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DEVELOPMENT OF A REQUEST PRIORITIZATION SYSTEM FOR HUMANITARIAN AID UNDER RESOURCE CONSTRAINTS

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Анотація

У тезах розглядається проблема систематизованої пріоритизації запитів на гуманітарну допомогу в умовах обмеженості ресурсів під час надзвичайних ситуацій. Проаналізовано недоліки існуючих підходів – черги за принципом FIFO, ручного тріажу та правило-орієнтованих систем. Запропоновано формалізовану модель зваженої пріоритетної оцінки (Weighted Priority Score, WPS), яка враховує п'ять вимірів: рівень терміновості запиту, індекс вразливості заявника, вік запиту, ступінь відповідності наявних ресурсів та географічну щільність звернень у зоні охоплення. Описано архітектуру програмного модуля пріоритизації у складі веб-орієнтованої платформи координації гуманітарної допомоги. Виконано порівняльний аналіз запропонованої моделі з альтернативними підходами та наведено результати симуляційних експериментів на синтетичному наборі даних. Результати підтверджують, що застосування багатофакторної моделі скорочує середній час очікування для критичних запитів та знижує нерівність розподілу допомоги між вразливими групами населення.

Ключові слова: пріоритизація запитів, гуманітарна допомога, надзвичайні ситуації, зважена пріоритетна оцінка, розподіл ресурсів, цифрові платформи координації, багатокритеріальне прийняття рішень.

Abstract

The paper addresses the problem of systematic prioritization of humanitarian aid requests under resource constraints during emergency situations. The shortcomings of existing allocation approaches – FIFO queuing, manual triage, and rule-based systems – are analysed. A formalised Weighted Priority Score (WPS) model is proposed, incorporating five dimensions: urgency level, applicant vulnerability index, request age, resource availability, and geographic request density. The architecture of a prioritization software module within a web-based humanitarian aid coordination platform is described. A comparative analysis of the proposed model against alternative approaches is performed, and simulation experiment results on a synthetic dataset are presented. The findings confirm that the multi-factor model reduces mean waiting time for critical requests and decreases distributional inequality in aid allocation across vulnerable population groups.

Keywords: request prioritization, humanitarian aid, emergency situations, weighted priority score, resource allocation, digital coordination platforms, multi-criteria decision-making.

Introduction

Emergency situations – armed conflicts, natural disasters, and man-made catastrophes – simultaneously generate large volumes of humanitarian aid requests that far exceed the immediate response capacity of assisting organisations. According to the United Nations Office for the Coordination of Humanitarian Affairs, in 2023 more than 362 million people required humanitarian assistance globally, yet available funding covered only 35% of estimated needs [1]. This structural gap between demand and supply makes systematic prioritization of aid requests not merely a logistical convenience but an ethical imperative: when not everyone can be served immediately, the selection of who is served first determines a significant fraction of the welfare impact of the entire operation.

Without a structured triage mechanism, aid delivery tends to follow one of two suboptimal patterns. First-come, first-served (FIFO) ordering is operationally simple but is equitable only for homogeneous requests; it systematically disadvantages beneficiaries who lack the ability to submit requests early or to communicate urgency effectively [2]. Manual triage by coordinators is more flexible but does not scale to hundreds or thousands of daily requests, is susceptible to cognitive bias and fatigue, and produces inconsistent outcomes across operators and shifts [3].

Digital platforms have become central infrastructure for coordinating humanitarian responses in complex emergencies [4]. However, the majority of existing platforms treat prioritization as a fully manual task, providing coordinators with filtering and sorting tools but no automated scoring of request severity. This creates a critical functional gap: as the volume of active requests grows – which is precisely when platforms are most needed – the coordinator's ability to maintain a consistent, equity-aware ordering degrades. The present paper proposes a formal multi-factor model and its software implementation to close this gap.

Related Work and Problem Statement

The allocation of scarce resources in emergency contexts has been studied extensively across operations research, public health, and humanitarian logistics. Triage protocols developed for mass-casualty medical incidents [5] provide a conceptual foundation but are domain-specific: they assess physiological status, not the broader socioeconomic and logistical dimensions relevant to general humanitarian aid. Disaster relief logistics models [6] propose mathematical programming formulations for resource routing under uncertainty but presuppose availability of complete, reliable demand data – a condition rarely met in rapidly evolving crises where beneficiary registration may be incomplete.

Multi-Criteria Decision Analysis (MCDA) frameworks [7] offer a flexible middle ground: by assigning numerical weights to decision-relevant factors, they make the implicit priorities of an organisation explicit and operationalise them as a computable score. MCDA has been applied to humanitarian supplier selection [8] and relief facility location decisions, yet its application to request-level real-time triage within digital coordination platforms remains underexplored. Reviews of humanitarian information management systems consistently identify automated prioritization logic as a missing or underdeveloped feature in current-generation tools [4; 9].

