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Analyzing and Optimizing the Logistics Chain of National Examinations in Cameroon: A Case Study of the BTS Process in Douala Using Pareto, Ishikawa, and FMEA Methods

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Abstract

Logistical disruptions in the organization of national examinations present critical risks to fairness, operational efficiency, and educational governance. In Cameroon, where examination processes span diverse and complex operational contexts, limited research has been conducted on systematically analyzing and mitigating logistical incidents. This study addresses this gap through an empirical investigation centered on the Brevet de Technicien Supérieur (BTS) in Douala, a city whose examination candidate population increased by over 50% between 2015 and 2024, exacerbating logistical challenges. A mixed-methods approach was employed to collect and analyze data from 164 stakeholders (correctors, invigilators, secretariat members, and administrators). Quantitative data were gathered using a structured questionnaire aligned with 12 key logistical phases. Incidents were classified and prioritized through Pareto analysis to identify the critical 20% that generate 80% of disruptions. Root causes of major incidents were explored using Ishikawa diagrams (5M approach), while Failure Modes and Effects Analysis (FMEA) was applied to quantify risk levels (Severity, Occurrence, Detectability). Qualitative insights were supplemented by the author's direct experience as a participant in the BTS logistical chain. The analysis revealed six major recurring incidents responsible for more than 80% of disruptions: delays and disparities in payments, regulatory weaknesses, poor geographical staff allocation, errors or missing documents, insufficient invigilation ratios, and ineffective incident management. Root cause analysis highlighted significant issues in processes, human resources, documentation, technological tools, and environmental constraints. FMEA results emphasized high risk priority levels, particularly for financial and regulatory issues, underscoring their urgent need for corrective action. The study proposes actionable strategies, including regulatory harmonization, enhanced financial process automation, optimized staff allocation, improved document control, robust incident management protocols, and the institutionalization of feedback mechanisms. Together, these measures aim to strengthen the resilience, traceability, and efficiency of examination logistics at national scale. This work constitutes an original contribution to the literature by introducing an integrated methodological framework (Pareto–Ishikawa-FMEA) adapted from industrial risk management to the educational logistics domain. It offers both theoretical insights and practical guidelines to improve the governance of national examination processes in Cameroon and comparable contexts in Sub-Saharan Africa.

Keywords

Logistics Chain, National Examinations, BTS, Pareto Analysis, Ishikawa Diagram, FMEA, Educational Governance

1. Introduction

1.1. Background

In complex systems, whether industrial, humanitarian, or educational, logistics plays a decisive role in ensuring operational success. Within the educational sector, the organization of national examinations increasingly depends on robust logistical systems that extend beyond the mere management of academic content. Logistical failures can severely disrupt operations, compromise fairness, and undermine the credibility of national certifications [1].

Despite its critical importance, educational logistics remains an underexplored domain in the scientific literature, particularly in developing countries where research often prioritizes pedagogical, regulatory, or sociological aspects over operational concerns [2] [3]. As educational systems expand in scale and complexity, the need for efficient logistical management becomes increasingly urgent, especially for high-stakes assessments involving large numbers of candidates, sensitive materials, and complex human and financial resource flows [4] [5].

Derived from industrial supply chain management principles, educational logistics refers to the coordinated mobilization of human, material, and informational resources necessary to deliver educational services at scale [6]. While traditional logistics emphasizes tangible goods movement [7], educational logistics focuses on the orchestration of information flows, administrative actions, and human resource deployment, thus playing a crucial role in preserving the integrity and operational resilience of national examination systems.

1.2. Problem Statement

The Brevet de Technicien Supérieur (BTS) examination in Cameroon, particularly at the Douala center, provides a vivid illustration of the escalating logistical challenges confronting national examinations. Between 2015 and 2024, the number of candidates registered in Douala grew from approximately 6500 to 9799 (Author's data, 2024) (see Figure 1 below), reflecting a demographic surge of over 50%. Although this expansion demonstrates improved access to higher education, it has simultaneously strained logistical systems that were not originally engineered for such volumes. Managing the BTS logistics chain today requires the synchronized management of diverse fronts, including examination material preparation, staff deployment, administrative information management, and transparent financial operations. However, field observations and experiential data have revealed systemic and recurrent vulnerabilities, notably: delays in payment of correctors, discrepancies between services rendered and payments received, inefficient assignment of secretariat members and invigilators without regard to geographic proximity, leading to staff delays and exam start-time disruptions, omissions and typographical errors in examination subjects, absence of critical documents in candidate packets, and an insufficient ratio of invigilators and secretariat members to candidates.

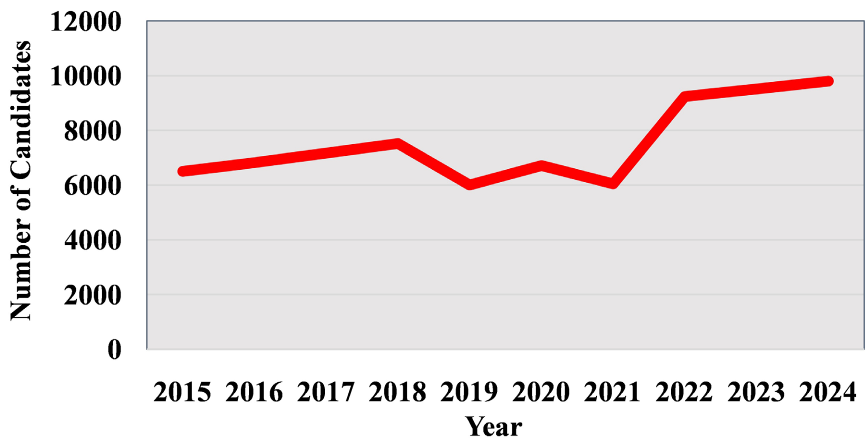

Figure 1. The trend in examination candidates registered in Douala (2015-2024). Source: (Author).

These incidents, if left unaddressed, erode trust, fairness, and transparency in the examination process while undermining the credibility of the national certification system. Despite their critical operational impact, systematic scientific studies diagnosing, prioritizing, and quantifying these logistical failures remain rare, both internationally and within the Cameroonian context. This highlights the urgent necessity for structured, empirical, and risk-driven approaches to enhance examination logistics governance.

