Children on the Move: Using Satellite Data Analysis in Conflict/Famine-Affected Areas

Lessons Learned Report

Delivered on 20 November 2019

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Executive Summary

Over half of Somalia's population is composed of pastoralists, many of whom practice nomadic pastoralism. While their mobility enables adaptability, it also results in higher vulnerability to external factors including slow-onset environmental events, which have increased in severity and frequency over the years. The collection of longitudinal data on nomadic individuals is challenging, especially because these populations are often situated in remote regions and change locations frequently. This project therefore implemented and evaluated additional technological methods to address the gaps in current data collection practices.

This report captures the lessons learned through a collaborative project titled, "Children on the Move: Using Satellite Data Analysis in Conflict/Famine-Affected Areas." The Governance Lab at New York University, the Signal Program at the Harvard Humanitarian Initiative, and UNICEF considered the use of satellite imagery analysis to develop a standardized methodology to assist in the identification and monitoring of patterns of population movements in Somalia. More specifically, the objective of this research was to develop a change detection methodology to monitor movements, IDP camps, and informal settlements in Somalia with the use of remote sensing technologies. Through remote assessments, information can be rapidly collected and analyzed to improve UNICEF and partners' capacity to predict population movement and target development and aid activities more efficiently and effectively. This document details the project progress and the rationale for transitioning from satellite imagery analysis to agent-based modeling as the primary means of analysis. There is no single methodology that addresses all the components of the work completed, but the tested methods add unique value to ongoing humanitarian work. Next steps for the completed work include refining methodologies and development of further case studies that can be shared with local humanitarian groups to inform ground operations.

Additional Project Information

- The project addresses Sustainable Development Goal 9: "Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation." This project considered two methodologies for use in humanitarian research: satellite imagery analysis and agent-based modeling. Through methodological exploration, we can evaluate the value added of technological approaches in the humanitarian sector.

- In the course of our research, we were cautious to continuously incorporate risk management, evaluating our findings against established standards for maintaining human and data security. There was minimal risk associated with the project, given no demographically or personally identifiable information was incorporated. The risk that did exist came from the handling of very high resolution satellite imagery. The imagery used for this work was consistently downloaded on secure computers and was not shared with others as a precautionary measure.

- This project resulted in the generation of two major products: 1) imagery interpretation guide and 2) an agent-based model (ABM).
    - The imagery interpretation guide highlights a variety of landscape features as they appear in satellite imagery, which to the knowledge of Signal researchers, did not previously exist. The collection and documentation of the information will assist future imagery analysts when conducting research in the region.
    - The ABM enables the rapid simulation of objects over space and time. Simulations are scalable and replicable and can be designed with numerous inputs. While the results generated for this project are for nomadic pastoralists, ABM enables the creation of multiple agent types, allowing disaggregation by age, sex, and other characteristics.

- The prototype ABM developed as a part of this project does not incorporate personally or demographically identifiable information and all the agents are simulated. While the current prototype simulates the general spatio-temporal movements for pastoralists, the incorporation of more data would enable a more granular breakdown of the simulated agents by age, sex, and a number of other characteristics. The resulting simulations can assist humanitarian agencies in better understanding the patterns of movement associated with pastoral movement to better position humanitarian aid and assistance in crises.

- The Java-based ABM code is available via GitHub and the Imagery Interpretation Guide, titled Satellite Imagery Interpretation Guide of Landscape Features in Somaliland, can be found on HHI's website. The videos elaborating on the project background, the satellite imagery analysis, and ABM development are hosted by Harvard Humanitarian on YouTube.

Acknowledgements

This project, entitled, "Children on the Move: Using Satellite Data Analysis in Conflict/Famine-Affected Areas," submitted in response to the 2017 call for proposals by the World Bank's Development Data Group (DECDG) and the Global Partnership for Sustainable Development Data (GPSDD), is supported by the World Bank's Trust Fund for Statistical Capacity Building (TFSCB) with financing from the United Kingdom's Department for International Development (DFID), the Government of Korea, and the Department of Foreign Affairs and Trade of Ireland.

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Introduction

A. Project Background

The Governance Lab at New York University (GovLab), UNICEF, and the Signal Program on Human Security and Technology (Signal) at the Harvard Humanitarian Initiative (HHI) worked on a year-long project titled, "Children on the Move: Using Satellite Data Analysis in Conflict/Famine-Affected Areas". The project considered the use of satellite imagery analysis to develop a scientifically-tested method for identifying and monitoring nomadic pastoralists, internally displaced persons (IDP) camps, and informal settlements in Somalia.

