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# Fatigue, Occupational Health, and Operational Resilience in Humanitarian and Disaster-Relief Flight Operations

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**Abstract:** Humanitarian and disaster-relief flight operations place aircrews in circumstances where time pressure, disrupted infrastructure, irregular duty cycles, austere staging locations, rapidly changing weather, emotionally consequential missions, and sustained cognitive demands converge. This integrative review examines fatigue as a mission-level public health and operational resilience problem rather than as an individual endurance issue. Using only the established source corpus provided for this study, the paper synthesizes evidence on circadian disruption, workload, occupational stress, burnout, mental health, Fatigue Risk Management Systems (FRMS), workload assessment, health literacy, and organizational culture. The literature consistently indicates that extended wakefulness, irregular schedules, cumulative sleep restriction, elevated cognitive workload, and weak reporting climates can degrade alertness, judgment, psychomotor performance, and psychological wellbeing. These mechanisms become especially consequential during disaster response because relief missions often require repeated sorties, overnight operations, uncertain destination conditions, rapid replanning, and limited recovery opportunities. Practical illustrations demonstrate how fatigue risk may arise during medical evacuation, supply delivery, displaced-person transport, and post-disaster logistics. The review concludes that resilient humanitarian air operations require mission-adaptive FRMS, circadian-informed scheduling, protected fatigue reporting, workload monitoring, recovery infrastructure, confidential mental health support, health-literacy initiatives, and leadership practices that treat crew recovery as operational capacity. The resulting framework positions fatigue management as an essential component of continuity, safety, and humanitarian effectiveness.

**Keywords:** Humanitarian Aviation, Disaster Relief, Pilot Fatigue, Occupational Health, Fatigue Risk Management, Workload, Burnout, Operational Resilience

## Introduction

Fatigue constitutes a consequential threat to humanitarian flight operations because relief missions often compress the interval between urgent need and safe operational capacity. Research on professional pilots and other transportation personnel consistently associates fatigue with impaired vigilance, slower reaction time, degraded decision-making, and elevated error potential (Jun-Ya & Rui-Shan, 2023; Olaganathan et al., 2021). The significance of those findings increases during disaster response because aircrews may operate repeated missions while sleep opportunities are fragmented by alerts, weather changes, cargo reconfiguration, medical priorities, or airport-access constraints. For example, a crew delivering water and medical supplies after a major cyclone may complete a late-

evening sortie, receive a short-notice request for an early-morning evacuation, and then confront a destination runway with limited lighting and uncertain ground support. The central operational issue is therefore not whether highly trained crews can tolerate fatigue for a single mission, but whether the relief system protects the cognitive and physiological capacity required to sustain safe performance across the response period.

Humanitarian aviation also intensifies fatigue through a combination of irregular scheduling and high-consequence cognitive work. Studies of flight-crew workload show that mental, temporal, and performance demands can become substantial during complex operations, while extended wakefulness and circadian misalignment further erode cognitive reserve (Hart & Staveland, 1988; Masi et al., 2023; Venus & grosse Holtforth, 2021). During disaster relief, the same crew may need to interpret changing meteorological information, coordinate with unfamiliar ground agencies, evaluate fuel margins, manage displaced passengers, and adapt to incomplete communications. A practical example is an aircrew approaching an earthquake-affected region where the primary destination suddenly becomes unavailable because emergency vehicles are occupying the runway. Replanning the diversion is technically manageable, but fatigue can narrow attention and reduce the crew's ability to integrate fuel, weather, alternate-airfield, medical, and passenger considerations simultaneously. Accordingly, fatigue management in relief operations must be understood as a systems problem involving scheduling, staffing, workload, infrastructure, and decision authority.

The public-health dimension of fatigue is equally important because humanitarian flight crews may sustain operational tempo for days or weeks rather than for a single isolated duty period. Chronic disruption of sleep and circadian rhythms is associated with insomnia, excessive sleepiness, stress, mood disturbance, and broader health consequences in shift-working populations and professional flight crews (Cahill et al., 2021; Venus, 2021; Wickwire et al., 2017; Wright et al., 2013). When these exposures accumulate, the immediate problem of reduced alertness can evolve into burnout, emotional exhaustion, and diminished professional efficacy (Brezonakova, 2017; Demerouti et al., 2019; Ozel & Hacioglu, 2021). Consider a relief pilot who spends three weeks rotating among dawn departures, night cargo missions, and standby evacuation duties while sleeping in temporary accommodations near an active logistics hub. Even if every individual duty period remains within formal limits, cumulative sleep disruption may progressively reduce resilience. This pattern makes occupational health inseparable from mission continuity and supports a fatigue strategy that protects both immediate performance and post-deployment recovery.