1.3. Review of Related and Previous Studies

The management of incidents and disruptions within logistics systems has been a recurrent theme in industrial, humanitarian, and educational research. Incidents, defined as operational disruptions with significant impacts, can arise from a wide range of causes, including natural disasters, political instability, infrastructure breakdowns, human error, and technological failures [8]-[10].

In industrial logistics, several frameworks have been proposed to classify and mitigate supply chain risks. For instance, researchers in [11] categorized disruptions into nine major types, ranging from natural catastrophes to supply failures and intellectual property risks. Similarly, authors in [12] identified five broad categories of risks based on their origin: process, control, demand, supply, and environmental risks. Other researchers in [13] [14] emphasized the systemic and cascading effects of disruptions within supply chain networks, underscoring the need for resilience strategies.

Recent works have extended these principles to educational logistics, albeit in a limited fashion. Sarrico and Rosa (2016) [15] highlighted the challenges of quality management in educational supply chains, pointing to issues such as information sharing, trust, leadership, and systemic integration. However, empirical studies focusing specifically on national examination logistics, particularly incident identification, classification, prioritization, and risk analysis, remain virtually absent, especially in Sub-Saharan Africa.

Previous research has emphasized the importance of resilience in logistical systems [16]-[18]. Resilience strategies include preventive, concurrent, and reactive measures aimed at anticipating, absorbing, and recovering from disruptions. Human factors, such as absenteeism, communication breakdowns, and demotivation, have also been identified as major contributors to system failures [19] [20].

However, despite the wealth of knowledge in industrial and service logistics, educational examination systems have rarely been subjected to systematic risk assessments using proven operational management tools such as Pareto Analysis, Ishikawa Diagrams, and Failure Modes and Effects Analysis (FMEA). There is thus a pressing need to adapt and apply these analytical frameworks to the context of national examinations.

1.4. Identification of Research Gaps

The review of existing literature reveals several critical gaps:

- First, the empirical identification, classification, and prioritization of logistical incidents affecting national examinations remain largely unexplored.
- Second, while structured tools such as Ishikawa Diagrams and FMEA are extensively used in industrial and healthcare logistics, their application to educational examination logistics has been virtually nonexistent.
- Third, despite the recognition of human factors as critical sources of operational vulnerability, their compounded effects on educational logistics chains remain insufficiently documented.

- Finally, there is a lack of quantitative, data-driven studies addressing operational risks and proposing systematic resilience strategies specifically tailored to examination systems in developing countries.

These gaps necessitate a structured, empirical, and risk-based approach to diagnosing, analyzing, and mitigating logistical vulnerabilities in educational examination systems.

1.5. Research Contributions

This study provides significant contributions to the advancement of educational logistics and operational risk management. It systematically documents and classifies logistical incidents that occurred within the BTS examination logistics chain in Douala between 2015 and 2024, thereby filling an important empirical void in the literature. It introduces a structured prioritization process through the application of Pareto analysis to identify incidents with the greatest operational impact. It further applies Ishikawa Diagrams at the level of each prioritized incident to conduct a detailed and systematic root cause analysis, deepening the understanding of operational failures. The study subsequently utilizes Failure Modes and Effects Analysis (FMEA) to assess the severity, occurrence, and detectability of each root cause, enabling the quantification and prioritization of risks based on Risk Priority Numbers (RPNs). Finally, it provides evidence-based operational recommendations aimed at strengthening resilience, transparency, and efficiency within national examination logistics systems. By transferring proven industrial quality management tools into the domain of educational logistics, this study pioneers a structured methodological approach to operational risk management in high-stakes educational environments.

1.6. Originality and Methodological Innovation

The originality of this study lies in its pioneering application of a multi-tool quality management framework to educational examination logistics. By sequentially integrating Pareto Analysis for incident prioritization, Ishikawa Diagrams for structured root cause analysis at the incident level, and FMEA for quantitative risk assessment, the study moves beyond broad strategic planning tools such as SWOT or PDCA cycles to deliver an operational, risk-driven diagnostic methodology. Drawing inspiration from successful implementations in industrial contexts, such as the operational loss reduction reported by [21], this research adopts rigorously structured diagnostics to educational logistics. It thus offers a replicable model for enhancing operational resilience in examination governance, laying the groundwork for future research and improvements in educational logistics risk management.

2. Methodology

2.1. Study Context and Research Setting

The present study focuses on the logistical management of the Brevet de Technicien Supérieur (BTS) national examinations organized in the city of Douala, Cameroon, during the period 2015-2024. Douala, recognized as the economic capital of Cameroon, is characterized by its dense population, its role as the country's largest industrial and commercial hub, and the presence of Cameroon's main seaport. These features make Douala a dynamic but complex environment for the organization of large-scale public events, including academic examinations.

The BTS examination plays a critical role in certifying vocational and technical competencies across a wide range of specialties, including Industrial Engineering, Business Administration, Communication, and Information Technology. In Douala alone, annual BTS candidate registration numbers increased from approximately 6500 in 2015 to over 9799 in 2024 (Author's data, 2024), representing a growth rate of more than 50%. This demographic expansion has led to greater logistical pressure on an infrastructure initially designed for smaller candidate volumes.

The logistics chain for the BTS exams in Douala involves multiple interdependent operations, including the customized preparation of examination materials, specialized arrangements for candidate supervision, transport and security of examination documents, and the management of financial flows related to examiner compensation. These activities must be coordinated across several geographically dispersed examination centers and sub-centers, compounding the risk of logistical incidents.

A distinctive feature of this study is the privileged access to operational data, enabled by the author's active involvement as a logistics coordinator in multiple BTS examination cycles. This insider perspective allows the study to benefit from firsthand experiential observations, direct access to incident reports, official planning documents, logistical memos, and confidential internal audits.

The organizational framework is under the authority of the Ministry of Higher Education (MINESUP), particularly through the Commission Nationale d'Organisation des Examens Nationaux et des Concours (CNOENC) and the Direction des Accréditations Universitaires et de la Qualité (DAUQ). Nevertheless, despite this formal structure, persistent operational challenges such as payment inconsistencies, human resource shortages, last-minute assignment issues, delays in material distribution, and gaps in incident reporting remain prevalent.

