Leveraging Artificial Intelligence and Mathematical Modelling for Enhanced Mpox Outbreak Response and Preparedness in Africa

Abstract

The mpox outbreak in Africa has escalated significantly, with cases spreading across 14 countries as of September 2024. The Democratic Republic of the Congo (DRC) is the most affected, reporting over 5,610 confirmed cases and 25 fatalities. This growing public health crisis underscores the need for enhanced preparedness and response mechanisms. Mpox transmission dynamics have evolved, moving from zoonotic spillovers to extensive human-to-human spread. This shift, compounded by limited vaccine access and widespread misinformation, poses significant challenges to Africa's public health systems.

To address these challenges, this project leverages Artificial Intelligence (AI), Big Data, and Mathematical Modelling to improve mpox outbreak management across Africa. Building on AI-powered tools developed during the COVID-19 pandemic, the initiative aims to optimize public health strategies, enhance surveillance, and support equitable vaccine distribution. AI-driven dashboards will provide real-time data visualization, while predictive models will forecast outbreak trajectories and identify potential hotspots. Additionally, Natural Language Processing (NLP) will be used for sentiment analysis to monitor misinformation and support targeted communication strategies, ultimately improving public trust and vaccine acceptance.

Expected outputs include AI-powered surveillance systems, optimized vaccination strategies, predictive models, and public health dashboards. The project will also produce monthly blogs, peer-reviewed articles, and a special journal issue to share findings. Expected outcomes are improved outbreak detection, equitable healthcare access, data-driven decision-making, and stronger public health resilience in Africa. This initiative not only aims to mitigate the current mpox outbreak but also to strengthen Africa's capacity to respond to future public health crises, ensuring a more resilient and adaptable healthcare infrastructure

1.) Problem and Justification.

Mpox (formerly known as monkeypox) remains a persistent and concerning public health issue in Africa, where cases continue to surge despite prior containment efforts. Since its identification in humans in 1970 in the Democratic Republic of the Congo (DRC) [1], mpox has primarily affected Central and West African countries, with periodic outbreaks in other regions due to international travel and animal trade. However, the past two years have seen a significant global increase in mpox cases, with multiple countries reporting outbreaks and the DRC remaining the epicenter, recording over 5,610 confirmed cases and 25 fatalities in 2024 alone [2]. This alarming situation underscores the urgent need for improved preparedness and response mechanisms across the continent, particularly as fourteen African countries have reported mpox outbreaks as of September 2024.

The epidemiology of mpox has shifted dramatically in recent years. Historically, human infections were primarily associated with zoonotic spillovers from infected animals, such as rodents or primates. However, recent outbreaks have shown extensive human-to-human transmission, underscoring a changing dynamic in how the virus spreads [3]. This evolving transmission pattern, combined with the ongoing issue of limited vaccine access, as well as infrastructural and logistical hurdles, poses significant challenges to African public health systems. Vaccine inequity is particularly problematic, as many African nations face substantial barriers to acquiring sufficient doses to protect their populations and curb outbreaks effectively [1]. The situation is further complicated by a surge in misinformation, which has

rapidly spread through social media, contributing to vaccine hesitancy and undermining public trust in health authorities [4].

During the COVID-19 pandemic, African countries faced similar obstacles, which revealed critical gaps in the healthcare system's ability to detect, track, and respond to disease outbreaks. Lessons learned from this global health crisis underscore the potential for Artificial Intelligence (AI), Big Data, and Mathematical Modelling to revolutionize outbreak response and preparedness by providing data-driven insights and improving decision-making processes. However, the lack of targeted resources and strategic frameworks to leverage these advanced technologies against mpox has resulted in limited progress toward containing this outbreak.

The current mpox outbreak in Africa presents a critical opportunity to integrate AI and Mathematical Modelling as evidence-based tools to enhance response efforts. By leveraging these technologies, public health officials can develop real-time dashboards for accurate data visualization and utilize predictive models to forecast outbreak trajectories, identify potential hotspots, and streamline vaccine logistics. Such tools are invaluable for effective outbreak management, especially in low-resource settings where timely access to reliable data is often a limiting factor. Additionally, AI-powered sentiment analysis and topic modelling can help monitor public perception, enabling authorities to combat misinformation and enhance communication strategies, which are essential for promoting vaccine uptake and ensuring community compliance with public health guidelines.

Ignoring the escalating mpox outbreak risks not only further spread within affected countries but also poses a threat of cross-border transmission, which could precipitate a larger regional health crisis. As the epidemic spreads, the strain on already fragile healthcare systems will intensify, potentially leading to increased mortality rates and prolonged societal and economic disruption. This project's focus on leveraging AI, data analytics and mathematical models for outbreak response aligns with the broader objective of strengthening Africa's healthcare resilience and promoting equitable access to vaccines, ultimately helping mitigate the impact of mpox on vulnerable populations.

2.) Overall Objective and Specific Aims:

The overall objective of this project is to enhance mpox outbreak response and preparedness across Africa by leveraging Artificial Intelligence (AI), Big Data, and Mathematical Modelling. This initiative aims to optimize surveillance, early warning systems, and vaccination strategies, as well as to address public misinformation and support equitable healthcare access. To achieve this, we will focus on the following specific aims:

- Aim 1: Develop and implement AI-powered dashboards for real-time data visualization and analysis of mpox outbreaks. These dashboards will integrate predictive models and forecasts from multiple sources, facilitating timely data sharing and effective decision-making for public health officials across Africa.
- Aim 2: Utilize deep learning and mathematical modeling to optimize clinical public health strategies and vaccination roll-out for mpox in resource-limited settings. This aim includes creating a deep neural network model to prioritize vaccination targets and designing a mechanistic model to evaluate the impact of various vaccination strategies, thereby addressing vaccine inequities and improving access to vaccination for high-risk populations.
- Aim 3: Establish AI-driven technologies for real-time surveillance, forecasting, and early warning of mpox outbreaks, along with hotspot detection capabilities. Building on our experience with COVID-19, we will deploy a multi-layer neural network model to forecast mpox case trends and detect potential outbreak hotspots, enabling preemptive interventions in at-risk communities.

- Aim 4: Leverage Natural Language Processing (NLP) for sentiment analysis, topic modeling, and misinformation detection to enhance communication strategies and address mpox-related stigma. This will involve analyzing social media and other digital platforms to identify and counter misinformation, thereby supporting public education and improving vaccine acceptance through targeted messaging and community engagement.

3.) Method

The graphical abstract of our approach is presented in Figure 1.

