 – 90%		
Uganda (Kizito, 2020)	56% / 90%[7]	71%[8]	76%	See text
Uganda (Bakaaki, 2020)	50% / 75% / nearly all[9]	75%		See text
Baseline Tanzania (Powell, 2018)	10%		5%	
Value used for SEB study	**85%**	**70%**	**75%**	**70%**

1 This includes all KMD information, not just specific analysis of the HIGHWAY information.
2 There was a large difference in those who rated accuracy as 'very' versus 'moderately'. Value shows those who considered moderately or very accurate. See main text.
3 There was a large variation in the use of information, i.e. whether fully acted on (63%) or additionally interviewees who acted around half the time (taking the total to 93%). See main text.
4 Average values for each of two focus group areas. There was high variation in when the information was received (same day, within last week). See main text.
5 Average values for all focus groups in both counties. There was variation in the number of days the forecast was considered accurate. Value shown is accurate more than 5 days out of 7. See main text.
6 Average values for each of two focus group areas. There was a large difference in the use of information by focus group, and for individuals across the wider BMU community. There was variation in the number of days the forecast was considered accurate. See main text.
7. There was high awareness at four locations (90%), but low awareness at one site where the community intermediaries were no longer active, which led to a low overall average of 56%.
8 There was variation in the number of days the forecast was considered accurate. Value shown is accurate more than 5 days out of 7. See main text.
9 There was large variation. Some districts reported around half were aware, some three quarters, and some nearly all.

Looking at the overall value chain, the improvement (in % accuracy, reach, communication and use) at each stage is impressive. Nevertheless, there is still a significant loss of efficiency across the entire weather chain. This is shown in the flow chart below.

This takes the average figures above, and applies them to an example of a severe weather forecast for a storm. At each successive stage there is a fall-off in the efficiency, e.g. due to the % of people who hear the forecast, or the ability to accurate predict a storm, as well as the trust that users have in the forecast and thus their willingness to take action. Overall, the level of benefits, as compared to perfect information and use, are just over 30%.

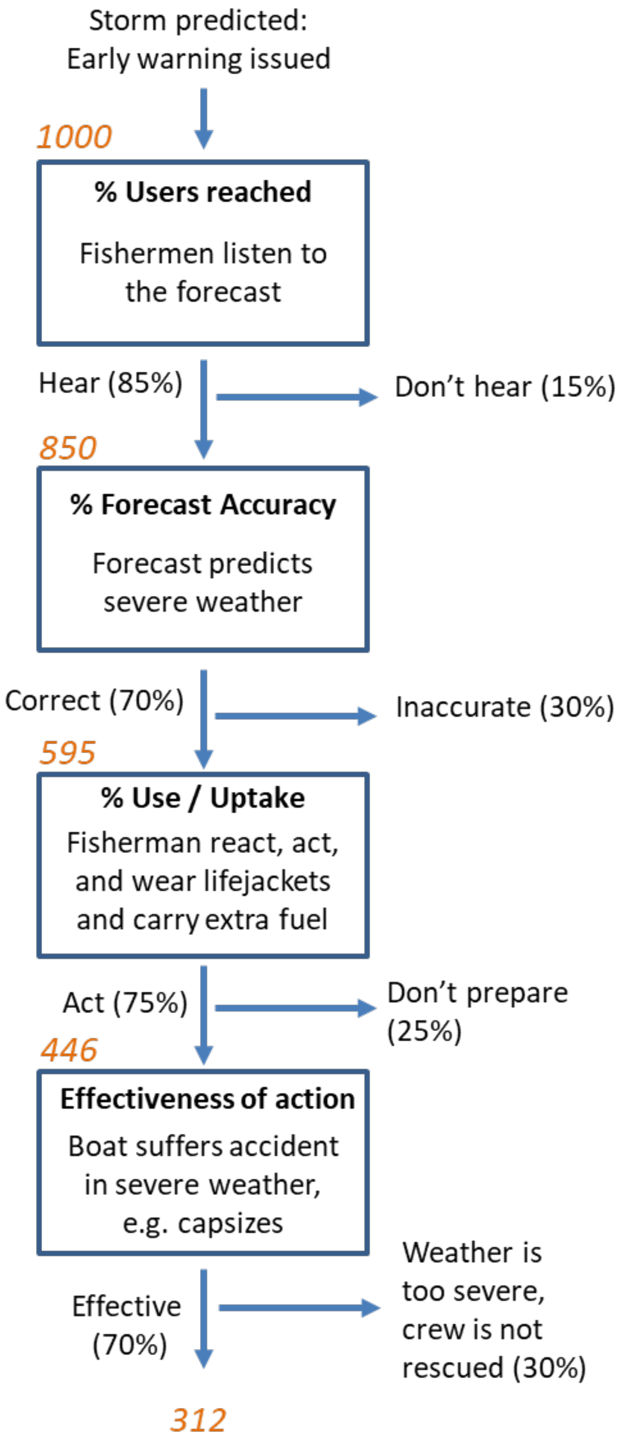


Figure 5 Weather service chain analysis, showing the efficiency losses through to final end user action and benefits

This information has been used to estimate benefits. However, it also provides key information on how the service can be enhanced in the future.

- Cleary, the number of users who are aware of and receive (communication efficiency) dictates the overall benefits, because it influences the maximum number of people who take action. A high communication level (reach) improves socio-economic benefits. In practice, the quality of the communication and the method matters a lot. There is information on the preferences on mode of messages, e.g. WMO (2019) in Kenya report beneficiaries would prefer to receive weather information directly through their phones.
- While the data above indicates a large increase in the % of beneficiaries who receive relevant information, some caution should be taken, as the detailed analysis indicates high variation (e.g. as seen across islands in Uganda). Awareness of information was improved in areas where community outreach initiatives had taken place, such as in some pilot areas in Kenya (Powell and Agangu, 2020). This highlights that benefits could be improved further by further outreach activities. This also leads to recommendations on how to improve communication and uptake of information, including future training (radio, use of WhatsApp, social media, weather apps).
- The number who consider the forecasts are accurate has improved (though there are not reliable baseline figures). However, the values above mask different levels of confidence in the forecasts, i.e. from very good to moderate. It is also the case that the forecasts have different levels of accuracy for different hazards. For example, there are currently no accurate forecasts for water spouts. This highlights there are further scientific improvements that could improve forecast accuracy. Previous studies have estimated the technical forecast accuracy improvement (comparing predicted with observations) and such detailed analysis would be beneficial going forward, especially for new products.
- The number of direct beneficiaries who act on the information is generally reported to be high. However, again, the numbers above mask differences. For example, in Kenya (WMO, 2019) around two thirds of respondents used (acted on) around half the time.
- It is much more difficult to know how effective the actions taken are. There is information on the action taken (e.g. % who change activities), but less information on how effective such actions is in reducing the impact, i.e. reducing the risk of drowning.

Analysis of baseline fatalities and benefits from HIGHWAY

Baseline vulnerability of fishermen

The discussion of current vulnerability is outlined by Powell (2018: 2020), and summarised below.

Nearly all fishing in Lake Victoria is done from small wooden boats between four and 10 metres long. They are open topped with plank sides and no decking. About half the fishing boats in Lake Victoria are powered by paddles. They generally stay within 4 km of land. Paddle-powered boats tend to be smaller and lighter than those powered by outboard motors. The proportion of paddle-powered boats is highest in Tanzania and lowest in Uganda. Sailing boats, often go further than boats with paddles – 10 or 20 km into the lake. Fishing boats with sails are more common in

Kenya than in Tanzania or Uganda. Outboard motors allow the boats to travel faster and against the wind if necessary, so motorised fishing boats often venture 20 or 30 km out on a fishing trip. Fishing boats in all three countries are steadily becoming larger in size and switching to outboard motors as their means of propulsion[15]. This means that more and more fishing takes place in deeper more distant water further away from the shore.

Very few fishing boats carry ice or cold storage boxes. Caught fish simply lie in the bottom of the boat until they are unloaded and sold. This factor limits the time that fishermen can remain on the water once the catch has been hauled on board since the dead fish starts to spoil rapidly in the warm temperatures. This means that in practice most fishing trips only last six to 18 hours. Day fishermen go out at dawn and return to their landing site in the afternoon. Night fishermen go out an hour or two before sunset and return at dawn or during the course of the following morning. This also accounts for the fishing settlements on small remote islands. Fishermen work the surrounding waters and sell their fish to traders at these settlements.

Each fishing boat has a crew of two to six men. The number of crew is determined by the size of boat and the type of fish being caught. Most boats have a crew of two to three. Some skippers own their own fishing boat. However, most are contracted to operate the boat on behalf of the owner. He or she remains on shore and takes a percentage of the catch. The owner equips, maintains and licences the boat. He or she also buys the fishing gear. If the boat is engine-powered, the owner supplies and maintains the outboard motor. The owner is also responsible for rescuing the boat and its crew if they get into difficulties. In Kenya and Uganda, boat owners typically own between two and 20 wooden fishing canoes each. In Tanzania some have much larger fleets numbering up to 100 small vessels. The boat owners view themselves as businessmen, and are wealthier and more risk averse than the crews they employ. The owners of fishing boats powered by outboard motors are most heavily exposed to financial loss if the boat capsizes or sinks since the engine is generally worth two or three times as much as the boat itself.