The specific study setting therefore, offers an ideal empirical environment for investigating logistical disruptions, prioritizing their causes, and developing a structured, risk-based improvement model applicable to similar educational contexts.

2.2. Study Design

This research adopts a mixed-methods approach, integrating both quantitative and qualitative techniques to ensure a comprehensive diagnosis of logistical incidents affecting the BTS national examination logistics chain in Douala. The choice of mixed methods was motivated by the complexity of the operational environment, requiring both numerical evidence (incident frequency, severity, risk prioritization) and qualitative insights (contextual causes, perceptions, organizational practices).

The quantitative component relies on structured questionnaires targeting the key actors of the BTS logistics chain (correctors, invigilators, secretariat members, and administrators). This phase aims to collect measurable data on incident occurrence, severity, frequency, and detectability.

The qualitative component capitalizes on experiential learning [20] [22], enriched by direct participation in the logistics operations. Firsthand observations, informal interviews, and the analysis of operational documents (e.g., incident reports, logistical memos, meeting minutes) provide rich contextual information that complements the structured data collection.

Recognizing the potential limitations of experiential learning (cognitive biases, incomplete memory recall [23] [24]), systematic triangulation was applied between personal observations, archival documents, and survey responses to enhance the validity and reliability of findings.

This methodological design aims to achieve four specific objectives:

- Identify and classify the incidents occurring along the twelve phases of the BTS logistics chain.
- Prioritize incidents based on frequency and severity using Pareto Analysis.
- Analyze root causes for critical incidents using Ishikawa Diagrams (5M approach).
- Quantify and prioritize risks using an adapted Failure Modes and Effects Analysis (FMEA) method.

The mixed-methods architecture therefore ensures that the study captures not only the "what" of logistical incidents but also the "why" and "how" underlying their occurrence and escalation.

2.3. Methodological Objective

This study adopts a structured methodological framework built around five core objectives that collectively support the systematic diagnosis, prioritization, and risk analysis of logistical incidents within the BTS examination logistics chain. Each phase contributes to constructing a comprehensive model for process improvement.

1) Identification and Classification of Incidents

The initial phase involves compiling a detailed inventory of logistical incidents using a triangulated approach that incorporates experiential knowledge from the field, operational documents, and structured survey responses. These incidents are then systematically mapped across the twelve critical phases of the BTS examination logistics chain, ensuring complete coverage of the process from planning to post-exam evaluation. This mapping allows for a holistic visualization of where and how disruptions occur.

2) Prioritization of Critical Incidents Using Pareto Analysis

To manage the volume and complexity of identified incidents, the study applies the Pareto principle (80/20 rule) to the incident database. This statistical technique helps isolate the small subset of incident types responsible for the majority of disruptions. Focusing on these top-priority incidents enables targeted, high-impact corrective interventions while optimizing the use of analytical resources.

3) Root Cause Analysis via the Ishikawa 5M Method

For each high-priority incident identified through Pareto filtering, the Ishikawa (fishbone) diagram is used to conduct a root cause analysis. Causes are categorized under the classical 5M framework:

- *Manpower* (e.g., insufficient training, absenteeism),
- *Methods* (e.g., unclear or outdated procedures),
- *Materials* (e.g., missing or defective examination materials),
- *Environment* (e.g., weather-related disruptions, inadequate infrastructure),
- *Measurements* (e.g., absence of standardized performance indicators).

This diagnostic tool facilitates a structured exploration of potential contributing factors and uncovers systemic weaknesses.

4) Risk Evaluation Through Adapted Failure Modes and Effects Analysis (FMEA)

Once root causes are identified, they are assessed using an adapted FMEA approach. Each cause is scored across three dimensions:

- *Severity* (*S*): the impact on the examination process if the failure occurs,
- *Occurrence* (*O*): the likelihood of the failure happening,
- *Detectability* (*D*): the probability that the failure will be detected before causing harm.

All criteria are scored on a scale of 1 to 4, producing a Risk Priority Number (RPN) by multiplying the three scores (RPN = S × O × D). This quantification allows for the ranking of root causes by risk level and facilitates prioritization of mitigation strategies.

5) Formulation of Operational Recommendations

The final phase of the methodology transforms analytical insights into actionable recommendations. These are designed to enhance the resilience, efficiency, and transparency of the BTS examination logistics chain. Recommendations include both preventive strategies—such as procedural reforms, personnel training, and optimization of logistics resources—and reactive strategies, including incident response planning and development of contingency logistics protocols.

2.4. Justification for the Analytical Approach

In examining the logistical organization of national examinations, particularly the BTS in Douala, a descriptive analysis of surface-level symptoms proves insufficient. Given the complexity, scale, and recurrence of operational disruptions, a structured and analytical approach is required to move beyond anecdotal reporting and into empirical diagnosis. This justifies the adoption of industrial-grade quality management tools for identifying, categorizing, and prioritizing logistical incidents.

Educational logistics, unlike industrial supply chains, lack standardized diagnostic frameworks, making the adaptation of proven tools like Pareto analysis, Ishikawa diagrams, and FMEA both a necessity and an innovation. These tools have been extensively validated in industrial, humanitarian, and service supply chains for their ability to translate qualitative disruptions into quantifiable decision metrics [25]-[27].

More specifically:

- Pareto analysis serves to focus analytical attention on the minority of incidents (≈20%) generating the majority of disruptions (≈80%), aligning with the efficiency logic of Juran's principle.
- Ishikawa (5M) diagrams facilitate a systematic root cause breakdown per incident, classifying disruptions across manpower, methods, materials, measurements, and environment, ensuring that organizational complexity is fully represented.
- FMEA (Failure Modes and Effects Analysis) introduces a quantitative dimension, assigning risk scores (RPN: Risk Priority Numbers) to each root cause based on severity, frequency, and detectability.

The sequenced use of these tools is crucial: unprioritized Ishikawa analyses lead to overwhelming complexity, while non-quantified FMEA lacks operational focus. Conversely, using Pareto to isolate incidents, Ishikawa to investigate causes, and FMEA to score risks provides hierarchical filtering, causal clarity, and actionable decision criteria.