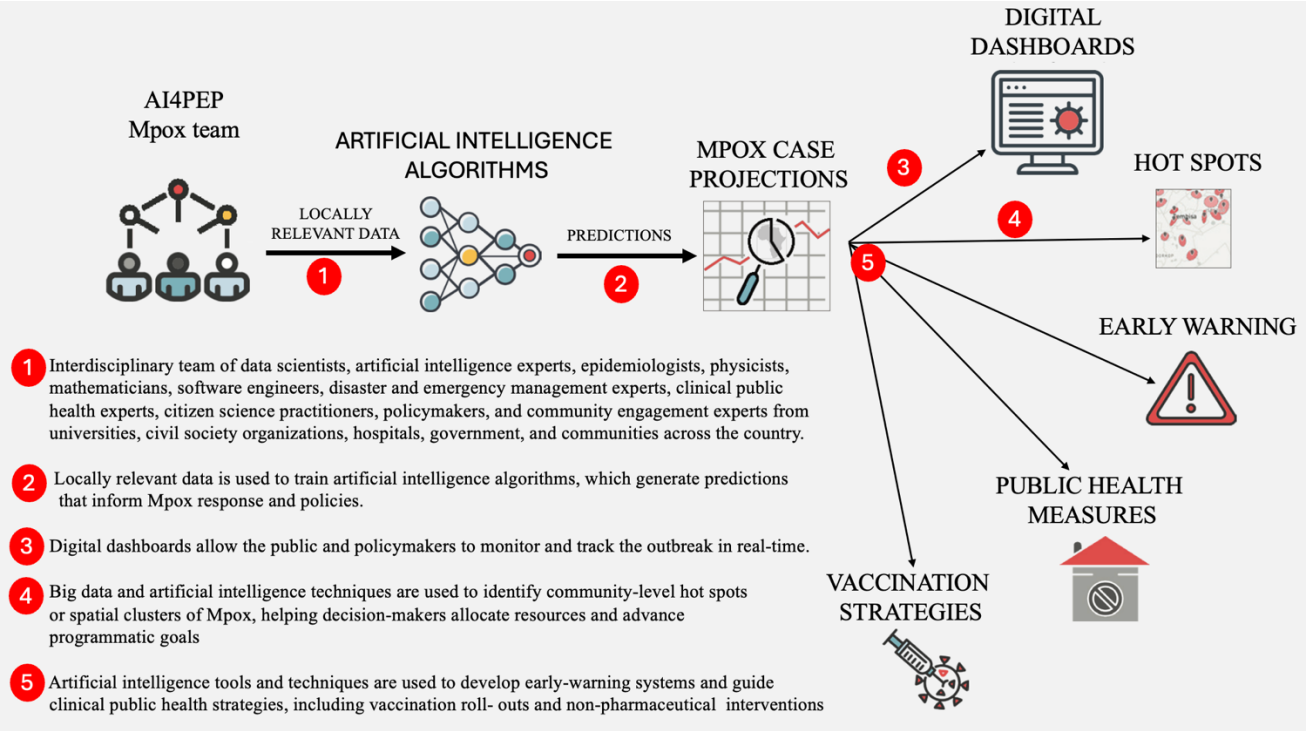


Figure 1: Graphical Abstract

Aim 1: Data and Dashboards:

One of the key requests from governments has been for AI-powered dashboards, driven by the success of similar tools we developed during the COVID-19 pandemic. Under the Africa-Canada Artificial Intelligence and Data Innovation Consortium, our teams delivered highly effective, locally tailored dashboards that monitored COVID-19, predicted resurgences, identified hotspots, stratified patients by risk, and helped guide vaccine distribution strategies. These dashboards were officially adopted by governments for decision-making and public communications. Members of our team served on national COVID-19 advisory committees, and our models were directly used to inform policy at both the national and international levels.

The COVID-19 dashboards were widely praised and received extensive media coverage across TV, radio, newspapers, and international outlets (see link to some of the media coverage here: https://acadic.org/media-coverage/). They provided not only real-time visualization but also predictive modeling down to the smallest administrative units. These dashboards became essential tools for policymakers in countries such as Botswana, Eswatini, Cameroon, Mozambique, Namibia, Nigeria, Rwanda, South Africa, and Zimbabwe. In South Africa alone, the dashboard received over one million daily views, with the others being viewed by more than 100,000 users daily. This visibility extended the reach and impact of our work, as reflected in UNESCO's request for us to contribute to their

book *Mathematics for Action: Supporting Science-Based Decision-Making*, where our use of AI and Big Data to shape outbreak policies was highlighted. (see English version here: https://unesdoc.unesco.org/ark:/48223/pf0000380883.locale=en (pages 8-9); French Version: https://unesdoc.unesco.org/ark:/48223/pf0000384607?fbclid=IwAR2pzbjT3Nt1zI_TNb1xHK5ogIiVKqwpC5q5SByCkU38BLvxNX25_hi73Z). Below is a link to some of the COVID-19 dashboards that the mpox dashboards will build upon:

- http://www.covid19sa.org/
- https://acadic.org/covid-19-dashboards/
- COVID-19 Sentiment Dashboard: https://acadic.org/covid-19-sentiment-dashboard/
- Monkeypox Stigmatization: https://acadic.org/monkeypox-stigmatization/

Building on this success, we will develop similar AI-powered dashboards for mpox, designed to be user-friendly and integrated with predictive models from researchers across Africa. These dashboards will provide real-time visualization, comprehensive data analysis, and aggregated predictions from multiple sources. They will serve as critical tools for public health officials, enabling them to make informed decisions and respond swiftly to mpox outbreaks.
Our team's involvement on mpox advisory committees across various countries ensures access to relevant government data. Through collaboration with the Africa-Canada Artificial Intelligence and Data Innovation Consortium and AI4PEP, we will turn this data into actionable insights, guiding policy and public health interventions across the continent.

Data sources:

The data for this project is sourced from a wide range of platforms and channels to ensure comprehensive monitoring and response to mpox outbreaks. These sources include community-level reporting, health facilities, social media, and a toll-free call center (in some countries) dedicated to mpox reporting. Additionally, we have identified inventories of mathematical and AI models, which are essential for robust mpox surveillance and outbreak response. Below is a breakdown of the key data sources we will use**:**

1. **Primary Data Sources:**
    - **Surveillance Data, Case Management Data, Laboratory Testing Data, and Master Linelist of Cases:** These data are primarily sourced from the **District Health Information System (DHIS2)** portal (https://dhis2.org), made available by the respective governments of the countries we are working with. The AI-powered dashboards we are developing will extract real-time data from DHIS2 for immediate analysis. These data are updated weekly and are collected through:
        - **Active surveillance** at points of entry (PoEs), including ports and airports.
        - **Land PoEs** that are designated for 'zero' notification in cross-border regions.
        - **Weekly notifications** from health districts.
2. **Community Health Workers & Social Media:**
    - Additional data is sourced from **community health workers** during household visits, which is facilitated by our partnerships with local NGOs. This grassroots-level data provides a more granular view of the situation on the ground.
    - **Social media platforms** also serve as a data source, particularly for monitoring public perception and potential misinformation related to the outbreak.

- In some countries, **toll-free mpox reporting** via call centers further supplements our data streams.