All fishermen live a very hand-to-mouth existence. Skippers and crew members are not paid a fixed wage by the boat owner. They only receive a share of the proceeds from the fish that they catch. The formula for sharing the income from each fishing trip varies from place to place. If fishermen do not go out to fish on the lake, they will get no money. They are philosophical about the risk of drowning and are often prepared to take big risks in order to earn money. Many fishermen are willing to go out in rough weather – particularly thunderstorms - because they associate these conditions with good fish catches. Fishing conditions are particularly good immediately before and after a thunderstorm. This is because the strong gusty winds and high choppy waves associated with thunderstorms stimulate fish to move around more actively in the surface layers of water. This behaviour enhances the likelihood

[15] In 2018 the Ugandan government decreed that all fishing boats had to be at least 28 feet (8.5 metres) in length in order to obtain a fishing licence. Since then, the construction of smaller fishing boats has been largely phased out. A 28-foot boat is too large and heavy to be propelled easily over long distances by a two or three-man crew using paddles, so nearly all new fishing boats built in Uganda are designed to be powered by an outboard motor.

that the fish will be caught in gill nets. However, these weather conditions are more dangerous for navigation

The net financial proceeds from each fishing trip depend on the type of fish caught, the weight and size of fish caught, the cost of fuel used to travel to and from the fishing ground (if the fishing boat is engine powered). Lake Victoria is heavily over-fished and the average weight of fish caught by each boat has declined steadily over the past 30 years. The size and value of the catch often depends on the prevailing weather conditions. The weather not only determines where the boat is able to fish, it also influences the likelihood of catching fish in the surface layers of the water.

All fishing boats carry a cheap basic mobile phone kept in a waterproof container – often just a plastic bag – to summon help in the event of an emergency. Some fishermen also carry a personal phone which they use with ear buds to listen to FM radio stations during the long hours of waiting between setting the nets and pulling them up again. However, most fishermen only take cheap basic phones onto the lake. Some fishermen also have smartphones, but they leave them at home because they are considered too valuable to risk losing or damaging on the lake.

Baseline vulnerability of small boats

The discussion of current vulnerability is outlined by Powell (2018: 2020), and summarised below.

Most transport of passengers and cargo between the islands in Lake Victoria and the mainland takes place in open wooden boats powered by outboard motors. These vessels are larger than fishing boats – 10 to 15 metres long on average -, but they are similar in construction. In Uganda, a new transport canoe costs 13 million to 18 million shillings ($2,730 to $3,780) to build, depending on the quality of wood used.

Most are powered by outboard motors of 40 to 75 horsepower and reach speeds of 10 to 20 kph in good weather and water conditions. However, most travel at speeds at the lower end of this range in order to conserve fuel. Most transport craft use 40 horsepower engines because this gives them greater versatility and better fuel economy. If the boat is large or heavily loaded, it may use two 40 horsepower engines together. If it is smaller or lightly loaded, it may use just one. A new 40 horsepower engine costs 15.5 million to 18 million Ugandan shillings ($3,260 to $3,780) as much as the wooden hull of the vessel. A second hand 40-horsepower engine costs 7.5 million to 9.0 million shillings ($1,580 to $1,890) depending on its age and condition. Transport boats typically consume 15 to 25 litres of fuel per hour – the slower they travel, they less fuel they use. This gives them a fuel cost of $15 to $25 per hour.

Nearly all transport boats operate during daylight hours because most of the crossings are quite short and the skippers rely on landmarks to navigate. A ferry the crossing from one island to its neighbour may last no more than a few minutes. But longer trips, from remote islands to a major landing site on the mainland, may last several hours.

The accidents on Lake Victoria which cause the greatest loss of life in a single incident involve transport vessels. These are frequently overloaded with passengers and cargo and are easily destabilised. Very few of the large steel-built car and passenger ferries on Lake Victoria are vulnerable to capsizing or sinking in severe weather conditions if they are properly loaded. However, the overloading of transport vessels of all sizes is common and can lead to extremely serious accidents.

In September 20th 2018, 228 of the 269 people aboard the Tanzanian vehicle and passenger ferry MV Nyerere were drowned as the vessel capsized while approaching the quay on Ukara island. The steel ship suddenly healed over and turned turtle as passengers rushed towards the landward side of the vessel to disembark. The weather on this occasion was good and was not a factor in causing the accident. But the MV Nyerere was seriously overloaded. The vessel was licenced to carry 100 passengers, but it was actually transporting more than twice as many. Heavy overloading of transport vessels of all sizes is common, particularly around the time of major national holidays when people travel back to their home village.

Some of the wooden transport canoes powered by outboard motors are able to pack in 30 or more people at a time on their wooden benches. When they are heavily loaded with passengers and cargo these vessels lie very low in the water with little freeboard. This means that they take in water easily if they encounter waves. They also become unstable in rough water. It does not take much deterioration in weather or wave conditions for these vessels to capsize. Large waves may even cause them to break up. Some small ferries provide life jackets for all their passengers and insist they are worn, but many do not. When transport canoes are faced with severe weather conditions, they often ditch cargo overboard in order to lighten the vessel. They can therefore lose money on a trip as a result of bad weather without the vessel capsizing or sinking. Poor weather may also cause transport boats to use more fuel on a crossing, increasing the financial cost of the journey. Since transport craft travel between fixed points they do not have as much flexibility as the fishermen to vary their route in response to forecast weather conditions.

Baseline estimates of fatalities (drownings) and losses on the Lake

As highlighted earlier, the current estimates of drowning each year are generally reported at 3000 to 5000 per year. Using the economic values from Step 2 (see previous section), the baseline economic costs can be calculated. This equates to a central estimate baseline impact of $195 million (3000 fatalities) to $325 million per year (5000 fatalities), but with a high estimate (higher WTP estimate) of $669 million (3000 fatalities) to $1,115 million per year (5000 fatalities).

There is an additional impact on dependants from these fatalities. A number of approaches can be used for this. The first uses a simple uplift based on TRL (1995) and thus increases the values above by 30%. The second looks at the likely number of dependents, which would be five times the numbers shown (so 15,000 to 25,000), and estimates the impact on this group. It has proved difficult to get valuation estimates for the second approach, so the first has been used here.

Alongside the human tragedy of these events, there are also more material losses associated with the loss of boats and gear. There is no evidence on whether the drownings are associated with individual fatalities, or the loss (sinking of boats). It is possible to consider possible losses with some indicative analysis. An upper estimate can be derived from assuming that all events are associated with loss of boats. As each fishing boat will have a 2 – 3 man crew, we can assume that the 3000 to 5000 fatalities is (very approximately) associated with loss of 1000 boats (note passenger boats would have higher numbers of passengers). We can further assume that these losses reflect the proportion of small (two thirds) vs motorised (one third) boats, though in practice smaller boats are likely to be more vulnerable. Values are based on replacement costs, which for larger motorised boats are approximately $3000 to $4000 for the boat, and $3000 to $4000 for the engine. Smaller non-motorised boats are estimated at $1000 to $2000 to replace. While there are additional costs from lost gear (e.g. nets) these are low relative to these costs. The loss of 1000 boats is therefore equivalent to $3.3 million.

Table 7 Economic valuation of annual <u>baseline</u> fatalities, indirect and asset losses

Direct Fatalities/year	**valuation central**	**valuation high**
3000	$195 million / year	$669 million / year
5000	$325 million /year	$1115 million / year
Indirect (Dependents)	**valuation central**	**valuation high**
15000 (related to 3000)	$58.5 million / year	$201 million/year
25000 (related to 5000)	$97.5 million / year	$335 million/year
Loss of boat and engines		$3.3 million / year

However, <u>we consider the estimate of 3000 to 5000 fatalities/year is likely to be high</u>.

Previous survey work (Kobusingye et al, 2016) in Uganda in four Ugandan lakeside districts (Buikwe, Kampala, Mukono, and Wakiso) found very high levels of drowning in lakeside communities, with a drowning fatality rate of 502 deaths per 100,000 population, which is extremely high. All the four districts are fishing and transport hubs connecting various islands in Lake Victoria to towns and communities on the mainland. The survey interviewed 544 people of which half were involved in the fishing industry either as fishermen or fish traders. Less than half were able to swim. Nearly 4 out of 10 respondents reported that at least one member of their family had ever been in a life-threatening event in water, and more than two-thirds of those family members drowned in the identified life-threatening event. With a total household population of 2804 persons, there was a drowning fatality rate of 502 deaths per 100,000 population in this boat using community (but this is assumed to be a total rate, not an annual rate, based on interpretation of the paper). Importantly, the <u>majority of drowning events reported by respondents occurred either during transportation (51.6%) or fishing (39.0%).</u> This highlights that fishermen are not the only, or indeed the primary, people affected by drowning on the Lake.

This incidence rate can be used to explore potential rates. For example, taking the population of fishermen across all three countries (217,000), a rate of 502 per

100,000 equates to 1089 fatalities from drowning (cumulative, rather than annual). Similarly, applying to the lake island community of 610,000, would equate to just over 3000 fatalities. This is still an extremely high death rate, but it suggests the figure of 3000 to 5000 per year is likely to be an overestimate (it may instead reflect the recent cumulative number of deaths, not annual).

Tushemereirwe et al. (2017), again in Uganda, interviewed 215 people at landing sites. Over half of the respondents reported that they travelled by boat on Lake Victoria on a daily basis. They report that over 33% (one third) of the respondents knew at least one community member who had died on the lake due to lightning in the last year (and 51/215, i.e. 24% know of more than one person who had died). When asked specifically what they believed was responsible for these deaths, multiple responses were given including high winds (88%; 62/70) and poorly maintained boats (30%, 21/70). It is difficult to translate this to quantitative estimates, but it implies very high fatality rates on the lake due to lightning strikes/high winds.

Atieno et al (2017) provide some additional survey work on Lake fatalities in Kenya. They interviewed 625 Respondents including 401 Fishermen. 82.9% of respondents reported that drowning was common on the lake.

As highlighted above, it is extremely difficult to get baseline fatalities, as reliable national or even district statistics on drownings and boat accidents do not exist and because many incidents simply go unreported. As part of the SEB study, further work was undertaken to try and establish an improved baseline level of fatalities, and to investigate reported benefits with the HIGHWAY forecasts in place.