Ultimately, this analytical stack shifts the study from a descriptive posture to a decision-support orientation, enabling authorities to deploy finite resources where the risk-to-impact ratio is greatest. Such rigor is rarely observed in educational assessment logistics research, especially in Sub-Saharan Africa, positioning this methodology as both empirically grounded and methodologically original.

2.5. Phases of the BTS Logistics Chain

The logistical organization of the BTS examination is a complex multi-stage process requiring the coordination of diverse human, material, and informational resources. To accurately diagnose operational vulnerabilities and structure the data collection instrument (questionnaire), it was essential to first deconstruct the BTS examination process into its fundamental logistical phases. Each phase represents a critical point where specific incidents can occur, potentially disrupting the smooth flow of operations and affecting examination integrity. The 12 main phases identified are described below:

Phase 1: Planning

This initial phase includes the elaboration of the examination budget, the establishment of exam schedules, and coordination with host institutions. Any errors or delays during this stage tend to cascade throughout the subsequent phases of the logistics chain.

Phase 2: Material Organization

Activities in this phase include the design and validation of exam questions, printing of examination materials, and acquisition of essential supplies such as answer booklets and attendance sheets. High standards of precision, timing, and confidentiality are necessary to ensure examination quality.

Phase 3: Transportation and Distribution

This phase is dedicated to the secure transfer of examination materials to various centers and sub-centers. Particular attention is required to maintain document integrity and avoid incidents related to loss, damage, or delays.

Phase 4: On-site Administration

At the center level, operations include the assignment of examination rooms, the mapping of candidate seating, and the provision of necessary signage and materials. Inadequate preparation can lead to confusion, stress among candidates, and scheduling disruptions.

Phase 5: Mobility and Cartography

The deployment of invigilators, secretariat personnel, and supervisors must be strategically planned, with optimized travel routes and adherence to arrival times. Insufficient coordination in this phase often causes late arrivals and delays in exam start times.

Phase 6: Financial Management (Financial Flows)

This segment includes the processing of payments to all exam personnel, the disbursement of operational budgets, and the implementation of transparent financial procedures. Delays or inconsistencies may generate discontent and reduce staff commitment.

Phase 7: Surveillance

Exam monitoring involves the deployment of invigilators, strict enforcement of examination regulations, and the management of any cases of misconduct. The integrity of this phase directly affects the credibility of the examination.

Phase 8: Grading of Scripts

This phase entails the secure transmission of scripts to correctors, the evaluation of candidate responses, and the standardization of grading procedures. Errors here can significantly compromise fairness and result accuracy.

Phase 9: Secretariat Management

Administrative responsibilities include the consolidation of exam records, management of attendance and grading sheets, and liaison with the national examination board. Weaknesses in this area may result in information loss or contestable outcomes.

Phase 10: Incident Management

Unforeseen events such as absenteeism, equipment failure, or material loss must be managed in real-time. The documentation of such incidents and immediate decision-making support are essential to prevent minor problems from escalating.

Phase 11: Monitoring of Regulations

This phase ensures that all procedures align with official examination frameworks and that rules are applied consistently. Non-compliance or irregularities undermine trust in the system.

Phase 12: Publication of Results and Complaints Management

The final stage includes the release of examination results and the handling of candidate appeals. Delays or lack of transparency in this phase can damage public confidence in the process.

Each of these twelve phases has been linked to incident categories based on observations collected between 2015 and 2024. The questionnaire used in the study was designed to reflect these phases, ensuring a comprehensive evaluation of logistical risks.

2.6. Mapping Potential Incidents by Phase of the BTS Examination Logistics Chain

Following the detailed description of the twelve (12) critical phases structuring the logistics chain of the BTS examination in Douala, a clear mapping of the potential incidents that may arise at each phase is established (see Table 1). This incident mapping aims to ensure the comprehensiveness of the risk identification process and to prepare the ground for the prioritization and causal analysis to be conducted later using structured quality management tools. The incidents have been classified phase-by-phase as follows:

Table 1. List of incidents by phase of the BTS examination logistic chain.

Phases	Potential Incidents
Phase 1: Planning	-Late establishment of examination calendar. -Lack of clarity in communication of examination dates. -Insufficient or delayed budget allocation. -Inadequate collaboration with examination centers.
Phase 2: Material Organization	-Errors in printing examination papers (wrong subjects, typos). -Shortages of essential materials (e.g., exam papers, pens). -Late validation of examination subjects.
Phase 3: Transportation and Distribution	-Delay in delivery of examination materials to centers. -Loss or damage of examination materials during transport. -Wrong dispatching of materials to wrong centers.
Phase 4: On-site Administration	-Lack of proper equipment or insufficient materials in centers. -Delay in setup of examination rooms. -Miscommunication between central and sub-centers.
Phase 5: Mobility and Cartography	-Poor assignment of staff without considering proximity. -Delayed arrival of staff at examination centers. -Difficult access to some centers due to poor mapping or infrastructure.
Phase 6: Financial Management	-Delay in payment to supervisors, correctors, and secretariat staff. -Payments not aligned with services rendered. -Lack of transparency in fund allocation.

Continued

Phase 7: Surveillance	-Insufficient number of invigilators compared to candidates. -Absence or late arrival of invigilators. -Poor briefing and supervision of invigilators.
Phase 8: Grading of Scripts	-Delay in delivery of scripts to correctors. -Errors in marking (misgrading, omissions). -Loss or misplacement of scripts during correction phase.
Phase 9: Secretariat Management	-Administrative delays in processing documents. -Errors in candidate lists, room allocations, attendance sheets. -Lack of proper control mechanisms for secretariat operations.
Phase 10: Incident Management	-Lack of contingency plans for unexpected incidents. -Slow incident reporting and response. -Poor communication of corrective actions.
Phase 11: Monitoring of Regulations	-Inconsistent application of official procedures. -Absence of standardized remuneration policies. -Regulatory gaps leading to confusion or disputes.
Phase 12: Publication of Results and Complaints Management	-Delay in publication of results. -Errors in results communicated to candidates. -Poor management of complaints and re-evaluation requests

