



Artificial Intelligence-Powered Optimisation of Food-Energy-Water Resource Allocation in Nigerian Internally Displaced Persons' Camps

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Abstract

The rising number of internally displaced persons (IDPs) in Nigeria, caused by insurgency, armed conflict, and climate-related disasters, has exposed serious weaknesses in how food, water, and energy are managed in IDP camps. Conventional manual distribution methods are slow, fragmented, and prone to shortages, over-allocation, and avoidable waste. This study addresses the problem by developing an Artificial Intelligence (AI)-enabled mobile decision-support system for resource allocation in Nigerian internally displaced persons camps. The mobile application provides a simple conversational interface that allows camp administrators to enter routine operational data on populations, stocks, water supply, and energy availability. The AI component processes these data to validate entries, estimate short-term needs, and recommend allocation plans that respect the interdependencies between food, energy, and water. The prototype was implemented with Flutter, Firebase, and the Gemini application programming interface (API), and evaluated against a manual planning baseline under four representative camp scenarios. The evaluation covered response time, usability, feasibility, transparency, explainability, auditability, and allocation outcomes. The results show that the AI-assisted approach produces structured allocation plans faster and with fewer avoidable stockouts than manual planning, while keeping human decision-makers in control of every recommendation. The work offers a practical foundation for operationalising the Food–Energy–Water (FEW) nexus at camp level in Nigerian internally displaced persons operations.

Keywords: Artificial Intelligence, internally displaced persons, resource allocation, mobile decision support system, Food-Energy-Water nexus.

1.0 Introduction

By the end of 2023, an estimated 3.34 million people were living in internal displacement in Nigeria as a result of conflict and violence, with about half concentrated in Borno State [1]. Most conflict-related displacement has been concentrated in the north-eastern states of Borno, Adamawa and Yobe, where insurgency and armed attacks have left many households homeless [2], [3]. Beyond conflict, floods and droughts also displace households, further straining the humanitarian response and complicating service delivery [4], [5].

Access to three essential services, namely good food, safe water, and reliable energy, is critical for the welfare of internally displaced persons in camps and host communities. These services are tightly linked: a power failure can stop boreholes and jeopardise stored food; a water shortage undermines hygiene and nutrition; and irregular food supply deepens nutritional vulnerability. The Food–Energy–Water (FEW) nexus captures these interdependencies and shows why the three systems cannot be managed in isolation [6], [7].

Planning and allocating basic needs in internally displaced persons camps still rely heavily on manual processes, even though the scale and volatility of humanitarian operations have grown. Camp officials and humanitarian staff use paper forms, spreadsheets and periodic meetings to design rations, track water supply, schedule pumping, and manage fuel allocation. These methods are useful but slow when conditions change quickly: if population counts are not updated promptly and delivery records are not maintained, some camps run out of supplies while others become overstocked. Limited access to clean water and reliance on diesel-powered generators continue to increase operational pressure in affected communities [8], [9].

Recent works have explored data-driven methods and Artificial Intelligence to improve humanitarian planning and aid delivery [10]–[12]. Predictive analytics has been used to forecast population movements and humanitarian needs, as demonstrated by Project Jetson [11]. In the FEW space, digital and AI tools have supported demand forecasting, energy scheduling and food distribution planning [13], [14]. Lightweight Internet-of-Things-based monitoring can sustain food production in resource-constrained settings [15], and integrated appliance scheduling for autonomous hybrid renewable-energy systems shows how energy optimisation can be aligned with food production [16]. Digital-twin methods also enable decision-makers to examine scenarios before implementing resource-management interventions [17]. Nevertheless, there is limited evidence of these approaches being evaluated as integrated, routine decision-support workflows within Nigerian internally displaced persons camp operations.

This study is guided by a central question: can a mobile-based tool that uses Artificial Intelligence help camp managers allocate food, water and energy more systematically and efficiently in Nigerian internally displaced persons camps? It hypothesises that if routine operational data (stock levels, new arrivals, supply delays, outages, and similar variables) are captured promptly and processed with simple, explainable rules and constraints, then resource needs can be assessed more consistently and allocation plans generated faster with less avoidable waste. A mobile-first design is appropriate in Nigeria because mobile phones are widely used for communication and information sharing within displaced communities and humanitarian settings [18]. National and international systems such as the Displacement Tracking Matrix (DTM) and United Nations High Commissioner for Refugees (UNHCR) dashboards already provide baseline population and displacement information that such an approach can build on [19], [20]. Informed by Nigeria's National Policy on Internally Displaced Persons and humanitarian data-protection principles, the study aims to develop and evaluate a lightweight, explainable AI system that supports camp managers in day-to-day resource planning [10], [21]–[23].

The work bridges the gap between national policy provisions and the practical technological needs of internally displaced persons camp management. By implementing a simple AI-enabled mobile application that uses available operational data, the proposed system supports the integrated planning of food, water, and energy. The study contributes to ongoing efforts to improve resource efficiency, operational responsiveness, accountability, and sustainability in humanitarian settings.

2.0 Related works

The Food–Energy–Water (FEW) nexus provides a framework for understanding how resources can be managed collectively rather than separately. Hoff's foundational work projected the nexus as a policy and managerial tool, demonstrating that an intervention in one system can create co-benefits or negative effects in other systems [6]. Subsequent studies have extended the approach within environmental planning and the Sustainable Development Goals framework, showing the value of collaborative and integrated resource management [14], [24], [25]. Recent research continues to emphasise that integrated FEW modelling matters because a change in one resource can affect the demand, availability and environmental consequences of the others [26], [27]. The FEW Nexus 4.0 framework further applies nexus principles to digital and data-intensive resource management [7].

The systems perspective is particularly relevant to displaced populations, where disruptions in one resource spill over into others: power failures can stop boreholes; water shortages compromise hygiene and food preparation. Recent FEW research has also shown that integrated optimisation can reveal cross-sectoral effects beyond the immediate point of intervention, supporting the value of modelling resource relationships jointly rather than in isolation [26], [27].