Kenya

In Kenya, most fatal accidents end up being reported to the emergency management department of the county government. Each BMU in the Kenyan sector of Lake Victoria has a canoe with an outboard motor that is designated as a search and rescue boat. At any given time, there is a rescue boat and a search and rescue team on standby to respond to any calls for assistance. All accidents are reported to the BMU county chairmen who have a good overview of all fishing activities in their county. Kenyan government statistics of deaths from drowning on Lake Victoria are therefore likely to be quite accurate. However, they are not systematically published each year on a county-by-county basis.

To explore this, new work was commissioned (Deaths from drowning and other accidental causes in the Kenyan sector of Lake Victoria 2017-2020: Statistics from BMU County Chairmen (David Agangu, 2020). BMU county chairmen are systematically informed about all fatal accidents on Lake Victoria that involve people from the landing sites under their jurisdiction. The survey undertook telephone surveys with BMU chairmen of Migori, Homa Bay, Kisumu, Siaya and Busia counties (the five counties that border Kenya’s sector of the lake), to ask how many people had drowned or died in other types of accident on the lake between 2017 and the first quarter of 2020. While government statistics were not available, estimates of fatalities were compiled.

According to the BMU county chairmen, the number of people who died in boat accidents in the Kenyan sector of Lake Victoria rose from 60 in 2017 to 75 in 2018, before falling to 47 in 2019. This would support the conclusion above that the total figure of drownings on the lake is likely to be much lower than 3000 to 5000 per year.

Table 8 Estimates of Deaths by drowning and other accidental causes in the Kenyan sector of Lake Victoria between Q1 2017 and Q1 2020 (Source: this study, based on discussion with BMU county chairmen).

Fatalities	Migori	Homa Bay	Kisumu	Siaya	Busia	Kenya total
2017	16	18	15	5	6	**60**
Q1	3	5	6	2	1	17
Q2	7	4	4	0	0	15
Q3	2	6	3	3	4	18
Q4	4	3	2	0	1	10
2018	29	16	12	3	15	**75**
Q1	8	6	5	0	4	23
Q2	10	2	4	3	6	25
Q3	7	5	2	0	0	14
Q4	4	3	1	0	5	13
2019	7	21	9	5	5	**47**
Q1	2	4	2	2	2	12
Q2	5	6	4	1	3	19
Q3	0	5	1	0	0	6
Q4	0	6	2	2	0	10
2020						
Q1	10	8	4	2	1	25

The figures provided by the BMU county chairmen are likely to be accurate for fishermen and other BMU members. While these numbers are still high, they again imply much lower baseline numbers of deaths as compared to previous estimates. They suggest fatalities from drowning are less than 100 per year from the Kenyan side of the lake.

However, they may not include deaths arising from accidents involving the small transport craft that ply between islands in the lake and the mainland. As highlighted in earlier survey work, the numbers who die from smaller boats in such travel is potentially large (in numbers) when compared to fishermen. In the Kenyan sector of Lake Victoria, fatalities involving transport craft are likely to be small in comparison with those suffered by fishermen. About 40,000 people live on Kenyan islands in Lake Victoria. However, in recent years modern Waterbus ferries have taken over most of the passenger traffic to and from these islands. These are larger and safer than open canoes powered by outboard motors that previously provided all transport on these routes. So far, the Waterbus passenger ferries have not suffered any fatal accidents. The Waterbus that plies to and from Mageta Island in Siaya County capsized in large waves on May 2 2020 with 20 people on board, but all were saved.

Benefits of HIGHWAY in Kenya

In terms of the newly commissions surveys, this provides some additional estimates of direct impacts of the benefits of HIGHWAY.

In Kenya, looking at the estimates from BMU county chairmen (see section above), the number of people who died in boat accidents in the Kenyan sector of Lake Victoria rose from 60 in 2017 to 75 in 2018, before falling to 47 in 2019. This trend was not uniform across all counties.

Three of the five BMU chairmen ascribed the overall fall in deaths between 2018 and 2019 to two main factors:

- Stronger precautions taken by fishermen who use the KMD forecast for fishermen in Lake Victoria to plan their boat trips.
- An improvement in the weather.

However, the BMU chairmen of Homa Bay and Siaya reported that drownings had increased in their counties over this period and in the first half of 2020 because the weather had got worse. It is noted that East Africa experienced exceptionally heavy rainfall between October 2019 and June 2020, causing the water level of Lake Victoria to rise.

Further, not all accidental deaths in the lake are weather related. The Busia County chairman said that two of the six fatalities in Busia County in 2017 were caused by wild animals attacking fishermen. The Homa Bay chairman also noted that some fishermen had become careless over safety precautions, partly as a result of negligence and drunkenness and partly due to a sense of fatalism about the risk of drowning. Focus groups discussions with BMU members at 10 landing sites in Homa Bay and Siaya Counties in May 2020 also indicated that some deaths involving fishermen on the lake were (partly) caused by negligence and drunkenness.

Uganda

In Uganda, it is very difficult to obtain reliable figures for the number of deaths by drowning because Ugandan fishermen are cautious of the police and of government officials in general. Many accidents and deaths are not officially recorded.

Previous work by Powell has reported on anecdotal information. Henry Kizito, the coordinator of KAFOPHAN, based in Kalangala which serves as one of ActionAid's implementing partners in the Ssese Islands, estimated that one or two people died from drowning each month in the Ssese Islands – a total of 12 to 24 people each year. Given the estimated population of 54000 (although probably closer to 70,000 in some estimates), this implies a much lower rate that the surveys above). Willy Lugoloobi, the Chairman of Kalangala District Council, (the elected head of the local government authority), estimated that about 50 people drowned each year in the islands. But he noted that this figure varied considerably from year to year in accordance with the amount of severe weather experienced.

To explore this, new work was commissioned (The influence of the UNMA marine weather forecast on drownings in the Ssese Islands, Robert Powell and Henry Kizito, 2020). These gathered police statistics. There were also Telephone and WhatsApp survey of fishermen's leaders in the Ugandan sector of Lake Victoria on drownings and use of the UNMA marine forecast (Bakaaki and Powell, 2020).

Reduced Fatalities from HIGHWAY in Uganda

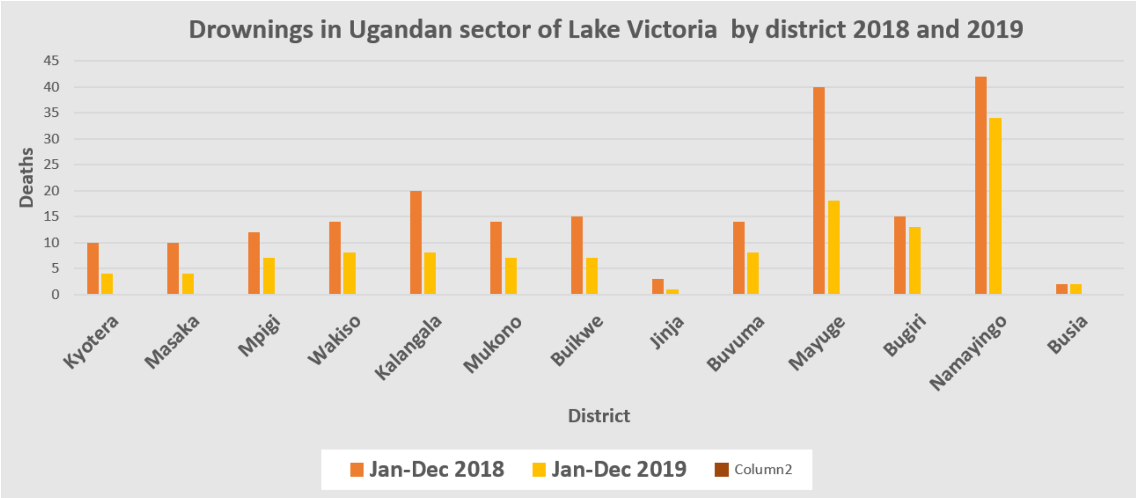
The focus groups on the Ssese islands found a reduction in most of the landing sites. This was partly attributed to forecasts. 60% of all focus group members said the UNMA forecasts had contributed to an improvement in safety on the water and 90% thought they had contributed to a decrease in the number of drownings in Lake Victoria. However, focus group participants noted that more frequent routine use of life jackets, the trend towards using larger boats, and intervention by the authorities to prevent boats going out in bad weather had also contributed to a sharp fall in the number of drownings in the islands. Further, some drownings were attributed to swimming accidents and people falling into the water while drunk.

Interviews were also undertaken to look for statistics. The police officer in charge of marine security in Kalangala District, which covers the whole of the Ssese Islands, an archipelago of 63 inhabited islands with a population of about 70,000, was interviewed. He reported that the Uganda National Meteorological Authority (UNMA) marine forecast for Lake Victoria forecast has helped to bring about a sharp fall in the number of people who had drowned in the Ssese Islands. In an interview in early June 2020, police records showed 18 people had drowned in the district during the 11-month period since UNMA launched the marine forecast for Lake Victoria in July 2019. This was 40% down on the 30 fatalities registered in the previous 12 month-period from July 2018 to June 2019. However, it is stressed that there are issues over the level of reporting of fatalities. The information from the focus groups on the Ssese Islands indicates baseline numbers are higher, perhaps significantly so (e.g. by a factor of 3 to 4). While based on insufficiently long-term data, and with no account of various attribution factors, the separate sources for the Ssese Islands (police, fisherman leaders, focus groups) all indicate a fall of around one third in drownings with the new forecasts in place.