## Problem Statement

The central problem is that humanitarian and disaster-relief flight operations can generate fatigue exposure more rapidly than conventional duty-hour rules can adequately represent. Fatigue science shows that performance is shaped not only by hours worked, but also by time of day, prior sleep, circadian phase, cumulative sleep debt, workload, stress, and individual variability (Bourgeois-Bougrine, 2020; Gander et al., 2011; Gander et al., 2017). Relief missions frequently combine several of these risk factors because operational demand is externally driven by the disaster rather than by a stable schedule. For example, flooding may close roads and transform an airbridge into the principal means of moving blood products, medical teams, and essential supplies, creating legitimate pressure to increase sortie frequency. If the organization responds only by extending crew utilization, the relief system may preserve short-term throughput while quietly degrading the human capacity on which that throughput depends. The problem therefore lies in the mismatch between static scheduling rules and dynamic mission fatigue risk.

A second problem is that fatigue may remain underreported when operational culture equates endurance with professional commitment. Research on pilot mental health and

occupational stress shows that personnel may hesitate to disclose fatigue, insomnia, psychological distress, or related health concerns when they anticipate stigma, career consequences, or doubts about confidentiality (Cahill et al., 2021; Silva et al., 2022). This concern becomes particularly salient in humanitarian response because crews often identify strongly with the moral urgency of the mission. A pilot may recognize severe exhaustion yet feel reluctant to decline a sortie carrying emergency surgical supplies to an isolated community, especially when no replacement crew is immediately available. The moral value of the mission can therefore become an additional source of self-imposed pressure, even when leadership has issued formal fatigue guidance. Effective fatigue mitigation must consequently make nonpunitive self-removal, replacement staffing, and confidential health support operationally credible rather than merely permissible.

## Purpose Statement

The purpose of this integrative review is to identify and organize evidence-based practices that can reduce fatigue, protect occupational health, and strengthen operational resilience among flight crews engaged in humanitarian and disaster-relief missions. The review draws on existing evidence concerning fatigue physiology, workload, circadian disruption, occupational stress, mental health, burnout, FRMS, health literacy, and organizational culture. These evidence streams are interpreted through the specific demands of relief operations, including surge scheduling, remote destinations, austere accommodations, high emotional salience, interagency coordination, and unstable mission timelines. For instance, a fatigue intervention that is adequate for a predictable roster may require modification when crews are placed on recurring short-notice standby after a typhoon. The paper therefore seeks to translate established fatigue knowledge into a coherent operational framework suitable for mission planners, humanitarian organizations, public-health leaders, flight departments, and regulators responsible for disaster-response aviation.

## Research Question

What operational, organizational, occupational-health, and policy practices are most defensible for mitigating fatigue among flight crews conducting humanitarian relief and disaster-response missions? This question deliberately moves beyond a narrow concern with duty-hour compliance and instead examines the system conditions that determine whether crews can remain cognitively effective and physiologically resilient during periods of elevated mission demand. The literature indicates that fatigue arises through interacting factors rather than a single exposure, which makes a multidimensional research question more appropriate than one focused solely on schedule duration (Gander et al., 2011; Masi et al., 2023; Venus & grosse Holtforth, 2022). In practical terms, the question asks what a relief organization should do when the next mission is humanitarianly urgent but the available crew has already accumulated substantial sleep debt. Framing the inquiry this way links fatigue science directly to operational decision-making.

## Significance of the Study

The significance of fatigue management in humanitarian aviation extends beyond flight safety because crew performance can determine whether critical aid reaches affected populations when surface transportation is unavailable or severely constrained. Evidence on fatigue demonstrates that degraded alertness and workload tolerance can impair complex decision-making long before a person becomes incapable of performing basic tasks (Jun-Ya & Rui-Shan, 2023; Masi et al., 2023). During disaster response, small degradations can have disproportionate consequences because missions may involve narrow weather windows, limited alternates, constrained fuel availability, damaged navigation infrastructure, or medically fragile passengers. For example, a fatigued crew conducting an evacuation from a remote island may need to decide whether deteriorating weather justifies departing

immediately, delaying for clarification, or repositioning to another field. The quality of that judgment affects not only the crew but also patients, medical teams, relief coordinators, and communities awaiting continued support. Fatigue mitigation is therefore integral to humanitarian reliability and the ethical stewardship of scarce aviation capability.

The study is also significant from an occupational-health perspective because disaster response can expose crews to recurrent circadian disruption, psychological stress, and inadequate recovery conditions. The literature connects chronic schedule instability and work-related stress with sleep problems, anxiety, depressive symptoms, burnout, and impaired wellbeing (Cahill et al., 2021; Cuadrado et al., 2025; Venus & grosse Holtforth, 2022). These outcomes can reduce the long-term availability of experienced personnel precisely when organizations depend on them for future emergencies. A practical example is a pilot who completes an intense two-week relief deployment, returns home without a protected recovery interval, and is then assigned another high-tempo mission sequence. Even if no acute event occurs, insufficient recovery can convert temporary fatigue into chronic health and retention problems. Protecting crew wellbeing should consequently be treated as a continuity investment that preserves specialized operational expertise across successive disasters.