Recent humanitarian research has increasingly examined data analytics and Artificial Intelligence as tools for improving operational planning. Predictive analytics has shown potential for anticipating displacement and humanitarian needs through projects such as Project Jetson [11], and recent reviews identify AI applications across disaster prediction, resource allocation, communication and supply-chain support while stressing the importance of privacy, bias mitigation and responsible deployment [12], [28]. Humanitarian-AI research also flags risks related to privacy, accountability, protection, bias, human control and the possible effects of automated decision-making on affected populations [10], [23]. AI systems intended for humanitarian operations should therefore generate useful recommendations while also providing meaningful mechanisms for human oversight and understanding.

Digital twins and spatial analytics represent another emerging direction. Digital-twin approaches combine digital representations, operational data and scenario analysis to help decision-makers examine alternative interventions. Recent work has applied digital-twin technology to integrated Water–Energy–Food–Environment (WEFE) management in a refugee-camp setting, showing how digital modelling can be linked with local community information and resource-management decisions [17]. Spatial optimisation has also been explored for improving the organisation of refugee camps through AI-assisted planning [28]. These approaches are relevant to the present study because they demonstrate how digital models can support resource and infrastructure decisions under constrained conditions.

Within the water sector, AI and optimisation methods have been applied to water-demand management and related resource-planning problems [13]. In the energy sector, optimisation models have supported energy scheduling and reduced resource consumption while maintaining critical services [16]. In the food sector, data-driven methods can improve planning and resource allocation across supply and distribution systems [13], [15]. Multi-objective optimisation has also been used to model interactions among food, water and energy resources jointly. A 2024 study introduced a multi-objective optimisation tool that models the three nexus sectors together and applies scenarios to examine changes in resource production and consumption [26]. More recent work has addressed the modelling and computational complexity associated with large-scale FEW optimisation problems [27]. These studies strengthen the case for integrated resource planning rather than isolated sectoral decisions.

Nigeria-focused humanitarian information systems rely on sources such as DTM and UNHCR population data, while humanitarian situation reports describe operational conditions and humanitarian needs [8], [9], [19], [20]. These sources are valuable but may have limitations in timeliness and representativeness. Research on humanitarian data therefore emphasises transparent methodologies and careful interpretation when using displacement information [22]. Mobile communication is also relevant: research on internally displaced people in Nigeria has documented the importance of mobile phones for communication and social inclusion [18].

Climate variability is another important factor affecting displacement and humanitarian resource demand in the Lake Chad Basin. Recurrent floods and droughts damage infrastructure, affect livelihoods, and contribute to displacement [5]. Such conditions shift demand, disrupt supply systems, and increase operational costs, reinforcing the need for flexible short-term planning.

The governance of Artificial Intelligence in humanitarian operations remains an additional concern. Humanitarian-AI research identifies transparency, explainability, accountability and human oversight as essential when AI-supported systems are used in decision-making [10], [23]. Recent work on explainable AI and decision support further emphasises the importance of helping users understand how AI systems produce their decisions and recommendations [24]. The operational application of these principles is particularly important in humanitarian settings, where operational decisions affect vulnerable populations. Recent reviews also confirm the value of AI in humanitarian healthcare, including disaster prediction, resource allocation and supply-chain logistics, while emphasising transparent and explainable deployment [12].

Recent Nigerian research has applied optimisation methods to internally displaced persons resource allocation. A 2026 study developed a linear programming–geometric programming model for relief-material allocation to IDP camps in Abuja, demonstrating the applicability of mathematical optimisation to Nigerian humanitarian logistics [29]. Although that study addresses relief-material allocation rather than an integrated food–energy–water mobile decision-support system, it provides directly relevant evidence that data-driven optimisation approaches apply to Nigerian internally displaced persons resource-management problems. This review highlights four recurring gaps:

By addressing these gaps, the present work proposes an interpretable, mobile-oriented system integrated with the FEW nexus framework. The system incorporates routine operational updates, generates constraint-aware recommendations and plans, evaluates them against realistic Nigerian internally displaced persons camp scenarios, and aligns its use with relevant national and humanitarian policy frameworks.

1. Most humanitarian operations still separate food, water and energy systems without adequately applying the nexus perspective.
2. Operational data from many camps are slow, lack detail or fail to reflect rapid operational changes, limiting the ability to make prompt planning adjustments.
3. Although predictive analytics, optimisation tools and digital twins are promising, end-to-end testing of integrated AI resource-planning workflows in Nigerian internally displaced persons camp operations remains scarce.
4. Although policy and research increasingly stress ethics and accountability, practical safeguards such as transparency, explainability and auditability embedded directly into operational systems are still limited [10], [23], [24].

3.0 Methodology

3.1 Research design

The study adopted a practical system-development design. The objective was to design, build, and evaluate a mobile decision-support tool that helps camp managers allocate food, water, and energy resources systematically and sustainably while saving time. The work proceeded in three stages: designing and developing the mobile application, establishing an AI-based data-processing solution for operational data, and performance testing the proposed system against a manual planning baseline using scenarios representing typical camp conditions. The evaluation was scenario-based and conducted in an experimental environment. It was intended to assess prototype feasibility and operational usefulness rather than to provide a population-level field evaluation.

3.2 Study area and users

The study is grounded in internally displaced persons camps in North-East Nigeria, particularly Borno, Adamawa and Yobe States, which have experienced substantial conflict-related displacement. The system's primary intended users are camp administrators and aid personnel who manage everyday operational records, including population numbers, food stocks, water-supply schedules and energy logs. Because mobile devices are central to communication within displaced communities and humanitarian settings, a mobile-first system was selected as the practical interface for the proposed solution.

