

Field Driven Heuristics for Routing Decisions in Humanitarian Supply Chains

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ABSTRACT

Routing in humanitarian supply chains (HSCs) in sudden onset disaster response must contend with fragile infrastructure, volatile security conditions, and limited information. Although several HSC studies have suggested supporting routing under uncertainty through stochastic or robust optimization, the suggested methodologies typically assume known probability distributions, stable network topology, and continuous information flow. In reality, many of such assumptions often do not hold: road access may be structurally uncertain, regulations can change abruptly, and communication between field teams and coordination centers may be intermittent. Thus, how do field-based decision-makers actually route humanitarian cargo in HSCs under access fragility and communication latency? This work-in-progress research uses a case study design to explore heuristics commonly used by field-based decision makers for routing in HSCs. Drawing on operations in the South Caucasus and Türkiye, we identify latency-aware heuristics such as pre-validated alternative corridors, engineering-first feasibility screening, decentralized trigger-based rerouting, multimodal buffering, and regulatory pre-clearance strategies. We describe how these heuristics function, their benefits, and limitations, and offer an initial foundation for developing an empirically grounded methodology to support routing decisions in sudden onset disaster response.

Keywords

Humanitarian Supply Chain, routing decision, communication latency, uncertainty, disaster response, heuristics

INTRODUCTION

In 2024, nearly 299m people worldwide were in need of humanitarian assistance and protection; it is estimated that this number increased to around 305m in 2025 (ALNAP, 2025). Humanitarian supply chains (HSCs) are central to delivering aid to the affected people. HSC management refers to end-to-end planning, procurement, shipment, storage, and last mile distribution of relief goods and services to the affected populations effectively and efficiently (Altay et al., 2023; Maroof et al., 2023).

Routing in the last mile distribution covers the planning and execution of feasible transport paths for humanitarian cargo subject to various constraints such as physical (e.g., road/bridge conditions), administrative (e.g., permits, checkpoints), and operational (e.g., fleet/convoy rules) (Bayram et al., 2023; Maroof et al., 2023). In the context of sudden onset disaster response, field-based decision makers who deal with routing often face severe access issues (e.g., damaged, or narrow roads), dynamic border regulations, and security disruptions in the target region (Du et al., 2023; Dubey et al., 2020). Moreover, they may not be able to validate infrastructure conditions at the time of dispatch (e.g., unverified bridges). Besides, communication with other teams on the ground could be intermittent, acting primarily as a timing constraint. Furthermore, delayed, or partial updates reduce opportunities for real-time re-routing. Access conditions may change quickly long before the relevant information reaches monitoring systems or is shared through coordination mechanisms.

Given the challenges and uncertainties, routing requires effective approaches that remain feasible despite potential disruptions and late-arriving information (Kabra et al., 2023; Palen et al., 2007). In humanitarian literature, several mathematical and simulation models have been proposed to support routing in HSCs. In the available research, routing uncertainties are commonly represented through probabilistic, scenario-based, or bound uncertainty

formulations defined over a known road network (Bayram et al., 2023; Maroof et al., 2023). Yet most of the proposed methodologies suffer from unrealistic assumptions such as stable road networks or pre-specified probability distributions for uncertain parameters (e.g., travel times, edge failure probabilities, or demands) (Rodríguez-Espíndola et al., 2023). Some contributions assume reliable, continuous information flow that can inform the routing decision. Some examples include multi-stage stochastic programming frameworks that require timely updates (Ji & Fu, 2023), time-dependent vehicle-routing problem (VRP) models reliant on continuous data streams (Hartama et al., 2024), and dynamic VRP or deep reinforcement learning (DRL) based routing approaches that depend on frequent communication and state updates (Anuar et al., 2021; Mili & Argoubi, 2025). Baharmand et al. (2022) contend that unrealistic assumptions behind proposed methodologies in the literature limit their utility in the field. As Comes et al. (2015) state, the volatility, uncertainty, and complexity of humanitarian operations demand rapid actions. As such, field-based humanitarians typically find themselves engaged in intuitive forms of decision-making. Yet literature offers limited empirical insight into how routing decisions are actually made when access conditions are structurally uncertain and information is delayed. The puzzle is therefore, whether, and to what extent, field-based decision-makers rely on heuristics for routing. Heuristics are defined as experience-based decision rules that guide action under limited information and time pressure, without guaranteeing optimality (Altay et al., 2023).

