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Who Should Sit at the Exit Row? A Human Factors Perspective

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Abstract

Emergency exit row seating allocation represents a critical and underexamined safety decision in commercial aviation. Whilst regulatory frameworks mandate passenger capability assessments, limited empirical research exists on systematic methodologies for evaluating passenger suitability profiles. This study addresses this gap by developing a comprehensive framework for assessing optimal and contraindicated passenger characteristics for emergency exit responsibilities. We employed a triangulated Human Factors approach integrating Work Domain Analysis (WDA), Hierarchical Task Analysis (HTA), and Event Analysis of Systemic Teamwork (EAST). The WDA framework mapped the functional requirements of emergency exit operation within the broader cabin evacuation system, identifying critical physical, cognitive, and temporal constraints. HTA decomposed exit operation tasks into constituent actions, revealing seventeen discrete task elements requiring specific competencies. EAST methodology captured the distributed cognition, and coordination demands between passengers, cabin crew, and the operational environment during emergency scenarios. Analysis identified six primary selection criteria: physical capability (strength, mobility, reach), cognitive capacity (stress response, decision-making under pressure), communication ability (language proficiency, assertiveness), absence of impairments (visual, auditory, mobility limitations), willingness to assist, and social responsibility factors. Optimal passenger profiles demonstrate high scores across all criteria, whilst contraindicated profiles include those with mobility impairments, cognitive limitations, unwillingness to assist, or care responsibilities for dependents. The research contributes a theoretically grounded, methodologically rigorous framework applicable to airline operational procedures and regulatory policy development. By explicating the systemic interdependencies between passenger capabilities and emergency task demands, this work advances organizational safety culture through evidence-based seat allocation protocols.

Keywords: aviation safety, emergency evacuation, passenger selection, human factors, work domain analysis, task analysis

1. Introduction

Empirical evidence consistently demonstrates that passengers designated to emergency exit rows exhibit significant performance variability when required to operate exit mechanisms under stress conditions. Controlled evacuation trials conducted for the FAA Civil Aeromedical Institute documented hesitation, incorrect lever operation, and difficulty managing door weight among designated exit row passengers — with crew intervention required to compensate for performance failures even under controlled non-emergency conditions (Muir and Cobbett, 1995). Despite this documented evidence, a fundamental contradiction persists in operational aviation: regulatory frameworks across jurisdictions establish capability criteria for exit row occupancy, yet implementation remains inconsistent, operationally superficial, and systematically overridden by commercial prioritization logic. This study investigates the systemic constraints preventing effective implementation of known functional selection criteria, addressing the question: What are the structural barriers that explain why technically known optimal criteria for emergency exit seat passenger selection are not effectively implemented in operational practice?

Emergency evacuation in commercial aircraft represents one of the most critical scenarios in civil aviation, where passenger and crew response capacity can determine the difference between life and death. International regulations from the International Civil Aviation Organization (ICAO) and national authorities such as Brazil's Agência Nacional de Aviação Civil (ANAC) establish that commercial aircraft must evacuate all passengers within a maximum of 90 seconds, using only half of available exits (ICAO Annex 6, 2018).

Historical evidence illustrates the consequences when evacuation system components fail to perform as required near exit rows. The British Airtours Flight 28M accident at Manchester International Airport on 22 August 1985, involving a Boeing 737-236 engine fire during takeoff, resulted in 55 fatalities. The UK Air Accidents Investigation Branch investigation documented that passenger behaviour near exits — including obstruction of egress pathways and failure to operate exits efficiently — was among the contributing factors to casualties (AAIB, 1988). This accident directly motivated significant regulatory reform in the United Kingdom and informed subsequent ICAO standards, demonstrating that inadequate passenger performance at exit rows constitutes a documentable causal pathway, not merely a theoretical concern.

The Air France Flight 358 accident at Toronto Pearson International Airport on 2 August 2005, in which an Airbus A340-313 overran the runway and caught fire with 309 occupants aboard, further underscores the importance of passenger responsiveness at exit positions during emergency evacuations (TSB Canada, 2007).

The case of Japan Airlines Flight 516 (JAL516), which occurred at Haneda Airport on January 2, 2024, provides a counterpoint: a documented success case in which all pre-established crew protocols were rigorously followed both in pre-flight preparation and in the critical moments of the incident. An Airbus A350-900 successfully evacuated 379 occupants in approximately 18 minutes under extreme conditions — massive fire, compromised fuselage, and multiple unusable exits (Japan Transport Safety Board, 2024). The JAL516 case is cited not as evidence of a passenger selection failure, but as an illustration of what optimal system performance looks like when crew training, organizational culture, and redundant communication systems function effectively, and to demonstrate that real-world evacuations frequently face more restrictive conditions than regulatory certification scenarios anticipate.