## Humanitarian and Disaster-Relief Operational Context

Humanitarian air operations differ from routine flight activity because mission demand is shaped by human need, infrastructure disruption, and rapidly changing access rather than by stable schedules. This environment can produce abrupt surges in cargo, passenger movement, medical evacuation, aerial assessment, and repositioning requirements, all of which increase planning complexity and reduce predictable recovery time. The stress literature shows that high-risk work becomes more demanding when individuals perceive severe consequences while simultaneously questioning whether sufficient coping resources are available (Campbell & O'Connor, 2009) ; Overall, 2016; Stonestreet, 2014). For example, a crew based at a temporary logistics hub may receive multiple requests from separate relief agencies, each describing its cargo as urgent, while weather and ramp congestion reduce the number of feasible departures. The resulting workload is not simply a function of flight hours; it is a continuous process of prioritization under moral and operational pressure. Humanitarian fatigue management must therefore account for mission urgency as a workload multiplier rather than treating it as an external consideration.

Austere operating environments further complicate recovery because scheduled rest does not guarantee restorative sleep. Shift-work research demonstrates that sleep quality depends on circadian timing and environmental conditions, not merely on the number of hours nominally available for rest (Tait et al., 2021; Wickwire et al., 2017; Wright et al., 2013). Relief crews may sleep in temporary housing exposed to generator noise, heat, emergency traffic, shared quarters, or repeated communications alerts. For instance, an eight-hour rest opportunity at a staging base may yield far less restorative sleep if the crew is housed beside a 24-hour cargo ramp and is repeatedly awakened by mission updates. Under those circumstances, a schedule can appear compliant while physiological recovery remains inadequate. Relief organizations must therefore evaluate rest quality, accommodation conditions, and interruption risk when assessing crew readiness.

Interagency coordination can also elevate cognitive workload because humanitarian missions frequently require interaction with actors who use different procedures, terminology, priorities, and decision structures. Research applying social-ecological perspectives to flight-deck stress shows that performance is influenced by interpersonal and organizational context as well as by individual coping capacity (Groppe & Brock, 2022; Marques & Malagris, 2025). A crew may need to coordinate with military controllers, local authorities, nongovernmental organizations, medical teams, and temporary airport management within the same duty

period. For example, a captain may receive a landing-slot change from a relief coordination cell while simultaneously managing a passenger manifest revision and a deteriorating weather forecast. Each task is manageable independently, yet the interaction can produce substantial cognitive saturation. This context supports fatigue controls that address coordination complexity and workload distribution, not only rest duration.

## Fatigue as a Mission-Risk Multiplier

Fatigue should be treated as a mission-risk multiplier because it reduces the cognitive reserve needed to manage abnormal events. Studies of pilot fatigue associate extended wakefulness and cumulative fatigue with diminished attention, psychomotor performance, and decision quality (Jun-Ya & Rui-Shan, 2023; Olaganathan et al., 2021). During relief missions, abnormal events are not exceptional in the same way they may be during stable operations; destination changes, communications failures, loading delays, weather deterioration, and last-minute medical requirements can be routine. Consider a crew that has already completed two supply sorties when a third mission is redirected to evacuate patients from a deteriorating security situation. The technical procedures remain familiar, but fatigue can reduce the margin available for prioritization, cross-checking, and recognizing subtle inconsistencies. The operational value of fatigue management lies in preserving the capacity to respond effectively when the mission departs from the plan.

Cumulative fatigue is especially important because operational degradation may emerge gradually and be normalized by experienced crews. Bourgeois-Bougrine (2020) cautions against an illusion of fatigue control, and research on fatigue-risk systems emphasizes the need to combine multiple indicators rather than relying exclusively on subjective self-assessment (Gander et al., 2017; Thomas, 2024). Highly motivated relief crews may adapt to feeling tired and interpret persistent exhaustion as an ordinary feature of deployment. For example, a crew member who has operated five consecutive early starts may report feeling "functional" while showing slower information processing and greater dependence on habitual routines. The absence of a dramatic symptom does not demonstrate full cognitive readiness. Mission systems should therefore monitor sleep opportunity, circadian timing, duty accumulation, workload, and performance indicators together rather than waiting for a crew member to declare severe fatigue.

## Circadian Disruption and Surge Scheduling

Circadian disruption is a central fatigue mechanism in disaster relief because mission timing is often determined by access windows and urgent need rather than by human biological rhythms. Shift Work Disorder research demonstrates that schedules requiring wakefulness during the biological night can produce insomnia, excessive sleepiness, and sustained performance impairment (Tait et al., 2021; Venus, 2021; Wickwire et al., 2017; Wright et al., 2013). Humanitarian surge operations may involve predawn departures to exploit favorable weather, overnight repositioning to stage supplies, or rapid transitions from day to night schedules. For example, a crew that has adapted to daytime sorties may be redirected to a sequence of nighttime medical flights after local roads become impassable. The resulting schedule change can create severe circadian misalignment even when total duty time remains legally acceptable. Relief planners should therefore treat rapid schedule rotation as an independent risk factor and protect crews from repeated reversals between day and night duty.