This work-in-progress paper presents the primary results of ongoing research on routing decisions in sudden onset disaster response under conditions of structural access uncertainty and communication latency. The presented study explores: how field-based decision-makers actually route humanitarian cargo in HSCs under access fragility and communication latency. The objective is to identify recurring decision heuristics observed in field operations, and to assesses their advantages and limitations in the volatile sudden onset disaster response contexts. Methodologically, our study relies on observations from the ground and reviewing public operational documents. In the scope of our study, latency-aware routing heuristics explicitly remain operable when information updates are delayed or intermittent (HELP Logistics & CHORD, 2025; Reuter & Kaufhold 2023). We introduce structural access uncertainty, defined as situations in which corridor or route feasibility cannot be reliably verified due to damaged infrastructure, volatile administrative regimes, or contested access rather than being representable as probabilistic variation around a known, observable road network (Bayram et al., 2023; Reuter & Kaufhold 2023). We further foreground communication latency, defined as the delay between changes in field conditions (e.g., road closures, checkpoint regime changes) and the point when these changes become known and actionable at coordination or decision-making levels, thereby constraining centralized control (HELP Logistics & CHORD, 2025; Reuter & Kaufhold, 2023).

Our study contributes by identifying field-driven routing heuristics used in operational environments characterized by communication latency and structural access uncertainty. The remainder of the paper is as follows. We briefly review the literature on mathematical models for the routing decision in Background Section (2). Then, we describe the methodology in Methodology Section (3) and elaborate on our methods for data collection and analysis. Next, we present our findings such as identified heuristics and their advantages and risks in Findings Section (4). We discuss the findings in Discussion Section (5). Finally, the paper concludes in Section 6.

BACKGROUND

Humanitarian routing is primarily constrained by uncertain physical access—deteriorated infrastructure, evolving security incidents, and abrupt administrative changes (Du et al., 2023; Rodríguez-Espíndola et al., 2023). Classical stochastic or robust optimization is often inapplicable because disruptions cannot be reliably modeled probabilistically. Moreover, communication latency—delayed or intermittent updates—further limits routing by constraining field-level coordination and update frequency (Palen et al., 2007; Reuter & Kaufhold, 2023). Crisis informatics literature shows that such information gaps disrupt coordination and decision-making in emergencies (Comes et al., 2015). As a result, routing decisions rely heavily on pre-validated corridors, engineering feasibility checks, and structured fallback paths, with communication latency shaping the timing and autonomy of adjustments rather than the fundamental routing problem (Dubey et al., 2020).

Table 1 demonstrates representative and recent publications (2023–2025) that address routing and related logistics decision-making under uncertainty in humanitarian contexts. Publications were selected because they (i) explicitly engage with routing/transport decisions or executability of logistics decision support, (ii) represent dominant methodological streams for uncertainty handling and decision support, and (iii) reflect recent developments and sector constraints relevant to access fragility and communication disruption. The aim is not exhaustiveness, but to surface recurring assumptions that matter for latency- and access-constrained operations.

Table 1. Representative Approaches to Routing and Decision Support Under Uncertainty in Humanitarian Operations (2023–2025)

Authors (Year)	Problem addressed	Context	Methodology	Core assumptions
Du et al. (2023)	Multi-stage emergency logistics decisions under uncertainty	Disaster response	Robust decisions / optimization framing	Uncertainty can be bounded/structured; constraints formalizable
Maroof et al. (2023)	Vehicle routing optimization for humanitarian supply chains	HSC / disaster management	Systematic review of VRP for HSC	Uncertainty formalizable; objectives/constraints/data usable
Bayram et al. (2023)	Planning under uncertainty for evacuation/sheltering (incl. routing/assignment)	Humanitarian logistics / evacuation	Synthesis of robust, chance-constrained, stochastic paradigms	Demand/capacity parameterizable; network-modelable
Rodríguez-Espíndola et al. (2023)	Implementation and decision-maker involvement in HL optimization models	Humanitarian logistics	Review + implementation perspective	Operationalization is feasible given fit/engagement/data
Altay et al. (2023)	Innovation in humanitarian logistics/supply chains	HSC under crises	Systematic review and synthesis	Innovation transferable; complex field evidence limited
Carnero Quispe et al. (2024)	Prioritization models for humanitarian decisions	Humanitarian logistics	Systematic review (MCDA/prioritization)	Preferences elicitable; processes structured
Reuter & Kaufhold (2023)	Human-centered crisis informatics challenges & trends	Crisis response ICT	Narrative review	Fragmented info; coordination constraints
Singh, R. (research conducted in 2024, published in 2025)	Technology adoption - collaboration/agility - outcomes	Humanitarian supply chains	Survey-based empirical model	Benefits depend on adoption conditions
HELP Logistics & CHORD (2025)	Barriers/enablers (digital transformation, coordination)	Global humanitarian operations	Practitioner survey	Adoption constrained; coordination hard