This research employs an evolutionary methodological approach, beginning with task analysis and distributed cognition tools (HTA and EAST) to identify ideal passenger requirements, subsequently employing Cognitive Work Analysis (CWA) to understand the systemic constraints preventing effective implementation of these requirements. The research is structured across three progressive phases, each informing and reorienting the subsequent investigation: Phase 1 (Exploratory) identified functional requirements through HTA and EAST; Phase 2 (Analytical) discovered contradictions through international comparative analysis; Phase 3 (Systemic) mapped constraints through CWA. Accordingly, the research objectives are threefold: (1) identify functional and cognitive requirements for effective emergency exit operation through HTA and EAST (Phase 1); (2) analyze contradictions between ideal requirements and current regulatory and commercial practices through international comparative analysis (Phase 2); (3) map systemic constraints explaining these contradictions through CWA and propose evidence-based regulatory reforms (Phase 3).

2. Theoretical Foundation and Methodological Evolution

2.1. Identifying requirements through HTA and EAST

Hierarchical Task Analysis (HTA), developed by Annett and Duncan (1967), constitutes a consolidated method for decomposing complex tasks into hierarchically organized objectives, operations, and plans. In the emergency evacuation context, HTA explicates the discrete elements composing the "operate emergency exit" task, revealing required specific competencies without prescribing normative procedures. Unlike approaches that describe how tasks should ideally be performed, HTA focuses on describing task logical structure independently of executors, subsequently enabling identification of necessary human capabilities.

Event Analysis of Systemic Teamwork (EAST), developed by Stanton et al. (2013), analyzes distributed cognition in complex sociotechnical systems, mapping how information and responsibilities are shared among human, technological, and organizational agents. EAST comprises three integrated networks: Task Network (decision-action sequences mapping workflows), Social Network (communication and coordination channels between agents), and Knowledge Network (information and expertise distribution). In emergency evacuation contexts, EAST reveals that system performance depends not on isolated individual actions but on effective coordination among multiple agents (pilot, flight attendants, passengers) mediated by technological artifacts (PA system, alarms, signaling) and organizational protocols (procedures, training).

2.2. Discovering the regulatory paradox through comparative analysis

International comparative analysis of emergency exit seat regulations revealed significant variations despite shared ICAO foundation standards. Brazil's RBAC 121 (ANAC, 2022) establishes implicit 60-year maximum age restrictions and vague physical capability criteria ("capacity to perform functions"). The United States FAA 14 CFR § 121.585 (FAA, 2023) establishes 15-year minimum age, no maximum age specification, requires "sufficient mobility, strength, dexterity," and mandates individual briefing. Japan's Civil Aviation Bureau (JCAB/MLIT) establishes 15-60 year age range, BMI 18.5-30 criterion, explicitly lists vulnerable categories (pregnant women, visual/auditory impairments, reduced mobility), and mandates both verbal and written briefing (MLIT/JCAB, 2024; JAL/JCAB, 2024).

This comparative analysis, combined with examination of the JAL516 successful evacuation case, revealed a critical paradox: despite apparent technical knowledge of optimal passenger characteristics emerging from HTA and EAST analyses, regulatory implementations varied dramatically across jurisdictions, and commercial practices frequently contradicted safety principles. This paradox demanded methodological reorientation from identifying ideal requirements to understanding why these requirements fail implementation.

2.3. Understanding systemic constraints through CWA

The Cognitive Work Analysis framework, established by Jenkins, Stanton, Salmon, and Walker (2009), represents a significant evolution in complex systems analysis methodologies. Unlike normative approaches (how work should be done) or descriptive approaches (how work is done), CWA is formative, identifying viable possibilities within system constraints. As Naikar and Elix (2016) clarify, CWA is particularly valuable when systems must function under unanticipated conditions — precisely the case of emergency evacuations, where each event presents unique constraint configurations.

CWA comprises five phases: Work Domain Analysis (WDA) identifies domain-imposed constraints; Control Task Analysis examines required control activities; Strategies Analysis maps available strategies; Social Organization Analysis examines responsibility distribution; Worker Competencies Analysis identifies necessary cognitive competencies. This research primarily employs WDA to understand structural constraints preventing implementation of known optimal practices, analyzing constraints across five abstraction levels: Functional Purpose (system objectives), Abstract Function (fundamental values and priorities), Generalized Function (general processes), Physical Function (equipment and procedures), and Physical Form (specific actors and objects).

3. Methodology: An Evolutionary Three-Phase Approach

This research adopts a qualitative exploratory approach with evolutionary methodological design, where each phase is informed and reoriented subsequent investigation. Phase 1 (Exploratory) identified functional requirements through HTA and EAST; Phase 2 (Analytical) discovered contradictions through international comparative analysis; Phase 3 (Systemic) mapped constraints through CWA.