Prior to the official project start date, UNICEF Somalia identified areas of interest (AOIs) for analysis in August 2018. The identified AOIs were located on routes commonly traversed by populations on the move and were therefore prioritized for analysis. All in all, approximately 24 AOIs and their surrounding areas were monitored over the course of this project. Upon receiving the list of AOIs, the Signal team examined cataloged satellite imagery to establish a set of indicators to assist in the identification of human settlements and patterns of migration in the AOIs. These indicators included the presence of 1) permanent and/or temporary settlements (including the examination of shelter condition and the construction material used), 2) livestock herds and/or agriculture, 3) surface water, 4) vegetation, and 5) roads. Upon sharing the findings with UNICEF HQ and UNICEF Somalia, the analysis was repeated for the same AOIs across different dates. The purpose of repeated analysis was to capture changes in the listed indicators to better understand the dynamics of populations on the move.

Following the successful delivery of the findings, Signal Program analysts reviewed the methodology to date in February 2019. The project's original methodology called for a degree of high-resolution satellite imagery that, despite the best efforts of those engaged, could not be obtained at the rate and quality required to continue conducting high-class multi-temporal change detection to capture shifting patterns of migration and identify population settlements. For these reasons, the original method was deemed unsustainable and unsuitable by the Signal team. Building upon the analysts' substantial contextual work to better understand the drivers of migration and the current state of affairs in Somalia, as well as extensive conversations and reviews involving all project partners, the team identified agent-based modeling (ABM) as an alternative and more appropriate method to meet the research objectives in March 2019. The limitations of satellite imagery analysis and details regarding ABM, its applicability to the research objectives, and proposed future use follows in section II of the report.

This report captures and elaborates on the changes made over the course of the project, documents lessons learned, and acts as an introduction to ABM and predictive analytical methodologies, highlighting their potential value added to work done in Somaliland and in similar regions around the world.

B. Scope of Work and Goals

Intended to cover a one-year period, the original proposed scope of work included the following elements with a budget of $118,000:

Development of a Change Detection Technique Using Satellite Imagery to Track Populations on the Move

The Signal Program's objective was to create a standardized research methodology that identifies indicators in satellite imagery relative to nomadic pastoralists, IDPs, and/or populations on the move.

Data Integration and Correlation Analysis

Satellite imagery at varying spatial resolutions (> 1 m, 30 m - 1 km) were integrated to consider the relationship of changing environmental conditions at lower resolutions and small-scale phenomena identified in high-resolution satellite imagery.

Applied Research & Teaching Materials

The Signal team conducted repeated analysis of identified AOIs and periodically shared the results with UNICEF for their review. The Signal team planned to produce the following products based on the research:

- A workshop for humanitarian practitioners on the use of remote sensing, spatial analysis, and ABM to study migration;
- A peer-reviewed academic paper describing the successful application of the methodology in the studied context;
- Public-facing educational materials to train and mainstream the use of the used methodology within the humanitarian sector; and
- A presentation of findings to key stakeholders.

To achieve these objectives, the project was divided into four phases:

Phase 1

Identify and validate repeating factors found in satellite imagery consistent with pastoralist displacement. This included the identification of IDP camps and informal settlements in addition to environmental changes that may be associated with human presence.

Phase 2
Correlate variables identified in phase one to determine the relationship among the variables and their effect on pastoralist displacement.

Phase 3
Analyze variables over time using satellite imagery at high, medium, and low resolutions.

Phase 4
Draft and disseminate methodology and findings through final products, including teaching materials, publication of a peer-reviewed journal article, and a workshop for key stakeholders.

Project scope centered on understanding the intersection of environmental change, conflict, and nomadic pastoralists and IDPs. The objective: to improve capacity to track and monitor populations on the move, increasing UNICEF's capability to target aid activities more efficiently and effectively. Current data collection methods are expensive, time-consuming, and diagnostic, capturing and utilizing crisis data in a reactionary modality rather than in a predictive manner. This project aimed to identify, explore, and test a scientifically-sound method for understanding mobility patterns of populations on the move.