A further initiative was undertaken to hold telephone and WhatsApp survey of fishermen's leaders in all13 districts bordering Lake Victoria in Uganda. The responses showed clearly that there has been a sharp fall in the number of drownings since 2018. Fishermen's leaders attributed this to four main factors:

- A significant number of fishermen listen to the UNMA marine weather forecasts on the radio and take greater precautions as a result.
- More frequent and consistent wearing of life jackets by the crews and passengers of small boats, mainly in response to police enforcement (38%)
- The trend towards using larger boats which are inherently safer in rough weather and water conditions than smaller craft (23%).
- The end of conflicts between fishermen and the authorities in Bugiri, Namayingo and Mayuge districts in south eastern Uganda (23%)

Based on these discussions, the estimated number of drownings in the Ugandan sector of Lake Victoria fell from 210 in January-December 2018 to 129 in January-December 2019. However, the UNMA forecast was only on air for six months of this period. Tougher police enforcement of the use of life jackets, the trend towards using larger boats and an end to conflicts between fishermen and law enforcement authorities over illegal fishing probably accounted for most of the improvement over this timeframe. Following the launch of the UNMA marine forecast in July 2019, deaths from drowning fell even more sharply; from 175 in the 12 months from July 2018 to June 2018 to 71 in the 11 months from July 2019 to May 2020. These are shown below. It is stressed that these are not official statistics but unofficial approximate estimates. This might indicate a working assumption of several hundred deaths per year from drowning in Uganda.



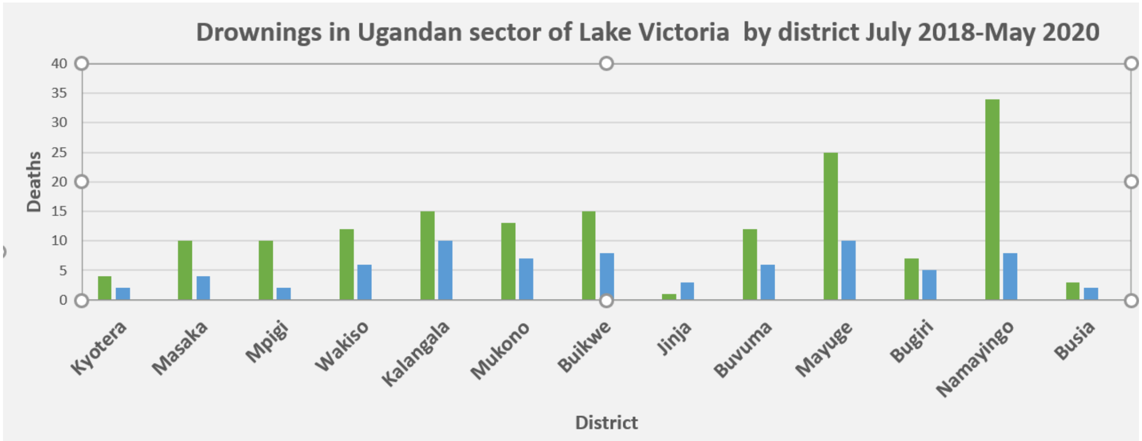


Figure 6 Approximate estimated drownings in the Ugandan sector of Lake Victoria in 2018 and 2019 **(top)** ***and July 2018-June 2019 and July 2019-May 2020*** **(bottom).**

The survey found that across the Ugandan sector of Lake Victoria as a whole, more than half of fishermen were aware of the UNMA marine forecasts broadcast by local radio stations. Most of those who were aware of the bulletins listened to them regularly. Low levels of awareness and use were only reported in two districts. On average fishermen regarded the forecast as being 75% accurate. The survey highlighted four main types of behaviour change in response to the weather information received:

- Crew and passengers wear life jackets if bad weather is forecast (cited by 85% of districts)
- Boats adjust their route to avoid sailing into wind or through large waves (62%)
- Boats do not go out if bad weather is forecast (38%)
- Transport craft carry lighter loads if bad weather is forecast (7%)

Overall, these estimates would support the conclusion that the total figure of drownings on the lake is likely to be much lower than 3000 to 5000 per year. It indicates that the number of people who die on the lake annually is likely to be lower than 3000/year.

This appears to be due to the more routine use of life jackets, the trend towards using larger boats powered by outboard motors (rather than sail), and administrative interventions to stop boats going out in bad weather. Furthermore, not all of these deaths are due to weather events, i.e. there are drownings due to other reasons (non-weather-related accidents, people swimming on the lake who drown, etc). An indicative baseline of 1000 weather related fatalities/year was therefore used.

Total Estimates of Reduced Fatalities Lake Victoria

The analysis has assessed the potential reduction in benefits from HIGHWAY. This looks at the likely theoretical maximum benefits first, then looks at the likely benefits associated with the advances made by the HIGHWAY Pilots. The starting point is the numbers presented in Figure 4 (the baseline economic benefits). As a theoretical maximum, a perfect EWS, with perfect uptake and use, by all potential users, would have the same economic benefits as current impacts. This is shown at the top of the Table. Clearly these values are very large.

However, in practice there are efficiency losses along the EWS value chain. The values must therefore take account of the losses from the forecast accuracy (and ability to predict major events that could threaten life), the number of potential users who receive information (communication losses), the number who trust and take action based on the information, and the level of action taken and is effectiveness (in reducing the potential impact). As shown in the earlier flow diagram (Figure 5), the efficiency losses from the information gathered in the SEB study (from field research, focus groups, etc.) indicates around 31%, or just over one third, of potential deaths are prevented (35%) as a direct result of the forecasts. Similar figures are assumed for all countries.

It is difficult to verify this due to the quality and reporting of statistics on drowning. The statistics from Kenya and the gathered information from the Ssese Islands seems to indicate drownings have fallen by around one third with the forecasts in place. The reduction in drownings from interviews (not statistics) in Uganda indicates a higher reduction in drownings, potentially by one half (or even more. However, as noted above, there is insufficient data series, causal factors, weather variation, etc. to attribute this alone to the forecasts. However, this seems to be broadly in line with the figure above.

To estimate the benefits attributable to HIGHWAY, these should be estimated net of the baseline figures, see Table 5. Noting that these would also need to account for communication, accuracy, use and effectiveness. It is noted that the baseline numbers are extremely low (1% to 10%) in terms of reach, and with the adjustments down for accuracy, use and effectiveness, they are much lower than this. For simplicity, they are not included (netted out) from the estimates in the Table above.

Table 9 Possible annual benefits from EWS in reducing Fatalities (for baseline of 3000 deaths per year).

	Economic benefits central	**Economic benefits (high valuation sensitivity)**
Direct Fatalities/year		
Baseline deaths	3000	3000
Awareness	85%	85%
Accuracy	70%	70%
Use	75%	75%
Effectiveness of action	70%	70%
Number deaths prevented	1071	1071
Reduced Deaths	$60.9 million/year	$209.0 million/year
Reduced impact in terms of dependents affected	$18.3 million/year	$62.7 million/year
Loss of boat and engines	$1.0 million/year	$1.0 million/year
TOTAL annual benefits	**$80.1 million/year**	**$272.7 million/year**

However, as above, we believe the estimate of 3000 drownings per year is high. This is based on the (limited) statistics gathered and previous studies and surveys. The number of official statistics on Lakeside drownings in Kenya (less than one hundred/year), and the unofficial estimates gathered in Uganda (several hundred/year), indicate the number is likely to be well below 3000. Tanzania has a large lakeside and lake island community, but even accounting for this, it might be the number of drownings are closer to 1500/year, although this is still an extremely high number. We also consider that not all of these will be weather related. There are no statistics on the cause of drownings, but we factor down the total deaths by one third, and thus use a baseline of 1000 weather related deaths year. **When the efficiency along the weather chain is accounted for, we estimate that the marine information in HIGHWAY is avoiding 312 deaths/year.**

Table 10 Possible annual benefits from EWS in reducing Fatalities (for baseline of 1000 deaths per year).

	Economic benefits central	Economic benefits (high valuation sensitivity)
Direct Fatalities/year		
Baseline deaths	1000	1000
Awareness	85%	85%
Accuracy	70%	70%
Use	75%	75%
Effectiveness of action	70%	70%
Number deaths prevented	**312**	**312**
Reduced Deaths	$20.3 million/year	$69.6 million/year
Reduced impact in terms of dependents affected	$6.1 million / year	$20.9 million/year
Loss of boat and engines	$0.35 million/year	$0.35 million/year
TOTAL annual benefits	**$26.4 million/year**	**$90.6 million/year**

Boat operations, fuel savings and improved catch

The WISER HIGHWAY resilience study (WMO, 2019), which undertook analysis in Kenya only, reports that benefits identified by the beneficiaries include;

- Early preparations which contribute to reduced loss of lives and property.
- Earlier preparation helps fishermen know what kind of hazard to expect and therefore budget for the amount of fuel needed;
- Predicting the weather helps the fishermen decide on the appropriate fishing method, therefore increasing their catch;
- Living status has improved due to increased income from the fishing industry.

The study asked interview questions on socio-economic benefits of improved HIGHWAY weather and early warning, including 'Approximately how much have you saved by reducing losses from hazards? (USD per year)'

Table 10 Survey responses in Kenya on savings made (reduced losses) of improved weather information from HIGHWAY

USD	Busia	Siaya	Homabay	%
10,000 and above	0	4	0	**1.50%**
5,000 and above	3	1	6	**3.75%**
1,000-5,000	18	17	53	**32.96%**
Below 1,000	15	48	102	**61.80%**

These numbers can only be considered as being indicative. The study found that 61% of the beneficiaries had saved less than $1,000, although a small number (~5%) had saved more than $5,000 annually.

The analysis also asked 'Have your earnings improved due to use of weather information? If so, by how much (amount in USD) (per year)'.