3.1. Participants and data collection

Semi-structured interviews were conducted with four Brazilian aviation professionals selected by convenience and relevant expertise: Participant A (flight attendant and emergency evacuation instructor with 30 years' experience); Participant B (commercial pilot with 15 years domestic and international experience); Participant C (flight attendant with 12 years' experience at major airline); Participant D (Brazilian Air Force pilot with search and rescue operations experience). Interviews were conducted remotely via Google Meet between September and October 2025, averaging 60 minutes duration, addressing experiences with emergencies and evacuation simulations, observations about passenger adequacy in emergency seats, perceptions about regulatory-commercial contradictions, and specific reallocation cases.

Documentary analysis encompassed regulatory documents (Brazil RBAC 121, 135, 67; USA FAA 14 CFR § 121.585; Japan Civil Aviation Bureau operational regulations), JAL516 preliminary investigation report (Japan Transport Safety Board, 2024), and airline standard operational procedures from Brazilian and international carriers.

It is acknowledged that the present sample is circumscribed to Brazilian aviation professionals, comprising flight attendants and commercial and military pilots. The absence of perspectives from external specialists — including ergonomics researchers without operational aviation affiliation, airport operations professionals, regulatory authority representatives, and frequent travellers — constitutes a limitation of this exploratory phase. The current study is appropriately framed as an exploratory, hypothesis-generating investigation: CWA methodology, particularly Work Domain Analysis, is specifically designed for this formative purpose, and the selected sample is adequate for mapping systemic constraints as perceived by operational actors within the domain. Inclusion of non-aviation professional perspectives and participant validation from regulatory authorities constitute priorities for the subsequent validation phase of this research.

3.2. Analytical tools application across three phases

Phase 1 employed HTA to decompose the "operate emergency exit by passenger" task into hierarchical levels, specifying execution plans, decision conditions, and identifying required competencies (physical, cognitive, communicational). EAST constructed Task Networks (decision-action sequences during evacuation), Social Networks (communication channels and coordination), and Knowledge Networks (expertise and information distribution). Integration of HTA and EAST findings enabled synthesis of primary passenger selection criteria.

Phase 2 systematically compared three jurisdictions (Brazil, USA, Japan) regarding minimum and maximum age criteria, physical capability requirements, language proficiency specifications, dependent responsibility restrictions, vulnerable category definitions, belt extender policies, and individual briefing mandates. Analysis examined the JAL516 case to understand success factors in evacuations under extreme conditions.

Phase 3 applied Work Domain Analysis (WDA) to construct the Abstraction-Decomposition Space across five levels and analyze means-ends relationships revealing systemic dependencies. Qualitative interview data underwent thematic analysis following Braun and Clarke (2006): familiarization, initial coding, theme identification, theme review, theme definition, and report production. Identified systemic constraints were organized according to WDA abstraction levels, enabling visualization of inter-level interactions producing observed contradictions.

4. Results

4.1. Requirements identified through HTA and EAST

4.1.1. Hierarchical task decomposition

HTA decomposed the "operate emergency exit by passenger" task into 17 subtasks organized across two hierarchical levels. Level 1 comprises the main objective: open and operate emergency exit in minimum time, ensuring safe evacuation flow. Level 2 encompasses seven main subtasks: (1) receive and understand pre-flight safety briefing; (2) maintain situational awareness during flight (monitoring crew activity, perceiving environmental changes); (3) recognize evacuation command (alarm, PA announcement, verbal flight attendant instruction); (4) evaluate external conditions through window (presence of fire, fuel, terrain/water characteristics, obstacles); (5) make opening/non-opening decision based on evaluation; (6) execute door opening sequence [critical task]; (7) coordinate evacuation flow and assist other passengers [critical task].

Critical subtask 6 (door opening) decomposes into eight operations requiring specific competencies: unfasten seatbelt; locate and identify opening mechanisms; read and understand pictographic door instructions; remove safety protections/locks; apply traction force (150-250N) to pull lever (per Type Certificate Data Sheets for Boeing and Airbus aircraft, as specified in FAR-25/CS-25 certification requirements); maintain door control during movement (door weight 20-45kg, as specified in aircraft technical documentation); adequately position door or discard outside; verify slide inflation if applicable (deployment time 5-10 seconds per FAA/ICAO certification standards). Analysis identified four critical failure points: briefing comprehension failure compromises all subsequent steps; incorrect external condition evaluation may result in opening toward fire/fuel; physical incapability causes 30-60 second delays until alternative action (estimated from interview data and evacuation simulation studies); panic or baggage blocking prevents effective evacuation flow.