2.7. Description of Data Collection Instrument: The Questionnaire

2.7.1. Development Rationale

The questionnaire was carefully developed to align with the twelve identified phases of the BTS examination logistics chain. Each phase presents unique operational challenges; thus, the survey instrument was structured to systematically capture observations of incidents, their frequency, severity, root causes, and associated risks. The questionnaire construction followed a progressive design logic:

- Phase identification: Each logistics phase was associated with a distinct set of potential incidents derived from archival reports, experiential learning, and preliminary field investigations (2015-2024).
- Incident formalization: Clear, observable incidents were defined for each phase, avoiding ambiguous or redundant wording.
- Scoring systems: Incident severity, frequency, and cause detectability were operationalized using standardized, easy-to-interpret rating scales.
- Cause mapping: Incidents were mapped to root causes using the 5M structure (Manpower, Methods, Materials, Measurements, Environment).
- Risk evaluation: FMEA-inspired scales were integrated to allow Risk Priority Number (RPN) calculation later during analysis.

This structure ensures that the questionnaire is both phase-specific and analytically robust.

2.7.2. Structure and Sections

A comprehensive questionnaire was developed to assess the operational vulnerabilities across the BTS examination logistics chain. This instrument was carefully structured to ensure both empirical rigor and contextual relevance. It consists of six interlinked sections, each designed to capture specific dimensions of incident occurrence, severity, causation, and risk evaluation.

Section A: Respondent Profile

This opening section captures essential background variables, including the respondent's role in the examination process (e.g., invigilator, corrector, secretariat member, or administrator), their years of experience, the specific center or sub-center to which they were assigned, and any prior involvement in examination logistics. Collecting this contextual information allows for the differentiation of responses based on role-based perspectives and exposure, which is critical for interpreting patterns of perception and incident reporting.

Section B: Incident Observation

Using a binary (Yes/No) format, respondents indicate whether they have personally observed specific logistical incidents during the examination process. This section aims to gather experiential data and establish the empirical presence or absence of various disruptions across centers.

Section C: Frequency of Occurrence

For each incident observed, respondents rate how often it has occurred using a five-point Likert scale ranging from "Never" to "Always." This section seeks to measure the regularity and systemic recurrence of each type of incident across examination sessions, providing insight into whether the issues are isolated or chronic.

Section D: Perceived Severity

Here, respondents assess the seriousness of the impact of each incident using a four-point scale, from "Very Low Impact" to "Very High Impact." This allows for the evaluation of how disruptions are perceived in terms of operational efficiency and fairness, offering a nuanced understanding of their practical consequences.

Section E: Cause Attribution (5M Framework)

To enable structured root cause analysis, this section invites respondents to select the most likely cause of each incident based on five classic Ishikawa categories: *Manpower* (e.g., staffing issues or human error), *Methods* (e.g., procedural lapses or communication breakdowns), *Materials* (e.g., shortages or defects), *Measurements* (e.g., tracking errors), and *Environment* (e.g., external disturbances or inadequate center conditions). This standardized classification aids in identifying patterns across incidents and phases.

Section F: Risk Evaluation (Mini-FMEA Approach)

For each identified cause, participants rate three dimensions of risk: *Severity*, *Occurrence*, and *Detectability*, using a 1 - 4 scale. The Risk Priority Number (RPN), calculated as the product of these three values (RPN = S × O × D), serves as a quantitative index to prioritize corrective actions. This approach integrates principles of Failure Mode and Effects Analysis (FMEA), commonly used in industrial quality management, adapted here for educational logistics.

2.7.3. Strategic Alignment

By closely mirroring the phases of the logistics chain and embedding validated incident assessment frameworks (5M and FMEA), the questionnaire serves as a structured, reproducible, and statistically exploitable data collection instrument tailored to the unique realities of educational logistics systems.

2.8. Sampling Strategy and Study Population

2.8.1. Target Population

The study population comprises individuals directly involved in the organization and execution of the BTS national examination logistics chain in Douala from 2015 to 2024. These actors represent different hierarchical and operational levels within the logistics framework, each offering distinct insights into the occurrence and management of logistical incidents. The four identified stakeholder groups are:

- Invigilators: Responsible for supervising examination sessions at candidate-facing sites.
- Correctors: Tasked with evaluating candidate responses during the post-examination phase.
- Secretariat Members: Ensure document processing, record management, and coordination of scripts and reports.
- Administrators: Actors from the higher command chain (coordinators, center chiefs, and MINESUP-appointed representatives) are involved in budgeting, policy application, and strategic decisions.

These groups were selected due to their first hand operational experience and their exposure to logistical bottlenecks at different nodes of the examination chain.

2.8.2. Sampling Strategy

A purposive sampling approach was adopted. This method, also known as judgmental sampling, was appropriate for ensuring the inclusion of respondents with substantial experiential knowledge of the examination logistics chain. The criteria for inclusion were:

- Minimum of one year of experience in the BTS examination process, Assignment in one of the official examination centers or sub-centers in Douala between 2015 and 2024.
- Involvement in at least one logistics-critical function (e.g., supervision, correction, coordination, dispatch, secretariat processing).
- Efforts were made to balance the representation across groups and to avoid over-representation of actors with purely administrative or ceremonial functions.

2.8.3. Sample Size and Distribution

The final sample consisted of 164 respondents, broken down as follows:

This sample offers a broad perspective across operational roles and allows for stratified analysis by stakeholder category.

2.8.4. Representativeness and Limitations

While the purposive approach enhances the depth of insight, it may limit statistical generalizability beyond the Douala BTS context. However, the targeted sample ensures content validity, as only experienced actors with operational exposure were surveyed. To mitigate potential biases:

- Sampling included both junior and senior-level actors,
- Geographical coverage extended across all major BTS sub-centers in Douala,
- Confidentiality was emphasized to encourage honest responses.

2.8.5. Non-Response and Participation Rate

Out of the 180 questionnaires distributed to participants across various examination roles and locations, a total of 170 were returned, representing a high initial return rate. Among the returned questionnaires, six were excluded from analysis due to incomplete or inconsistent responses, resulting in 164 fully valid and usable responses. This corresponds to a valid participation rate of 91.1%, which is generally considered robust and sufficient to support reliable statistical analyses and generalizable insights within the study's context.