3.3 System requirements and materials

Flutter, a cross-platform mobile application development framework, was used to build the mobile application because it supports a common codebase deployable on both Android and iOS devices. Firebase, a cloud-based application development platform, provided backend services such as authentication, real-time database functions, and cloud functions. Riverpod, a Flutter state-management framework, was used to manage application state. Data were stored and transferred in JSON format, which is lightweight and well-suited to mobile networks. The Gemini application programming interface (API) by Google was integrated to provide the AI capabilities used in the application. The application was designed to remain clear, accessible and minimally data-intensive so that it could support use in settings with weak or intermittent connectivity. The system was designed around three layers:

- **Input layer** – the mobile interface where staff enter daily updates such as new arrivals, food stock levels, water-trucking schedules and energy status.
- **Processing layer** – a cloud-based pipeline that combines Firebase functions and Gemini AI to validate operational data, estimate short-term resource requirements and generate allocation recommendations.
- **Output layer** – a dashboard that presents the results in a simple form, including allocation plans, early warnings, analysis steps, recommendations and audit logs for supervisory review.

3.4 Data sources

The system received information from three main categories of data.

The first consisted of baseline and contextual information from the Displacement Tracking Matrix and UNHCR dashboards, including population estimates and camp-related information [19], [20]. The second consisted of operational scenarios based on conditions reported in humanitarian settings, including sudden population inflow, delayed food delivery, water-supply interruption and generator breakdown [8], [9]. The third consisted of operational values entered within the prototype for the scenario-based tests. To protect privacy, the testing process did not rely on personally identifiable information from individual internally displaced persons; operational and aggregated information was used instead. This approach is consistent with the principle of limiting unnecessary personal-data processing in humanitarian settings [10], [21], [22].

3.5 AI analysis pipeline

The AI element was designed to operate in three stages:

- **Validation:** the system checks whether submitted data are complete, internally consistent and within predefined operational limits.
- **Assessment:** the system estimates short-term requirements for food, water and energy based on population, resource availability and recent consumption information.
- **Recommendation:** the AI generates direct planning recommendations, for example, send 40 more food parcels to Sector B or increase water delivery to Block A tomorrow.

The approach was designed so that the generated recommendations could be viewed and interpreted by staff without requiring extensive technical training. The AI output was treated as decision support rather than as an automatic replacement for the judgement of camp managers.

3.6 Testing procedures

The system was subjected to four situations representing operational disruptions common in Nigerian internally displaced persons camp environments:

- a sudden rise in the number of families;
- a delay in the delivery of food;
- water-supply disruption; and
- the impact of generator downtime on pumping and cold storage.

Each scenario was executed using the AI-powered mobile tool, and the outputs were compared with those produced through the corresponding manual planning approach. The comparison focused on response time, allocation outcomes, practicality, transparency, explainability and auditability.

Table 1: Test scenarios

No.	Scenario	Short description	Comparison
1	Population surge	Sudden increase in households	Manual plan vs. AI-assisted plan
2	Food delay	Pipeline delay before scheduled distribution	Manual plan vs. AI-assisted plan
3	Water interruption	Borehole or trucking interruption	Manual plan vs. AI-assisted plan

No.	Scenario	Short description	Comparison
4	Generator downtime	Reduced runtime affecting pumps and cold chain	Manual plan vs. AI-assisted plan

3.7 Evaluation metrics

The system was evaluated using six aspects:

- **Usability:** how easily staff can use the system with little or no extensive training.
- **Feasibility:** the ability of the system to operate under weak internet connectivity and unstable power conditions.
- **Transparency:** the extent to which staff and managers can understand the information presented by the system and the basis on which recommendations were generated.
- **Explainability:** the extent to which users can understand the operational basis of recommendations through displayed inputs, validation checks, analysis steps and recommendation details.
- **Auditability:** the ability of supervisors to review recorded system actions, analysis outputs and recommendations after an operation.
- **Response time:** the time from data entry to the generation of the allocation plan.

Table 2: Evaluation metrics

Metric	Measurement focus
Usability	Ease of task completion with little or no training
Feasibility	Operation under weak internet and unstable power conditions
Transparency	Visibility and understandability of the information and recommendation process
Explainability	Visibility of validation, analysis steps and recommendation basis
Auditability	Availability of recorded actions and analysis outputs for supervisory review
Response time	Time from data entry to generation of the allocation plan

3.8 Ethical considerations

This study was conducted in line with ethical principles for humanitarian technology. The tool was developed to support, rather than replace, decisions made by camp managers. Only operational and aggregated information was used within the testing environment, and no personally identifiable information of internally displaced persons was retained. The approach was informed by the Federal Republic of Nigeria's National Policy on Internally Displaced Persons and humanitarian AI and data-governance principles [10], [21], [23]. The system was designed around human oversight. AI-generated recommendations were presented for review rather than treated as automatic instructions. This is important because contextual, cultural, social, or protection considerations may not always be captured adequately in structured operational data. Human decision-makers therefore remain responsible for reviewing, accepting, modifying or rejecting recommendations.

4.0 Results

The IDP Resource Manager application's prototype was tested in an experimental environment simulating Nigerian internally displaced persons camp operations. The application operated on the tested Android devices under intermittent internet conditions, satisfying the feasibility requirements considered in the methodology.

During first-time use, users were guided through the application's interface by the onboarding screen (Figure 1) and were then presented with the login interface (Figure 2). New administrators could create accounts with specified access rights through the administrator-creation interface (Figure 3).

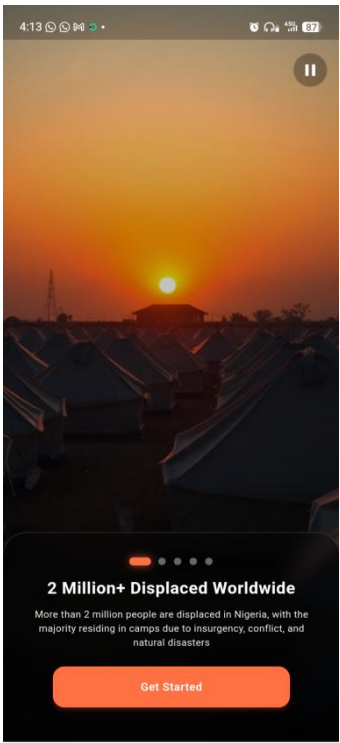


Figure 1: Onboarding screen. An introductory window familiarising the user with the IDP Resource Manager system