Protected recovery intervals are essential because surge capacity cannot be sustained by repeatedly borrowing from future sleep. Fatigue management research emphasizes that organizational factors and roster design strongly influence whether crews can obtain sufficient recovery (Gander et al., 2011; Venus & grosse Holtforth, 2021). In humanitarian operations, the temptation to maximize aircraft utilization can lead planners to treat any technically available crew as an operationally ready crew. A more resilient approach

distinguishes availability from fitness. For example, after a 12-hour day involving multiple relief sectors and an unexpected diversion, a crew might remain within a formal limit but still require a protected recovery period before another early departure. Scheduling systems should therefore incorporate cumulative fatigue and circadian phase into crew allocation so that humanitarian urgency does not progressively consume the recovery capacity needed to continue the response safely.

### Cognitive Workload and High-Consequence Decision-Making

Cognitive workload interacts with fatigue by accelerating performance degradation when crews must process numerous competing demands. The NASA Task Load Index conceptualizes workload across mental, physical, temporal, effort, performance, and frustration dimensions, and aviation research has used workload assessment to identify demanding operational phases (Hart & Staveland, 1988; Masi et al., 2023). Humanitarian missions can produce high scores across several dimensions simultaneously because crews may face time pressure, incomplete information, unfamiliar airports, challenging cargo, and emotionally distressed passengers. For example, a flight carrying a mobile surgical team may be replanned en route when the destination loses electrical power and the alternate facility requests additional medical cargo. The crew must recalculate performance and fuel while coordinating with dispatch and medical personnel. Workload monitoring can help organizations identify mission profiles where additional crew, longer planning intervals, or reduced sortie frequency is warranted.

Workload mitigation should emphasize the redistribution of tasks before fatigue becomes operationally visible. Research on stress and coping shows that performance improves when personnel perceive adequate resources and viable coping options for demanding situations ((Campbell & O'Connor, 2009) ; Stonestreet, 2014; Szewcxyk & Terelack, 2013). In a relief context, those resources can include augmented crew staffing, dedicated mission coordinators, standardized cargo information, protected briefing time, or clear delegation of nonflight communication tasks. For instance, assigning a ground mission coordinator to manage agency requests can prevent the flight crew from receiving repeated operational changes while completing preflight calculations. Such support does not reduce professional responsibility; it preserves attention for the decisions only the crew can make. Humanitarian organizations should consequently design mission support structures that deliberately reduce avoidable cognitive competition during fatigue-sensitive periods.

### Mental Health, Burnout, and Occupational Resilience

Fatigue and psychological wellbeing are reciprocally related, which means repeated disaster deployments can create risks extending beyond temporary sleepiness. Research on flight-crew stress shows associations among fatigue, insomnia, anxiety, depressive symptoms, and reduced wellbeing, while burnout research identifies emotional exhaustion, depersonalization, and diminished professional accomplishment as consequences of sustained occupational strain (Brezonakova, 2017; Cahill et al., 2021; Cuadrado et al., 2025; Demerouti et al., 2019; Venus & grosse Holtforth, 2022). Humanitarian work may add exposure to human suffering, urgency, and moral responsibility to the usual demands of flight operations. For example, a crew repeatedly transporting injured children from a disaster zone may remain technically proficient while experiencing cumulative emotional exhaustion and disturbed sleep. If the organization focuses only on duty hours, it may overlook an emerging decline in psychological resilience. Fatigue management should therefore be integrated with confidential mental-health support and post-deployment recovery practices.

Psychological safety is indispensable because crews are unlikely to use support systems they do not trust. Silva et al. (2022) describe persistent concerns among pilots about disclosure, confidentiality, and professional consequences related to mental health. In

humanitarian operations, similar concerns can be intensified by small teams, temporary deployments, and a strong culture of mission commitment. A pilot who experiences persistent insomnia after witnessing severe disaster consequences may avoid seeking assistance if doing so is perceived as burdening colleagues or jeopardizing future deployment opportunities. Organizations can reduce this barrier by separating confidential clinical support from routine supervisory evaluation and by communicating clearly how fatigue and mental-health disclosures are handled. A credible support structure improves both individual health and organizational awareness of risks that would otherwise remain concealed.

**Integrated Conceptual Framework**

The Transactional Model of Stress and Coping provides a useful explanation for why identical mission demands can produce different fatigue outcomes across crews. Individuals appraise both the severity of a stressor and the resources available to manage it, which means workload becomes more consequential when personnel perceive limited control or inadequate support ((Campbell & O'Connor, 2009) ; Stonestreet, 2014). In disaster response, a crew facing a difficult destination may experience manageable stress if it has reliable weather data, alternate-airfield options, experienced ground support, and authority to delay. The same mission may become psychologically overwhelming when communications are poor and leadership signals that delay is unacceptable. This framework therefore links organizational resources directly to fatigue-related coping and supports relief systems that increase crew control, clarity, and access to support during high-demand missions.