Across these methodological streams, a shared set of assumptions emerges. First, scholars often assume network observability in their models. Academic models require known road availability, capacity, and feasibility data; for example, mixed-integer programming models that depend on predefined feasible edges (Mutlu et al., 2026), probabilistic location–routing models that assign probabilities to road closures (Temiz et al., 2025), and stochastic VRP formulations that rely on known travel-time and capacity parameters (Maroof et al., 2023). Second, studies assume stable access and administrative conditions. Several analytical approaches encode access as fixed, e.g., probabilistic location–routing models that define road availability through pre-specified scenarios (Temiz et al., 2025) and numerous VRP formulations reviewed in Anuar et al. (2021). Yet field practice shows volatile access regimes, sudden closures, and shifting permit requirements. Third, available research commonly assumes timely communication for re-optimization. Time-dependent VRP formulations rely on continuous data streams (Hartama et al., 2024), and both dynamic VRP models surveyed by Anuar et al. (2021) and DRL-based routing approaches (Mili & Argoubi, 2025) require frequent communication with field teams to update states or uncertainty parameters. The assumption is incompatible with intermittent or delayed communication in crisis settings. Lastly,

humanitarian researchers assume complete, reliable, and quantifiable data in their models. Stochastic and robust optimization models require uncertainty to be parameterizable, yet field teams face structural uncertainty, incomplete inputs, and information arriving too late to be used for model-driven re-planning.

To summarize, many routing methodologies rely on assumptions that do not reflect operational realities in the disaster response. There is therefore a need to examine heuristics that field-based decision-makers often use for routing decisions when information is incomplete or delayed.

METHODOLOGY

This study uses case study design aimed at understanding recurring patterns of practice and decision logic in complex real-world settings. We argue that the case study design is appropriate as we want to explore and identify heuristic decision structures used under access fragility and latency constraints. The unity of analysis is the routing decision in disaster response. We selected the following two operational contexts purposively where the lead author was deployed:

(1) Türkiye Earthquake Response (2023)—characterized by severe infrastructure impacts and evolving coordination products (partially collapsed roads were addressed through multimodal buffering (rail, coastal transport), with trigger-based rerouting used to reduce delays (Türkiye–Syria Earthquake Response Logistics Cluster, 2023).

(2) South Caucasus cross-border access constraints (August 2023)—characterized by corridor-level administrative volatility and limited independent verifiability of movements and deliveries (UN convoys faced sudden administrative closures). Pre-validated alternative corridors allowed rapid rerouting and uninterrupted aid delivery (operational documents from UN OCHA, 2023; ICRC, 2023).

The selected cases represent recent operations characterized by disrupted infrastructure, volatile access regimes, and intermittent communication, making them suitable contexts for examining routing decisions under structural access uncertainty.

The lead author's field exposure informed case selection and interpretation. In Türkiye, she supported UN Women operations during a short mission in Ankara (2024), providing direct insight into coordination products and operational constraints. In the South Caucasus, she previously managed heavy-lift, multimodal logistics projects across Georgia, Azerbaijan, and Armenia (2014–2018; 2020–2021), including route surveys, bridge/load checks, and corridor-level permitting—experience that contextualized engineering-first feasibility in access-fragile corridors. These roles shaped the study's focus on corridor redundancy, engineering feasibility gates, and governed autonomy (i.e., the capacity of field teams to take independent rerouting decisions within a pre-authorized set of rules and constraints, without requiring real-time approval from central coordination) under communication latency.

In addition to notes from field observations, we collected twelve publicly available documents: operational bulletins/CONOPS from the Logistics Cluster (n=4), situation briefings from the UN Office for the Coordination of Humanitarian Affairs (UN OCHA) (n=3), communication reports from the International Committee of the Red Cross (ICRC) (n=2), and technical/industry case reports (n=3). Documents were selected for direct relevance to routing decisions, access constraints, and execution.

For data analysis, the lead author conducted thematic coding to extract recurring routing patterns, triggers, and fallback mechanisms. Key corpus anchors include the Logistics Sector ConOps for the Türkiye/Syria earthquakes, the UN OCHA Security Council briefing on the Lachin corridor, and ICRC communications describing resumed deliveries via multiple routes.

The study draws on multiple complementary data sources to support heuristic identification and validation. Table 2 summarizes the types of data used, their operational context, and their analytical role in the development of routing heuristics. The data sources were used for analytical triangulation rather than statistical inference, consistent with the exploratory design of the study.

Table 2. Data Sources and Analytical Role in Heuristic Development

Data source category	Operational context	Type of evidence	Role in analysis	Contribution to heuristics
Field observations	Private-sector heavy and oversized cargo logistics (2020–2021; 2024–2025)	Operational logs, dispatch records, routing adjustments	Identification of recurring routing decision patterns	Engineering-first screening; buffer-node staging
Public operational reports	Türkiye–Syria earthquake response (2023)	Situation reports, logistics cluster updates, corridor status reports	Validation of access disruptions and route instability	Corridor viability assessment; staged movement logic
Coordination documents	Regional humanitarian operations in the South Caucasus and Central Asia	Coordination notes, access constraints, regulatory updates	Identification of administrative and regulatory barriers	Regulatory clearance sequencing; routing delay anticipation
Practitioner experience	Field decision-making under communication constraints	Observed operational behavior and decision logic	Synthesis of decision heuristics across contexts	Latency-aware rerouting and decentralized decision triggers

We acknowledge the limitations of the methodology. The analysis relies primarily on secondary public documents and practitioner observations, which constrains the ability to make claims about frequency, effectiveness, or performance. We argue that our findings should be interpreted as descriptive that provide an initial conceptual understanding of the phenomenon. Future work in the broader research project will include expert validation, interviews, and simulation to assess robustness and practical applicability.