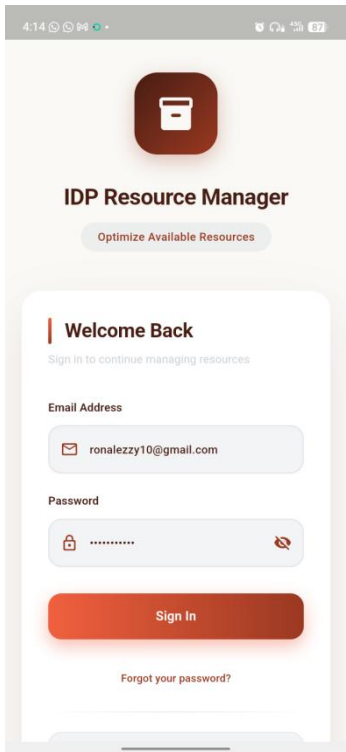


Figure 2: Login screen. A secure entry page used by camp administrators and field staff to access the system.

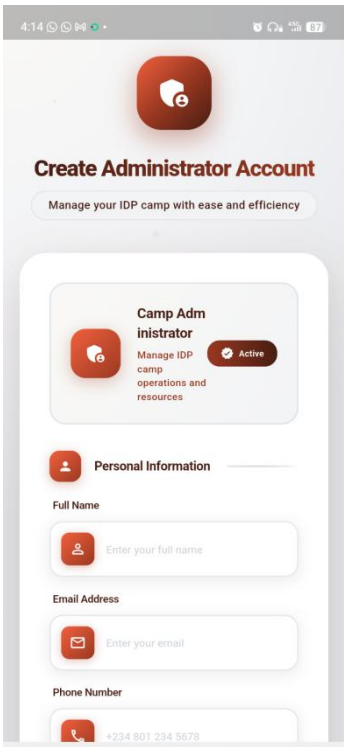


Figure 3: Create Administrator Account. A registration window used to set up new administrator accounts with corresponding privileges

Once logged in, users were presented with the IDP Manager Dashboard (Figure 4), which displayed information such as population figures, daily demand for food, water, and energy, and general operational information. The dashboard served as the main control panel from which the AI-powered analysis modules could be accessed.

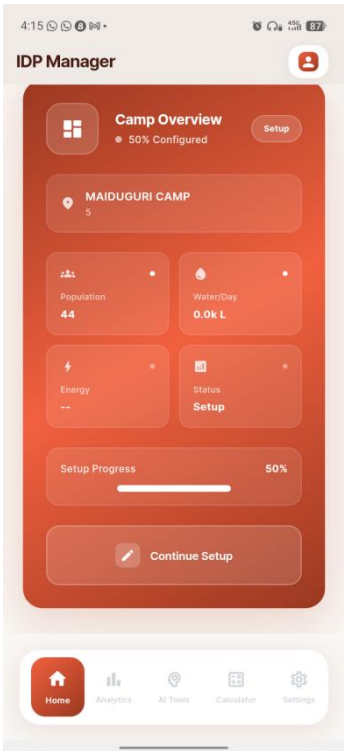


Figure 4: IDP Manager Dashboard. The central window displays the current number of people in the camp and the daily demand for food, water, and energy

Data collection was separated into modules for baseline camp information and resource records. The Camp Information module (Figure 5) allowed entry of general information concerning the camp, while the Population Overview (Figure 6) described variables such as total households, average household size, and total population.

Resource inventory was carried out systematically and included food (Figure 7), water (Figure 8), and energy (Figure 9).

The screenshot shows the 'Camp Management' interface with a 'Basic Information' section. The section includes fields for Camp Name, Location/Address, State, Country, and Managing Organization. The values entered are MAIDUGURI CAMP, 5, Bornu Street, Borno, Nigeria, and Government. There is a 'Save Changes' button at the bottom right.

Field	Value
Camp Name *	MAIDUGURI CAMP
Location/Address	5, Bornu Street
State	Borno
Country	Nigeria
Managing Organization	Government

Figure 5: Camp Basic Information module. The module allows camp administrators to enter general information about the camp, including location, capacity, and other relevant details

The screenshot shows the 'Population Overview' interface. It includes a 'Demographics' section with a 'Population Overview' card. The card displays 'Total Po...' as 2567 and 'Total Ho...' as 45. Below this, the 'Average Household Size' is shown as 8. There is a 'Save Changes' button at the bottom right.

Metric	Value
Total Population	2567
Total Households	45
Average Household Size	8

Figure 6: Population Overview module. The module allows users to enter information about the number of households, average household size, total population, and related details

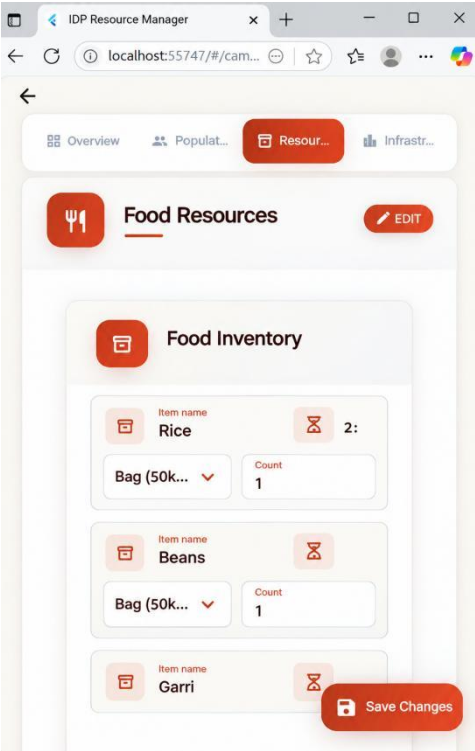


Figure 7: Food Resources module. The module allows users to enter information about food stocks, rations distributed and other relevant food-resource details