2.9. Ethical Considerations

Ethical rigor was prioritized throughout the study to ensure that data collection, handling, and analysis adhered to both academic and professional standards of integrity.

2.9.1. Informed Consent

All respondents were informed of the study's objectives, the voluntary nature of participation, and their right to withdraw at any point. Prior to filling out the questionnaire:

A detailed consent statement was provided in both printed and electronic versions. Consent was explicitly confirmed through a checkbox for online submissions or a signed field for printed versions. This process ensured free and informed participation in compliance with ethical guidelines for human subjects research [28] [29].

2.9.2. Confidentiality and Anonymity

To protect respondent identity and sensitive data:

- No names, ID numbers, or institutional affiliations were collected in the dataset.
- Group classifications (e.g., Invigilator, Corrector) were used solely for analytical stratification and never disclosed in raw outputs.
- Responses were stored on a password-protected, offline system accessible only to the principal investigator.
- Anonymity was guaranteed during data collection, processing, and publication, ensuring the non-traceability of individual inputs.

2.10. Analytical Tools

To systematically prioritize, diagnose, and assess the critical logistical incidents identified along the BTS examination logistics chain, three structured quality management tools were selected: Pareto Analysis, Ishikawa (Fishbone) Diagram, and Failure Modes and Effects Analysis (FMEA). Each tool plays a specific, complementary role in the incident analysis process.

2.10.1. Pareto Analytical Tool

To identify the most disruptive logistical issues within the BTS examination system, a Pareto Analysis was employed, grounded in the well-established 80/20 principle [30]. This analytical approach isolates a limited number of high-impact incidents, approximately 20%, that account for around 80% of the total disruptions. Incidents were ranked by combining data on their observed frequency and severity, derived from the questionnaire responses. A cumulative impact curve was then constructed to visually highlight which events contribute most significantly to the overall logistical burden. This prioritization approach enabled the study to focus subsequent root cause investigations on a limited set of critical events, thereby optimizing the allocation of corrective and preventive resources. The Pareto method thus served as an operational filter, guiding deeper analytical efforts toward the most consequential incidents in the system.

2.10.2. Ishikawa (Fishbone) Diagram: Root Cause Identification (5M Approach)

For each of the high-impact incidents identified through Pareto Analysis, a structured root cause analysis was conducted using the Ishikawa (or Fishbone) diagram methodology [31]. This technique organizes potential causes into five core categories defined by the 5M model: Manpower (e.g., human error, absenteeism), Methods (e.g., procedural flaws, communication breakdowns), Materials (e.g., defective or insufficient supplies), Measurements (e.g., tracking and verification errors), and Environment (e.g., infrastructural or external disruptions).

Each Fishbone Diagram was tailored to a specific incident, allowing for a comprehensive visualization of its potential root causes. This approach enhanced analytical depth by systematically exploring all plausible contributing factors, thereby reducing reliance on intuitive or anecdotal explanations. The Ishikawa methodology thus ensured a robust foundation for identifying targeted and evidence-based interventions.

2.10.3. Failure Modes and Effects Analysis (FMEA): Quantitative Risk Assessment

Building on the qualitative insights from the Ishikawa analysis, the study applied Failure Modes and Effects Analysis (FMEA) to quantitatively assess the relative risk associated with each identified root cause. This involved scoring each cause along three dimensions: Severity (S), the potential impact of the failure, Occurrence (O), its expected frequency, and Detectability (D), the likelihood of its early identification before consequences arise. Each parameter was rated on a uniform 4-point scale to maintain methodological consistency.

From these ratings, a Risk Priority Number (RPN) was computed using the formula:

$$RPN = S \times O \times D$$

The resulting RPN values facilitated a hierarchical ranking of risks, allowing the study to prioritize mitigation efforts toward the most critical and least controllable failure modes. FMEA thereby provided an objective, data-driven mechanism for guiding operational improvements in the examination logistics process.

2.11. Hybrid Analytical Model: Pareto-Ishikawa-FMEA

The combined use of Pareto-Ishikawa-FMEA models is well-documented in several domains:

- Industrial Logistics: To reduce production and delivery failures [26] [32].
- Healthcare Systems: To improve patient safety by prioritizing medical errors [33].
- Humanitarian Operations: To prioritize and mitigate supply chain risks in disaster contexts [25].

However, despite its proven efficiency, this hybrid approach has not yet been systematically applied to educational logistics chains, particularly in national examination contexts in developing countries. This study thus constitutes an original application of industrial risk management models to the domain of educational operations.

In operational risk management, the use of a single analytical tool often results in a partial view of systemic vulnerabilities [8] [25]. To achieve a comprehensive diagnosis of logistical incidents affecting the BTS examination chain, it was necessary to combine complementary tools, each offering a distinct layer of analysis.

The chosen hybrid strategy integrates:

- Pareto Analysis: Prioritizes critical incidents based on observed frequency and severity.
- Ishikawa (Fishbone) Diagrams: Identifies and organizes the root causes of each prioritized incident.
- Failure Modes and Effects Analysis (FMEA): Quantifies the risk associated with each root cause by calculating Risk Priority Numbers (RPN).

Each tool was deliberately selected to reinforce the findings of the others, ensuring both qualitative depth (cause exploration) and quantitative rigor (risk ranking) (see **Table 2**).

Table 2. Complementarity of tools.

Tool	Purpose	Added value in hybridization
Pareto Analysis	Incident prioritization (20% of causes, 80% of effects	Focuses resources on the most critical incidents
Ishikawa Diagram	Systematic identification of root causes	Ensures deep structural diagnosis
FMEA	Risk quantification (severity, occurrence, detectability)	Prioritizes interventions based on critical scores

The sequential application follows a logical diagnostic chain:

Identify major incidents (Pareto) → Diagnose root causes (Ishikawa) → Quantify risk (FMEA). This approach ensures that corrective measures are not only relevant but also risk-prioritized, enhancing their operational impact.