3. **Animal Surveillance & Environmental Monitoring:**
   - We also incorporate **animal surveillance data** provided by ministries of wildlife, forestry, and animal husbandry to monitor potential zoonotic transmissions.
   - **Aircraft wastewater monitoring (in some of the countries)** is another innovative data source.
4. **Data from Partner Organizations:**
   - We will leverage data from our partners, including **WHO Afro** (https://aho.afro.who.int/analytics-dashboard/af), **Africa CDC**, and the **African Society for Laboratory Medicine (ASLM)** (https://aslm.org/). Although much of the data from these organizations overlaps with the data in DHIS2, we will clean and de-duplicate this information during our AI pipeline's data preparation phase.
5. **Genomic Data:**
   - Publicly available genomic data from platforms such as the **Bacterial and Viral Bioinformatics Resource Center (BV-BRC)** (https://www.bv-brc.org/outbreaks/Mpox/#view_tab=overview), **GISAID** (https://gisaid.org), **Nextstrain** (https://nextstrain.org/monkeypox/hmpxv1), **mpoxSpectrum** (https://mpox.genspectrum.org/explore), and **MPoxVR** (https://ngdc.cncb.ac.cn/gwh/poxvirus/) will be integrated to monitor the evolution and variants of the mpox virus.
6. **Surveillance at Borders and Airports**:
   The government is actively conducting surveillance at **airports and border crossings**. These data will be integrated into our dashboards, enabling us to monitor and analyze Mpox transmission related to travel and cross-border movements effectively.

Data curation will follow current practices, e.g., using Findability, Accessibility, Interoperability, and Reuse (FAIR) Principles. This will ensure data are readily usable by AI4Mpox network researchers and available beyond the network, if ethically acceptable. It will also facilitate access to model outputs by knowledge users and stakeholders. A local catalog index of publicly available data will be prepared. Decisions will be taken on a case-by-case basis regarding local replication within the program, which is useful when data sources do not implement good data stewardship practices (that is to say, management of data sets to provide users with high-quality data). Locally replicated data, as well as private data, will be made available to all project members, following any licensing constraints. However, private data will not be disseminated. Particular attention will be placed on data from marginalized communities, in respect of the Ownership, Control, Access, and Possession (OCAP®) principles. A separate data management strategy will be articulated for any data involving marginalized communities. Data produced within the project will be made publicly available if this does not contravene (ethical and legal) regulations. The challenge of aggregating and aligning several multi-system, multi-species data sources will be addressed using/adapting previous solutions, if available. However, there is no formal method of integrating these techniques for merging data from various sources that can be structured, semi-structured, or unstructured. In addition, scaling and real-time requirements are unique challenges. Therefore, the grantees are expected to propose a new data alignment framework that is not only flexible to extract data from various sources in disparate structures but also offers real-time large-scale data aggregation. The framework includes portable modules for data from all epidemiological surveillance sources, as well as a common interface for querying the data to construct a dataset for various learning and analytical purposes. The design of the framework will take advantage of Apache Spark and a Docker container for scalable real-time performance.

Aim 2: Leveraging Artificial Intelligence, Big Data and Mathematical Modelling to Optimize Mpox Clinical Public Health and Vaccination Roll-Out:

While many developed countries have already vaccinated their high risk population against Mpox, most African nations are still waiting for vaccine stocks to be allocated and are relying on clinical public health (CPH) strategies to control the outbreak. The unequal access to vaccine supplies, combined with locally specific logistical and vaccine delivery challenges, adds complexity to national CPH strategies and underscores the urgent need for effective CPH policies. Big data, machine learning techniques, and collaborations can be instrumental in providing accurate, timely, and locally nuanced analyses of multiple data sources to inform CPH decision-making, vaccination strategies, and their staged roll-out. We will leverage the data at our disposal to train a deep neural network (DNN) to identify and prioritize target groups who can benefit most from vaccination. Optimizing vaccine distribution is a key interest of most governments. This will build on [7, 11, 16, 24, 25]. Following the work we did in [26], we will also develop mechanistic mathematical models to study the impact of various vaccination strategies, including pre-exposure and post-exposure Mpox vaccination, smallpox vaccination, policies focused on vaccinating only children, and policies targeting high-risk adults, etc.

Aim 3: AI-powered Technologies for Real-Time Surveillance, Forecasting, Early Warning and Hotspot Detection of Mpox Outbreak:

The objectives here are twofold: to design and deploy i) Technology for Real-Time Surveillance, Forecasting, and Early Warning of Mpox Outbreaks, and ii) an technology for potential hotspot detection. The first objective will build upon COVID-19 AI-powered real-time prediction, forecasting, and early warning framework we developed for the South African government during the COVID-19 pandemic [27]. Working with our colleagues in South Africa, under the Africa-Canada Artificial Intelligence and Data Innovation Consortium [22], we developed a framework using a recurrent neural network with long short-term memory (LSTM) to predict and forecast daily confirmed cases effectively [27]. Our framework proved highly efficient, enabling us to predict all waves (16 days) and detect variant strains, including Omicron, ahead of genomic analysis. We have since augmented this framework for Canada with additional layers in the deep learning model component and additional unconventional data sources. This enhanced framework is currently being used for real-time surveillance, forecasting, and early warning of COVID-19 (real-time data dashboard in preparation; to be live in 2-3 weeks). Our deep learning model now comprises four main layers: a Convolutional Neural Network (CNN), a Graph Neural Network (GNN), a Gated Recurrent Unit (GRU), and a linear stacked Neural Network (NN) layer. Hyperparameters were optimized to provide accurate 56-day-ahead predictions for each province in Canada. The current framework not only forecasts and provides early warnings 56 days ahead but also has lower computational and space complexity compared to its initial South African counterpart. We propose to adapt this novel GNN-CNN-GRU-NN framework for real-time surveillance, forecasting, and early warning of mpox outbreaks. The framework is divided into three blocks: data preparation, graph creation, and model construction.

i) Data Preparation: Several features will be organized as time series, including the number of Mpox cases, image data, wastewater data parameters (where applicable), animal data, Google News, Google Trends, social media and satellite data. The data of different provinces/regions/cities/communities will be converted into tensors, and fed into the second block.

ii) Graph Creation: After arranging the nodes and edges of the GNN graph, the graph creation part defines the inputs and their corresponding labels. A sequence of length $\tau + 1$ (t-τ, t-τ+1, t-τ+2,…, t, where t means time in days) is taken as an observation and t, t+1, …, t+T are set as its labels. The model is

trained for up to T-day ahead prediction. The sequence length and the step-ahead length, T, are determined using hyperparameter optimization. The train and test data are separated, and the weights of the edges of the GNN graph are set based on the correlation between the number of mpox cases of the provinces/regions/cities/communities in the training dataset.

iii) Model Construction: The deep learning model, composed of four main layers (CNN, GCN, GRU, and a linear neural network layer), is built using the train and test data. The first layer is a two-dimensional CNN that has several input channels (one for each feature) and one output channel. The CNN combines all the data feature sequences of a province and provides one sequence for each province/community to the GCN layer. The GCN, the spatial layer of the model, applies the aggregation and update procedures and feeds the result to the GRU, the temporal layer of the model. The GRU, capable of remembering relationships in data sequences, provides its result to the linear layer, which has T outputs for 1- to T-days ahead prediction. Between each layer, a dropout component is placed for regularization. Each layer has its own hyperparameters, optimized prior to training and testing the model.