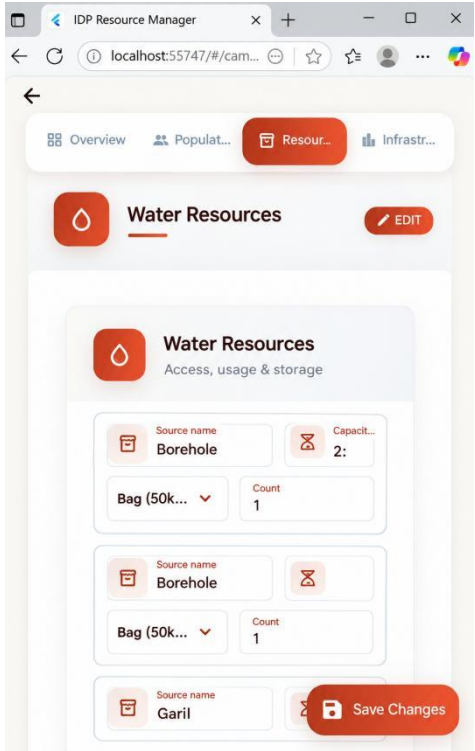


Figure 8: Water Resources module. The module allows users to enter information about water trucking, borehole activity and consumption

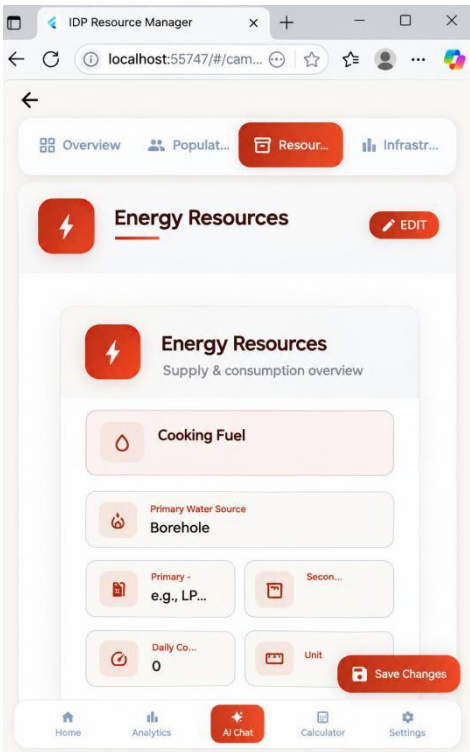


Figure 9: Energy Resources module. The module allows users to enter information about generator running time, fuel levels, and critical loads

To make the data understandable and consistent, recorded quantities were converted to common operational units, including 50 kg bags of rice, litres of water per day, and generator operating logs. These datasets served as input data for the AI-assisted analysis. The Resource Analysis dashboard (Figure 10) provided an organised entry point for planning data relating to food, water and energy.

Users could either start the analysis process or interact with the AI assistant through typed or verbal queries (Figure 11). Examples of queries included how to adapt the food ration for breastfeeding women and what is the fastest way to reduce the water queue. The application also included an integrated language selector (Figure 12), with English and Hausa available as output-language options in the prototype.

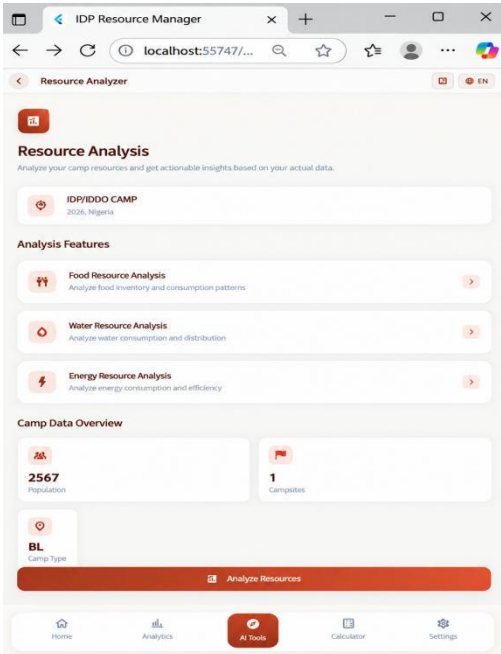


Figure 10: Resource Analysis Hub. The entry point for planning data from the food, water and energy sectors

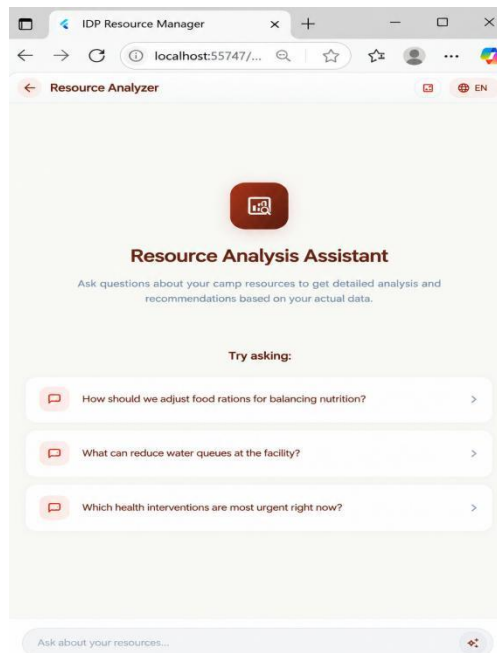


Figure 11: Resource Analysis Assistant. Natural-language entry window for typed or verbal interaction with the AI-assisted resource-analysis system

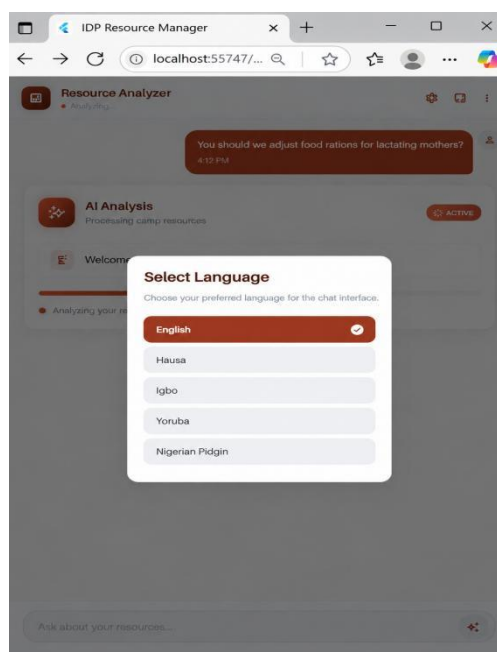


Figure 12: Language Selector. Interface for switching between available output languages

During the analysis, the system displayed an AI-processing screen (Figure 13) while the analysis pipeline was running. This indicated that processing was in progress and reduced the possibility of users interpreting the interface as unresponsive.