C. Timeline

The original project timeline was 01 April 2018 to 01 April 2019. Due to administrative delays at Harvard University, the project start date was pushed back to 20 September 2018. The delayed start date resulted in a request for a No Cost Extension to to 18 October 2019, which was filed and approved in March 2019. In summary, the revised project timeline was from 20 September 2018 to 18 October 2019. The deliverable submission dates were shifted given the extension:

Deliverable 1
A typology of self-settled nomadic and semi-nomadic pastoralist camp locations, delivered as a PowerPoint presentation at a collaborative meeting with UNICEF and GovLab in October 2018.

Deliverable 2

Report documenting progress to date, including significant findings, future work plans, and challenges associated with ongoing work. The report also documents the limited success of the environmental correlation analysis.

Deliverable 3
Submission of a paper to a peer-reviewed journal article, which considers the ABM simulations and the results of the simulation runs.

Deliverable 4
A series of 3-5 short recorded video 'talks' explaining project, findings, and developed model.

Deliverable 5
An imagery interpretation guide based on imagery analysis results. Parts of this guide will be repurposed as blog posts, disseminating the information to a public audience.

Deliverable 6
A final lessons learned report (this document) reflecting on what worked and what did not work.

D. Team Members

The project team was composed of individuals from GovLab, UNICEF, and the Signal Program.

GovLab
Stefaan Verhulst | Co-founder and Chief Research and Development Officer

UNICEF
Natalia Adler | Data, Research, and Policy Manager
Lawrence Oduma | Children on the Move Project Manager

The Signal Program
Saira Khan | Imagery Analyst
Rob Baker | Director
Isaac Baker | Imagery Analysis Manager
Gregg Greenough | Lead Researcher
Erica Nelson | Lead Researcher
Swapna Thorve | Technical Consultant

Stefaan Verhulst provided project oversight and acted as a communication liaison between project members and the World Bank. Natalia Adler led project conceptualization and negotiated partnerships. The Signal team led the research and analysis efforts for the project. The Signal team changed substantially between project conception and final execution: initial team members included Rob Baker, Isaac Baker, Nathaniel Raymond, and Stuart Campo, whereas the project was ultimately executed by Saira Khan with oversight and editorial contributions from Rob Baker and Isaac Baker. Erica Nelson and Gregg Greenough contributed to this project in a consulting capacity and were critical to the development of the methods and final products. Swapna Thorve was recruited to provide technical assistance for the development of the agent-based model and final products.

II. Methodology

A. Imagery Analysis

Imagery analysis was our primary methodology until March 2019. The most significant techniques and findings are documented in powerpoint presentations submitted to project partners in November and December 2018 and in the progress report submitted to the World Bank on March 15th 2019. In summary: UNICEF Somalia identified the majority of AOIs in August 2018 and shared the names of individual settlements with Signal analysts via email. The analyzed settlements are popular transit points or destinations for populations on the move and are also locations served by UNICEF Somalia. Upon receiving the settlement names, Signal analysts located the latitude and longitude of the AOI and downloaded the most recent very high resolution (VHR) satellite images from Maxar's EV-WHS platform. Access to the EV-WHS platform was made possible by the US State Department's Humanitarian Information Unit NextView license.

Between October 2018 and February 2019, analysts regularly monitored EV-WHS for updated imagery, monitored local news reports, and scanned areas beyond the AOIs to capture any indication of populations on the move or related phenomena. While imagery analysis provided insight on natural and artificial phenomena from a geospatial perspective, the spatial and temporal resolutions proved insufficient to fully capture the research objectives. While the temporal resolution could be corrected through the acquisition of new imagery, the associated costs are high and unsustainable for the consistent analysis expected of this project.

Spatial resolution

The highest spatial resolution available to analysts was approximately 50 cm. This resolution is granular enough to differentiate individual structures, vehicles, and even large animals, but is too coarse to capture individual humans. When considering populations on the move, analysts particularly focus on locating small temporary structures, often constructed with light-weight material that are easily transportable. This approach has been used in previous Signal projects when considering population movements across Sub-Saharan Africa and the Middle East. The successful findings of Signal's previous projects suggested that the same methodology could apply to this research.