4.1.2. Distributed cognition analysis through EAST

EAST application revealed the highly distributed nature of the evacuation system. Task Network identified the critical sequence: Detection (sensors + crew) → Evaluation (commander + cabin chief) → Evacuation Decision (commander) → Communication (PA + interphone + alarms) → Exit Opening (flight attendants + assisting passengers) → Evacuation Flow Coordination (flight attendants + assisting passengers) → Final Verification (commander). Temporal dependencies include: decision time 15-45 seconds (variable by severity, based on interview data from Participants A and D); door opening by trained crew 5-8 seconds versus untrained passenger estimated 15-30 seconds (based on professional observations from Participants A and D); slide inflation 5-10 seconds (per FAA/ICAO certification requirements for evacuation systems, as specified in FAR-25/CS-25).

Social Network analysis revealed Commander as central hub (final decision, maximum authority), Cabin Chief as secondary hub (crew coordination, commander communication), Flight

Attendants as intermediate nodes (execution, flow coordination, assistance), and Emergency Seat Passengers as critical peripheral nodes (exit opening when crew unavailable or overloaded). Communication channels operate hierarchically: primary PA system (commander → all), secondary interphone (commander ↔ cabin chief ↔ attendants), tertiary direct verbal communication (command voice), quaternary visual signaling (gestures, emergency lights).

Knowledge Network analysis demonstrated asymmetric distribution: Commander possesses aircraft general status knowledge and emergency nature; Flight Attendants hold specific door operational procedures; General Passengers retain basic briefing instructions (use mask, brace position, exit locations); Emergency Seat Passengers require specific opening procedures, external condition evaluation capability, and flow coordination skills.

4.1.3. Synthesis: Six primary selection criteria

HTA and EAST integration enabled synthesis of six primary criteria for optimal emergency seat passenger selection: (1) Physical Capability — muscular strength ≥200N (equivalent to lifting 20kg single-armed, derived from door operation force requirements of 150-250N specified in FAR-25/CS-25 Type Certificate Data Sheets), rapid mobility capacity, overhead reach capability, absence of limitations excluding belt extender use; (2) Cognitive Capacity — decision making under pressure, stress response capacity, complex instruction following, cognitive flexibility for unanticipated conditions; (3) Communication Ability — language proficiency (flight language comprehension), assertiveness, situational leadership capacity; (4) Absence of Impairments — visual capability for instruction reading and environment evaluation, auditory capability for commands and alarms, mobility for rapid movement; (5) Willingness to Assist — voluntariness accepting additional responsibility, commitment maintaining attention during flight, altruism prioritizing collective safety; (6) Social Responsibility Factors — absence of dependent responsibility during flight (not accompanying young children, elderly, or persons with disabilities requiring assistance), total task availability.

4.2. The revealed regulatory paradox

Comparative analysis revealed significant divergences among three jurisdictions with excellent aviation safety standards. Japan adopts the most rigorous and measurable criteria through BMI objectivity (eliminating subjectivity inherent in terms like "sufficient mobility") and explicitly defined vulnerable categories. The United States prioritizes process over prescriptive criteria through mandatory individual briefing but employs less specific selection criteria than Japan. Brazil presents the vaguest criteria, with terms like "capacity to perform functions" lacking operational definition and exhibits a flagrant contradiction between 60-year emergency seat limit versus permitting pilots to fly until 65 years with valid aeronautical medical certification.

Regarding age criteria, Brazil implicitly restricts to 60 years maximum (though not explicitly in regulation text, as per RBAC 121 interpretation), USA establishes 15-year minimum with no maximum specification (FAA 14 CFR § 121.585), and Japan explicitly defines 15-60 year range (MLIT/JCAB, 2024). For physical capability, Brazil requires vague "capacity to perform functions" (RBAC 121), USA requires "sufficient mobility, strength, dexterity" (14 CFR § 121.585), while Japan employs objective BMI 18.5-30 criterion with strength testing (MLIT/JCAB, 2024). Language requirements show Brazil mandates Portuguese comprehension, USA requires English or flight language, and Japan requires Japanese or English. All three jurisdictions prohibit passengers with dependent responsibilities. Regarding vulnerable categories, Brazil and USA do not provide detailed lists, while Japan explicitly enumerates pregnant women, visual/auditory impairments, and reduced mobility (MLIT/JCAB, 2024). None of the three jurisdictions explicitly prohibit seatbelt extender use in emergency seats. For individual briefing, Brazil does not mandate it, USA requires mandatory verbal briefing (14 CFR § 121.585(b)), and Japan mandates both verbal and written briefing (JAL/JCAB, 2024).

