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MedicAid Disaster Estimator (MADE): A Digital Tool for Humanitarian Relief Material Demand Estimations

Introduction

In 2023, the United Nations reported a staggering increase, with approximately 360 million people worldwide in dire need of humanitarian assistance, increasing by 30% since the start of last year [\[1\]](#). This surge in humanitarian demand was driven by an unprecedented convergence of crises, including climate change-related disasters like flooding in Pakistan, widespread food insecurity

across the Sahel and greater Horn of Africa, the ongoing conflict in Ukraine, and the devastating health consequences of conflicts in Yemen, Afghanistan, and Syria. This existed in tandem with the ongoing disruptions to health systems caused by the COVID-19 pandemic and outbreaks of diseases such as measles and cholera. These emergencies have created a greater need to uplift and support disaster relief organizations operating within this complex web of intersecting challenges.

When disaster strikes, relief organizations experience an immediate need to supply necessities such as food, water, and medical supplies. Non-Governmental Organizations (NGOs), which have played an integral role in the humanitarian response realm since their origins during World War II, aim to alleviate suffering and support the recovery efforts of communities impacted by disasters, conflicts, and crises. They function in recognizing the needs of an affected population and employing their expertise in fundraising, transportation, distribution, and acquiring supplies and services to aid those affected (Negi, 2022). The United Nations estimates that in 2024 alone, \$46.4 billion is needed for disaster relief in 72 countries around the world (Zarocostas, 2024). Such a magnitude of disaster relief calls for a tool that can advise relief agencies on the number of resources needed at the beginning of a crisis and can easily be updated as conditions rapidly change. When disaster strikes, relief organizations experience an immediate need to calculate demand for necessities such as food, water, and medical supplies, and would benefit from utilizing a demand calculator.

Resource demand calculation is vital for relief organizations to efficiently mitigate the impact of disasters. In the wake of a natural disaster, the initial uncertainty and unpredictability surrounding the needs of the affected population creates a need for urgency. Time becomes a critical factor as access to essential aid across those affected, especially among low-income communities, becomes a determinant in the fatality rates of a disaster (Baporikar & Shangheta, 2018). With limited resources, not only is timely response important but also accurate estimation of the needed resources. Humanitarian organizations have recorded significant waste in food and medicine with excessive material movement due to poor planning (Giedelmann-L et al., 2022). This lack of preparedness hampers the ability to effectively allocate resources and coordinate relief efforts, prolonging the recovery of communities in need. Therefore, there is a need for technology that efficiently and accurately estimates the essential needs of communities impacted.

Although large humanitarian organizations have private demand estimators, a plethora of local organizations that respond to disasters worldwide lack access to a demand calculator. A natural disaster can happen anywhere in the world. Multinational humanitarian organizations play a great part in the relief response to natural disasters. However, the presence of local NGOs, and the community input that is associated with their work, has proven to be vital in ensuring relief efforts are informed by local context and cultural commitment (Ali, 2016). Local organizations that are still functioning and capable join the effort to provide aid, but often lack an organizational memory to inform a quantitative calculation of initial needed resources (Baporikar & Shangheta, 2018). This often acts as a barrier to their ability to serve their communities after a natural disaster. Many established national NGOs already have the institutional resources to compute immediate basic needs, but the presence of competition between NGOs often deters organizations from sharing such knowledge (Kovacs & Spens, 2010). This gap in the sharing of institutional knowledge emphasizes the need for publicly accessible relief logistics technology.

Previous academic articles have introduced mathematical models for disaster needs analysis, but their findings and resulting calculators have remained largely limited to the academic community. Extensive and technical jargon, as well as restricted access to subscribers, have created a barrier between prior mathematical disaster aid models and the organizations that would benefit from

implementing them. Technology and Global Health Initiative, in collaboration with Health Tech Without Borders, aims to address this disconnect by creating a digital tool for humanitarian relief material demand estimations.

Materials and Methods

While research has been published on mathematical models for humanitarian relief demand calculations, there is a lack of applicable technology. One of the most important components to providing effective humanitarian aid following a disaster is an estimation of the types and amounts of resources demanded, which requires accurate data on impacted demographics, including the number of individuals requiring aid, their geographical distribution, and the specific support they require (Shao et al., 2020; Kirac & Milburn, 2018). Conventional methods for gathering such data encompass aerial surveys, ground-based assessment teams, and emergency reporting channels; however, in such time-sensitive situations, delays in data collection and inundation of emergency hotlines pose significant consequences (Kirac & Milburn, 2018). Several methods for forecasting resource demands are described below.