By adopting the Pareto-Ishikawa-FMEA hybrid model, the BTS examination logistics chain in Douala can:

- Efficiently allocate corrective actions to the most critical logistical failures.
- Improve preventive planning by understanding systemic vulnerabilities.
- Quantify residual risks and develop targeted risk mitigation strategies.
- Enhance resilience, transparency, and operational fairness in examination organization.

Thus, the hybrid model is not only analytically robust, but also strategically actionable for governance and quality improvement.

2.12. Data Processing and Statistical Validation

This section outlines the procedures employed to clean, validate, and statistically process the data collected from BTS examination logistics stakeholders. The objective was to ensure the reliability, coherence, and analytical robustness of the dataset used to diagnose logistical dysfunctions.

2.12.1. Data Cleaning and Outlier Detection

Prior to statistical analysis, questionnaire responses reporting logistical incidents were screened:

- Completeness & Consistency: Only responses with fully completed Likert-scale items (severity, frequency, detectability) were retained.
- Outlier Detection: Boxplots of reported incident frequencies by role and phase were constructed. For example, if any respondent reported an implausibly high frequency (e.g., >80%) for less severe incidents like "Under enforced invigilator to candidate ratio," Z-score filtering was used to flag and remove such anomalies.

2.12.2. Reliability Testing: Internal Consistency

To validate the internal reliability of Likert-scale items used in the questionnaire, Cronbach's Alpha (α) was computed for key subscales, with the accepted threshold set at $\alpha \geq 0.75$ [34]. The following constructs were assessed:

- Incident Frequency
- Perceived Severity
- FMEA Dimensions: Severity (S), Occurrence (O), and Detectability (D)

All subscales recorded values exceeding the threshold, indicating a high degree of inter-item consistency and reinforcing the reliability of the instrument.

2.12.3. Descriptive Statistics and Cross-Tabulations

Descriptive statistics were computed to offer a foundational understanding of the dataset. These included:

- Frequencies and means of incident types across exam phases (preparation, administration, correction).

- Severity ratings disaggregated by stakeholder role.
- Distribution of Risk Priority Numbers (RPNs) calculated from the FMEA framework.

Cross-tabulations were then performed to examine patterns and discrepancies in perception between respondent categories (e.g., invigilators vs. administrators) and between logistical phases. This allowed for the contextualization of incident data across various institutional roles.

2.12.4. Correlation Matrices

To explore potential interdependencies among logistical variables, Pearson correlation coefficients (r) were computed. Key relationships examined included:

- The correlation between incident frequency and perceived severity.
- Interrelationships among FMEA components (Severity, Occurrence, Detectability).
- Associations between respondent profiles (role, seniority) and types or volumes of reported incidents.

These correlation matrices were used to uncover latent patterns and confirm the structural coherence of the risk diagnosis model.

2.12.5. Data Analysis Tools and Techniques

Data collected from the questionnaire were subjected to a multi-layered analytical process combining both descriptive and inferential techniques. Preliminary steps, including data coding, cleaning, and tabulation, were conducted using Microsoft Excel, ensuring structural consistency and readiness for deeper analysis.

Subsequent statistical analyses were carried out using a combination of descriptive statistics and reliability assessment to evaluate the internal consistency of questionnaire items. Cronbach's alpha was computed to validate the reliability of each section of the instrument.

For visual exploration and interpretation of relationships within the dataset, Python, specifically the Pandas and Seaborn libraries, was employed. These tools enabled the generation of detailed visualizations and advanced correlation plots, enhancing the detection of trends, associations, and potential anomalies within the logistical incident data.

This blended approach ensured both accuracy in data handling and depth in analytical insight, supporting robust conclusions and evidence-based recommendations.

3. Results

3.1. Overview of Reported Incidents

3.1.1. Descriptive Statitistics

A total of nine major incident types were analyzed. The descriptive statistics are summarized in Table 3. These results show a high concentration of incidents in a few categories. With a range of 21% and a standard deviation of 7.02%, the frequency distribution indicates notable disparity among incident types. The mode at 4% and a median of 8% confirm that most incidents occur less frequently, while a few dominate the overall impact.

The analysis revealed that a few recurring issues dominate the logistical failures reported. The top three incidents include:

- Payment delays and remuneration disparities (24%)
- Regulatory weaknesses and inconsistencies (18%)
- Improper geographical assignment of staff (14%)

Together, these account for 56% of all reported incidents, highlighting systemic problems in financial management, regulatory application, and staff deployment.

Table 3. Descriptive statistics of the majors reported incidents.

Statistic	Value
Number of Incidents (N)	9
Minimum Frequency (%)	3%
Maximum Frequency (%)	24%
Mean (Average) (%)	9.11%
Median (%)	8%
Mode (%)	4%
Range (%)	21% (24% - 3%)
Standard Deviation (%)	≈7.02%
Total Frequency (%)	100%

To better understand the proportions and relative importance of these incidents, two charts were developed. (Figure 2 & Figure 3)