The JAL516 accident provides insights into successful evacuation factors despite extreme conditions. Initial unfavorable conditions included: collision during landing (17:47 local time), massive immediate fire engulfing fuselage, compromised structural integrity, inoperative PA system due to fire damage, only 3 of 8 exits usable (L1, R1, L4), and 379 occupants requiring evacuation (367 passengers, 12 crew). Results demonstrated: complete 18-minute evacuation, zero fatalities among A350 occupants (5 fatalities in Coast Guard aircraft), complete passenger instruction compliance, and zero hand luggage carried during evacuation.

Success factors identified include: robust crew training (Japanese crew undergoes evacuation training every 6 months versus 12 months in many countries), obedience and discipline culture facilitating rapid compliance, redundant communication systems (crew used megaphones and verbal communication when PA failed), crew initiative (L4 flight attendant made autonomous opening decision without command contact), and complete verification (commander personally traversed entire cabin before final evacuation). However, Japan Transport Safety Board (2024) preliminary report analysis reveals no evidence that emergency seat passengers were specially selected for superior capabilities. Successful evacuation resulted primarily from intensive crew training, favorable organizational and social culture, system redundancy, and individual flight attendant proficiency. This finding crystallizes the regulatory paradox: if optimal passenger criteria are technically known (as HTA and EAST revealed), why are they not effectively implemented even in jurisdictions with rigorous regulations like Japan?

	Brazil	Japan	USA
Age	15-60 years [MLIT/JCAB, 2024]	15-60 years [MLIT/JCAB, 2024]	≥15 years (no maximum)
Physical	"Capacity to perform"	BMI 18.5-30, strength test [MLIT/JCAB, 2024]	"Sufficient mobility, strength, dexterity"
Briefing	Not mandatory	Mandatory (verbal + written) [JAL/JCAB, 2024]	Mandatory (verbal only)
Vulnerable categories	Not detailed	Explicit list (pregnant, impaired) [MLIT/JCAB, 2024]	Not detailed
Belt extenders	Not prohibited	Discouraged	Not prohibited

Table 1. Comparative regulatory criteria: Brazil, Japan, and USA

4.3. Systemic constraints explaining the paradox through CWA

Work Domain Analysis application revealed that observed deficiencies derive not from isolated failures but from inter-related systemic constraints creating an environment where inefficient evacuations become structurally predictable. Six systemic constraints were identified operating across multiple WDA abstraction levels.

Systemic Constraint 1: Age contradictions in regulations. A fundamental contradiction emerges between aeronautical medical certification regulations and emergency seat restriction regulations. Brazil's RBAC 67 certifies the physical and cognitive capability of 60-65 year pilots for commanding aircraft with 200+ passengers through rigorous semi-annual medical examinations, while RBAC 121 prohibits these certified professionals from occupying emergency seats based solely on age. Reporting an episode involving a third party observed in operation, Participant B — a commercial pilot with 15 years of domestic and international experience — described the following case: "It is an absurd incoherence. A 64-year-old pilot, passing rigorous semi-annual medical examinations including cardiac stress tests, neurological evaluations, vision and hearing tests to command an aircraft with 200 passengers, cannot sit in an emergency seat? But an untrained 25-year-old smoker, sedentary, with no verification, can?" This second-hand field narrative constitutes evidence of how active operational professionals perceive regulatory incoherence when observed in practice — not a self-interested position, but an observation about systemic inconsistency encountered with third parties. Participant A reported a structurally similar case: "I have had to remove retired commanders, 65, 68 years old, who were travelling with us as passengers and sat in emergency seats. They know the aircraft better than any passenger, have updated emergency training... but the rule says they cannot be there because of age."

WDA analysis shows this affects the Functional Purpose level (preserve lives by maximizing operational capabilities) and Abstract Function level (age criterion purportedly ensuring physical capability for emergency tasks). The contradiction reveals regulatory criteria based on simplistic heuristics (age as proxy for capability) rather than functional competence evaluation. An aviation professional certified competent at 64 years for aircraft command is deemed incompetent for emergency door opening at the same age, exposing the conceptual incoherence of age-based restrictions divorced from functional assessment.