The **second objective** will build on our COVID-19 AI-powered hotspot detection technology we developed for the South African government [28]. The aim of this current project is to identify potential Mpox outbreak hotspots. We will utilize case data, ecological parameters, proximity to forest, animal data etc. We will use a variety of models, including MaxEnt and Expectation-Maximization.

Aim 4: Leveraging Topic Modeling and Sentiment Analysis to Support Communication Strategies with Local Stakeholders to Address Mpox Stigmatization and Dis- and Misinformation about Mpox:

This project builds upon our COVID-19 work (see [6-7, 9, 11-14, 16-21]). We will use Natural Language Processing (NLP) to comprehensively analyze social media platforms for posts and comments related to Mpox. We will perform sentiment analysis, topic modeling, and trend analysis on the data. We will also leverage NLP to scan news articles, blogs, and online forums to detect and flag potentially misleading or false information related to Mpox. By understanding the public discourse surrounding Mpox, the project aims to provide valuable insights, including common misconceptions and false information about Mpox, that can inform monitoring and response strategies. To collect data, we will utilize several APIs, including the Pushshift Reddit API. For topic modeling, we will utilize state-of-the-art transformer models, including the BERTopic model. For sentiment classification, we will employ several transformer models, including the zero-shot Facebook BART-large-mnli model and Pysentimiento.

4. Expected Outputs

The expected outputs from this research include:

1. AI-Powered Surveillance and Early Warning Systems (7): Real-time monitoring tools that use AI and Big Data to detect and predict mpox outbreaks, providing timely alerts for quick and effective response.
2. Optimized Vaccine Distribution Strategies (for 7 countries if they choose to vaccinate): Data-driven strategies to prioritize vaccine allocation for high-risk populations, ensuring equitable access across Africa.
3. Predictive Models for Outbreak Forecasting (7 countries): Advanced AI and mathematical models to forecast outbreak trajectories, helping identify hotspots and allocate resources.

4. Sentiment Analysis and Misinformation Management Tools (7): AI-based tools to analyze public perceptions on social media, identify misinformation, and support communication strategies that improve vaccine acceptance and reduce stigma.
5. Public Health Dashboards (for all the 7 countries): User-friendly, AI-powered dashboards for real-time data visualization, integrating case data, predictive models, and vaccination progress for national and regional decision-makers.
6. Policy Recommendations and Best Practice (for all the 7 countries): Evidence-based guidelines for integrating AI, Big Data, and Mathematical Modelling into outbreak responses, enhancing resilience and preparedness for future health crises.
7. Capacity Building in AI and Data Science for Health Response (the number depends on the need): Training programs and resources to build local capacity in African nations for using AI and data science in public health, supporting long-term improvements in outbreak preparedness.
8. Blogs (7): Regular blog posts aimed at public and professional audiences, sharing updates on project progress, research findings, and insights into outbreak management.
9. Scholarly, Peer-Reviewed Articles (Senegal(1); Ghana(2); Cameroon (5); Nigeria (5); Burundi (4); DRC (5); Ethiopia (5)): Publications in impactful, open-access journals to disseminate research findings and share best practices, ensuring that insights are accessible to a global audience.
10. Special Issue on Strengthening the Use of Epidemiological Modelling for mpox (1): A curated collection of articles in collaboration with impactful journals, focusing on the advances in epidemiological modeling to inform public health strategies and strengthen responses to mpox.

5. Expected Outcomes

The expected outcomes from this research include:

1. **Enhanced Outbreak Detection and Response Capabilities:** Improved ability for African public health authorities to detect and respond to mpox outbreaks quickly, reducing the spread and impact of the disease.
2. **Equitable Vaccine Distribution:** More effective vaccine allocation that ensures high-risk populations receive timely access to immunization, particularly in underserved regions, contributing to reduced morbidity and mortality.
3. **Improved Predictive Accuracy for Outbreak Trajectories:** Accurate forecasting models that allow for proactive public health planning, helping to identify potential hotspots and optimize resource allocation.
4. **Data-Driven Decision Making:** Establishment of robust, AI-powered public health dashboards that enable real-time data visualization and informed decision-making for national and regional authorities.
5. **Sustainable Capacity Building:** Strengthened local expertise in AI and data science, providing African nations with the skills needed to sustain and build upon this project's work in future public health emergencies.
6. **Reduced Disease Stigma and Misinformation:** Effective public health communication that mitigates misinformation and addresses mpox-related stigma, improving community engagement and compliance with public health measures.

6. Significance

The mpox outbreak in Africa exposes vulnerabilities in public health systems, particularly in outbreak detection, vaccine distribution, and communication. With thousands of cases reported and limited vaccine access, Africa faces a mounting crisis. This project's use of AI, Big Data, and Mathematical Modelling aims to bridge these gaps, providing tools for real-time surveillance, predictive modeling, and data-driven

strategies to enhance outbreak response. By fostering equitable vaccine distribution and countering misinformation, the project strengthens Africa's healthcare resilience. Beyond immediate impact, it builds capacity for future disease control, establishing a sustainable, adaptable model for managing emerging infectious threats worldwide.

7. **Team**

The AI4Mpox project brings together a diverse, interdisciplinary team, including AI experts, data scientists, epidemiologists, physicists, mathematicians, software engineers, and specialists in disaster and emergency management, clinical public health, citizen science, and community engagement. Collaboration among most team members has been ongoing since 2020, with many previously involved in the Africa-Canada Artificial Intelligence and Data Innovation Consortium (ACADIC) (https://acadic.org/) and the Global-South Artificial Intelligence for Pandemic and Epidemic Preparedness Response and Network (AI4PEP) (https://ai4pep.org/). Each team within the network is distinguished by its diversity. Given their experience with ACADIC and AI4PEP, these team members possess the necessary expertise to carry out the proposed work. In many cases, they are already engaged in data modeling with government data, and many are part of national mpox advisory boards. The teams also have established relationships with key entities such as the Africa CDC, WHO, and various government bodies, and are equipped to receive and manage grant funds. Some of these entities are also involved in the project. The countries, names, and affiliations of the teams are listed in the table below.