Table 11 Survey responses in Kenya on higher earnings from improved weather information from HIGHWAY

USD	Busia	Siaya	Homa Bay	%
10,000 and above	4	4	0	3.25
5,000 and above	2	1	15	7.32
1,000 - 5,000	26	14	35	30.49
Below 1,000	4	49	92	58.94

The table indicate the use of climate information has improved the earnings of 61% of the beneficiaries by more than $1,000 annually. 30% of the respondents stated that their earning has increased by between $1,000 and $5,000, and 10% responded it had saved more than $5000/year. These numbers seem high when compared to the bottom up calculations on fuel savings from earlier in this report. It is possible interviewees are mixing up avoided losses and higher earnings. We therefore do not use these numbers.

More detailed analysis was undertaken using focus groups.

Fuel savings

There was widespread agreement in the focus groups in Kenya and Uganda that the forecasts were reducing costs, in particular, reducing the fuel consumption of boats powered by outboard motors by 12 to 24 litres a week (2-4 litres per trip) in Kenya and 15 to 30 litres per boat per week in Uganda. Using the latter figures, this equates to 750 to 1500 litres per year, and a broadly equivalent $ saving (fuel varies typically between $1.00 and $1.30 per litre).

Focus group members said the amount varied according to the size of the engine and the prevailing weather on the lake. The biggest savings were made by transporters, who use larger boats and more powerful engines than the fishermen. The estimates given for the amount of fuel saved all referred to May 2020, when there was heavier rainfall than usual for the time of year.

The estimated benefits are set out below, based on the number of boats. Note that less than half the fishing boats on Lake Victoria are engine-powered. The FRAME surveys provide information on the number of powered boats, though these are increasing. This is likely to be the case particularly in Uganda, because of the minimum length of boats introduced. The awareness, accuracy and use are based on average values from the table above. The effectiveness is based on reported savings from focus groups, and thus considered to reflect observed effectiveness and thus entered as 100%.

Table 12 Potential Annual Fuel Savings from improved weather information from HIGHWAY

	Kenya	Tanzania	Uganda	total
Fishing Boats	13,500	31,800	29,400	74,700
Motorised*	3,400	11,083	10,996	27,479
Fuel savings/boat/yr	$750 to $1500			
Max savings/all boats	$2.5 to 5.1 million/yr	$8.3 to 16.6 million/yr	$8.2 to 16.4 million/yr	$ 19.1 to 38.2 million/yr
Awareness %	80%	80%	80%	
Accuracy%	70%	70%	70%	
Use %	75%	75%	75%	
Effectiveness %	100%	100%	100%	
Estimated benefit/yr	$ 1.1 to 2.3 million/yr	$3.7 to 7.4 million/yr	$3.7 to 7.4 million/yr	$8.5 to 17.1 million/yr
		4		
Passenger Boats	-	1115	1725	2840
Fuel savings/boat/yr	$1500			
Max savings/all boats		$1.7 million	$2.6 million	$4.3 million/yr
Awareness %	85%	85%	85%	
Accuracy%	70%	70%	70%	
Use %	75%	75%	75%	
Effectiveness %	100%	100%	100%	
Estimated benefit/yr		$0.7 million/yr	$1.2 million/yr	$1.9 million/yr
TOTAL ANNUAL BENEFIT				**$10.4 to $19.0 M/yr (central $14.7M)**

*Information from frame surveys.

This indicates the fuel savings could be $10 to $20 million year due to improved weather information (with a midpoint of $14.7M/yr). This benefit was not foreseen at the start of the project, and is a very significant benefit. There are also additional benefits from the reduction in GHG emissions associated with fuel use. These are estimated in the later CBA section.

Fish catch

Although most fishermen said they had been able to achieve larger catches with the help of weather information from the forecast, this was disputed by others who said the size of the catch depended more on seasonal factors.

In Kenya, estimates of the additional income received from improved fish catches varied between the four landing sites (Kenya) from 14,000 to 21,000 Kenya shillings (US$130 to $195 per boat per week). However, we do not think these benefits are plausible, due to the size of the increase relative to baseline values.

The Uganda focus groups did not report additional fish catch (other than 1 landing site out of 5, with only a very modest increase).

Given the uncertainty, these estimates have not been added, but if true, they would be significant. It is also highlighted that given the Lake is already over-fished, increase fish landings might also have some detrimental effects.

Fish Drying

Baseline vulnerability of fish drying

A further group of end-users benefits were found to arise for fish driers (Powell, 2020). In Uganda, women buy silver fish from the fishermen and dry it in the sun for two or three days. The fish are dried on mats spread out on the ground at the landing site or – less frequently - on racks of raised netting. The women brush the drying fish constantly to turn it over. Once the fish is fully dried it is bagged up and sold wholesale.

If rain falls on Silver Fish while it is drying, it starts to rot and is no longer fit for human consumption. In such cases the women are forced to sell the dried fish at a steep discount of up to 40% to 50% for use as animal feed instead. This represents a large direct weather impact on the earnings of fish traders.

Silver Fish processors in Uganda said that before the UNMA forecast came along they used to lose up to 40% of their fish in this way during the March, April, May and October, November, December rainy seasons.

Benefits from HIGHWAY

Powell interviewed women in Uganda in November 2019. The silver fish (omena) are normally dried for three to five days in the sun on mats spread out on the ground or on raised racks of netting. He found that they had started to use the UNMA marine weather forecast to inform their fish buying activities. If there is a strong likelihood of rain, they buy less fish to cut their losses if it gets wet and rots. The women said the forecasts also helped them with fish marketing.

This was investigated further with focus groups in Kenya and Uganda.

In Kenya, a special focus group with 20 women fish processors and traders (Powell and Agangu, 2020) was convened at Koguna landing site in Kenya to gauge the impact of the KMD forecasts on the shore-based women who buy, dry and sell silver fish (omena, or mukene in Uganda), a small fish which is widely targeted by night fishermen. Six of the 20 women in the focus group owned fishing boats which supplied them with fish. The other 14 purchased fresh fish from fishermen to dry and sell.

These women reported that they had also benefitted economically from the forecasts. All those present followed the KMD forecasts carefully to know whether conditions would be good for drying silver fish (omena). The women said more than half their fish can rot if rain falls on the fish while it us spread out on mats on the ground to dry in the sun. Sometimes heavy rain causes flooding which sweeps the omena off the drying mats completely, giving rise to a 100% loss. The weather information helped them to decide how much fish to buy so. If rain is forecast, they buy less fish in order to minimise their losses if fish spread out to dry in the sun gets rained upon. They also used the forecasts to decide when it would be safe to travel on the lake.

The women's other main concern is that rain often makes the dirt roads leading to the landing site impassable for the trucks of traders who come to buy their dried fish. If there is heavy rain in the forecast, they often send their fish to market earlier than planned to make sure it gets there in good condition. The women noted that in view of these factors, the weather often affects fish prices. They therefore use information from the forecast to their advantage in fish trading.

Those who owned fishing boats were also concerned about the impact of weather on their boats and crews. They said that whenever KMD forecasts bad weather they instruct their crews to wear life jackets and carry extra fuel for the outboard motor. Three of the six boat owners said they do not allow their boats to go out to fish if the forecast is really bad.

The women were unable to reach a consensus on the volume of dried fish or the amount of money that they saved by using the KMD forecast to help plan their activities. They said the savings varied from one person to another, but that in all cases they were significant.

Similar focus groups in Uganda found similar findings (Bakaaki and Powell, 2020).

Silver fish (mukene) dryers said the forecasts helped them to reduce the amount of drying fish that they lost from rotting in the rain by up to 25% (this is lower than some other reports in other areas, which finds 40%). Nonetheless, the forecasts enabled each one to save between 30,000 and 100,000 shillings (US$8 and $27) per week.

This would equate to $400 to $1400 per year per trader.

There are not statistics on the number of fish traders (at least this is not captured in the FRAME survey, although there is some information on fish drying racks). It can be assumed there are multiple fish traders at all landing sites/ BMUs. There are 1500 BMUs, although fish drying does not take place at all sites (though were drying does take place, there are normally several drying businesses per landing site). In the absence of information, we make an estimate of 5000 fish drying businesses around the lake.

This would mean theoretical losses in the baseline of $2 million to $7 million/year. Again, these estimates must be adjusted by efficiency losses, and thus awareness, accuracy, and use (noting effectiveness is based on observations). Applying the same % values for these as above, this generates benefits of $0.93 to $3.1 million/year.

This indicates the savings to fish driers could be $1 to $3 million year due to improved weather information (with a central estimate of $2 million/year). These benefits also accrue to women. It is stressed these estimates are uncertain and need further validation, but this benefit was not foreseen at the start of the project, and is a very significant benefit. Further work to improve estimates of the number of fish dryers would help improve this estimate.

Direct benefits from HIGHWAY

The total direct benefits are brought together and indicate large economic benefits, even with the efficiency losses across the value chain.

As highlighted above, the number of people who die on the lake annually is likely to be lower than 3000/year. The benefits of HIGHWAY are presented below assuming 1000 weather-related fatalities/year.

Table 13 Total direct annual benefits (with revised baseline estimates)

	Central estimate $M/year	High valuation sensitivity $m/year
Reduced fatality*	20.3	69.7
Indirect benefits (dependents)	6.1	20.9
Reduced lost assets	0.3	0.3
Fuel savings	14.7	19.0
Fish Drying benefits	2.0	3.1
TOTAL (annual benefit)	**43.5**	**113.0**

*based on baseline rates of 1000 weather related deaths/year. Note benefits of HIGHWAY for Tanzania based on evidence from Uganda and Kenya.

The estimated economic benefits (central estimate) are $43.5 Million/year. With a higher VSL, the economic benefits rise significantly (to over $100M/year). As the improved weather forecasts will deliver benefits in future years, the cumulative benefits of time will be very large.

Wider (other indirect) benefits from HIGHWAY

There are also indirect benefits that arise from the improved Lake weather and severe weather forecasts.