First, demand for emergency resources can be calculated using case-based reasoning (CBR), a problem-solving methodology that involves solving new problems by recalling and adapting solutions from similar past cases utilizing artificial intelligence (Aamodt & Plaza, 1994). In CBR, a new case for immediate resource allocation is compared to a database of past cases, with similarities identified through various methods such as matching features, attributes, or context (Aamodt & Plaza, 1994). Another technique that has been used to forecast resource demand is a gray model system, in which mathematical modeling techniques are used for forecasting based on a limited amount of data. Chen & Liu (2015) describe how this can be applied to natural disaster relief: first, resource demand is transformed into the predicted number of casualties; then, factors influencing the casualties are analyzed with the gray degree of association model, gray relational coefficient, and correlation degree are calculated, and a prediction is outputted. Predicted values have been shown to have a high level of accuracy. Several other mathematical and statistical models have been applied to predict emergency resource demands following natural disasters. Sun et al. (2013) designed a fuzzy rough set model specifically for disaster relief calculations, while Mohammadi et al. (2014) applied radial basis function (RBF) networks for the same calculations.

As outlined, mathematicians and researchers have created and published accurate and efficient methods of calculating the quantities of resources needed for disasters. However, amid disaster, it's impractical to expect that local organizers should conduct a literature review on material demand calculation models, and then manually calculate quantities of resources needed according to such models. These models require advanced mathematical and computer science expertise to employ, rendering them unusable by volunteer-based disaster relief organizations amidst a crisis. Therefore, while there are many papers detailing mathematical models for material demand calculations, there is a gap between useful research and applicable technology. A maximally user-friendly tool that does not require intensive research or mathematical background knowledge does not exist for demand forecast of emergency supplies in a natural disaster.

Project MedicAid Disaster Estimator (MADE) was formed to address the lack of a user-friendly and accessible demand calculation tool. The primary stakeholders involved in the creation of project MADE are Harvard Computer Society's Technology and Global Health Initiative (TGHl) and Health Tech Without Borders (HTWB). TGHl is an umbrella organization within the Harvard Computer Society composed of undergraduate students with the mission of promoting equitable technologies for global health. Health Tech Without Borders, Inc. (HTWB) is a global non-profit organization that supports local communities affected by sudden humanitarian emergencies via digital tools. The first

stage of the project involved extensive searching for existing digital tools that satisfy the project aim. Such a tool was not found. Subsequently, the team interviewed various experts in the humanitarian field including doctors, nurses, pharmacists, and NGO CEOs regarding current tools used in the field. A publicly accessible and easy-to-use tool was not uncovered. The team conducted further research in the literature regarding humanitarian demand calculations and found an abundance of models. Taken together, the scope of project MADE was determined: build a website that calculates water, food, and medication quantities needed in response to a natural disaster, provided the number of people and the number of days. The content available through the MADE website is for informational or educational purposes only. Please see our complete online Terms for more information.

Results

MedicAid Disaster Estimator (MADE) is a user-friendly and accessible tool for the quantitative calculation of food, water, and primary medicine needed in response to a natural disaster. As outlined in Figure 1, the website has three calculators: a water calculation tool, a food calculation tool, and a medication calculation tool. Currently, the calculators incorporate a linear model relying on user input. MADE is designed to serve organizations that engage in disaster aid distribution in any affected region of the world. As a result, the user has control over model inputs, allowing flexibility in the output of the relief demand calculation. Each calculator has a standard model and an advanced model. Users can input more or less data points based on the knowledge available to them, enabling functionality for a variety of target users; the simple models display any assumptions made.



Models

Save time and energy with our estimators!

Calculate water needed now!

Calculate Medicine needed now!

Calculate food needed now!



Figure 1 MADE Website Calculators

The website, visualized in Appendix A, focuses on maximizing the user experience by incorporating hard-to-find data such as the average amount of food needed into easy-to-understand and scaled results. The backend incorporates metrics on food, medicine, and water needed in a disaster context, eliminating the need for users to cross-check and compile these estimates during a fluid and emergent catastrophe. The website design is simple and prioritizes user accessibility. Users can access all three calculators on the first page, with an easily accessible “return home” button at the bottom of each calculator’s page. Both customary and metric units are available, so results are meaningful in various geographic locations.