Country	**Team**	**Affiliation**	**Project**
Burundi	Prof. David Niyukuri	Prof of Mathematical Epidemiology, University of Burundi	Aims 1, 2 (when vaccines become available), 3, and 4.
	Prof. Joseph Nyandwi	Director General of National health of Public Health	
Cameroon	Prof. Dickson Shey Nsagha	Aims 1, 2 (when vaccines become available), 3, and 4.	Aims 1, 2 (when vaccines become available), 3, and 4.
	Dr. Ndoula Shalom	Director of Vaccination, Ministry of Public Health, Yaounde, Cameroon	
	Dr. Ginyu Innocentia	Prof of Epidemiology, University of Buea and Ministry of Public Health, Regional delegation, Buea, Cameroon	
	Dr. Bilounga Ndongo Chanceline	Director of Diseases Surveillance and forecasting, Ministry of Public Health, Yaounde	
	Mr. Kinang Edwin Ngenge	Prof of technology, College of Technology, University of Buea, Cameroon	
	Dr. Georges Nko'Ayisi	Director of Neglected diseases in the Ministry of Public Health in yaounde	
	Dr Fomboh Mary	Senior Mathematics lecturer, University of Buea, Cameroon	
	Prof. Gideon Ngwa Akume	Professor of Mathematical modelling, University of Buea, Cameroon	
	Dr. Farnyu William Tantoh	Lecturer University of Buea	

	Prof. Mimche Honore	Institut de Formation et Recherche Demographique	
DRC	Prof Félicien Kasali Mashagalusa	Université Offciellle de Bukavu	Aims 1, 2, 3, and 4.
	Dr Fatuma Lydia	Epidemiologist , Conseil sur la Santé et l'Académie de Médecine (COSAMED)	
	Dr Esther Uwera	Advocacy, COSAMED	
	Dr Esther Fatuma	Epidemiologist, COSAMED	
	Dr Alice Zabibu	Advocacy, COSAMED	
	Prof Munyanga MUKUNGO	Prof of Public health, UNIKIN School of public health	
	Prof Herman chelo	Prof of Public health, UNIGOM school of public health	
	Prof Wembonyama	Prof of Public health, UNIGOM school of public health	
	Ir Pacifique Molo	Web developer, COSAMED	
	Ir Emery Kambale	Web developer, COSAMED	
	Ir Samuel Baeni	Mobile developer, COSAMED	
	Dr Bindu Jean	Program manager, COSAMED	
	Dr Roger Kamba	Strategic and coordination level, Ministry of Public Health	
	Prof Dr Stephane Hans Bateyi	Chef de section des opérations réponse Mpox au Nord-Kivu Coordonnateur du PEV Nord-Kivu, Ministry of Public Health	
	Prof Tresor MUSOMO	Chargé de la recherche opérationnelle, Ministry of Publc Health	
	Dr Dan KAPUKU	Surveillance officer, Ministry of Public Health	
	Dr Alengo Aimé	Chief of Division in South Kivu, Ministry of public health	
	Prof Dr Daniel Mukadi	Directeur provincial de INRB in North Kivu, Ministry of Public Health	
	Dr Alou Badara	Health cluster coordinator, WHO Afro	
	Dr AJONG Brian	Health operator, WHO Afro	
	Dr Francis DJIMTESEM AYAMBAYE	Health cluster coordinator North Kivu, WHO Afro	
	Amos KIUKA EBONDO	Surveillance, WHO Afro	

	Dr Aladin Mahano	Université Offciellle de Bukavu	
	Dr. Elia Badjo	Conseil sur la Santé et l'Académie de Médecine "COSAMED Asbl")	
Ethiopia	Prof. Netsanet Workneh Gidi	Head of the Oromia Health Bureau	Aims 1, 2 (when vaccines become available), 3, and 4.
	Prof. Ahmed Zeynudin	Professor of Medical Parasitology, Jimma University	
Ghana	Dr. Franklin Asiedu-Bekoe	Head of public health, Ministry of Health Accra Ghana	Aims 1, 2 (when vaccines become available), 3, and 4.
	Dr Emmanuel Allegye Cudjoe	Chief veterinary officer of Ghana	
	Dr Danso Fenteng	Chief Epidemiologist, Veterinary service department	
	Dr Ziekah Meyir	Forestry commission	
	Dr Theophilus Odoom	Accra Veterinary laboratory	
	Seth Owusu-Agyei	Chief epidemiologist Ministry of health	
	Prof Benjamin Emikpe	Dean, School of veterinary medicine Kwame Nkrumah University of Science and Technology	
Nigeria	Prof. Adesina Simon	Prof of Computer Science, Federal University of Agriculture Abeokuta	Aims 1, 2 (when vaccines become available), 3, and 4.
	Mr. Hakeem Abiola Yusuff	Department of Public Health, Ogun State Ministry of Health, Abeokuta, Nigeria	
Senegal	Prof Sylvain FAYE	Socio-anthropologist, member of Mpox Incident Manager System Committee	Aims 1, 2 (when vaccines become available), 3, and 4.
	Dr Boly DIOP	Epidemiologist, National Mpox Incident Manager	
	Georgette SOW	Communication and community engagement specialist	
	Dr Seydina Moussa Ndiaye	AI and Data Analytics expert.	

8.) Timelines:

Period	Activities
Nov. 2024 – Feb. 2024	Partnership building meetings (weekly meetings); Gathering data for Projects 1-4; Developing models for the various projects; Developing dashboards, integrating data into the dashboards, and creating visualizations; Virtual workshop; monthly lecture series; Monthly blogs.
March 2025 - June 2025	Weekly meetings; Training and testing of models; Integrating Projects 1-4 preliminary results into the dashboard; monthly lecture series; Publication of some findings in peer-reviewed open-access journals; Policy reports; Monthly blogs

July 2025 - Oct 2025	Weekly meetings; Publication of findings in peer-reviewed open-access journals; Policy reports; Monthly lecture series; Modeling templates; Integrate results into the dashboard; Monthly blogs; An online searchable repository comprehensively compiling resources containing locally relevant data; Special issue in a journal.

9.) Gender/Sex, Equity, Inclusion, Diversity, and Decolonization (GEIDD): We have embedded these priorities into our program's goals, methods, governance, and implementation plan. Our team has an approximate ratio of men and women. In our weekly meetings, we will discuss how the project is addressing GEIDD both within the team and in all aspects of our work. This will allow team members to raise any issues they have noticed so we can take action. Most members have completed GEIDD and Unconscious Bias training, such as the online modules recently developed by the Canadian Tri-Council (https://www.chairs-chaires.gc.ca/program-programme/equity-equite/bias/module-eng.aspx; https://www.cihr-irsc-igh-isfh.ca/?lang=en). We will encourage does who have not done so to complete the GEIDD and Unconscious Bias trainings. We will consider transmission heterogeneity and disease burden inequality due to race, gender, economic status, age, and ability in our efforts towards successful recovery and adaptation. We will document and evaluate the challenges and successes of our GEIDD initiatives, including this aspect in our publications and the dissemination of the project's work for both academic and general audiences. This approach will specifically demonstrate the connections between GEIDD and transformational change.