These include benefits reported by the field research, which includes the use of the forecasts for decisions about farming, tourism activities and the operation of electricity and water services.

Many fishermen are also farmers. Several fishermen interviewed (Powell, 2019) said they were also using the forecasts to decide when to cultivate or harvest, and this would also apply to other farmers, notably those on the islands of the Lake and in the immediate lakeshore vicinity.

It was also found that hotels use the marine forecasts to help plan tourist activities and the use by Kalangala Infrastructure Services (which distributes forecasts to all its employees by WhatsApp) and especially the potential impact of lightning.

As highlighted above, there are almost 5.4 million people – approximately 1.2 million households – who live in fishing communities around the coastline of Lake Victoria and on islands in the lake. This is ten times higher than the number of direct beneficiaries (which is assessed as 450 thousand). This highlights the potential for large indirect benefits, although this would require new forecast products (as compared to the marine products in HIGHWAY).

Rwanda

Alongside the three lake countries, Rwanda was also included in HIGHWAY, as it is part of the wider Lake Victoria basin.

The country's meteorological agency and staff benefited from HIGHWAY activities, including various capacity building exercises HIGHWAY has delivered, especially in terms of IBEWS.

There were benefits from the HIGHWAY funded investment in forecast information, science, and forecast training, although these have not been quantified of valued. These activities will have supported and enhanced the severe weather warning forecasting for Rwanda.

There is also the potential for Rwanda to use the approach from HIGHWAY and apply to Lake Kivu in the future, with a similar severe weather forecast.

Step 5. Costs of the Project / Step 6 Benefits versus Costs

This section reports on the next two steps. Step 5. Assess the costs of the project, including investment in meteorological stations, system operation and information provision (capturing equipment and resource (labour) costs). Step6. Compare benefits against costs where possible in monetary terms.

The costs of HIGHWAY is approximately £4.2 million, approximately equivalent to $5.5 Million.

The annual economic benefits, per year, are estimated above at $44M/year and thus the project has an extremely high benefit to cost ratio.

A cost-benefit analysis was carried out to assess the cost-effectiveness of the Highway project. A discount rate of 3.5% and 10% were used to discount benefits over a period of 5 years.

However, a further assumption was made on the sustainability of the project benefits beyond project completion. Unless all the beneficiary countries commit to securing the necessary funding to support the operation and maintenance of the EWS equipment and activities, it is reasonable to assume that the stream of benefits will gradually diminish over time, starting from year 2. In the CBA, it was estimated that, without further donors' support, benefits could disappear in about 3-4 years, reducing by 20% (at the end of year 2), 50% (year 3), and 100% (year 4).

The economic benefit stream set out above was used. An additional benefit of reduced greenhouse gas emissions from reduced motor fuel was also included. This used the Defra Greenhouse gas reporting: conversion factors 2020 (Defra, 2020) and the international carbon prices in the UK Appraisal guidance (HMT, 2020). These were compared to the costs of HIGHWAY.

Table 14 Net Present Value and Benefit to Cost Ratio for HIGHWAY

CENTRAL		**$Million**		HIGH VALUATION		**$Million**
NPV @3.5%		87.97		NPV @3.5%		227.8
NPV @10%		73.33		NPV @10%		192.9
BCR (10%)		15.6		BCR (10%)		39.5

The analysis finds the net present value of HIGHWAY is $73 million, with a benefit to cost ratio of 16:1, at 10% discount rate. This increases at lower discount rate, and with the high valuation estimate.

This compares extremely favourably to other W&CS investments.

There are a reasonable number of studies (Clements, 2013: ECONADAPT, 2015) that undertake economic analysis of meteorological or hydro-meteorological information) for use in early warning systems (EWS) for evacuation or preparation in advance of tropical storms or floods. The benefits arise from the anticipation and preparation for extreme events and the reduction in damage costs to assets and fatalities and injuries avoided. These report high benefit to cost ratios, with values of

5:1 (i.e. $1 invested would lead to $5 of benefits), though with a wide range, and much higher BCrs for introduction in some highly vulnerable least developed countries (Shreve & Kelman, 2014). Estimates of benefits vary according to the effectiveness assumed, whether non-market impacts are valued (especially avoided fatalities and injuries/health impacts), and on fully capturing the categories of activities (and costs) associated with effective systems. The benefits of these systems generally increase under climate change, because of the higher storm surges with sea-level rise, the potential changes in storm intensity and frequency and because of increasing flood risks in many areas. The recent Global Commission on Adaptation (GCA, 2019) reported that strengthening early warning systems had high benefit to cost ratios (9:1).

<u>The fact that HIGHWAY is delivering BCRs that are higher than these benchmark values indicates the project is delivering very high value for money.</u>

Step 6 Exploring how benefits could be enhanced (Future Phase)

Possible benefits from a Regional EWS Vision 2025 (Business Plan) -

In June 2019, the National Meteorological and Hydrological Services (NMHSs) of the East African Community (EAC) agreed to develop a more integrated and collaborative regional approach to the delivery of Early Warning Services (EWS) over the period 2020 - 2025. The project builds on work undertaken through the World Meteorological Organization managed HIGHWAY project, which has been engaged in developing regional EWS capacity around the Lake Victoria Basin with a particular focus on fishing and marine transport. This EWS Vision 2025 takes this work forward with a view to expanding both the geographical scope (e.g. to the wider East African region) and sectoral coverage (to other sectors impacted by severe weather).

The EWS Vision 2025 Programme will deliver activities aimed at 4 objectives:

- To establish an effective institutional framework for the generation, uptake and use of a Regional Early Warning System
- To improve access to all operational data sources to support the generation and maintenance of a Regional Early Warning Services
- To strengthen integration between producers and users to develop innovative, accurate tailor-made EWS products through co-production
- To improve methods, strengthen the capacity of communicating and promote understanding and use of EWS products with relevant producers, technicians, forecasters intermediaries and users

The **Regional EWS Vision 2025** will enhance regional cooperation with pooled resources, harmonise practices, and facilitate knowledge exchange to deliver impact-based early warnings across East Africa in a consistent way. To that end, the Severe Weather Forecasting programme (SWFP) will underpin the operationalisation of the Vision in delivering the regional consensus forecasts and potentially aggregating at the regional level the warnings produced at the national level through a proposed East Africa Community multi-hazard Alert System (EACAS).

The 2025 Vision Programme will deliver activities by following a “value chain approach” (see Figure 1). For each step of the value chain, from production to use of weather and climate information (vertical columns) activities will be undertaken which address the current barriers to an effective EWS, including investment in infrastructure, technical and institutional capacity building, training and research.

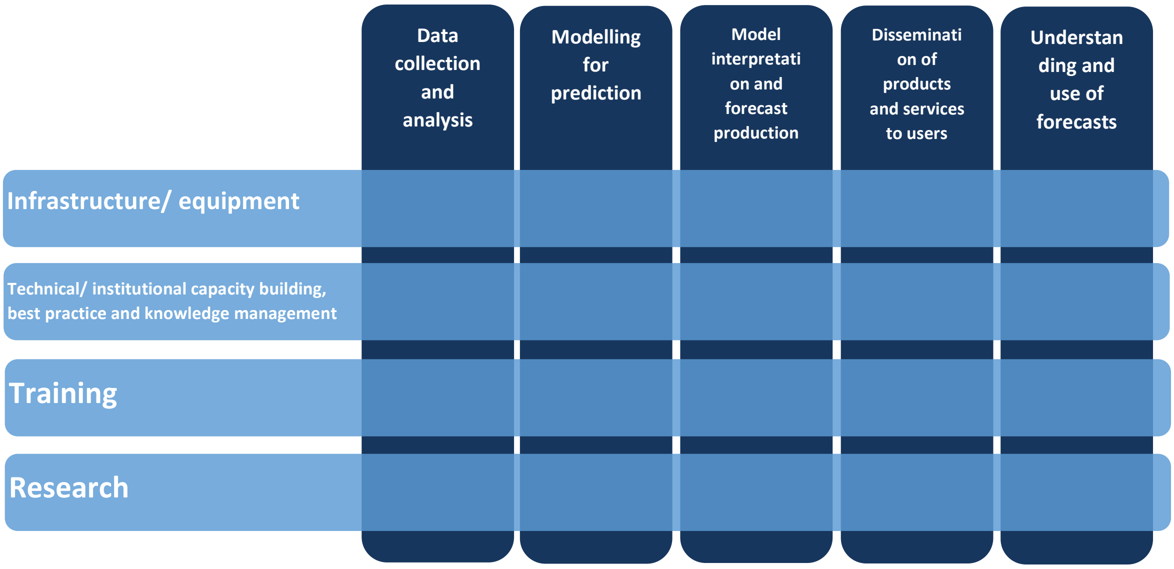


Figure 7 Graphic depiction of the proposed value chain, based framework for the implementation of Vision 2025. (Note that this figure is identical to Figure 3 of the Concept Note)

In particular, the activities of the Programme will be:

1. **Collection and calibration of quality data and its integration into national climate databases.** Investment is required to achieve an optimum observing network to comply with the Global Basic Observing Network (GBON), with significant intervention required in some countries to establish even the most basic observations network. Further investment in weather radar in the region is needed to produce national composites with the possibility of generating a regional radar composite for East Africa from national composite images. Other infrastructure needs in support of the Regional EWS include improving communication links for data collection at the national level and for data sharing at the regional level, including improving connectivity with the Regional Telecommunications Hub (RTH) hosted by KMD to ensure data sharing using WIS.

2. **Training and working groups to enhance capacity in NWP and wave modelling and improve the accuracy of modelling**. Activities include training on Numerical Weather Prediction (NWP) fundamentals and specific training for different aspects of NWP, as well as investment in the necessary infrastructure to support operational NWP. Technical working groups to build capacity and capability for key thematic areas (e.g. radar and NWP) will be supported to share experience and knowledge, and to develop best practice through a knowledge sharing system.