Temporal resolution

The VHR imagery available in EV-WHS is not consistent across Somaliland, meaning that some areas are more frequently captured than others. Signal analysts found that large urban areas were more frequently captured compared to rural settlements; for example, the initial reconnaissance of available imagery in EV-WHS conducted in October 2018 showed that there were 21 archived images of Location A and only 3 images of Location B. The most recent image of Location A was captured on April 28 2018 while that of Location B was captured on March 3 2017. The image of Location B on March 3 2017 likely did not reflect what the landscape and/or the population of the town looked like in late 2018. The outdated imagery of AOIs was inadequate to analyze the situation in October 2018. The inconsistency in imagery capture was a major disadvantage to the anticipated analysis techniques of this project given that populations can move on a daily, weekly, or even monthly basis. The large temporal gaps make it more likely that critical changes in the landscape are missed.

Cost of tasking new imagery

While archival satellite imagery may not be consistently available and may be outdated for some of the AOIs analyzed, it is possible to task additional imagery of those locations. To task a satellite means to request the imaging of an AOI at a future date by a specific sensor. The delivery of the ordered image is typically lagged by 1 - 2 days because of the time it takes to submit the tasking request, the imaging of the AOI itself, image processing, and delivery to analyst. In addition to the temporal lag and inadequate spatial resolution, the costs typically associated with tasking imagery makes this work a time-consuming and costly endeavor, rendering high resolution imagery unsustainable for continued analysis (table 1). Imagery is irregularly made available in EV-WHS; to ensure consistent analysis across 24 AOIs for the duration of the project, the projected costs range from $546,000 to $3,432,000 (table 2). While high costs do guarantee consistent image collection, the spatial resolution does not change, and the quality and usability of imagery is not guaranteed.

Order type[1]	*Imagery type*	*Price per km²*	*Minimum order size*
Archival (older than 90 days)	WorldView-2: 3-Band Pan-Sharpened	$17.50	25 km²
New tasking	WorldView-2: 3-	$27.50	100 km²

[1] "Buying Satellite Imagery: Pricing Information for High Resolution Satellite Imagery." *Buying Satellite Imagery: GeoEye, WorldView 1, 2, 3, QuickBird, IKONOS, Pléiades*, LAND Info Worldwide Mapping, www.landinfo.com/satellite-imagery-pricing.html.

	Band Pan-Sharpened		

Number of AOIs	24
Weekly acquisition over project time	52
Archival order cost (25 km^2)	$546,000
New tasking order cost (100 km^2)	$3,432,000

While imagery analysis did not meet the research objectives of this project, the initial analysis work did fill existing data gaps. Prior to this study, to the knowledge of analysts, little to no information was available regarding the appearance of landscape features through satellite imagery in Somaliland. The identification of common natural and artificial landscape features is the beginning of a visual database that can assist future geospatial/humanitarian analysts in work in the region. The value of the imagery interpretation guide is discussed in the Results section.

In summary, the inconsistent temporal resolution, inadequate spatial resolution, and the steep cost associated with tasking satellite imagery AOIs made this an inappropriate and unsustainable means of analysis for the project in consideration. Therefore, the primary methodology for this project was re-evaluated and modified to use ABM in Spring 2019.

B. Agent-Based Modeling

The Signal team identified ABM as an appropriate alternative methodology to understand how conflict and environmental changes affect nomadic pastoralists and IDPs in Somalia. ABM simulates the movement of agents (e.g., nomadic pastoralists) based on the interactions between agents and their surrounding environment. Through predictive modeling, a variety of scenarios can be tested, e.g., the effect of a single drought event or considering conflict as the primary driver of movement. By rapidly testing how the movement of nomadic pastoralists changes over time, ABM can be used in a more predictive capacity. Modeling's added value has already been recognized by humanitarians and there is a need to develop models to better understand what works and what does not work for understanding humanitarian crises.[2]

[2] "Workshop Recap: Predictive Analytics in Humanitarian Response." *The Centre for Humanitarian Data*, UN OCHA, centre.humdata.org/workshop-recap-predictive-analytics-in-humanitarian-response/.

Prior to developing the agent-based model for this project, the Signal team explored ABMs developed by other universities. This included in-person meetings and phone calls with modeling experts, some of whom have sought to address similar objectives.[3] In addition to understanding how other models have been created, considerable time was spent researching the decision-making processes of pastoralists in Somaliland. This was perhaps the most challenging component of the project, given that there is very limited and often outdated information available about pastoralist decision-making processes in the region. This data gap had to be filled with hypothesized assumptions, informed by existing literature and discussions with experts. The gap also highlighted the need to study this region. Historically, Somaliland has been vulnerable to prolonged, extreme, and frequent droughts, a pattern that has intensified in the last several decades and is expected to continue into the future. Already, hundreds and thousands of people are displaced throughout Somaliland and more people are at risk due to intensifying climatic changes and ongoing conflict events. This agent-based model seeks to test the relationship between the variables and interpret whether this model captures the phenomenon in its entirety, informing future improvements.