10.) Research Ethics:
Our collaboration with the government significantly reduces the risk of the authorities being unaware of the research project. We will consult any country-specific clearance guidelines for the relevant institutions and obtain the necessary approvals where required. Our Strategic Working Committee (SWC) will ensure that all research complies with the 2021 World Health Organization's *Ethics and Governance of Artificial Intelligence for Health* (see Ethics Section above). Additionally, we will adhere to the recommendations from the 2011 workshop on *Sex-Specific Reporting of Scientific Research,* convened by the US Institute of Medicine (IoM), as well as the *Sex and Gender Equity in Research* (SAGER) guidelines. This approach helps mitigate the risk of the findings unintentionally targeting or victimizing vulnerable populations. We will also regularly monitor the Gantt chart of each sub-grantee to ensure that the grant objectives are being met. If they are not, we will assist the sub-grantee in making necessary adjustments, which may include completely revising the project.

11.) Risks and Mitigation Strategy

Among the 6 projects to be supported by this initiative, 4 are in countries on IDRC's List of Higher Risk Countries and Territories. Components within the 4 countries are to be administered by University of Buea (Cameroon), Université Offciellle de Bukavu and Conseil sur la Santé et l'Académie de Médecine (COSAMED) (DRC), Jimma University (Ethiopia), Federal University of Agriculture Abeokuta (Nigeria) and Al Quds University (West Bank) and University of Burundi (Burundi).

11.1.) Risks Strategies

As outlined in the IDRC List of Higher Risk Countries and Territories, the sources of concern related to programming in Burkina Faso, Cameroon, Democratic Republic of the Congo (DRC), Ethiopia, Lebanon, Nigeria, Tunisia and West Bank are summarized in the table below.

	Burundi	***Cameroon***	***DRC***	***Ethiopia***	***Nigeria***
Government of Canada Sanctions			*X*		
Banking restrictions		*X*			*X*
Security environment	*X*	*X*	*X*	*X*	*X*
Ability to monitor research activities	*X*	*X*		*X*	*X*
Operational Issues			*X*		

11.1.1 Government of Canada Sanctions (DRC)

Democratic Republic of the Congo (DRC): On July 28, 2003, acting under Chapter VII of the Charter of the United Nations, the United Nations Security Council adopted Resolution 1493 imposing sanctions against the DRC in response to continuing hostilities in the eastern part of the country. Specific measures include:

- a prohibition on the export of arms and related materiel to any person in the territory of the DRC;
- a prohibition on the provision, to any person in the DRC, of technical and financial assistance related to military activities;
- an assets freeze against persons designated by the UN committee established by Resolution 1533 (2004) to oversee the sanctions against the DRC (the 1533 Committee); and
- a travel ban against persons designated by the 1533 Committee.

The sanctions regime was subsequently modified and strengthened with the adoption Resolutions 1533 (2004), 1552 (2004) and 1596 (2005). With Resolution 1807, of 31 March 2008, the Council decided that the Government of the DRC would no longer be subject to the arms embargo. Therefore, the embargo applies only to non-governmental entities and persons active in the DRC. Still, there remains an obligation to notify the Committee before sending arms or related material to the Government of the DRC.

The *United Nations Al-Qaida and Taliban Regulations*, also passed pursuant to the *United Nations Act*, prohibits IDRC from financial dealings with listed persons and entities. IDRC Legal's most recent review of the sanction's regulations found there were persons and entities in this list operating in DRC.

11.1.2 Banking restrictions (Cameroon, Nigeria)

Cameroon: Transferring money out of Cameroon is regulated, and authorization must be obtained from the Ministry of Finance for any such transaction. Cameroon is mostly a cash-based economy. The official local currency (XAF, or more commonly referred to as the CFA Franc) is controlled through the Banque des États de l'Afrique Centrale (BEAC). Although the institutions based on Cameroon may receive funds from outside the country and via other currencies, getting funds outside of Cameroon may be challenging for an institution.

Nigeria: Nigeria's economic volatility, exacerbated by global shocks like the Ukraine war and internal reforms by President Tinubu, has led to soaring inflation and a significant devaluation of the naira. To stabilize the economy, the Central Bank of Nigeria (CBN) has imposed strict banking regulations, including licensing requirements for international money transfer operators (IMTOs), a $2,000 cap on outbound transfers, and restrictions that inbound remittances must be paid in Naira. These measures aim to control foreign exchange and reduce economic instability.

11.1.3 Security environment (Burundi, Cameroon, DRC, Ethiopia, Nigeria)

Cameroon: The Government of Canada's travel advisory for Cameroon references the need to exercise a high degree of caution due to the high level of violent crime in some regions, and the tensions that exist in the Sahel region of the country. It advises against any travel to the following regions: North, Far North, Northwest and Southwest Regions, and Parts of East and Adamawa Regions due to crime and kidnapping; Far North Region due to terrorism; and Northwest and Southwest Regions due to armed violence, crime, and kidnapping; Gulf of Guinea, due to piracy and kidnappings by rebel groups. The Government of Cameroon continues to be in armed conflict with Ambazonian separatists seeking their independence from Cameroon.

DRC: The security situation in DRC particularly in the Eastern region remains unstable, with continued reports of attacks and kidnappings. Armed groups are present and intercommunal violence can affect the political, security and humanitarian situation. As noted in Canada's travel advisory for DRC, terrorism is always a threat, and street crime and robbery are common. Public gatherings and demonstrations can occur with little or no notice and can quickly turn violent. Protests may result in the closure of shops and public services and restrictions on movement. Previous periods of unrest have seen an increased military and police presence in Kinshasa and other major cities. Other areas of concern include Maniema, North Kivu, South Kivu, Tanganyika (northeastern area of the former province of Katanga), Bas-Uele, Haut-Uele and Ituri (northeastern area of the former province of Orientale), points of entry to Burundi, Uganda and Rwanda, and areas bordering South Sudan (including the Garamba National Park) and Uganda.

Ethiopia: The security environment in Ethiopia is volatile due to civil unrest, violence, armed conflict and crime. According to the Government of Canada's travel advisory, the security situation can deteriorate without warning and that travellers to Addis Ababa should exercise a high degree of caution due to violent demonstrations and crime. All travel to Northern, Central and Somali regions should be avoided. Border areas with Eritrea, Kenya, Somalia, South Sudan and Sudan should be avoided.

Nigeria: The Government of Canada advises travelers to Nigeria to exercise a high degree of caution due to the high risk of crime, terrorism, and kidnapping throughout the country. Specific regions have elevated risks, and travel advisories are in place for these areas:

- Northern and Northeastern Nigeria: The states of Borno, Yobe, and Adamawa are especially dangerous due to terrorist activities by groups such as Boko Haram and Islamic State West Africa Province (ISWAP). The government advises against all travel to these regions.
- Northwest and Central Nigeria: States like Kaduna, Kano, Katsina, and Zamfara are known for frequent incidents of banditry, kidnapping, and intercommunal violence.
- Southeast Nigeria: The regions of Abia, Anambra, Ebonyi, Enugu, and Imo states are noted for sporadic violence and civil unrest.

Travelers are encouraged to stay informed about the security situation, follow the advice of local authorities, and take personal security measures seriously.

11.1.4 Ability to monitor research activities (Burundi, Cameroon, Ethiopia, Nigeria)

The security situations described above might hamper the ability of the responsible officers at The University of Toronto and at IDRC to physically visit and monitor the research activities in these countries.