When the water estimator is selected, users are asked to input the number of individuals the user wants to support via water provision and the amount of water needed per person (in liters). The advanced model includes an option to specify the duration of water demand (in days). Water is

needed for the specified number of individuals (in liters) for the duration of water demand (in days). The output is the amount of water needed per day, per month, and per the specified amount of days for the specified amount of people. This output is based on a scaling factor of 3mL of drinking water/per person/per day recommendation proposed in Sphere's 2018 *Water and Sanitation Planning for Response Handbook* (Dyer & Lamb, 2018), detailed in Figure 2. Sphere is a global organization that defines standards for the quality of humanitarian response in five sectors, one of which is water. Utilizing recommendations from an industry leader in humanitarian water allocation ensures validity in MADE's outputs.

Water Calculator Page

Water Model

DESCRIPTION

DESCRIPTION OF INPUTS

Advanced Model

Number of people

e.g. 100,000

Average amount of water needed per person in ounces

e.g. 100

Calculate

Return home

Figure 2 Water Estimator Output

The standard food estimator asks for two inputs: the number of individuals the user is calculating food demand for, and the duration of food demand. The output is a comprehensive list of food categories, detailed in Figure 2, and the quantity (in grams) needed to meet essential caloric and nutritional goals. This output is based on per person/ per day adequate food rations in terms of energy, protein, and fat for populations entirely reliant on food assistance as recommended by the *Food and Nutrition Needs in Emergencies* guidelines. The recommended quantities were used as a scaling factor, as shown in Figure 3. The *Food and Nutrition Needs in Emergencies* guide was jointly developed by the World Health Organization, the World Food Program, the United Nations International Children's Emergency Fund (UNICEF), and the United Nations High Commissioner for Refugees (UNHCR) (UNHCR et al., 2002)). The categories and quantities of food were also cross-checked and in agreement with Unbound Medicine's General Feeding Program Field Operation Guide (Food and Nutrition, n.d.). This established the validity of the recommendations and the MADE outputs derived from them. The advanced food estimator allows the user the option to choose from a variety of preset food ration types, each following *Food and Nutrition Needs in Emergencies guidelines*. This allows users to customize their output based on available resources.

Food Model

DESCRIPTION

DESCRIPTION OF INPUTS

Advanced Model

Number of people:

e.g. 100,000

Amount of days:

e.g. 90 days

Calculate

Return home

Figure 3 Food Estimator Output

The input for the standard medicine calculator is the number of people the user intends to provide medicine to and the duration of medication demand. The output is a list of medications, scaling factor shown in Figure 4, and the quantities needed for the specified number of people. Input data was gathered from the World Health Organization’s *2017 Interagency Emergency Health Kit* (World Health Organization, 2017) and cross-checked with the *European List of Emergency Medicines* provided by the European Association of Hospital Pharmacists (Vinci et al., 2020). The two sources were in agreement regarding recommendations, suggesting credibility and generalizability. The medication calculator is intended for auxiliary use by trained medical professionals only.

Medicine Needs Estimator

Enter the number of people and the number of days to calculate the required medicine supplies.

Number of people:

e.g. 1000

Number of days:

e.g. 30

Calculate

Figure 4 Medicine Calculator Scaling Factors

MADE currently uses a web-based estimator tool, which is implemented using an HTML and CSS frontend and a Python backend, utilizing the Flask library for server-side operations. The tool is hosted on Pythonanywhere under the complimentary subscription plan. After the user presses the "Calculate" button, the inputs are passed to the respective backend models, detailed in Figure 5, which generate and return the calculated amounts for water amount, food types and quantities, and volume of medicine. Calculations are detailed in Figure 3. MADE currently does not track or store data collection. The free website MADE hosts is available for public use without an account. MADE does not use cookies or any other form of data collection techniques.

Figure 5
Backend Python Calculation

Water: Scaling Factor (Quantity of drinking water per person (liters)) x Number of people x Number of days
Food: Scaling Factor (Quantity of food category (g)) x Number of people x Number of days
Medications: Scaling Factor (Quantity of a given medication (variable)) x Number of people x Number of days

Note. Backend Python calculations of MADE for the Water, Food, and Medication Demand Calculators.

Figure 5 Backend Processing Flow

The Python script does not allow for real-time data processing as it is designed for static calculations based on the user's input through HTTP POST requests. The Flask application processes the user's input through functions for each respective model, where calculations are performed based on reliable base data to later be scaled up or down based on the input. Currently, our website is hosted on PythonAnywhere's free plan which will present several limitations for scalability. The plan only contains 512 MB of storage and restricted CPU time which can lead to future challenges when updating the website since it limits the amount of testing executed per day.