3. **The creation of impact-based forecasts and warnings which pertain to users' risk perception.** The EWS Vision 2025 will take forward the work previously carried out by the HIGHWAY Project and other WISER national projects (e.g. MHEWS in Tanzania) on impact-based forecasting by supporting

training activities on model, satellite and radar interpretation, on forecasting and nowcasting methods, developing a nowcasting component at the regional level, collaboratively develop, as a region, a set of user needs relating to Meteosat Third Generation (MTG) data (including lightning), building a knowledge system by cataloguing high impact weather and mapping them against the vulnerability and exposure of communities and sectors, and contributing to the production of the East Africa Forecaster Handbook.

4. **Training, capacity building and sharing of best practice to enhance the capacity of intermediaries responsible for the communication of forecasts to the public.** The programme will support activities to raise the awareness and understanding of weather and climate, including EWS, amongst users, and make EWS products accessible to remote communities including the most vulnerable groups. Intermediaries and community representatives will be involved in regional workshops to consolidate regional approaches to EWS, including the development of Standard Operating Procedures (SOP). Further, the project will promote multidisciplinary research focused on transformative behavioural change, use of indigenous knowledge, socioeconomic impacts of weather/ natural hazards and related socioeconomic benefits of the provision of EWS.

Regional EWS: Regional cost savings

In a regional context, an integrated system can generate significant economies of scale and scope. This means there are potential benefits from the cost savings from the implementation of a regional EWS (as compared to national EWS). A regional EWS would enable countries to pool resources and benefit from economies of scale. This is particularly relevant since individual investment is costly and developing countries face budget constraints due to other development priorities.

This is because the financial resources available to NMSs are usually relatively modest. Most NMSs are funded in the range of 0.010–0.050 percent of gross domestic product, with a global average of 0.012 percent. Per capita spending on NMSs ranges from less than US$0.10 (for at least one NMS in every World Meteorological Organization (WMO) region) to almost US$13.00. The average for developed countries is about US$3.50 per capita of national population, and the average for least developed countries is about US$0.25 (Zillman 2003, in Rogers and Tzirkunos 2013). The vast majority of NMSs receive most of their funding (about 80 percent) in the form of direct government appropriations (WMO, 2012). In developing countries, donors play an important role in supporting national and regional institutions.

NMSs do not typically operate on a cost-recovery basis. A 2000/01 WMO survey revealed that more than 50 percent of the NMSs responding reported cost-recovery levels of less than 10 percent of their cost of operation, but a small number (under 5 percent) had cost-recovery levels in excess of 50 percent. Cost recovery is most commonly practiced in Europe, and the cost-recovery levels are higher there (around

20 percent). 89 percent of the NMSs responding indicated that the overall level of government funding was either a very significant or a significant issue (WMO, 2012).

Lastly, if a part of NMHS costs are due to purchases or service fees abroad, the behaviour of the exchange rate can significantly influence the costs. In principle the same applies to revenues, but generally, for most NMHSs, sales abroad tend to be much smaller than purchases abroad. If the national currency depreciates, the costs of purchases abroad increases for the NMHS (WMO, 2015).

In the light of the above, regional consortia can contribute to reduce the costs of operating meteorological systems by exploiting economies of scale and scope. For example, certain elements of an advanced forecasting system can be funded collectively, and the resulting information shared by all the countries within a geographic region. Similarly, since multi-hazard early-warning systems (MHEWS) are activated more often than a single-hazard warning system they provide better functionality and reliability for dangerous high-intensity events that occur infrequently.

There are a few studies in the literature which attempted to estimate the cost-savings resulting from the economies of scale which can be achieved through regional and international programmes:

- UN/ISDR (2008), for example, estimated that if the NMHSs of seven countries of South Eastern Europe (Albania, Bosnia and Herzegovina, Croatia, the Former Yugoslav Republic of Macedonia, Moldova, Montenegro and Serbia) were strengthened individually, country by country, and without better cooperation with national aviation weather services, the cumulative investment needs (hardware plus operational costs; without interest) would be about €90.3 million over five years. However, if regional cooperation and data sharing could be carried out, and the hardware was designed to allow for cooperation with the rest of Europe, the total investment needs for these seven countries could be reduced to approximately €63.2 million. This means regional cooperation would generate savings worth 30% of the sum of the investment costs incurred individually by countries.
- Similarly, World Bank et al. (2013) estimated that through cross-border data sharing, technology transfer and capacity-building in the Mekong River Basin, individual NMHSs such as the Lao People's Democratic Republic Department of Meteorology and Hydrology could reduce investment needs for modernization by up to 40% (World Bank et al., 2013).
- In the Indian Ocean and South East Asia, the establishment of the Regional Integrated Multi-Hazard Early Warning System (RIMES)[16] is an example of

[16] The Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES) is an international and intergovernmental institution, owned and managed by its Member States, for the generation and application of early warning information. RIMES evolved from the efforts of countries in Africa and Asia, in the aftermath of the 2004 Indian Ocean tsunami, to establish a regional early warning system within a multi-hazard framework for the generation and communication of early warning information, and capacity building for preparedness and response to trans-boundary

both economies of scale and scope at work. In this case, capital investment costs have been covered by donors, namely UNESCA and DANIDA, for a total of USD 6 million; and individual countries in the region only pay for total annual recurring costs of USD 2.5 million. These compare very favorably with the USD 200 million capital cost and USD 30 million annual operating cost for the tsunami systems of four countries – Australia, India, Indonesia and Malaysia (Subbiah et al., 2008). Moreover, inclusion of a multi-hazard approach to RIMES enlarges its scope. Integration of other common hazards, such as floods, thunderstorms, cyclones/ typhoons, also acts as a pull-factor for some countries for whom tsunami is not a major concern compared to other more frequent, low-impact hazards (Subbiah et al., 2008).

- Global programmes such as the European program GMES (Global Monitoring for Environment and Security) cost-benefit assessments show that earth observation services generate an annual benefit of €10 billion by 2030 (Rogers and Tzirkunos, 2013).

For some countries, the costs of developing standalone forecasting services might be prohibitive and this makes a stronger case for joining regional programmes. For example, running Local Area Numerical (LNM) models require computing capacity, which depends on a number of factors such as which type of model will be chosen, which grid size is going to be used, and how often the model is gone to be run daily. The investment cost of a super-computer is around €1,2 – 1,5 million, although some modelling can also be done with much cheaper equipment starting from a powerful PC costing €2000 (Tammelin, 2012). However, running an advanced NWP model for a whole region is likely to be more cost-effective than having individual countries establishing a full scale (yet less advanced) numerical weather prediction system (Tammelin, 2012).

Similarly, radars require high capital investments as well as high operation and maintenance costs (10-15% of capital costs). Radars nevertheless are very powerful tools for short-term weather forecasts and tracking of precipitation. The most significant advantage of radar is the production of high-resolution near-real-time regional composite pictures that depict movements of precipitation areas and thunderstorms. This makes a strong economic case for regional cooperation, particularly for small countries. The same applies to lightning detection. If a network is established in cooperation the same accuracy for lighting detection can be achieved with less monitoring stations, and only one (regional) hub instead of multiple national hubs. Rough cost estimates are $75,000 per station (5 to 25 needed, depending on the country) and $450,000 per hub with software (Tamellin, 2012). A regional approach could therefore save several millions in investment expenses compared to a situation where countries build their own systems.

hazards. RIMES was established on 30 April 2009, and was registered with the United Nations on 1 July 2009. See http://www.rimes.int.

Regional EWS: Analysis of capacity benefits

Capacity building is a fundamental component for the success of regional programmes, and at the same time cooperation programmes have the benefit of strengthening the capacity of member countries by providing a platform for knowledge and expertise sharing.

The benefits of training are higher the lower the capacity of individual countries' NMSs. In such cases, Regional Specialized Meteorological Centers (RSMCs) can play an important role in helping countries develop, customize, and sustain their services. A greater use of RSMCs also enable countries to focus more on the principal role of communicating warnings and delivering other services to the public and weather- and climate-sensitive sectors (Rogers and Tzirkunos, 2013).

Face-to-face workshops are essential elements of meteorological and hydrological training. Economies of scale can be realised if training courses are implemented commonly on a regional scale rather than individually for each country. An example is provided by the European virtual organization for meteorological training, EUMETCAL, which was set up by EUMETNET to share training materials and exploit e-learning programs and methods. EUMETCAL brings together tools from many different sources, including EuMeTrain, the U.K. Met Office, the European Centre for Medium-Range Weather Forecasts, EUMETSAT. The exchange of knowledge is favoured within and among the various EUMETNET Projects by organizing conferences, workshops and other meetings and by liaising with external Forecasting bodies (WMO, EMS, WGCEF etc.).

Joint training sessions, including workshops and drills, are typically arranged for neighbouring countries in regional and bilateral exchange in order to familiarize them with practices and procedures in the region. This can be very beneficial for creating confidence and facilitating cross-border communication among forecasters. Training include topics such as (WMO, 2011):

- Interpretation and use of processed products;
- Use of conceptual models;
- The development, coordination and implementation of special indices for warnings of severe weather;
- Incorporation of local severe weather research results into operational practices;
- Improved communication skills; and,
- Familiarity with practices and procedures of neighbouring NMHSs.

Finally, regional platforms can contribute to generating knowledge, tools, and shared programs of action around climate change – both mitigation and adaptation. Models can be used to produce long-term forecasts and vulnerability maps, which can be used to raise awareness and inform regional responses to climate change-related hazards in member countries.

Regional EWS: Greater accuracy and reliability

Many regional programmes have improved the lead-time and reliability for alerts and warnings, which in turn contributed to improving the accuracy and the credibility of national systems. This helps increase trust amongst the public in the national weather systems, and increase the impact of weather services, for example by widening reach (greater number of users) and improving the response to warnings.