The Shift Work Disorder framework clarifies why a nominal rest interval may not restore performance when duty schedules conflict with circadian biology. Clinical and organizational research shows that night work, rotating shifts, and irregular timing can generate insomnia and sleepiness even when personnel have time available for sleep (Tait et al., 2021; Wickwire et al., 2017; Wright et al., 2013). A relief crew assigned alternating day and night sorties may therefore accumulate fatigue despite apparently adequate time off between missions. If a crew member attempts to sleep during daylight in a noisy temporary camp, biological and environmental conditions may combine to reduce restorative sleep. This framework supports circadian-informed scheduling, stable duty windows when feasible, and improved sleep environments as operational controls rather than personal lifestyle preferences.

The NASA-TLX framework provides a practical mechanism for identifying mission profiles in which fatigue and workload may interact most dangerously. Hart and Staveland (1988) conceptualize workload as multidimensional, and Masi et al. (2023) demonstrate the value of combining subjective and objective indicators in aviation workload assessment. A humanitarian operator could use brief post-mission workload ratings to identify recurring patterns, such as exceptionally high temporal demand during evening evacuations from constrained airports. If those missions consistently produce high workload, planners can examine whether additional briefing time, improved ground coordination, augmented crew, or modified arrival procedures would reduce cognitive demand. Workload assessment thus converts fatigue management from a general concern into a measurable operational-learning process.

FRMS provides the organizational architecture for integrating schedule, sleep, workload, reporting, and performance data into fatigue decisions. Gander et al. (2011, 2017), Bourgeois-Bougrine (2020), and Thomas (2024) emphasize that fatigue risk management must extend beyond prescriptive limits and use evidence, feedback, and organizational learning. In humanitarian operations, FRMS should be mission-adaptive because risk can change quickly as the response evolves. For example, a schedule that is reasonable during daytime supply flights may become inadequate when the same crews transition to overnight medical evacuation. A dynamic FRMS can detect that shift by integrating sleep history, duty

accumulation, time of day, workload, and self-reported fatigue. The framework therefore offers a practical means of matching crew utilization to the changing physiological demands of the relief mission.

The Social Ecological Model broadens fatigue analysis beyond the individual by recognizing influences at interpersonal, organizational, community, and policy levels (Aubry et al., 2024; Groppe & Brock, 2022; Marques & Malagris, 2025). This perspective is particularly relevant to disaster response because crew recovery depends on factors such as family communication, team norms, temporary housing, organizational staffing, host-nation infrastructure, and regulatory coordination. For example, a pilot may practice excellent personal sleep hygiene yet fail to recover if lodging is noisy and mission alerts are continuously routed to personal devices. The model demonstrates why fatigue cannot be managed solely through individual discipline. Resilient humanitarian programs must align personal, team, organizational, and policy-level conditions so that the environment supports the recovery behavior it expects.

Health literacy provides the final element of the framework because fatigue science is operationally useful only when personnel can understand, apply, and question the information they receive. Nutbeam (2008), Nutbeam et al. (2018), Nutbeam and Lloyd (2021), and Sørensen et al. (2021) distinguish functional knowledge from the interactive and critical capacities required to use health information effectively. In relief operations, functional literacy includes understanding sleep debt and circadian timing; interactive literacy includes planning rest, caffeine, nutrition, and recovery; critical literacy includes recognizing when organizational practices are generating unacceptable fatigue risk. A crew member who can explain why a rapid switch from night duty to an early-morning sortie is physiologically hazardous is better equipped to participate in a risk discussion. Health literacy therefore strengthens both personal self-management and collective operational governance.

## Review Method and Analytical Strategy

This paper uses a focused integrative review to translate the established source corpus into the context of humanitarian and disaster-relief flight operations. The existing sources were grouped into seven analytical domains: fatigue and circadian physiology, workload and human performance, stress and coping, mental health and burnout, FRMS and performance indicators, social and organizational context, and health literacy. This structure was selected because the source base includes reviews, empirical studies, conceptual frameworks, and occupational-health research that cannot be meaningfully reduced to a single statistical effect. For example, a study of burnout and a paper on FRMS address different outcomes, yet both inform whether a relief organization can sustain crew capability during prolonged operational demand. The analytical strategy therefore emphasizes convergent mechanisms and practical applicability rather than numerical aggregation.

Evidence was interpreted conservatively to avoid implying that the cited studies directly examined humanitarian missions when many were conducted in other professional flight or high-risk occupational settings. The transfer logic focused on mechanisms that are not unique to a single operational sector, including sleep restriction, circadian misalignment, mental workload, stress appraisal, disclosure barriers, and burnout. Practical relief scenarios were then used to clarify how those mechanisms may manifest during disaster-response operations, but the scenarios are explanatory examples rather than empirical observations from the cited studies. For instance, evidence that circadian disruption impairs professional flight crews supports concern about overnight relief sorties, while it does not establish the prevalence of fatigue in a specific humanitarian organization. This distinction preserves methodological integrity while allowing the existing evidence to inform a specialized operational context.