Systemic Constraint 2: Commercial prioritization over safety. Interviews revealed commercial interests frequently override safety considerations in emergency seat allocation. The following testimonials constitute phenomenological evidence of how operational professionals perceive and enact regulatory compliance in operational practice — not normative claims about passenger groups, but field data on how the absence of positive criteria manifests in real allocation decisions. Participant C (flight attendant, 12 years experience) stated: "Emergency exit seats are sold as 'premium' because they have more legroom. The sales system prioritizes who pays more or has more mileage, not who is more capable of helping in an emergency. I have seen clearly inadequate people in these seats simply because they bought the upgrade." This testimonial evidences a Social Organization-level constraint in the CWA Abstraction-Decomposition Space: the organizational incentive structure systematically favors commercial revenue over safety capability assessment. Participant B reported: "I have seen obese executives, with evident breathing difficulty walking down the aisle, clearly incapable of moving quickly, seated in emergency exits because they bought premium seats or have executive status. And we cannot do anything because they paid for that seat." This observation does not represent a normative claim about passenger groups; it documents a structural incompatibility between market-driven seat allocation logic and functional safety criteria — precisely the type of Physical Function-level constraint that WDA is designed to make visible. Documented cases include: seat exchanges post-boarding without crew notification (father occupying emergency seat exchanges with mother holding lap infant after boarding completion); online sales systems not blocking purchases by passengers with contraindicated profiles; first class or executive class passengers receiving automatic priority for emergency seat upgrades based on loyalty status rather than capability; passengers explicitly declaring inability to assist during online check-in yet system permits emergency seat purchase with payment. WDA analysis affecting the Social Organization level reveals airlines monetizing emergency seats as commercial product, creating structural incompatibility between market logic (maximize revenue per seat) and safety logic (maximize emergency response capabilities).

Systemic Constraint 3: Absence of positive selection criteria. Current regulations base almost exclusively on negative criteria (defining who cannot occupy emergency seats) rather than positive criteria identifying who would be ideal candidates for these positions. Regulatory analysis demonstrates this pattern consistently: Brazil RBAC 121 provides an extensive list of passengers who are not permitted to occupy emergency exit seats but does not establish positive criteria indicating which passengers should be preferentially allocated; USA FAA 14 CFR § 121.585 lists 12 specific exclusion conditions but does not establish positive prioritization criteria for selecting among qualified candidates; Japan Civil Aviation Bureau provides the most detailed list of excluded vulnerable categories but does not establish a capability-based prioritization system for emergency seat assignment.

Participant C articulated the operational consequence: "We can only remove who clearly should not be there — someone with crutches, someone with a baby. But we have no authorization to say 'this passenger here, who is a firefighter, should be in this seat instead of that businessman.' We work by exclusion, not by selection." In the absence of formally codified positive selection criteria, operational screening operates by intuitive perception — a systemic failure point that CWA analysis identifies as structurally predictable rather than exceptional. The practical consequence is that emergency seat allocation operates by residual exclusion (who remains after removing inadequate passengers) rather than optimal selection (actively choosing best candidates).

Three additional constraints complete the systemic picture. Constraint 4 (Seatbelt Extender Complications): None of the analyzed regulations explicitly prohibit seatbelt extender use in emergency seats, despite HTA analysis demonstrating that door operation requires rapid 1-2 metre movement and overhead reach. Constraint 5 (Screening Process Deficiencies): Multiple sequential failure points exist without redundant verification mechanisms across the full passenger journey from online purchase through post-boarding. Constraint 6 (Inadequate Safety Briefings): Briefings effectively transfer declarative knowledge but not procedural knowledge of how to execute exit operations under time pressure, stress, and potential panic. General passengers never physically practice door opening mechanisms, whereas flight attendants practice regularly in full-scale simulators, creating enormous competence asymmetry.

5. Discussion: From Technical Requirements to Systemic Barriers

5.1. Methodological contribution: Evolutionary research integration

This study demonstrates the value of evolutionary methodological approach where distinct analytical tools are sequentially employed as research progressively reveals deeper complexity layers. Phase 1 (HTA + EAST) successfully revealed WHAT is functionally necessary: specific functional, cognitive, and organizational requirements for effective emergency exit operation, producing 17 discrete task elements, 6 primary selection criteria, and well-defined optimal versus contraindicated passenger profiles. Phase 2 (International Comparative Analysis) unexpectedly revealed THE PARADOX: despite apparent technical knowledge of optimal requirements, regulatory implementations diverge dramatically across jurisdictions, and commercial practices systematically contradict safety principles. Phase 3 (CWA/WDA) ultimately revealed WHY the paradox exists: systemic constraints operating at multiple abstraction levels create an environment where optimal solutions cannot be implemented without fundamental structural changes.

This methodological integration demonstrates how Human Factors analytical tools can be strategically combined in evolutionary research design where each phase informs and potentially reorients subsequent investigation direction. Traditional research might have concluded after Phase 1 with identification of optimal criteria. However, the paradox revealed in Phase 2 demanded theoretical reorientation, motivating adoption of CWA framework specifically designed for analyzing why known optimal solutions fail implementation. As Naikar and Elix (2016) argue, CWA is particularly valuable when systems must function under unanticipated conditions; emergency evacuation personifies precisely this system type.