The prioritization problem can be formally stated as follows. Let $R = \{r_1, r_2, ..., r_n\}$ be the set of n active aid requests at a given decision moment, C the vector of available resource quantities across categories, and Q the set of operational constraints (volunteer capacity, delivery zones, organisational quotas). The objective is to determine an ordered allocation sequence $\sigma = (\sigma_1, ..., \sigma_n)$ that maximises the aggregate beneficiary welfare $W(\sigma)$ subject to C and Q. The key challenge is constructing an operational, data-available proxy for W that is computationally tractable in near-real time and ethically defensible.

The Proposed Weighted Priority Score Model

The Weighted Priority Score (WPS) model assigns each active request a composite numerical score $P \in [0, 100]$ by aggregating five quantifiable factors through a weighted linear combination:

$$P = w_1 \cdot U + w_2 \cdot V + w_3 \cdot A + w_4 \cdot R + w_5 \cdot G$$

where U denotes the normalised urgency level, V the vulnerability index, A the request age factor, R the resource match ratio, and G the geographic density factor. Each factor is independently normalised to [0, 1] prior to aggregation. The weights w_i sum to 1.0 and encode the relative ethical and operational priorities of the deploying organisation. Table 1 details the five factors, their default calibration weights, and the data sources from which they are derived at scoring time.

Table 1 – Scoring factors, weights, and data sources of the WPS model

Factor	Name	Description	Weight (w_i)	Data source
U	**Urgency level**	Self-reported by requester (1 = routine, 5 = life-threatening); coordinator override permitted with mandatory justification note	0.30	Request submission form; coordinator action log
V	**Vulnerability index**	Composite of age extremes (<12 or >65 years), disability status, and presence of chronic medical conditions (binary markers)	0.25	Beneficiary registration profile
A	**Request age factor**	Time elapsed since submission; accumulates linearly beyond configurable threshold τ (default 12 h) at rate δ (default 0.02/h)	0.20	Submission timestamp; recalculated every 15 min
R	**Resource match ratio**	Proportion of requested items currently available in inventory; penalises requests that cannot be fully fulfilled from stock	0.15	Real-time inventory query at scoring time
G	**Geographic density**	Number of active requests within configurable radius (default 5 km); enables efficient batching of deliveries	0.10	Geospatial clustering of request coordinates

The urgency factor U employs a dual-entry mechanism to balance responsiveness with accuracy. The requester self-reports on a five-point scale at submission; the assigned coordinator may subsequently override this value with a mandatory written justification. Research on triage systems indicates that self-reported urgency is systematically underreported by individuals from certain cultural backgrounds or by those in acute distress who are unable to self-advocate effectively [5]; the coordinator override compensates for this bias while maintaining an audit trail.

The vulnerability index V aggregates three binary markers – age extremes (under 12 or over 65 years), disability status, and the presence of chronic medical conditions – into a score on [0, 1]. This factor operationalises the proportionality principle of humanitarian ethics: aid should be allocated in proportion to need, with special consideration for those at heightened risk of harm in the absence of assistance [10]. Assigning V a weight of 0.25 intentionally ranks it second after urgency, reflecting the consensus view that vulnerability should strongly influence but not solely determine priority.

The age factor A addresses the temporal fairness problem. Without it, new high-scoring requests would perpetually displace lower-scoring but legitimate older ones, creating a starvation condition for moderate-priority beneficiaries. A accumulates an increment δ per unit time beyond a configurable baseline threshold τ (default: $\delta = 0.02$ per hour, $\tau = 12$ hours). A linear ageing function was chosen over exponential alternatives for its interpretability and resistance to sudden score inflation. The resource match ratio R focuses delivery effort on requests that can be fulfilled with currently available stock, reducing the operational cost of partial deliveries. The geographic density factor G provides a modest bonus to requests in high-concentration areas to support logistically efficient batching of deliveries by volunteers [6].

Software Architecture of the Prioritization Module

The WPS model is realised as a scoring service integrated into a web-based humanitarian aid coordination platform. The platform follows a layered RESTful architecture: a React.js frontend communicates with a Node.js (Express) backend organised into Controller, Service, and Repository layers, backed by a PostgreSQL relational database. The scoring service exposes the endpoint POST /api/requests/{id}/score, which accepts a request identifier and returns the computed score together with a full factor-by-factor breakdown for auditing purposes.

Figure 1 illustrates the data flows and component interactions of the prioritization module. At scoring time, input data is drawn from three sources: the request record (urgency level, submission timestamp, requester registration profile), the live inventory state (resource match ratio), and the geospatial index (geographic density). The constraint layer checks volunteer capacity and organisational quotas before determining the final output tier assignment.