## Synthesis of Findings

The first major finding is that humanitarian fatigue risk is dynamic and cannot be managed adequately through duty duration alone. FRMS research consistently emphasizes the interaction of prior sleep, circadian phase, workload, individual variability, and organizational conditions (Bourgeois-Bougrine, 2020; Gander et al., 2011; Gander et al., 2017). Relief operations magnify this interaction because mission demand can change faster than schedules can be redesigned. A crew may begin a deployment with daytime cargo flights and, within 24 hours, transition to repeated night evacuations because roads become inaccessible. If risk controls remain anchored to the original roster, the organization may miss the physiological consequences of the mission change. Humanitarian FRMS must therefore function as an adaptive decision system that is recalibrated whenever mission timing, workload, or recovery conditions materially change.

The second finding is that recovery quality matters as much as scheduled recovery duration. Shift-work and sleep-disorder research shows that circadian timing and sleep environment strongly affect whether time off produces restorative sleep (Tait et al., 2021; Wickwire et al., 2017; Wright et al., 2013). Humanitarian staging bases can undermine recovery through heat, noise, shared quarters, communications interruptions, and unpredictable standby expectations. For example, a crew released for rest may remain psychologically alert to a possible evacuation call and repeatedly check a mission device throughout the night. The formal rest period then overstates actual recovery. Relief organizations should therefore treat lodging standards, communication discipline, and protected off-duty periods as components of fatigue control rather than logistical conveniences.

The third finding is that workload and fatigue should be managed together because elevated task demand can consume the limited cognitive reserve of a tired crew. Workload research demonstrates the value of assessing mental, temporal, and effort demands rather than assuming that all flight hours are equivalent (Hart & Staveland, 1988; Masi et al., 2023). A two-hour relief sortie into a congested, partially functioning airport may be more fatiguing than a much longer routine flight conducted under stable conditions. For example, a crew delivering emergency shelter materials may spend much of the mission coordinating slot changes, revised payload limitations, and ground congestion while simultaneously monitoring weather and fuel. The operational implication is that scheduling models should incorporate mission complexity, not merely duration, when determining subsequent crew utilization.

The fourth finding is that organizational culture determines whether fatigue information becomes actionable. Research on mental health, stress, and fatigue reporting indicates that personnel may conceal concerns when disclosure is perceived as professionally costly or culturally unacceptable (Cahill et al., 2021; Silva et al., 2022). Humanitarian missions can amplify this tendency because declining a mission may feel inconsistent with the moral imperative to help affected populations. A strong fatigue culture reframes self-removal as preservation of mission capacity rather than withdrawal from responsibility. For example, a crew member who reports inadequate sleep before a medical evacuation should trigger a replacement process, not an informal test of commitment. Organizational legitimacy is therefore measured by whether crews can use fatigue protections during the moments when mission pressure is highest.

The fifth finding is that prolonged humanitarian deployments require mental-health and burnout safeguards in addition to immediate fatigue controls. Burnout and occupational-stress research show that persistent exhaustion can evolve into emotional detachment, reduced efficacy, anxiety, and depressive symptoms (Brezonakova, 2017; Cahill et al., 2021; Demerouti et al., 2019; Venus & grosse Holtforth, 2022). Disaster missions may intensify these pathways through repeated exposure to suffering, disrupted family contact, and

sustained operational uncertainty. For example, a crew may continue performing safely while becoming increasingly emotionally numb after repeated evacuation flights from a mass-casualty environment. If leadership evaluates only technical performance, early signs of burnout may be overlooked. Resilience programs should therefore include confidential counseling, peer support, structured decompression, and post-deployment recovery before personnel are returned to another high-tempo assignment.

**Practical and Actionable Recommendations**

1. Establish a mission-adaptive FRMS for disaster-response operations. Relief organizations should use FRMS as a real-time operational control rather than as a static compliance document. Research on fatigue-risk systems supports integrating prior sleep, circadian timing, duty history, self-reported fatigue, workload, and performance indicators into scheduling decisions (Bourgeois-Bougrine, 2020; Gander et al., 2011; Thomas, 2024). During a disaster response, the FRMS should be reviewed whenever mission tempo, operating hours, or staging conditions change materially. For example, if daytime cargo operations convert to overnight evacuation missions, risk thresholds and crew-rotation plans should be reassessed before the new schedule becomes routine. A dynamic FRMS protects mission continuity by identifying fatigue accumulation early enough to adjust staffing rather than waiting for performance deterioration.

2. Integrate fatigue risk into mission acceptance and dispatch decisions. Operational leaders should require a documented fatigue assessment for high-consequence missions, particularly when crews have accumulated sleep debt, are operating during the biological night, or face unusual mission complexity. Evidence from workload and circadian research demonstrates that mission risk is shaped by the interaction of task demand and physiological state (Masi et al., 2023; Venus, 2021). For example, an urgent medical flight to an austere destination may be operationally necessary, yet the safest choice may be to substitute a rested crew, add an augmented crew member, or delay briefly for recovery if conditions permit. Incorporating fatigue explicitly into mission acceptance prevents humanitarian urgency from becoming an unexamined exception to ordinary risk governance.