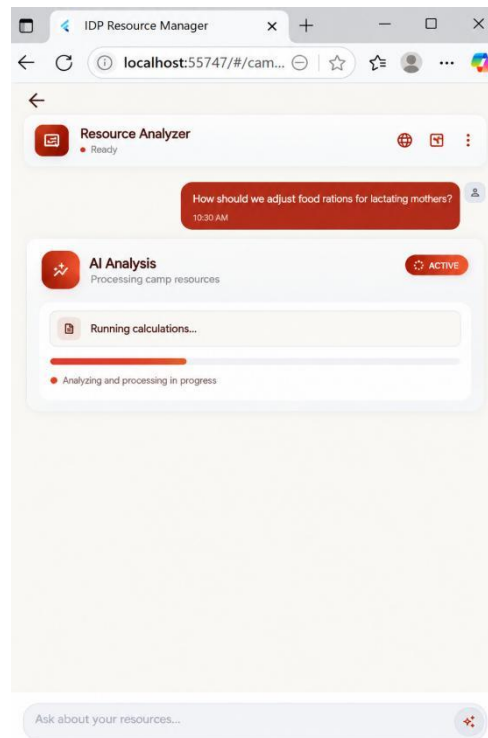


Figure 13: AI Processing Screen. Intermediate progress screen notifying the user that the AI analysis pipeline is running

The analysed reports and recommendations were presented in several sections. Users were provided with an analysis report header (Figure 14), the analysis steps (Figure 15) and a recommendations panel (Figure 16). The recommendation details remained subject to review by camp administrators.

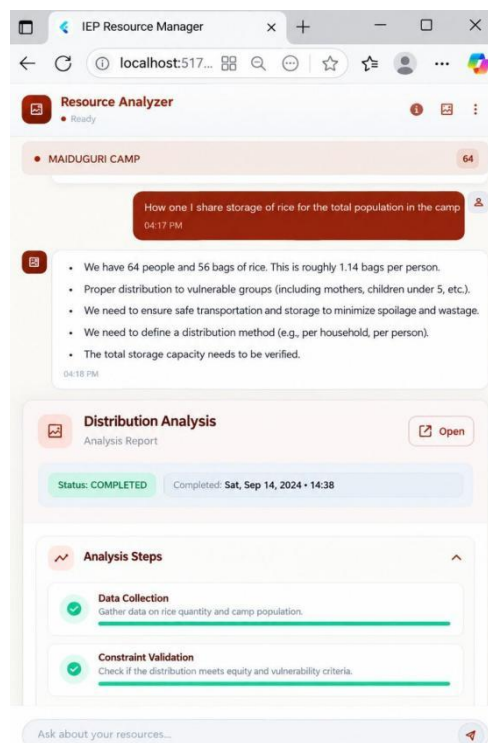


Figure 14: Analysis Report Header. The top banner of the generated analysis report, summarising the analysis run

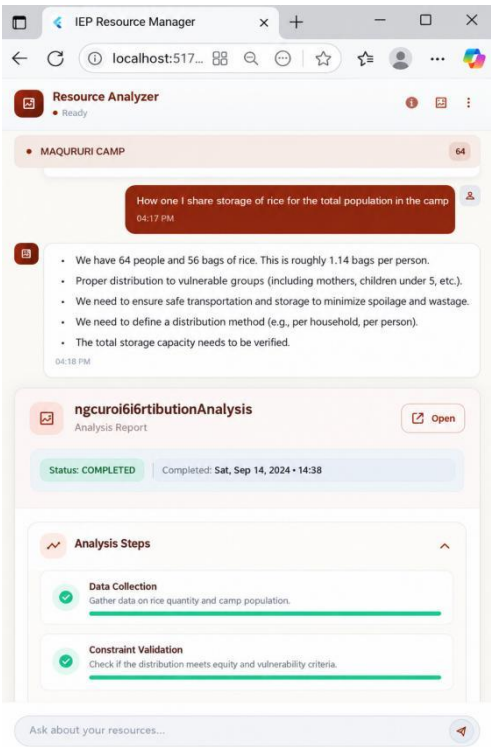


Figure 15: Analysis Steps Panel. The panel describing the operational steps used to produce the AI-supported output

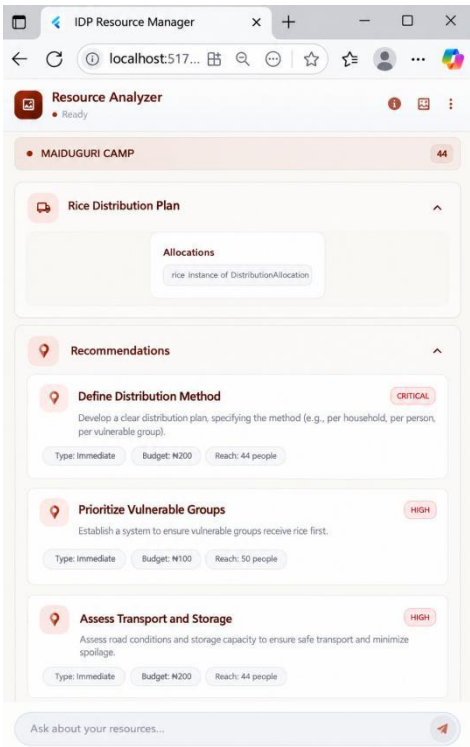


Figure 16: Recommendations Interface. AI-generated recommendations presented in natural language for review and implementation by the users

One of the scenario runs used Maiduguri as the sample camp context. According to Figure 17, the analysis identified "Assess Transport and Storage" as a recommended action, together with the associated budget and estimated reach values displayed by the prototype. The risk and optimisation panel provided an additional summary of the operational implications and optimisation potential of the available alternatives.