In some cases, regional programmes have contributed to greater cooperation between different actors and experts from different fields such as civil protection, hydrologists, avalanche experts, forest fire fighters etc. A common strategy and clear operational agreements between different experts and organisations have proven to be very helpful in improving the accuracy and reliability of forecasts and warnings. Importantly, collaboration between NMHSs and the civil protection has proven to be beneficial also for the design of a system for the dissemination of warnings to the public (WMO, 2011).

Finally, regional programmes can favour the ongoing strategic discussion among members which lead to the identification and initiation of projects for collaboration, harmonisation and coordination in support of more efficient forecasting systems, and improved regional and short-range weather forecasts.

Regional EWS: Regional response coordination

Regional programmes can contribute to strengthening the response of countries to regional hazard requiring a regional response. In the case of early warning systems, regional programmes of cooperation need regular reviews of the process and regular training of operational staff. Reviews of the process should be held at least once per year and it is highly recommended that they also take place after a significant event (WMO, 2011). NMSs can benefit from these review meetings, which also provide important occasions to identify shortcomings, assess training needs, and take common steps to mitigate against future risks.

NMHSs may set up bilateral and/or regional coordination arrangements according to circumstances. Localized and of short duration weather phenomena do not generally necessitate regional coordination. However, if the countries are geographically small, regional coordination with respect to localized and short duration hazardous weather phenomena might be advantageous too (WMO, 2011). On the other hand, large-scale phenomenon such as a tropical cyclone, can easily have a widespread disastrous effect and would necessitate multilateral coordination (WMO, 2011).

A review of the evidence on regional programmes

A review was conducted to gather information about five existing regional programmes and their effectiveness in achieving the benefits described above: capacity strengthening, greater regional coordination, greater accuracy and reliability of climate services, and economies of scale and scope. The programmes reviewed are briefly described below, and more in detail in the Annex. Unfortunately, the review revealed that the quantitative evidence of the benefits of such consortia is very limited, with benefits generally described in qualitative terms only. The estimation of the economies of scale and scope of such programmes is not available in the literature. Nevertheless, there is some evidence that they all contributed to strengthening the capacity of national institutions, improving the accuracy and reliability of weather forecasts, and improve regional coordination.

Table 15 Programmes reviewed for the regional analysis

Regional program	Geographical scope	Objective
EUMETNET -OPERA	Europe and Balkans	To improve the harmonization of radars and their measurements.
The WMO Severe Weather Forecasting programme (SWFP)	75 developing countries in eight sub-regions including Southern Africa, South Pacific, Eastern Africa, South-East Asia, South Asia, Central Asia, West Africa and Eastern Caribbean	To make global-scale products from the World Meteorological Centres (or Global Centres) available to the Regional Specialized Meteorological Centres (RSMC) that integrate and synthesize them in order to provide daily guidance for National Meteorological Centres (NMCs or NMHSs) in their geographical region.
EMMA / METAOALARM	Europe	To collect the authoritative warning information for meteorological and hydrological hazards delivered by National Meteorological and Hydrological Services (NMHSs) across the European domain for the next 48 hours and to publish these warnings online in a consistent way (via METEOALARM).
HIRLAM and ALADIN	10 countries (Denmark, Estonia, Finland, Iceland, Ireland, Lithuania, the Netherlands, Norway, Spain, and Sweden, with France as an associate member	To produce operational weather forecasts for the member services, with particular emphasis on the detection and forecasting of severe weather and services related to public safety.
ICPAC	Still in a demonstration phase, the Centre is a candidate to be fully designated as a WMO Regional Climate Centre (RCC) of excellence in the provision of climate services to national and regional users	Djibouti, Eritrea, Ethiopia, Kenya, Somalia, South Sudan, Sudan and Uganda as well as Burundi, Rwanda and Tanzania.

Analysis of costs of EWS Vision 2025

To implement the Vision, the high-level funding required, as estimated in the technical reports, is in the region of 17,000,000 USD (£13,025,000) for a five-year programme, in addition to the investments already proposed in CAPEX 2. A supplementary programme of approximately 8,000,000 USD (£6,130,000) over the same five-year period is proposed for weather radars.

Analysis of potential benefits in marine information from EWS 2025

The project has drawn on the lessons from the analysis above to consider how the further enhancements in the Regional EWS Vision 2025 might further improve marine information, and reduce existing high efficiency losses and thus increase benefits.

The field research and focus groups indicates that communication of information (the reach) could be improved. For example, some of the analysis indicated beneficiaries would prefer to receive weather information directly through their phones, and there has been success from the use of WhatsApp. This also leads to recommendations on improving communication and uptake of information, including future training (radio, use of WhatsApp, social media, weather apps). The information from some landing sites already indicates that with these improvements, 90% of potential beneficiaries could be reached.

There is also the potential to enhance the accuracy of the forecasts and the severe weather warnings which accompany them. The advancement of science set out in EWS Vision 2025, and planned NMS investments in infrastructure and staffing capacity, would deliver a higher rate of forecast accuracy, and we consider 90% accuracy is achievable.

Moving to use and uptake, the HIGHWAY study found much higher use of information at landing sites where community outreach initiatives had taken place to raise awareness of the new forecasts among potential users and communicate weather information to them via community intermediaries. The pilot activities in the Ssese Islands in Uganda and along the western shore of Homa Bay County in Kenya show that benefits could be improved further by extending such outreach activities to more areas. This means an improvement to a 90% level of uptake and use is feasible, especially given the activities in Regional EWS Vision 2025 on impact-based forecasts and capacity and training.

Finally, it would also be possible to improve the advice provided to fishermen and other stakeholders, to help them use the information most effectively. This could include the activities on Intermediaries and community representatives as well as other local emergency preparedness. With such measures, the overall effectiveness could also increase to 90%.

With these updates, the efficiency losses in the weather chain would fall dramatically. A reanalysis of the benefits from these improvements would lead to a more than doubling of benefits.

Working with the baseline of 1000 weather-related deaths/year, and using the improvements outlined above, the updated weather and severe weather forecasts are estimated to reduced deaths by 656 deaths per year (as compared to 312 deaths per year under HIGHWAY). This increases the weather-related deaths avoided from 30% (in HIGHWAY) to 66%. The revised overall benefits are shown below.

Table 16 Total direct annual benefits from a regional EWS for Lake Victoria users (relative to pre-HIGHWAY baseline)

	Central $M/year	**High valuation sensitivity $m/year**
Reduced fatality*	42.6	146.3
Indirect benefits (dependents)	12.8	43.9
Reduced lost assets	0.7	0.7
Fuel savings	24.0	31.0
Fish Drying benefits	3.3	5.1
TOTAL* annual benefit	**$83.5 million**	**$227 million**

* based on baseline rates of 1000 deaths/year

Adding these benefits together, the study estimates that the future direct economic benefits of future regional early warning could be $83.5million/year, with an upper estimate of $227million/year.

This compares to the annual benefits from HIGHWAY of $44 M (central valuation), i.e. benefits are almost twice as large under the EWS.

There would also be additional benefits from marine forecasts to other users as well as large indirect effects.

Cost benefit analysis: Direct Marine Benefits

A cost-benefit analysis was carried out on the Regional EWS 2025 vision, starting with improved marine information. A discount rate of 3.5% and 10% were used to discount benefits over a period of 10 years.

It was assumed that there was a falloff in effectiveness after the project funding (after 2025), with a 20% drop off in each subsequent year (through to 2030). This takes account of the fact that unless all the beneficiary countries commit to securing the necessary funding to support the operation and maintenance of the EWS equipment and activities, it is reasonable to assume that the stream of benefits will gradually diminish over time, starting from year 5.

The economic benefit stream from above was used, taking account of the higher benefits from the EWS Vision over and above HIGHWAY, i.e. the marginal benefits of EWS Vision compared to the additional costs. This used the Defra Greenhouse gas reporting: conversion factors 2020 (Defra, 2020) and the international carbon prices in the UK Appraisal guidance (HMT, 2020).

Table 17 Net Present Value and Benefit to Cost Ratio for EWS Vision 2025 for marine information – incremental benefits and costs over and above HIGHWAY

CENTRAL		**$Million**		HIGH VALUATION		**$Million**
NPV @3.5%		240.9		NPV @3.5%		708.3
NPV @10%		176.9		NPV @10%		521.5
BCR (10%)		10.7		BCR (10%)		31.6

The analysis finds the net present value of EWS Vision 2025 is $241 million, with a benefit to cost ratio of 11:1, at 10% discount rate. This increases at lower discount rate, and with the high valuation estimate. This compares extremely favourably to other W&CS investments.

Other EWS Benefits

It is also anticipated that EWS Vision 2025 will generate marine weather information for other lakes in the region, notably Lake Kivu and Lake Tanganyika. These would add to the benefits above. There is not information available of the drownings on these lakes, but it would be anticipated that similar reductions (as a %) for these lakes would be delivered under the new project.

Finally, EWS Vision 2025 extends beyond marine information and has activities that will benefit shore-based users. This could include severe weather warning for lakeside floods and storms, as well as improved weather forecasts, as part of multi-hazard Alert Systems. This could extend to the Lake Victoria basin, but also wider to East Africa.

At this stage, it is not possible to estimate the potential benefits of these activities, but weather-related damages from extreme events in East Africa are high. Furthermore, EWS have been found to be very effective in reducing down damages for such events (Clements et al., 2013: Shreve & Kelman, 2014: Vaughan C. et al 2019; GCA, 2019). The benefit to cost ratios vary with the context and application, but GCA reports an average value of 9:1. These additional EWS services would therefore increase the benefits above, reaching potentially millions of beneficiaries, and generating further large-scale economic benefits.

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