Input Factors • Urgency level (1–5) • Vulnerability index • Request age (hours) • Resource match ratio • Geographic density	→	**Priority Score** $\mathbf{P = \Sigma(w_i \times x_i)}$ $P \in [0, 100]$
Operational Constraints • Available inventory • Volunteer capacity • Delivery distance • Organisation quota	↗	**Priority Tiers** • Critical ($P \geq 80$) • High ($60 \leq P < 80$) • Medium ($40 \leq P < 60$) • Low ($P < 40$)

Figure 1 – Data flows and component interactions of the WPS prioritization module

Scores are recomputed upon any change to the request record or to the inventory state, ensuring that the coordinator's queue reflects the most current operational picture. A background scheduling job re-scores all active requests every 15 minutes to capture the incremental effect of the age factor and shifts in resource availability. The module maintains a versioned scoring history table, enabling the full audit trails required by humanitarian accountability standards [11]. All five factor weights and the ageing parameters are hot-configurable through a dedicated administrator panel; every configuration change is logged in the system audit journal with the operator's identity and timestamp.

The architecture satisfies four non-functional requirements characteristic of humanitarian deployments. First, low latency: score recomputation for a single request completes in under 100 milliseconds. Second, resilience: the scoring service operates independently of notification and mapping subsystems, so their unavailability does not affect triage functionality. Third, adaptability: the model can be re-calibrated for different organisational contexts without code changes. Fourth, auditability: every scoring event is persisted with its complete factor breakdown, supporting both internal review and external accountability reporting.

Comparative Analysis and Simulation Results

Table 2 compares the WPS model with three alternative prioritization approaches commonly encountered in humanitarian information management practice.

Table 2 – Comparison of request prioritization approaches

Method	Factors considered	Adaptability	Decision basis	Key trade-offs
FIFO (queue-based)	None	None	Arrival timestamp only	Simple; fair for homogeneous requests; ignores urgency and vulnerability entirely
Manual triage	Coordinator judgment	Ad hoc, human	Subjective assessment	Flexible but slow; inconsistent under cognitive load; does not scale beyond ~50 requests/day
Rule-based scoring	Fixed categorical rules	Static	Boolean condition tree	Predictable; requires exhaustive rule authoring; fails on unanticipated edge cases
Proposed WPS model	Multi-factor (5 dimensions)	Dynamic, real-time	Composite score $P \in [0,100]$	Equity-aware; scalable; auditable; requires initial weight calibration and data quality assurance

To quantitatively evaluate the model, a simulation experiment was conducted on a synthetic dataset of 500 aid requests generated with a known ground-truth urgency distribution calibrated against field data reported in [9]. Requests were drawn from a bivariate distribution over urgency and vulnerability levels, with 20% designated as Critical ground truth. Four allocation policies were simulated: FIFO, single-factor urgency rule, rule-based categorical triage (three tiers), and the proposed WPS model with default weights.

The WPS model reduced the mean waiting time for ground-truth Critical requests by 34% relative to FIFO and by 18% relative to the single-factor urgency rule. The coefficient of variation of waiting time across vulnerability quintiles – a standard measure of distributional equity – decreased by 22% compared to FIFO and by 11% compared to the urgency-only rule. The rule-based system performed comparably to WPS on high-urgency requests but was significantly outperformed on moderate-urgency, high-vulnerability cases, which constitute approximately 30% of the synthetic dataset. These results are consistent with theoretical predictions: single-criterion policies maximise performance on their chosen dimension at the cost of other relevant objectives, while the multi-dimensional WPS model achieves a Pareto-superior balance between efficiency and equity.

The primary limitation of the WPS model is its dependence on input data quality. The vulnerability index is only as accurate as beneficiary registration data, and self-reported urgency is susceptible to strategic inflation by requesters who learn the scoring rules. Both risks are partially mitigated by the coordinator override mechanism and by planned integration of case-worker validation flags in a future model revision. Weight calibration remains an open challenge: the default weights presented in Table 1 are derived from expert elicitation with humanitarian coordinators and should be iteratively refined using real operational data through a participatory Delphi process [7].

Conclusions

The paper has presented the Weighted Priority Score model, a formalised multi-factor approach to automated prioritization of humanitarian aid requests under resource constraints. The model integrates five complementary dimensions – urgency, vulnerability, request age, resource availability, and geographic density – into a single composite score that drives queue ordering in a web-based coordination platform. The software architecture ensures real-time recalculation, full auditability, and administrator-configurable weights, making the solution deployable across diverse humanitarian contexts without code modifications.

The comparative analysis and simulation experiments demonstrate that the WPS model outperforms FIFO, manual triage, and rule-based systems simultaneously on two key objectives: minimising waiting time for critical requests (efficiency) and reducing distributional inequality across vulnerability groups (equity). This dual improvement confirms the practical value of the multi-criteria approach over any single-criterion policy.

Three directions for future research are identified. First, empirical calibration of the weight vector using longitudinal operational data from partner non-governmental organisations, supported by a structured Delphi elicitation process. Second, investigation of adaptive weight adjustment via online learning algorithms that update weights based on observed beneficiary outcomes and coordinator feedback. Third, extension of the vulnerability index to incorporate dynamic situational indicators – such as displacement duration, shelter adequacy, and food security status – obtainable from integrated digital registration systems. These extensions would progressively align the WPS model with the goal of maximising aggregate beneficiary welfare in a rigorous, evidence-grounded manner.

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