5.2. From technical to systemic: Required paradigm shift

Analysis revealed that current failures in emergency exit seat passenger selection derive not from technical knowledge lack (HTA clearly demonstrated functional requirements and necessary competencies) nor from methodological absence (EAST comprehensively mapped critical distributed cognition dependencies), but rather from structural systemic constraints embedded in organizational, regulatory, and commercial practices.

Current inadequate approach operates under: negative criteria focus (defining only who should NOT occupy rather than who SHOULD be prioritized); simplistic proxy-based regulations (age as capability proxy, ignoring functional assessment); commercialization as operational priority (emergency seats monetized as premium product); crew as sole competent evacuation agents (passengers treated as passive cargo requiring assistance). Proposed systemic approach requires: positive criteria focus (proactive identification and prioritization of optimal candidates); measurable functional capability-based regulations (objective assessments of relevant competencies); safety as non-negotiable constraint (emergency seat allocation exempt from commercial monetization); emergency seat passengers recognized as critical backup agents (functional components of distributed evacuation system, especially when primary communication fails or crew becomes overloaded, as JAL516 demonstrated with autonomous L4 door opening).

Critically, the proposed framework does not increase crew workload at the time of boarding. The six-criteria framework is not a boarding-phase checklist — it constitutes a distributed digital pre-boarding verification architecture, in which the majority of capability screening is absorbed by online check-in and automated blocking systems before passengers reach the aircraft. What crew members gain under the proposed model is formalized procedural backing and explicit reallocation authority — not additional verification steps beyond the visual inspection practices already in use. The systemic change is in the architecture of the screening process, not in the number of steps performed by cabin crew at the gate.

5.3. Evidence-based normative recommendations

Based on this research's findings grounded in integrated HTA, EAST, and CWA frameworks, six structural reforms are proposed for aviation regulatory authorities and airline operational practices.

To illustrate the practical operationalization of the proposed framework — and to demonstrate that it does not generate additional crew workload beyond current practices — consider the following implementation scenario for a passenger who declares inability to assist during an emergency at the time of online check-in. Step 1 — Online purchase/check-in: upon selecting an emergency exit row seat, the system presents mandatory capability declarations consistent with the six-criterion framework; the passenger indicates inability to assist; the system automatically blocks the emergency exit seat purchase and redirects to alternative seats, refunding any price differential — no crew involvement required. Step 2 — In-person check-in: the ground agent performs standard visual verification (a procedure already applied for WCHR/WCHC passengers); no additional training burden is generated beyond current practice. Step 3 — Gate boarding: the crew member performs existing visual confirmation; any required reallocation is backed by formalized procedural authority and documented capability criteria. Step 4 — Post-boarding: any spontaneous seat exchange requires mandatory crew notification and capability re-verification — a procedural change, not a new operational task. This scenario demonstrates that the six-criteria framework functions as a distributed pre-boarding architecture, not a boarding-phase checklist; the vast majority of screening burden is absorbed digitally before the crew ever interacts with the passenger.

(1) Age Criteria Harmonization: Eliminate the RBAC 67/121 regulatory contradiction by permitting aviation professionals (pilots, flight attendants, air traffic controllers) with valid aeronautical medical certification (CMA Class 1 or 2) to occupy emergency seats regardless of chronological age, provided they are not currently on duty. This recognizes that functional capability assessment through medical certification is superior to chronological age as selection criterion.

(2) Belt Extender Prohibition: Explicitly prohibit seatbelt extender use in emergency, first, and last row seats as objective, measurable, non-discriminatory criterion directly linked to

demonstrated functional requirements (rapid movement, overhead reach) identified through HTA analysis.