FINDINGS

In this section, we present our case study findings in two parts. First, we elaborate on our findings about the routing decision, specifically the performance criteria and heuristics that field-based decision-makers often used. Next, we explain the advantages and risks that we could identify for the observed heuristics.

Routing Decision in HSCs

Performance Criteria Under Deep Uncertainty

In access-fragile and communication-constrained environments, field-based decision makers rely on performance criteria that differ markedly from the optimization objectives commonly found in the literature. Instead of minimizing cost, distance, or expected delay, their decisions emphasize continuity, feasibility, and controlled risk under conditions where network feasibility cannot be verified *ex ante* and information updates may arrive too late to support re-optimization. These criteria represent practical objectives that guide routing actions when uncertainty is structural rather than parameterizable. Deep uncertainty refers to situations where even the probability distributions are unknown (Walker et al., 2010).

We found the following descriptive performance metrics:

- Mission continuity that stresses ensuring delivery completion despite unforeseen disruptions. When access conditions shift during execution (e.g., checkpoints closing, bridges becoming impassable, or administrative permissions being revoked) teams prioritize the ability to continue the mission even if routing must deviate from planned paths. Continuity serves as a proxy for effectiveness when optimality cannot be evaluated due to missing or delayed information.
- Adaptability refers to maintaining operational momentum when updated constraints necessitate route switching. Rather than optimizing routes based on predicted conditions, field decision-makers value the ability to change courses without systemic paralysis. Under deep uncertainty, the capacity to reconfigure routing plans quickly (e.g., through using alternative corridors, fallback checkpoints, or improvised detours) becomes more important than adhering to the original plan.
- Risk containment: Given the prevalence of unverified bridges, insecure segments, and administratively

volatile corridors, decisions prioritize avoiding irreversible or high-consequence failures. These include structural failures (e.g., sending heavy trucks over unknown load-bearing infrastructure), security exposures, or movements into zones with contested access. Risk containment thus becomes a dominant objective when the consequences of a misjudgment outweigh the benefits of faster or shorter routes.

- Operational feasibility means field teams emphasize compliance with physical and regulatory constraints that may change rapidly: vehicle load limits, convoy rules, access windows, local authority directives, and checkpoint protocols. Under deep uncertainty, “feasible” means more than technically possible. It includes what is locally permissible at the moment of movement. As a result, operational feasibility becomes a dynamic objective shaped by evolving access regimes.
- Decision autonomy which reflects the need for governed flexibility when centralized coordination cannot intervene quickly enough. Communication latency often forces field teams to make rerouting decisions without immediate approval from coordination centers. A key performance criterion is therefore the proportion of successful autonomous rerouting actions. There were instances where local teams had to adjust their route based on situational awareness and still achieve safe, compliant delivery.

Heuristics

We found the following heuristics (H1-H6) in our analysis:

H1 — Pre-validated alternative corridors

Term definition (corridor): A logistics corridor refers to a predefined pathway or set of pathways (routes, border points, and associated arrangements) through which humanitarian cargo is expected to flow.

Evidence anchor: During the Türkiye/Syria earthquake response, the Logistics Sector CONOPS described the need for adaptive planning under evolving access and regulatory conditions. The document identified corridor options and emphasized that alternative routes had to be pre-validated due to damaged infrastructure and volatile administrative constraints, demonstrating the operational importance of maintaining multiple authorized routing pathways.

Design implication: Decision-support systems should represent corridors as first-class objects, storing time-stamped validation metadata (e.g., last survey date, known constraints, authorization status) and confidence flags that remain available offline to support rapid and informed rerouting decisions.

H2 — Engineering-first feasibility screening

Definition: Screen routes by engineering feasibility (bridge load, clearance, slope) before time/cost metrics; treat certain constraints as hard gates.

While this heuristic is adapted from private-sector heavy-lift logistics, its integration here is a direct response to the 'fragile infrastructure' typical of sudden-onset disasters, where technical road-bearing capacity often precedes traditional routing logic.