11.1.5 Operational issues (DRC)

The security situations described above might hamper the ability of the team at Université Offciellle de Bukavu and COSAMED to implement project activities

11.2 Mitigation Strategies

The University of Toronto will subgrant to these institutions.
Details about how the University of Toronto will mitigate risks are presented below. All grantees in designated 'high-risk countries' already developed a risk management strategy at the outset of the IDRC AI4PEP project. This strategy addresses the specific risks stated above in accordance with government of Canada regulations including sanctions, and the internal regulations and protocols for staff and research safety of the institutions receiving the funds. No funds will be released before the completion of the strategy for each country.

This strategy will subsequently be revisited and updated at least every six months (or sooner, subject to IDRC directives about the country situation).

The mitigation steps are presented here for each country:

11.2.1 Burundi (Security Environment & Ability to Monitor Research Activities)

Security Environment: The University of Burundi has many years of experience working with health centres across the country, and with navigating various security challenges that arise over the course of conducting a research project. The team at University of Burundi will monitor the security situation through the local researchers, local news outlets, as well as online security reports from credible multilateral organizations. There are no plans for Canadians to travel to Burundi as part of this project. If such travel arises, all relevant Government of Canada travel advisories and The University of Toronto protocols for staff and research safety will be adhered to. There are no field visits planned for this project. Data will be collected through functional health centres throughout the country.

Ability to Monitor Research Activities: The team at the University of Toronto will monitor (through virtual means) the project closely to keep an eye on the evolving security concerns that may affect the project's implementation. This includes regularly consulting the Government of Canada travel advisory, consulting with IDRC (as needed), and ensuring work and travel within Burundi does not occur in insecure environments. These will be clearly outlined in the risk management strategy to be submitted to the University of Toronto. All monitoring will occur during online meetings and at face-to-face workshops that are held in countries not on the IDRC List of Higher Risk Countries and Territories.

. The project will establish a management structure that includes representatives from each organization involved, as well as from the University of Toronto. The role of this body is to oversee the project's overall management, coordination and communication among the organizations.

11.2.2 Cameroon (Banking Restrictions, Security Environment & Ability to Monitor Activities)

Banking Restrictions: All funds will be sent to a secure account in Cameroon managed by the University of Buea. These funds will remain in the country. The University of Toronto will advise the recipient to ensure that funds can effectively be transferred to, refunded from, and used by all sub-recipients for the purposes of the project activities.

Security Environment: Mitigation strategies related to security environment and project monitoring will be outlined in the required risk management strategy that will be submitted to the University of Toronto prior to any fund disbursal or research activities. Research activities will take place in the southern part of the East region on the Congo republic border and in Vina division of the Adamaoua region by the University of Ngaoundere. The University of Buea will be working in the South West Region Higher risk regions outlined above will be avoided. The University of Buea has experience working with health centres in different regions of Cameroon, including the regions where this project will be implemented. Moreover, they have experience navigating various security challenges that can arise over the course of conducting a research project. There will be no Canadian researchers traveling to Cameroon for this grant.

Ability to Monitor Research Activities The team at the University of Toronto will monitor (through virtual means) the project closely to keep an eye on the evolving security concerns that may affect the project's implementation. This includes regularly consulting the Government of Canada travel advisory, consulting with IDRC (as needed), and ensuring work and travel within Cameroon does not occur in insecure environments. These will be clearly outlined in the risk management strategy to be submitted to the University of Toronto. All monitoring will occur during online meetings and at face-to-face workshops that are held in countries not on the IDRC List of Higher Risk Countries and Territories.

11.2.3 **Nigeria (Banking Restrictions, Security Environment & Ability to Monitor Activities)**

Banking Restrictions: All funds will be sent to a secure account in Nigeria managed by the Federal University of Agriculture Abeokuta. These funds will remain in the country. No funds will be transferred out of Nigeria.

Security Environment: Mitigation strategies related to the security environment and project monitoring will be outlined in the required risk management strategy that will be submitted to the University of Toronto prior to any fund disbursal or research activities. Research activities will take place in Ogun State (where the University is located), which is considered a moderate-risk area and is not listed under the highest travel advisories.

Ability to Monitor Research Activities: The team at the University of Toronto will monitor (through virtual means) the project closely to keep an eye on any evolving security concerns that may affect the project's implementation. This includes regularly consulting the Government of Canada travel advisory, consulting with IDRC (as needed), and ensuring work and travel within Nigeria does not occur in insecure environments. These will be clearly outlined in the risk management strategy to be submitted to the University of Toronto. All monitoring will occur during online meetings and at face-to-face workshops that are held in countries not on the IDRC List of Higher Risk Countries and Territories.

11.2.4 Democratic Republic of the Congo (Government of Canada Sanctions, Security Environment & Operational Issues)

Government of Canada Sanctions: None of the persons in the UN Consolidated Sanctions List (accessed October 23, 2024) currently have any known affiliation with this project. Given that the sanctioned parties are not related to the project and there are no activities related to military activity, only the sanctioned entities list will require ongoing monitoring.

Security Environment: Mitigation strategies related to security environment will be outlined in the required risk management strategy that will be submitted to the University of Toronto prior to any fund disbursal or research activities. This plan will be updated at least every six months. There are no field visits planned for this project. Data will be collected through functional health centres throughout the country. Université Offciellle de Bukavu and COSAMED have many years of experience working with health centres across the country, and with navigating various security challenges that arise over the course of conducting a research project. There will be no Canadian researchers traveling to the DRC for this grant.

Operational Issues: The lead institution in the DRC is experienced in managing research activities and mitigating operational risks. Project monitoring will take place virtually and face-to-face interactions will take place in another country or territory that is not deemed as 'high-risk' by IDRC. The project will establish a joint management structure that includes representatives from each organization involved, as well as from the University of Toronto. The role of this body is to oversee the project's overall management, coordination and communication among the organizations. Towards ensuring all consortium members share ownership of the project outcomes, the joint management structure will establish a governance framework that outlines the decision-making process and mechanisms for sharing resources and responsibilities. This framework will also define how the project findings and data will be shared among the different organizations and with external stakeholders.

11.2.5 Ethiopia (Security Environment & Ability to Monitor Research Activities)

Security Environment: A risk management plan will be submitted to the University of Toronto, which will clearly outline the risks and related mitigation strategies for managing the security environment and ensuring research activities can be monitored. This plan will be updated at least every six months. Jimma University is an established institution with experience managing research and making necessary changes to their research and monitoring practices, in response to a shifting security landscape. Research activities will take place in Oromia region and Jimma zone and will avoid the higher risk regions outlined in Section 3.3. There will be no Canadian researchers traveling to Ethiopia for this grant.