Additionally, the free plan presents the obstacle of being unable to change the current domain name and as a result, if we don't upgrade or switch services the URL will be locked to "accountusername.pythonanywhere.com". A possible solution to these issues is to make a modest investment into a higher tier plan on PythonAnywhere's hosting services, as they offer an upgrade path that includes a custom domain name, support for up to 100,000 daily hits, and 20 times more CPU usage, which will greatly enhance the scalability and performance of the website.

Future Directions

A variety of experts in the humanitarian field were interviewed to gain insight that shaped the scope of our project and feedback that will guide the future direction of the project. These experts include Marianna Petrea-Imenokhoeva, a digital health expert; Dr. Jarone Lee, an emergency medicine and critical care physician; David Eisenbaum, an organizational management professional who specializes in emergency, risk, and crisis management; Oleksandra Shchebet, a neurologist and clinical research coordinator; and Dr. Jeff Hersh, Chief Medical Officer and Founding Member of CARTx, a biotechnology company. Some example questions asked in interviews include "From your experience, what are the most critical healthcare needs immediately following different types of disasters?" and "What features should a disaster relief tool have to maximize its efficacy?". Questions were articulated based on the expert's field. The main outcomes of the interviews are as follows.

One possible future direction is to tailor demand forecasts to the specific region affected. To do this, "archetypes" would be created that categorize countries based on their unique conditions and current capacity to respond to a crisis. Factors to be considered include currently available local resources, the affected region's level of development and existing infrastructure, and the affected region's natural terrain/climate/geography. This specification would aid in logistical organization, such as medicine storage and resource transportation, as well as indicate the types of resources in higher demand (e.g., special attention should be paid to providing people with resources to protect against cold-related injury and illnesses in colder climates regions, or heat-related complications in warmer climates). Creating these "archetypes" eliminates the need to create an individual profile for each affected country; instead, we can simply select the most appropriate archetype that encompasses the needs and conditions of the relevant country, accelerating response time to disaster.

Another further direction is to tailor estimates to the specific genre of natural disaster (earthquake, hurricane, fire, tsunami, etc.). Different disaster types require different medical resources and equipment. For example, earthquakes might result in more traumatic injuries, while floods, hurricanes, and tsunamis are accompanied by increases in water-borne illnesses. We could also create a classification system to categorize disasters by severity (e.g., with "Level 1" being the least severe and "Level 5" being the most) to account for varied levels and types of demands in our estimations.

Experts also suggested the implementation of language and cultural accommodations. MADE is intended to model disaster relief in regions around the globe. Including language settings that can translate the entire website and resource recommendations into the user's native language, promotes global accessibility. We may also include preferential settings for countries where certain dietary restrictions, such as kosher or vegetarian, are common.

Lastly, it would be beneficial to users if the website was translated into an app that could be used offline since natural disasters may result in a loss of internet connection. Additionally, certain regions of the world do not have access to consistent and reliable internet. Translating our website

into an app that can be used offline would help ensure that the model is maximally accessible in any location, regardless of access to the internet.

Conclusion

Natural disasters occur globally and indiscriminately, causing tremendous damage to communities. In such times, access to water, food, and essential medications can make the difference between life and death for many. While large humanitarian organizations play a role in aiding communities in need, local organizations are at the heart of many humanitarian relief efforts. Local relief organizations must be equipped with the tools to respond to disasters to maximize their impact. Many mathematical models have been published regarding methods to calculate resource demand in natural disasters yet, a publically accessible tool for resource demand calculations is not available. Project MedicAid Disaster Estimator (MADE) was formed to address the lack of a user-friendly and accessible demand calculation tool. MedicAid Disaster Estimator (MADE) is a user-friendly website that has been created for the quantitative calculation of food, water, and primary medicine needed in response to a natural disaster.

The website utilizes data only from credible industry leaders such as the World Health Organization, Sphere, the European Association of Hospital Pharmacists, the World Food Program, and the United Nations International Children's Emergency Fund to ensure that calculations are reliable. The MADE website has a Water Demand Calculator, a Food Demand Calculator, and a Medication Demand Calculator. The output for the Water calculator is the recommended quantity for daily water consumption scaled by the number of people and the number of days specified. The output for the Food Demand Calculator consists of the recommended food categories scaled by the number of people and the number of days specified. The output for the Medication calculator consists of the recommended foundational medicines during a disaster scaled by the number of people and the number of days.

Future steps include user testing with a variety of focus groups to ensure that the website design is easy to navigate and language is coherent. Features such as tailoring the demand forecast to account for the specific region affected and specific genre of natural disaster are modifications that could be implemented to improve MADE. Additionally, language and cultural accommodations could be applied to increase accessibility across countries. Creating a MADE app would allow for offline access in places and situations where the internet is not available.

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