Evidence anchor: Heavy-lift and oversized-cargo logistics routinely prioritize engineering feasibility—such as bridge load ratings, turning radii, and structural clearances—before travel-time considerations. For instance, publicly documented heavy-lift deliveries along the Baku–Mingachevir corridor required advance verification of bridge loads, slope tolerances, and road geometry to prevent forced returns and ensure equipment safety (private-sector heavy-lift examples - Gianti Logistics, 2023; HHLA Project Logistics, 2023). While humanitarian documents rarely detail such checks explicitly, these engineering-first practices were visible in neighboring logistics corridors and will be validated further through planned expert interviews.

Note: Because public humanitarian documents rarely report detailed engineering checks, H2 is included as a practice-grounded heuristic to be validated through planned expert interviews/simulation exercises.

Design implication: Tools should encode hard feasibility gates upstream of routing and store check provenance (who/when/how).

H3 — Trigger-based decentralized rerouting

Definition: Use predefined trigger conditions to authorize local actors to reroute autonomously when communication with central control is delayed.

Term definition (trigger-based policy): A trigger-based policy is a set of predefined conditional rules mapping locally observable events to authorized actions, enabling decentralized decisions under delayed communication.

Evidence anchor: ConOps-style coordination in rapidly evolving conditions makes pre-authorized local action practical when updates lag.

Design implication: Decision-support systems should store trigger rules with clearly defined authority scopes, operational guardrails (security boundaries, vehicle constraints, administrative rules) and lightweight audit trails (easy-to-record logs that document what routing decisions were taken, by whom, and under what conditions — without requiring continuous connectivity) to enable governed autonomy under communication latency

H4 — Multimodal buffer integration

Definition: Maintain multimodal route sets and buffer nodes (ports, railheads, staging/transshipment points) to absorb road disruptions and stabilize throughput.

Term definition (buffer node): A buffer node is an intermediate holding or transshipment location used to decouple flow continuity from the reliability of a single road segment or mode.

Evidence anchor: ConOps described corridor analyses that recommend integrating seasonality and considering rail-road combinations, consistent with multimodal buffering logic.

Design implication: Support multimodal route sets, buffer-node capacity visibility, and synchronization features.

H5 — Regulatory pre-clearance strategies

Definition: Proactively secure permits, corridor agreements, and customs/notification documentation in advance to reduce administrative delays when access regimes are volatile.

Evidence anchor: UN OCHA described prolonged disruption and limited verifiability of corridor movements, while ICRC reported resuming deliveries once a humanitarian consensus enabled multi-route access.

Design implication: Systems should store regulatory metadata (permit copies, validity periods, route bindings, contact points) and surface it during routing decisions.

H6 — Communication-independent execution logic

Definition: Design playbooks and execution logic that remain operable during connectivity outages, including offline-first instructions and synchronization protocols for later reconciliation.

Evidence anchor: UN OCHA noted limits on independently verifying corridor movements, underscoring that routing decisions may proceed under delayed, partial, or contested information.

Design implication: Provide offline-first playbooks, version control, minimal event logging, and post-hoc reconciliation procedures.

Advantages and Risks

Table 3 summarizes the working conditions, operational advantages, decision-support implications, and evidence anchors for each identified heuristic. We found that the heuristics differ in their evidence base and operational scope. H1 and H5 are the most documentarily grounded in the available corpus. H2 is practice-inferred and will require expert validation. H3, H4, and H6 draw on coordination logic observable in the Türkiye ConOps and the South Caucasus case. We discuss our findings in Section 5.

Table 3. Latency-Aware Routing Heuristics: Working Conditions, Advantages, Decision-Support Implications, and Coded-Corpus Vignette Cross-References.

Heuristic	Working condition	Operational advantage	Decision-support implication	Evidence
H1 Pre-validated alternative corridors	Partial observability; rapid changes in road/border access	Continuity when a primary route fails; faster dispatch	Corridors with validity windows + confidence flags	Türkiye–Syria earthquakes (2023): evolving access and coordination products <i>The Logistics Sector ConOps documents severe infrastructure impacts and emphasizes that coordination products and activities are adapted as the situation evolves (“live document”). This environment creates recurring routing needs around corridor selection, staging capacity, and execution under changing conditions.</i>
H2 Engineering-first feasibility screening	Load limits, geometry, slope; heavy vehicles	Avoids structural failure and forced returns	Hard feasibility gates + provenance	Practitioner observations from heavy lift/oversized cargo logistics
H3 Trigger-based decentralized rerouting	Comms latency; checkpoint closures; security incidents	Faster local action; reduces central bottlenecks	Trigger rules + delegated authority + audit trails	Türkiye–Syria earthquakes (2023): evolving access and coordination products
H4 Multimodal buffer integration	Road saturation/damage ; access windows; port/rail availability	Reduces road dependence; stabilizes throughput	Multimodal route sets + buffer nodes + synchronization	Türkiye–Syria earthquakes (2023): evolving access and coordination products South Caucasus (2023): limited verifiability and corridor-level access volatility <i>UN OCHA reported in August 2023 that it could not independently verify movement through routes including the Lachin corridor, while simultaneous reports noted disrupted deliveries. In September 2023, ICRC reported resuming deliveries after a humanitarian consensus, using both the Lachin corridor and the Aghdam Road, illustrating multi-route execution under volatile access regimes.</i>
H5 Regulatory pre-clearance strategies	Border volatility; permits/corridor negotiations; customs delays	Shortens admin lead time; enables rapid switching	Regulatory metadata as constraints	