Ability to Monitor Research Activities: The team at the University of Toronto will monitor (through virtual means) the project closely to keep an eye on the evolving security concerns that may affect the project's implementation. This includes regularly consulting the Government of Canada travel advisory, consulting with IDRC (as needed), and ensuring work and travel within Ethiopia does not occur in insecure environments. These will be clearly outlined in the risk management strategy to be submitted to the University of Toronto. All monitoring will occur during online meetings and at face-to-face workshops that are held in countries not on the IDRC List of Higher Risk Countries and Territories.

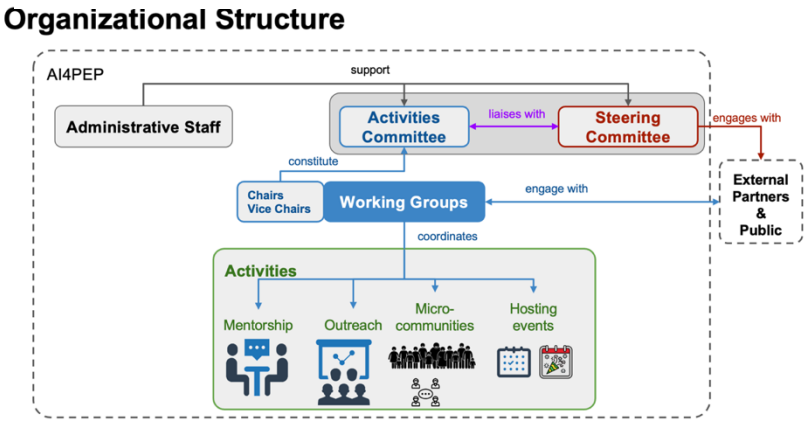
12. **Governance:**

These projects will work collaboratively across the continent. Country teams draw on their own set of experiences, community partners, local context, constraints, and possibilities. The transnational partnership's added value for all partners in our network is grounded in our sharing across contexts and specific situations regarding effective digital data generation, management, dissemination, and ways to address equity priorities for risk minimization by amplifying the voices and agency of marginalized and highly impacted communities centered on the most marginalized women as agents of change.

We will hold biweekly online meetings, lecture series, and an annual virtual conference to share progress, challenges, and perspectives, and to coordinate projects spanning multiple countries. During these meetings, we will share expertise, interdisciplinary perspectives, research processes, results, and conclusions, as well as foster inter-institutional student collaboration and community engagement to achieve project objectives. By sharing our processes and results, the transnational group will identify larger-scale comparisons, synergies, and conclusions in relation to our overall goal.

We will track project outcomes and outputs during our biweekly meetings. Various civil society organizations, including women's rights organizations, and governmental partners will champion the implementation of our research. Our governance structure includes (see Figure 2 below):

Figure 2:AI4Mpox Governance Structure



- **Members** who participate in the activities and from whom leaders are elected
- **Steering Committee** that provides overall leadership for the network.
- **Activities Committee** and associated **Working Groups** that lead initiatives and coordinate and support activities of the network and its members
- **Administrative Staff** who support the leadership in their service to the members.
- **Special Committees** as appropriate to address time-limited issues.

13. Knowledge Mobilization (KMb)

Knowledge Mobilization (KMb) activities will be prioritized to promote the expeditious translation of our research results into critical policies, to ensure the findings are meaningful to end-users, and to lead to measurable changes in practice and policy. We have already created connections between our network researchers and the community, and stakeholders for the development of strategic research partnerships and public dissemination of our findings. Moreover, highly qualified personnel with some KMb experience will be selected and hired as a valuable asset. We are committed to devising and implementing the best knowledge mobilization strategies according to existing guidelines, including the creation of a multilingual website, dashboard platforms, and computational tools, the use of TV, newspapers, social media, and networks, and the organization of workshops and summer schools. The Working Group of AI4Mpox will play a key role as well.

The pathways to this objective will include the following: knowledge mobilization between the AI4PEP network and knowledge users, embedding gender, equity, inclusion, and decolonization (GEID) in knowledge mobilization and the uptake of evidence, organizing activities that will help facilitate knowledge mobilization and the uptake of evidence

- **Knowledge Mobilization between the AI4PEP Network and Knowledge Users:** AI4Mpox will build on its existing expertise and capacity in knowledge mobilization and the uptake of evidence and continue to nurture and develop partnerships with knowledge users to ensure a rapid and sustainable flow of innovative ideas and solutions from the network to knowledge users. The network will adopt the knowledge-to-action process by actively involving knowledge users in clinical public health modeling projects: from forming research objectives and questions, and developing research methodologies, to translating research results and designing appropriate research dissemination to facilitate knowledge transfer to knowledge users. To achieve this, we will hold retreats with key knowledge users at the beginning of this new initiative to identify model needs. These will be identified by the research teams, and the feedback will inform the calls. We will regularly engage knowledge users through a policy brief series. We will interact with other networks to promote AI-based techniques in One Health research and leadership, including through co-hosting webinars to deepen network knowledge mobilization and uptake of evidence synergies. We will publish our research in high-impact journals and present findings at international scientific meetings, and then translate these findings through a Policy Brief Series into policy-relevant knowledge.
- **Embedding GEID in Knowledge mobilization and the Uptake of Evidence:** We will use an intersectionality-based approach to knowledge mobilization and the uptake of evidence. To do so, we will liaise with representatives of marginalized communities and we will use an APEASE approach (Affordability, Practicability, Effectiveness and cost-effectiveness, Acceptability, Side effects/Safety, and Equity) in reviewing and selecting knowledge mobilization interventions. More specifically, we will identify:
  - Barriers and obstacles faced by minorities in their process of knowledge mobilization and evidence uptake
  - Potential facilitators in the implementation of the process of knowledge mobilization and evidence uptake
  - How current practices could be improved and enhanced to become inclusive and equitable, by removing obstacles/barriers and involving facilitators
- **Organizing Activities That Will Help Facilitate Knowledge Mobilization and the Uptake of Evidence:** We will create a central multilingual website for archiving, sharing, exchanging, and disseminating research ideas, methodologies, and outputs for this new initiative. We will have a dedicated communication and community engagement expert to spearhead the activities of this particular initiative, as we are going to give it special focus. Our social media presence will include a monthly blog where senior and junior researchers across the network discuss aspects of network activity, engaging the public and media. Proposed products to share knowledge with each community include factsheets and infographics, radio advertisements, and newspaper editorials. The aim is to promote strategic sharing of expertise with project stakeholders, including training of local tradespeople, informing the broader communities about the research process and results (including possible outbreaks), and supporting researchers to gain a deeper understanding of the interplay of complex contextual factors and ensure relevance to each country. The intent is to support stakeholders to develop and translate culturally relevant knowledge outputs. We will host network-wide webinars and on-location workshops for the exchange of research ideas, methodologies, and results.

14. **Budget summary**:

Item of expenditure	Year 1 1st Half	Year 1 2nd Half	Year 2	Year 3	Year 4	Year 5	Total
DRC	48,673						48,673
Burundi	44,248						44,248
Nigeria	44,248						44,248
Cameroon	35,398						35,398
Senegal	13,274						13,274
Ghana	13,274						13,274
Ethiopia	13,274						13,274

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