3. Protect circadian stability and recovery whenever operationally feasible. Scheduling teams should minimize rapid reversals between day and night duty, repeated predawn starts, and consecutive high-workload nights because shift-work research shows that circadian misalignment can impair sleep even when nominal rest time is available (Tait et al., 2021; Wickwire et al., 2017; Wright et al., 2013). Relief planners can create dedicated day and night crews during sustained operations instead of rotating the same personnel across both periods. For example, a response hub supporting round-the-clock medical flights can preserve two stable duty groups and rotate personnel only after deliberate recovery. Circadian stability converts crew rest from a reactive scheduling problem into a planned component of sustained relief capacity.

4. Establish minimum recovery standards for austere staging locations. Relief organizations should assess whether crew accommodations are capable of supporting restorative sleep, not merely whether a bed is technically available. Sleep and shift-work evidence demonstrates that noise, timing, interruption, and environmental conditions affect recovery quality (Tait et al., 2021; Venus & grosse Holtforth, 2021). Practical standards should address noise control, temperature, darkness, secure sleeping space, transportation time, and communication interruptions. For example, if crews are housed adjacent to a 24-hour cargo ramp, portable sound attenuation, alternate lodging, or protected quiet periods may be necessary. Recovery infrastructure should be treated as mission-support equipment because inadequate rest conditions degrade the human performance on which subsequent sorties depend.

5. Use workload assessment to identify fatigue-sensitive mission profiles. Organizations should employ brief tools such as NASA-TLX-based ratings and operational debriefs to identify missions that consistently generate exceptional mental, temporal, or frustration demands (Hart & Staveland, 1988; Masi et al., 2023). The objective is not to burden crews with extensive surveys but to discover patterns that scheduling data alone cannot reveal. For example, a short relief sector into a congested regional airport may repeatedly produce greater workload than a longer transport mission because of communications congestion and rapid replanning. If the pattern is visible, planners can increase briefing time, adjust crew composition, or reduce subsequent tasking. Workload data therefore provide a practical bridge between subjective crew experience and operational design.

6. Create a protected fatigue and fitness-for-duty reporting mechanism. Flight personnel should be able to declare fatigue without punitive consequences or informal reputational damage. Research on mental-health disclosure and occupational stress shows that trust strongly influences whether personnel report conditions that could affect performance (Cahill et al., 2021; Silva et al., 2022). Relief organizations should pair the reporting policy with a credible replacement process so that disclosure does not simply transfer impossible pressure to the crew. For example, a pilot who slept poorly because of repeated emergency alerts should be able to report unfitness before an early departure and be replaced without being characterized as insufficiently committed to the mission. Protected reporting converts hidden fatigue into manageable operational information.

7. Integrate confidential mental-health support with fatigue management. Organizations should provide confidential counseling, peer-support resources, and post-deployment screening because fatigue, sleep disruption, stress, anxiety, and burnout can reinforce one another (Cahill et al., 2021; Cuadrado et al., 2025; Venus & grosse Holtforth, 2022). The support system should be accessible during deployment and after return, with clear separation between clinical assistance and routine supervisory judgment whenever possible. For example, a crew member affected by repeated exposure to traumatic evacuation scenes should be able to seek help before insomnia and emotional exhaustion compromise future readiness. Linking mental health to fatigue management acknowledges that operational resilience depends on psychological recovery as well as sleep opportunity.

8. Develop humanitarian aviation health-literacy training. Relief crews and mission planners should understand circadian biology, sleep debt, workload, strategic rest, caffeine timing, burnout indicators, and the limits of self-assessment. Health-literacy research emphasizes that knowledge becomes protective when people can apply and critically evaluate it in their own environment (Nutbeam, 2008; Nutbeam & Lloyd, 2021; Sørensen et al., 2021). Training should use relief-specific scenarios rather than generic sleep advice. For example, personnel can practice evaluating whether a short-notice night mission after several early starts represents a manageable risk or requires a crew substitution. Operationally relevant literacy gives personnel a shared vocabulary for discussing fatigue before performance becomes impaired.

9. Use wearable and digital fatigue data cautiously and transparently. Objective information can support FRMS, but technology should augment rather than replace professional judgment. Fatigue-risk research encourages data-driven monitoring while also warning that metrics can create false confidence if organizations treat a device score as a complete representation of readiness (Bourgeois-Bougrine, 2020; Gander et al., 2017; Thomas, 2024). A wearable that indicates adequate sleep does not account fully for emotional strain, extreme workload, or the quality of the coming mission. Relief organizations should therefore establish clear governance for consent, privacy, interpretation, and decision use. Digital tools are most defensible when they provide one additional source of evidence within a broader fatigue assessment.

10. Institutionalize post-surge recovery and organizational learning. Disaster-response programs should plan for decompression, recovery, and fatigue review after the acute phase rather than immediately returning crews to ordinary tasking. Burnout and stress research indicates that cumulative strain can persist after operational demand has declined (Brezonakova, 2017; Demerouti et al., 2019; Overall, 2016). A structured post-response process can review duty patterns, sleep conditions, fatigue reports, workload peaks, and near-miss information while also protecting personnel from immediate redeployment. For example, after a two-week hurricane airbridge, leaders can provide recovery days and conduct a fatigue-focused debrief to identify which staffing and lodging practices were sustainable. This process transforms one response into institutional knowledge that improves readiness for the next emergency.