H6 Communication- independent execution logic	Connectivity outages; delayed updates; limited awareness	Operable during outages; safer autonomous execution	Offline playbooks + versioning + reconciliation	Türkiye–Syria earthquakes (2023): evolving access and coordination products South Caucasus (2023): limited verifiability and corridor-level access volatility
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DISCUSSION

The findings extend the literature summarized in Table 1 by demonstrating how routing decisions are executed in volatile operational settings. Our findings highlight that routing decisions are often made in the field under deep uncertainty. The identified heuristics in this study correspond to the performance criteria that field teams usually prioritize: H1 and H3 support mission continuity and decision autonomy; H2 and H5 operationalize risk containment and feasibility; and H4 and H6 enable adaptability under volatile conditions.

The heuristics identified in our study can be interpreted as pragmatic complements to existing modeling approaches, clarifying decision structures that remain useful when common assumptions are weakened. Each heuristic operationalizes a field-tested decision logic that compensates for a specific assumption gap in the literature:

- H1 and H5 directly counter models that assume stable access regimes or scenario-based representations of road availability. Pre-validated corridors and regulatory pre-clearance create actionable alternatives when access rules shift unpredictably.
- H2 and H4 address the literature’s reliance on known or estimable feasibility parameters. Engineering-first screening and multimodal buffer integration re-prioritize feasibility and throughput continuity when infrastructure conditions cannot be formally parameterized.
- H3 and H6 respond to assumptions of reliable, continuous communication. Trigger-based decentralized rerouting and offline-first execution logic enable governed autonomy when central coordination cannot react at the pace of operational changes.

This perspective illustrates that the heuristics do not replace analytical models; rather, they clarify what kinds of routing decisions remain implementable when dominant modeling assumptions collapse. While analytical models aim for optimality under structured uncertainty, field heuristics aim for feasibility, continuity, and risk containment under deep uncertainty. In this sense, the heuristics extend the literature by articulating what “good routing” looks like when the informational foundations of optimization are absent: the ability to maintain mission continuity, avoid structural or security failures, and adapt safely without paralyzing operations.

Table 4 maps each heuristic to the dominant assumptions it relaxes or operationalizes. The purpose is not to criticize modeling work, but to clarify which decision structures become salient under structural access uncertainty and latency. This mapping contributes to ongoing calls for more implementation-ready, empirically grounded decision-support research in humanitarian logistics. It suggests that future tools should incorporate the observed decision structures (particularly corridor redundancy, feasibility gating, governed autonomy, and offline-first logic) to ensure usability in latency-prone, access-fragile environments.

Table 4. Heuristics and the dominant assumptions they relax (and how).

Heuristic	Dominant assumption	What changes in practice
H1	Single best-path planning; observable network at dispatch	Corridor sets with validity metadata and rapid switching
H2	Feasibility estimable via stable data; cost/time dominates	Hard feasibility gates before optimization
H3	Continuous connectivity; central approval feasible	Pre-authorized IF–THEN rules enable governed autonomy
H4	Road-dominant single-mode routing	Multimodal route sets + buffers stabilize throughput
H5	Stable administrative regime during execution	Route-bound permits/contacts enable switching
H6	Always-online decision support and timely updates	Offline-first playbooks + versioning + reconciliation

We argue that a decision-support system (DSS) incorporating these heuristics would require an offline-first architecture that maintains locally stored regulatory and operational metadata. Rather than relying on single-route optimization, such a system would emphasize multi-modal buffer visibility to support resilient decision-making under uncertainty. Core to this design is the use of pre-authorized IF–THEN trigger rules, which enable governed autonomy when connectivity disruptions prevent timely centralized coordination.

The identified heuristics can be embedded into the DSS as rule-based filters that prioritize route feasibility before optimization under conditions of uncertainty. For example, a routing DSS could implement trigger-based rerouting (H3) by storing predefined conditional rules that authorize local action under specified constraints:

IF checkpoint closure is detected
AND an alternative corridor is pre-validated
THEN authorize local rerouting without central approval.

By embedding such rule-based logic, the system allows field-level decision-makers to act within clearly defined governance boundaries during communication blackouts or latency-induced delays. This approach preserves regulatory compliance and accountability while maintaining operational continuity in degraded information environments.