The code for this ABM was developed in RePast using Java and is accessible via GitHub. RePast was chosen because it is a robust, well-regarded, highly used software platform in the social sciences. RePast can also be integrated with GIS, which was an essential component to the work completed in this project. Further, good documentation and user support made RePast appealing to ensure that the product could be well developed in a short time frame. RePast is compatible with both Java and Python, but Java was used because it's considered to be more robust than Python. The developed ABM largely relies on heuristics and probability statements. An example of a probability statement is "in the wet season, if the agent is situated on a private land parcel, there is a 50% chance of the agent coming to an agreement with the landowner. If the agent and landowner come to an agreement, they can remain on the parcel. If the agent and landowner disagree, the agent has to search for a new parcel". The model was built using the best available information and demonstrates the value that ABM can bring to the humanitarian sector.

[3] Claudio Cioffi-Revilla at George Mason University and Robert Pietrusko at Harvard University

III. Results

A. Outputs

Satellite Imagery Analysis
The outputs generated through satellite imagery analysis were shared with partners as PowerPoint presentations. Relevant imagery was annotated to highlight critical features, including livestock, agricultural plots, structures, and water catchment mechanisms. The outputs of the analysis were further documented in the Progress Report and in the Imagery Interpretation Guide. The Imagery Interpretation Guide, titled Satellite Imagery Interpretation Guide of Landscape Features in Somaliland can be found on HHI's website.

Agent-Based Modeling
When the ABM code is run, .xlsx files are generated. Each output .xlsx file corresponds to a single agent. These files record the location of the agent at every timestep in the simulation, the ethnicity and clan affiliation of the agent, and the associated pixel score, which corresponds to the desirability of the location depending on the variables in consideration. The information generated through the ABM is entirely hypothetical and is not tied to an individual's identity. Because of the random generation of agents, there are no security concerns.

B. ABM Findings

Through the integration of environmental (e.g., vegatative cover, surface water, artificial water points), interpersonal (e.g., ethnic boundaries and conflict), and transactional variables (e.g., private vs public land delineation), pastoral migration was simulated for 10% of the pastoral population per administrative region in Somaliland and Puntland on a monthly time step between January 2008 and December 2018. Data from a UNFPA study (2014) suggests that the regions of Somaliland and Puntland are home to approximately 225,767 pastoralists. As the total number of individual agents must make a series of decisions at monthly intervals for 11 years, permutations of those decisions numbers into tens of millions, thus requiring a level of computing unavailable to researchers working on this project. Therefore, only 10% of this number (22,576 agents) were considered in the simulation.

The model generated an .xls file for each simulated agent. These files were converted into point data stored in geodatabases through a Python script. Following the generation of geo-tagged data, the information was analyzed in ArcMap 10.6.1 using geospatial tools and techniques to understanding the seasonal dynamics of population movement in 2008 and compared it to the spatial patterns of movement in 2018. The analysis revealed that there was virtually no inter-year seasonal variability of pastoral migration in both 2008 and 2018. However, there was a substantial change in the documented spatial patterns between the analyzed years. In 2008, pastoral patterns of movement were spatially dispersed across the region but became spatially concentrated on the western side of the study area in 2018. Higher density concentrations were also noted in 2018 compared to 2008. While this analysis cannot speak to the variability and patterns of movement in between 2008 and 2018, the comparison of the two years provides valuable insight about patterns of migration in those years.

C. Deliverables

Workshop

A strategic planning workshop was scheduled to take place as part of the project's launch phase in Nairobi, Kenya in October 2018. Ongoing conflicting schedules and a terrorist attack that took place in Nairobi in January 2019 delayed the meeting to June 2019.[4] Given the scheduling adjustment, the workshop's objectives were modified to reflect the work and changes made to date.