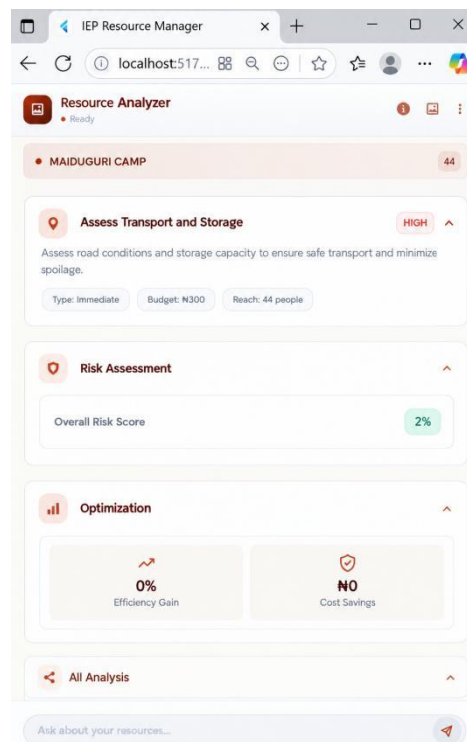


Figure 17: Risk and Optimisation. The risk levels, optimisation potential and highest-priority recommendation displayed within the simulated scenario

In addition to the analysis module, the programme included a built-in Smart Calculator (Figure 18). It was designed to interpret simple natural-language questions posed by the user, such as "50 bags ÷ 5 households," and return the calculation together with a step-by-step explanation, such as "10 bags per household." Its purpose was to assist users who might be unfamiliar with the application's interface or commands.

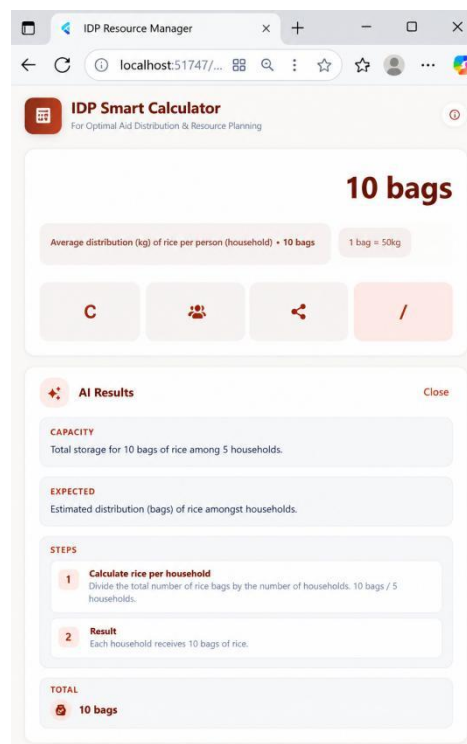


Figure 18: Smart Calculator. The in-app natural-language basic calculation feature

The Analytics Dashboard (Figure 19) provided an overview of user questions and AI-generated responses grouped according to topics such as food, water, energy, medical services and shelter. This feature supported the review of the types of information being requested through the system.

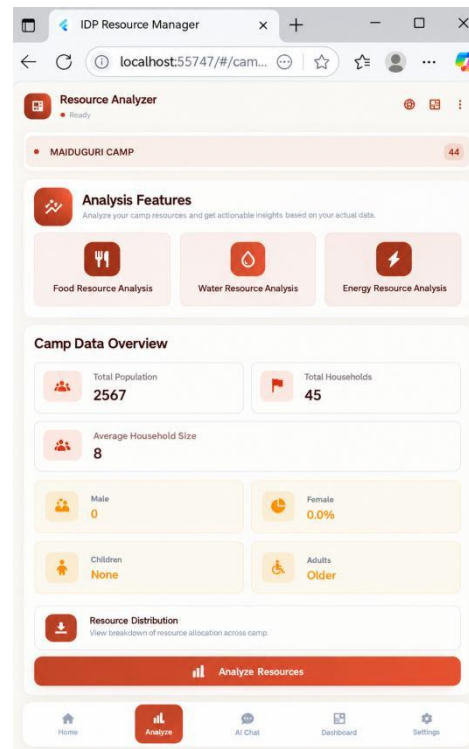


Figure 19: Analytics Dashboard. Overview of user questions and AI-generated answers grouped by operational topics

4.1 Scenario-based testing results

The system was evaluated using four testing scenarios: population surge, delayed food delivery, water-supply interruption, and generator downtime. In each case, outputs produced through manual planning were compared with those produced through the AI-assisted tool. In the population-surge scenario, the AI-assisted system used updated population information to support redistribution of available rations. The scenario indicated that the allocation plan could be adjusted in response to an increase in the number of households. In the food-delay scenario, the AI-assisted approach incorporated the delayed-supply condition and reprioritised available stock based on the updated situation. During the water-interruption scenario, the system incorporated the interruption into its analysis and generated recommendations relating to alternative supply arrangements. For the generator-downtime scenario, the system adjusted energy-allocation recommendations to prioritise critical services affected by reduced generator operation, including medical facilities and cold-chain storage. Taken together, the scenarios demonstrated the ability of the proposed system to consider food, water and energy information within the same operational planning process rather than treating each resource completely independently.

4.2 Evaluation of operational outcomes

The scenario-based evaluation indicated that the AI-assisted method required less manual planning effort than the corresponding manual approach and produced allocation recommendations in a more structured form. The scenarios also indicated fewer avoidable stockouts and reduced over-allocation when updated operational information was incorporated into the planning process. Table 3 summarises the observed outcomes.