CONCLUSIONS

This paper uses a case study design to examine how field-based decision-makers route humanitarian cargo under conditions of access fragility and communication latency. We use insights from two field operations to examine the routing heuristics and evaluate their advantages and limitations in environments where common assumptions of developments in literature do not hold. Heuristics refer to experience-based decision rules that guide action under limited information and time pressure, without guaranteeing optimality (Altay et al., 2023). Our analysis shows that field-based decision-makers rely on a set of latency-aware routing heuristics (vs. mathematical optimization) to maintain mission continuity under structural access uncertainty and communication latency. The identified heuristics include pre-validated corridor sets, engineering-first feasibility gates, trigger-based autonomous rerouting, multimodal buffering, regulatory pre-clearance, and offline-first execution logic.

Our study contributes by introducing latency-aware routing heuristics as a descriptive framework for field operations under deep uncertainty. It also suggests how private-sector engineering logistics practices may inform HSC design, enhancing resilience, autonomy, and mission continuity. This direction will be examined more rigorously in subsequent phases of our research project. For practice, the observed heuristics point toward design principles for routing systems that remain resilient under structural access uncertainty and communication latency. These principles emphasize feasibility, continuity, and governed autonomy over real-time optimality.

Heuristics formalizes practitioner intuition and provides a foundation for our future work on developing an evidence-based decision support system for the routing decision in HSCs. Future research directions include:

- Comparative analysis of heuristic-based versus stochastic/robust routing to quantify the economic value and operational trade-offs of heuristic adoption.
- Simulation studies to validate corridor redundancy and trigger-based rerouting.
- Integration of engineering feasibility checks into algorithmic routing tools.
- Development of decision-support tools effective in low-connectivity and high-latency environments.

Additionally, further studies are needed to validate these heuristics across a broader range of disaster typologies. Future research should also conduct comparative and simulation-based analyses to quantify the operational cost and coordination value of adopting these latency-aware heuristics compared to traditional optimization approaches, particularly regarding lead-time reduction and resource utilization.

REFERENCES

- ALNAP. (2025). *Global Humanitarian Assistance*.
https://alnap.hacdn.io/media/documents/GHA_Report_1408v1.pdf
- Altay, N., Heaslip, G., Kovács, G., Spens, K., Tatham, P., & Vaillancourt, A. (2023). Innovation in humanitarian logistics and supply chain management: A systematic review. *Annals of Operations Research*, 335, 965–987. <https://doi.org/10.1007/s10479-023-05208-6>
- Anuar, W. K., Lee, L. S., Pickl, S., & Seow, H.-V. (2021). Vehicle routing optimization in humanitarian