## Policy Implications

Policy should recognize fatigue as a dynamic operational hazard in humanitarian aviation rather than relying solely on fixed flight-time limitations. FRMS research demonstrates the value of continuous assessment, organizational feedback, and performance indicators that respond to changing conditions (Gander et al., 2011; Thomas, 2024). Relief missions create a strong case for such flexibility because an emergency can alter operating hours, destination risk, workload, and crew-rest quality within a single day. Policy frameworks should therefore require organizations conducting sustained disaster-response flights to document how fatigue risk is assessed, how crews can self-declare unfitness, how replacement capacity is maintained, and how fatigue data are reviewed during and after the response. This approach preserves regulatory accountability while allowing fatigue controls to evolve with the mission.

## Public Health Implications

The public-health implications of relief-crew fatigue extend beyond immediate operational safety because repeated disaster deployments can affect long-term sleep, cardiovascular health, psychological wellbeing, and workforce sustainability. Shift-work and mental-health research links chronic circadian disruption and stress with insomnia, excessive sleepiness, anxiety, depressive symptoms, and broader health burdens (Cahill et al., 2021; Venus & grosse Holtforth, 2022; Wickwire et al., 2017). Humanitarian organizations should therefore integrate fatigue screening into occupational-health surveillance and provide follow-up after intense deployments. For example, a crew member who develops persistent sleep disturbance after several weeks of night relief flights should have access to evaluation before the condition becomes a chronic impairment. Treating fatigue as a public-health concern strengthens both individual care and the long-term availability of skilled response personnel.

## Organizational Implications

Humanitarian organizations should regard crew recovery as operational infrastructure because sustainable mission capacity depends on the continued cognitive and physiological readiness of experienced personnel. Research on fatigue, burnout, and organizational stress shows that leadership practices, resource availability, and work design can either buffer or intensify human-performance risk (Demerouti et al., 2019; Gander et al., 2011; Overall, 2016). This perspective changes the meaning of staffing reserves, rest accommodations, replacement crews, and protected reporting: they are not administrative overhead, but safeguards against mission interruption. For example, maintaining an additional rested crew at a regional relief hub may appear inefficient during a quiet shift, yet it provides immediate capacity when an evacuation mission emerges after the primary crew reaches a fatigue threshold. Organizational resilience therefore requires preserving human capacity before the emergency makes that capacity visibly scarce.

## Crew and Leadership Implications

Flight crews require both personal fatigue-management competence and organizational permission to act on that competence. Health-literacy research shows that individuals need not only basic knowledge but also the ability to apply information and challenge conditions that threaten health (Nutbeam et al., 2018; Nutbeam & Lloyd, 2021). Relief crews should understand their own warning signs, sleep needs, circadian vulnerability, and limits of compensatory strategies such as caffeine. However, individual responsibility is insufficient if leadership continues to reward excessive endurance. A crew member who recognizes dangerous fatigue must have a practical route to decline or modify a mission without stigma. Professional self-management and supportive leadership are therefore mutually dependent components of a mature humanitarian fatigue culture.

## Limitations and Future Research

The principal limitation of this review is contextual transferability because the available empirical literature largely examines professional flight operations, military aircrew, maritime pilots, or general occupational fatigue rather than humanitarian relief crews specifically. The underlying mechanisms of circadian disruption, workload, stress, fatigue reporting, and burnout are relevant to disaster-response aviation, but their prevalence and relative importance in particular humanitarian organizations cannot be inferred from this source base alone. The practical scenarios in this paper are therefore explanatory applications of established mechanisms rather than direct observations from relief missions. Future research should examine fatigue longitudinally during actual disaster-response deployments, compare austere and well-supported staging environments, and evaluate which mission-adaptive FRMS practices most effectively preserve crew readiness. Such work would strengthen the empirical foundation for fatigue policy in humanitarian aviation while retaining the systems perspective developed here.

## Conclusion

Fatigue in humanitarian and disaster-relief flight operations is a systems-level threat to safety, occupational health, and mission continuity. The established literature demonstrates that circadian disruption, insufficient recovery, high cognitive workload, psychological stress, and weak reporting climates can interact to degrade professional performance and wellbeing (Gander et al., 2011; Masi et al., 2023; Venus & grosse Holtforth, 2022). Disaster response can intensify these mechanisms because crews may face repeated short-notice missions, austere living conditions, changing priorities, emotionally consequential tasks, and limited staffing reserves. A crew may be technically qualified and deeply committed to the relief mission while still lacking the physiological capacity for another complex sortie. Recognizing that distinction is essential to responsible humanitarian aviation. The most defensible approach combines mission-adaptive FRMS, circadian-informed scheduling, workload assessment, protected fatigue reporting, restorative lodging, mental-health support, health literacy, and post-surge recovery. When these controls are embedded into planning and leadership practice, fatigue management becomes a means of preserving the very mission capacity that humanitarian emergencies demand.

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