Table 3: Outcomes reported

Outcome area	What was observed in the scenario runs
Speed	Planning was faster than the usual manual-note approach
Allocation quality	Fewer avoidable stockouts and reduced over-allocation were observed
Practicality	The planning steps were presented in a form that could be followed by staff
Transparency	Analysis steps and recommendation details were visible within the system
Explainability	Validation checks, analysis stages and recommendation information provided an operational basis for understanding outputs
Auditability	Recorded actions and analysis information supported supervisory review

Because the evaluation was scenario-based, these findings are interpreted as evidence of prototype feasibility and operational potential rather than as statistically generalisable effects across Nigerian internally displaced persons camps.

5.0 Discussion

This study examined whether a mobile-based, AI-assisted decision-support tool could support the planning and distribution of food, water and energy resources in Nigerian internally displaced persons camp settings. The scenario-based results demonstrate the operational feasibility of the proposed approach. The prototype incorporated changing operational conditions and generated structured recommendations while keeping camp administrators involved in the final decision process. The findings are consistent with FEW nexus literature, which emphasises the need to manage interconnected resources rather than treating food, energy and water as isolated systems [6], [7], [14], [26], [27]. The proposed system applies this principle at the operational level by considering relationships among resource availability, population demand, water supply, energy availability, food stocks and critical services.

The results are also consistent with recent research showing the growing role of optimisation and digital decision-support tools in integrated FEW management. Multi-objective optimisation tools have demonstrated the value of examining changes across interconnected food, water and energy systems [26], while more recent work has addressed the computational complexity of large-scale FEW optimisation problems [27]. Research on FEW optimisation has shown that localised changes in one sector can create consequences across the wider nexus, reinforcing the importance of integrated analysis [27]. Recent review evidence further indicates that many FEW studies continue to focus on pairs of resources rather than considering all three together at smaller operational scales [30], [31]. The present study applies the integrated resource perspective at a smaller operational scale, focusing on camp-level decisions rather than large infrastructure or production systems. Humanitarian-AI literature also emphasises that technical capability alone is insufficient when AI-supported systems are used in sensitive humanitarian environments [10], [23]. The present prototype therefore incorporates human review, visible analysis steps, recommendation details and audit logs. These mechanisms make the operational basis of AI-supported outputs more accessible to users and supervisors. Recent reviews of AI in humanitarian healthcare reinforce the value of explainable and transparent deployment in crisis settings [12]. The proposed mobile-first tool is consistent with lightweight digital infrastructures developed for resource-constrained settings [15] and with energy-scheduling approaches for constrained resource systems [16]. The use of a digital decision-support interface further complements recent work on digital twins in humanitarian and community resource-management environments, including work conducted in a refugee-camp setting [17].

The study has important limitations. First, the quality of recommendations depends strongly on the completeness and timeliness of operational data; delays, omissions or inaccuracies in population, stock, water, or energy information will reduce the usefulness of the generated recommendations. This limitation is consistent with wider challenges involving humanitarian and displacement data [22]. Second, the AI system should not be treated as an autonomous decision-maker; social, cultural, protection and contextual considerations may not always be adequately represented in structured operational data, and humanitarian AI literature stresses human oversight and the principle of avoiding harm when deploying AI in crisis environments [10], [23]. Third, the current system focuses primarily on short-term camp-level planning; it does not comprehensively address long-term procurement, inter-camp logistics, national supply-chain coordination or upstream humanitarian resource planning. Fourth, the current evaluation was conducted through scenario-based testing rather than a long-term field deployment across multiple camps, so the findings demonstrate prototype feasibility and operational potential but do not establish statistical performance across the wider Nigerian internally displaced persons population.

The study also contributes to a growing Nigerian research context in which optimisation models are being developed for humanitarian resource allocation. Recent work on relief-material allocation to IDP camps in Abuja demonstrates the applicability of mathematical optimisation to Nigerian humanitarian logistics [29]. The present work extends this direction by integrating FEW resource relationships, mobile data capture, AI-supported recommendations, explainability and auditability within one operational workflow.

Overall, the proposed system does not generate additional resources. Instead, it is intended to help camp managers use available resources more systematically by incorporating changing operational information into structured decision-support recommendations.

6.0 Conclusion

This study set out to demonstrate that an AI-driven, mobile-first solution could support the planning and distribution of food, water, and energy resources in Nigerian internally displaced persons camps. Across four scenario-based tests involving population increase, food-delivery delay, water interruption and generator failure, the AI-assisted approach generated structured recommendations for adjusting resource plans in response to changing operational conditions. The system operationalises the FEW nexus by linking resource availability and demand across food, water and energy. Energy availability affects water pumping and cold-chain operations, while population changes affect food and water requirements. Integrating these relationships within a single decision-support workflow provides a connected approach to camp-level planning. The work also addresses practical

requirements for explainability and auditability. Unit normalisation, validation checks, visible analysis stages, and recommendation information provide users with an operational basis for understanding AI-supported outputs. Audit logs and recorded actions provide traceability for supervisory review. Human oversight remains central because the AI output is intended to support rather than replace camp-management decisions. The prototype was designed for mobile use and tested within a simulated environment representing low-resource operational conditions. The results therefore demonstrate the feasibility and potential usefulness of lightweight digital decision support for humanitarian planning, while recognising that broader field validation remains necessary.

The work has limitations. The quality of recommendations depends heavily on the completeness and timeliness of data entries; connectivity gaps may affect synchronisation in multi-user environments; and the present scope focuses mainly on short-term operational decisions rather than upstream procurement and inter-camp logistics. The scenario-based nature of the current evaluation also means that further field validation is required before broad operational deployment. Future research should involve longer-term testing in multiple Nigerian internally displaced persons camps, larger datasets, formal quantitative evaluation and deeper integration with existing humanitarian information systems. Additional research could extend the system toward real-time sensor data, wider supply-chain planning, advanced optimisation algorithms and more comprehensive evaluation of fairness, robustness, security and explainability. Overall, the study demonstrates that an AI-assisted mobile decision-support system can provide a practical foundation for integrating the FEW nexus into Nigerian internally displaced persons camp resource planning while maintaining human judgement, transparency, explainability and accountability.

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