- operations: A survey on modelling and optimization approaches. *Applied Sciences*, 11(2), 667. <https://doi.org/10.3390/app11020667>
- Baharmand, H., Vega, D., Lauras, M., & Comes, T. (2022). A methodology for developing evidence-based optimization models in humanitarian logistics. *Annals of Operations Research*, 319(1), 1197–1229. <https://doi.org/10.1007/s10479-022-04762-9>
- Bayram, V., Kara, B. Y., Saldanha-da-Gama, F., & Yaman, H. (2023). Humanitarian logistics under uncertainty: Planning for sheltering and evacuation. In H. A. Eiselt & V. Marianov (Eds.), *Uncertainty in Facility Location Problems* (pp. 81–105). International Series in Operations Research & Management Science, Vol. 347. Springer. https://doi.org/10.1007/978-3-031-32338-6_4
- Carnero Quispe, M. F., Couto, A. S., de Brito Junior, I., Cunha, L. R. A., Siqueira, R. M., & Yoshizaki, H. T. Y. (2024). Humanitarian logistics prioritization models: A systematic literature review. *Logistics*, 8(2), 60. <https://doi.org/10.3390/logistics8020060>
- Comes, T., Vybornova, O., & van de Walle, B. (2015). Bringing structure to the disaster data typhoon: An analysis of decision-making tools for situation assessment and planning. *IEEE Transactions on Engineering Management*, 62(3), 433–445.
- Du, J., Wu, P., Wang, Y., & Yang, D. (2023). Multi-stage humanitarian emergency logistics: Robust decisions in uncertain environment. *Natural Hazards*, 115, 899–922. <https://doi.org/10.1007/s11069-022-05578-3>
- Dubey, R., Bryde, D. J., Foropon, C., Graham, G., Giannakis, M., & Mishra, D. B. (2020). Agility in humanitarian supply chain: An organizational information processing perspective and relational view. *Annals of Operations Research*, 319, 559–579. <https://doi.org/10.1007/s10479-020-03824-0>
- Gianti Logistics. (2023). *Gianti Logistics delivers turbines to Mingachevir from Baku, Azerbaijan*. <https://www.pl-alliance.com/news/gianti-logistics-delivers-turbines-to-mingachevir-from-baku-azerbaijan>
- Hartama, D., Wanayumini, & Damanik, I. S. (2024). Optimizing disaster response: A systematic review of time-dependent cumulative vehicle routing in humanitarian logistics. *Journal of Information Technology and Engineering*, 10(3), 625–638.
- HELP Logistics & CHORD. (2023). *The state of logistics and supply chain in the humanitarian context 2021–22: Global survey findings*.
- HELP Logistics & CHORD. (2025). *The state of logistics and supply chain in the humanitarian context 2024: Global survey findings*.
- HHLA Project Logistics. (2023). *Support for wind energy expansion*. <https://hhla.de/en/media/news/detail-view/hhla-project-logistics-supports-the-expansion-of-wind-energy>
- ICRC. (2023). *Azerbaijan/Armenia: Sides must reach “humanitarian consensus” to ease suffering*. <https://www.icrc.org/en/document/azerbaijan-armenia-sides-must-reach-humanitarian-consensus-to-ease-suffering>
- Ji, X., & Fu, S. (2023). Modeling multi-objective optimization with updating information on humanitarian response to flood disasters. *Water*, 15(11), 2122. <https://doi.org/10.3390/w15112122>
- Kabra, G., Anbanandam, R., Jain, V., & Akhtar, P. (2023). Barriers to information and digital technology adoption in humanitarian supply chain management: A fuzzy AHP approach. *Journal of Enterprise Information Management*, 36(2), 505–527. <https://doi.org/10.1108/JEIM-10-2021-0456>
- Maroof, A., Ali, S., & Kacemi, M. (2023). Vehicle routing optimization for humanitarian supply chains: A systematic review. *International Journal of Disaster Risk Reduction*, 92, 103741.
- Mili, K. K., & Argoubi, M. A. (2025). Adaptive vehicle routing for humanitarian aid in conflict-affected regions: A practitioner-informed deep reinforcement learning approach. *Frontiers in Future Transportation*, 6, 1603726.
- Mutlu, İ. N., Kisa Toğrul, E., Uzgören Kazanç, H. C., Kılıç, K., & Soysal, M. (2026). *Improving last-mile delivery in humanitarian logistics by solving a two-echelon routing problem with infrastructure disruptions*. OPSEARCH.
- Palen, L., Vieweg, S., Sutton, J., Liu, S. B., & Hughes, A. L. (2007). *Crisis informatics: Studying crisis in a networked world*. Proceedings of the International Conference on e-Social Science.
- Reuter, C., & Kaufhold, M.-A. (2023). Crisis informatics. In Z. Yan (Ed.), *The Cambridge Handbook of Cyber Behavior* (pp. 737–770). Cambridge University Press. <https://doi.org/10.1017/9781107165250.029>
- Rodríguez-Espíndola, O., Ahmadi, H., Gastélum-Chavira, D., Ahumada-Valenzuela, O., Chowdhury, S., Dey, P.

- K., & Albores, P. (2023). Humanitarian logistics optimization models: An investigation of decision maker involvement and directions to promote implementation. *Socio-Economic Planning Sciences*, 89, 101669. <https://doi.org/10.1016/j.seps.2023.101669>
- Singh, R. (2025). Leveraging technology in humanitarian supply chains: Impacts on collaboration, agility, and sustainable outcomes. *Journal of Humanitarian Logistics and Supply Chain Management*, 15(2), 61–73. <https://doi.org/10.1108/JHLSCM-05-2024-0063>
- South Caucasus Pipeline Project. (2023). *SCP/SCPX factsheets*. https://www.bp.com/en_ge/georgia/home/who-we-are/scp.html
- Temiz, S., Kazanç, H. C., Soysal, M., & Çimen, M. (2025). A probabilistic bi-objective model for a humanitarian location-routing problem under uncertain demand and road closure. *International Transactions in Operational Research*, 32(2), 590–625. <https://doi.org/10.1111/itor.13475>
- Türkiye–Syria Earthquake Response Logistics Cluster. (2023). *Operational Updates And Access Constraints. (Various Bulletins)*. <https://logcluster.org/en/where-we-work/tur/tur-syr-eq-23>
- UN OCHA. (2023). *Briefing of the Emergency Relief Coordinator to the UN Security Council on the humanitarian situation around the Lachin corridor (16 August 2023)*.
- UN OCHA. (2023). *Global Humanitarian Overview 2024. United Nations Office for the Coordination of Humanitarian Affairs*. <https://www.unocha.org/publications/report/world/global-humanitarian-overview-2024-enarfres>
- UN OCHA. (2024). *Global Humanitarian Overview 2025. United Nations Office for the Coordination of Humanitarian Affairs*. <https://www.unocha.org/publications/report/world/global-humanitarian-overview-2025-enarfres>
- Walker, W. E., Marchau, V. A., & Swanson, D. (2010). Addressing Deep Uncertainty Using Adaptive Policies. *Technological Forecasting and Social Change*, 77(6), 917–923.