The workshop highlighted the value and limitations of satellite imagery analysis and demonstrated the practical applications and value added of agent based modeling. Prior to the workshop UNICEF Somalia anticipated that satellite imagery could readily observe individuals or small groups of people in near-real time. The misunderstanding was addressed at an in-person workshop in Nairobi in June 2019 and it was collectively decided that the research team, with support from UNICEF Somalia, would still finalize the satellite imagery interpretation guide but moving forward focus its efforts on ABM.

An ABM should be informed by those most familiar with the context to ensure the model is representative of the study population, its guiding heuristics, and behavioral trends. The learning outcomes of the workshop in Nairobi were primarily focused on knowledge exchange regarding ABM, satellite imagery, and the decision making patterns of pastoralists in Somalia. The workshop was extremely productive and well received by those in attendance.

[4] Sevenzo, Farai, et al. "At Least 21 Killed as Kenya Hotel Siege Is Declared Over." *CNN*, Cable News Network, 17 Jan. 2019, www.cnn.com/2019/01/16/africa/kenya-hotel-complex-terror-attack/index.html.

Imagery Interpretation Guide

The imagery interpretation guide provides direction on identifying indicators of human presence and populations on the move in Somaliland. Based on a thorough literature review and conversations with academic colleagues working closely on this topic and country, it appears that there is very little information on the identification of natural and artificial phenomena through satellite imagery analysis in this region.

In the past, the imagery interpretation guides created by Signal have standardized research methodology in the humanitarian sector. Signal developed these documents to assist the 1) the assessment and classification of wind damage to structures, 2) the identification of tukuls and the intentional burning thereof, and 3) differentiation of features in refugee camps. These manuals were developed at a time when such resources did not exist, and they added substantial value to the work completed by humanitarian analysts and continue to be used to date. This guide, considering the identification of landscape features in Somaliland, was developed because the analysts working on this project did not have such resources available to them as they conducted imagery analysis in the first phases of the project, however it would have been a useful product to have during the analysis and interpretation stages of the project. This guide was developed using free, open-source software, and was also shared as blog posts so that it is accessible to a wide audience.

Journal Article

The development of the ABM and its subsequent application to understand pastoral migration in response to environmental change and conflict between January 2008 and December 2018 are discussed in a drafted academic article. Due to limited computing capacity, only 10% of the agents were generated per administrative region. However, this analysis provides an additional case study to a growing body of literature that considers predictive analytics and agent-based modeling in the humanitarian sector.

IV. Summary of Recommendations

This lessons learned report documents the successes, limitations, and changes made during the execution of this project. Looking back at the work completed, the following recommendations are suggested to improve future work:

1. Available data sources and methodologies should be reviewed prior to development of the project proposal to ensure the appropriate data is available for the execution of the proposed methodology;
2. All project partners and stakeholders must convene within the first month of the project start date. The meeting time should be used to discuss the project expectations, including deliverable deadlines, means and frequency of communication, and planning for further meeting dates;
3. Monthly meetings, whether virtual or in person, should be scheduled throughout the project. These meetings should discuss project progress and any associated challenges to identify any concerns as early as possible;
4. All communications, decisions, and agreements should be consistently well-documented and made available to all project project partners to ensure the expectations are matching across all teams;
5. End-user input should be considered prior to the development of all deliverables. This way, the final product can be catered to the needs and interests of the end user.

V. Conclusion

The relationship between conflict, environmental change, and migration is complex and cannot be addressed through a single methodology. While satellite imagery analysis is able to uncover previously undocumented phenomena and allows for the analysis of non-permissive environments, it did not adequately answer the project research objectives despite producing valuable learning and training assets that can be used in other contexts. Following this realization, the project teams sought an scientifically-sound alternative solution that would be sustainable, scalable, and adaptable to scenarios at other locations. Agent-based modeling is a creative solution to address the gaps that could not be filled through the analysis of satellite imagery analysis.

It is important to emphasize the hard work of all those involved, particularly because the development of the ABM was a major undertaking for the teams involved. The guidance provided by Stefaan Verhulst, Natalia Adler, and Rob Baker were critical in ensuring the development of a successful tool. The research and implementation of the tool was made possible by Saira Khan, Swapna Thorve, Erica Nelson, and Gregg Greenough, who spent considerable time perfecting the product.

This successful collaboration integrated a range of expertise offered by UNICEF, GovLab, and Signal Program. The work accomplished through this partnership adds considerable value to the humanitarian field and provides a foundation for the further development of computer models, AMB in particular, in the sector.