(3) Positive Selection Implementation: Create systematic prioritization rather than mere exclusion: HIGH PRIORITY (professionals with relevant certified training: commercial/military pilots not on duty, flight attendants not on duty, firefighters, paramedics, emergency medical technicians, military personnel); MEDIUM PRIORITY (physically fit solo adults aged 18-60 without evident limitations); LOW PRIORITY (adults aged 60-70 without evident physical/cognitive limitations and valid medical assessment); PROHIBITED (minors under 18, evident physical/cognitive/sensory limitations, severe mobility reduction, dependent care responsibilities, seatbelt extender requirement).
(4) Digital Verification Obligation: Mandate multi-stage verification with progressive filtering: online purchase/check-in requires objective capability declarations with automatic system blocking for contraindicated profiles; in-person check-in includes trained agent visual verification with reallocation authority; gate boarding includes final crew review with reallocation authority even post-boarding; post-boarding seat exchanges require mandatory crew notification and capability re-verification.
(5) Enhanced Briefing Protocol: Implement three-component briefing model: mandatory individual verbal briefing with active comprehension confirmation (not passive listening); specific written instruction card detailing that particular exit type's operation (not generic briefing); simplified physical demonstration of mechanisms without actual operation (tactile familiarization with lever location, required force direction).
(6) Safety-Capability Decoupling: Safety as Non-Negotiable Allocation Criterion. The physical attribute of extra legroom remains a legitimate commercial product — its pricing and premium status are not contested by this recommendation. However, the assignment of a specific emergency exit row seat must be subject to capability verification at each screening point, independently of payment or loyalty programme status. In cases where reallocation is required on safety grounds, the passenger retains the commercial value paid and receives an equivalent alternative seat — directly analogous to existing airline practices for WCHR/WCHC passengers and regulatory medical fitness requirements. This model is commercially analogous to what airlines already do: seats are sold and priced, but occupancy at exit rows is conditionally subject to operational safety criteria. Critically, this safety condition should be a concern addressed prior to aircraft boarding — integrated into the purchase and check-in architecture rather than resolved at the gate or post-boarding. This structural decoupling preserves commercial viability while establishing safety as a non-negotiable constraint on seat allocation.

6. Conclusions

This study demonstrated that current commercial aircraft emergency exit seat passenger selection criteria present significant systemic constraints that fundamentally compromise evacuation system effectiveness under stress conditions. Through evolutionary methodological approach strategically integrating Hierarchical Task Analysis, Event Analysis of Systemic Teamwork, and Cognitive Work Analysis, this research revealed three progressive insight layers: Phase 1 successfully identified clear functional requirements (17 discrete task elements, 6 primary selection criteria, well-defined optimal versus contraindicated passenger profiles); Phase 2 revealed the regulatory paradox (dramatic implementation divergence despite apparent technical knowledge, with commercial practices systematically contradicting safety principles); Phase 3 comprehensively mapped 6 structural systemic constraints explaining the paradox (age contradictions, commercial prioritization, absent positive criteria, belt extender complications, screening deficiencies, inadequate briefings).
The methodological contribution demonstrates how Human Factors analytical tools can be strategically integrated in evolutionary research design, with each phase informing subsequent investigation direction and potentially reorienting research questions as deeper complexity layers emerge. CWA utility is specifically validated for revealing systemic constraints that remain invisible in traditional task-focused or procedure-focused analyses. Theoretically, empirical evidence demonstrates that contemporary aviation safety problems are fundamentally systemic-cultural rather than merely technical, requiring not only knowledge of optimal practices but also deep understanding of structural barriers preventing their implementation in operational contexts. Practically, six evidence-based normative recommendations are provided with theoretical grounding and empirical support, offering a transferable framework applicable to other safety-critical domains where technical knowledge demonstrably exists but implementation systematically fails due to organizational, commercial, or regulatory structural constraints.

Constraint	Systemic Issue
1. Age Contradictions	RBAC 67 certifies 60–65-year pilots while RBAC 121 prohibits emergency seats based solely on age
2. Commercial Prioritization	Emergency exits sold as "premium" with sales prioritizing payment over capability
3. Absent Positive Criteria	Regulations define only who CANNOT (exclusion) rather than who SHOULD (selection)
4. Belt Extender Complications	No explicit prohibition despite mobility requirements for door operation
5. Screening Deficiencies	Multiple failure points without redundant verification mechanisms
6. Inadequate Briefings	Transfer declarative knowledge but not procedural competence

Table 2. Summary of six systemic constraints in emergency exit seat selection

Aviation safety has achieved extraordinary reliability levels through continuous learning culture and rigorous evidence-based improvement processes spanning decades. However, the specific normative contradictions and systemic constraints identified in this research have not yet resulted in catastrophic evacuations primarily because the commercial aviation system is inherently redundant and remarkably resilient, extensively trained crew compensates for passenger deficiencies, multiple exit availability provides alternatives when specific exits fail, and robust organizational cultures create additional protection layers beyond minimum regulatory requirements. Yet this demonstrated resilience should emphatically not be interpreted as justification for complacency or as evidence that identified systemic vulnerabilities are inconsequential. As CWA analysis systematically demonstrated, structural constraints exist and persist, and under specific combined failure configurations (communication systems compromised plus crew overloaded or incapacitated plus multiple exits rendered unusable plus systematically inadequate passengers occupying remaining critical exit positions) these constraints can interact to produce catastrophic outcomes. Sufficient technical knowledge unquestionably exists for implementing substantially more rigorous and functionally effective passenger selection criteria. What demonstrably lacks are not knowledge, analytical capability, or methodological sophistication, but rather institutional will to fundamentally reform entrenched organizational and commercial structures that persistently prioritize operational convenience and revenue generation over uncompromising safety excellence.

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