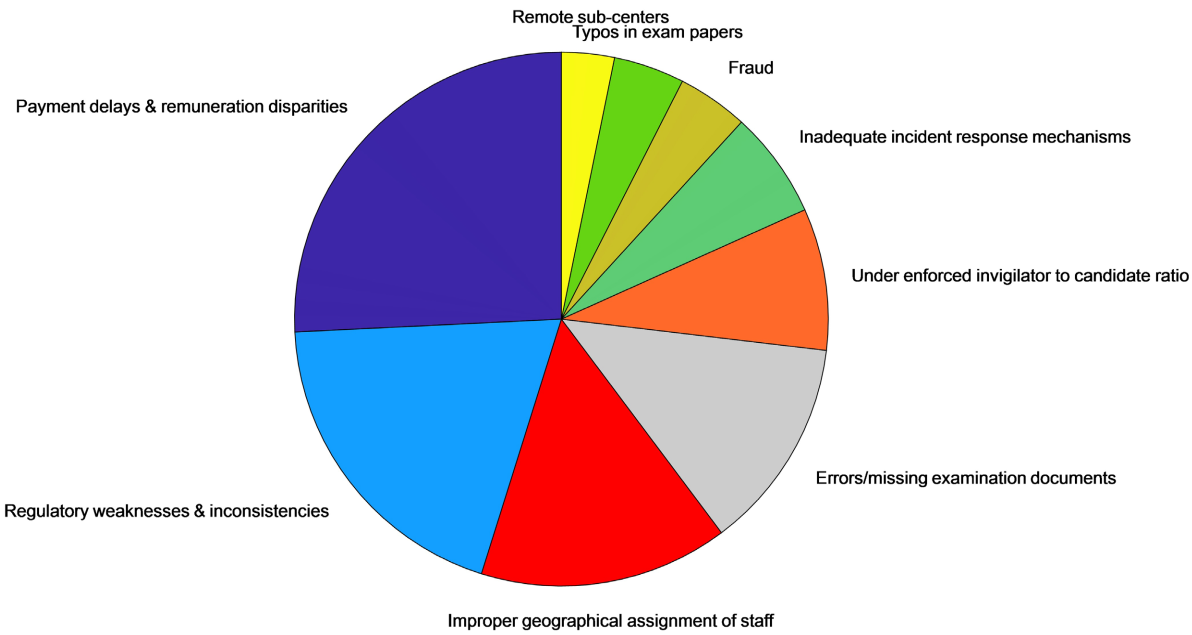

Figure 2. Incident distribution.

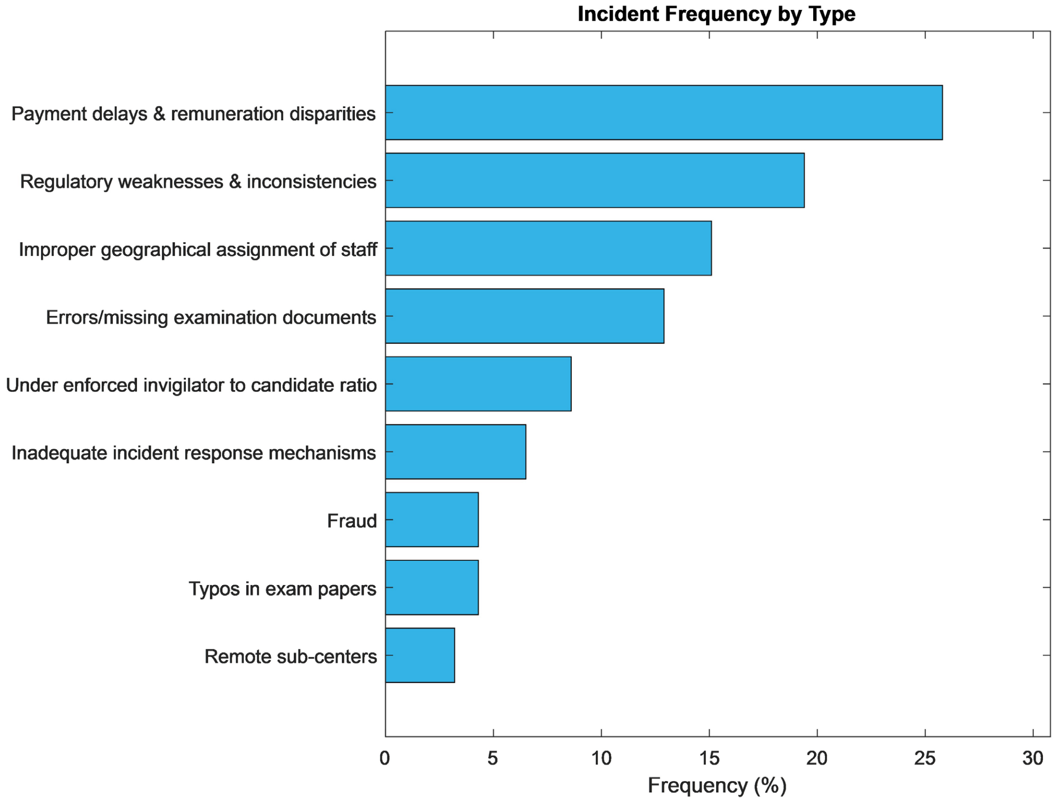

Figure 3. Incident frequency by type.

This pie chart shows the percentage share of each type of logistical disruption, with financial and regulatory issues dominating.

Other notable incidents include:

- Errors or missing examination documents (12%)
- Under-enforced invigilator to candidate ratio (8%)
- Inadequate incident response mechanisms (6%)
- Fraud (4%)
- Typos in exam papers (4%)
- Remote sub-centers (3%)

Although these are individually less frequent, they collectively represent 18% of the disruptions and significantly impact the efficiency and credibility of the examination process.

This horizontal bar chart ranks incidents by frequency, clearly displaying the concentration of problems in the top three categories. The results emphasize that the logistics chain is most vulnerable at the financial planning and regulation enforcement stages (Phases 5, 6, and 11). Planning flaws, under-resourced staff deployment, and lack of a proper incident response mechanism are recurring contributors to operational breakdowns.

Secondary incidents related to exam material integrity (typos, missing documents) and operational surveillance (fraud, invigilator ratios) also highlight the need for improved quality assurance and monitoring tools.

3.1.2. Cronbach's Alpha for Internal Consistency

To evaluate the internal consistency of the key variables used to measure incident risk in the BTS exam logistics process, we calculated the Cronbach's Alpha for the set of variables: Frequency, Severity, Occurrence, Detectability, and RPN (Risk Priority Number). The Cronbach's Alpha measures how consistently these variables are related to each other and whether they form a reliable scale to evaluate risks. Using the data for 9 incidents and the associated FMEA variables, we computed Cronbach's Alpha using the following formula:

$$\beta = \frac{k}{k-1}\left(1 - \frac{\sum \sigma_{\text{items}}^2}{\sigma_{\text{total}}^2}\right)$$

where:

- k is the number of items,
- σ_{items}^2 is the variance of individual variables
- σ_{total}^2 is the variance of the total score.

The calculated Cronbach's Alpha value for these variables was **0.8073**. This result suggests good internal consistency among the variables used to measure incident risk, indicating that the variables (Frequency, Severity, Occurrence, Detectability, and RPN) are strongly related and measure the same underlying concept of logistical risk in the exam process.

3.1.3. Correlation Between FMEA Variables

To explore the interdependencies between FMEA variables, a correlation matrix was generated (**Figure 4**).

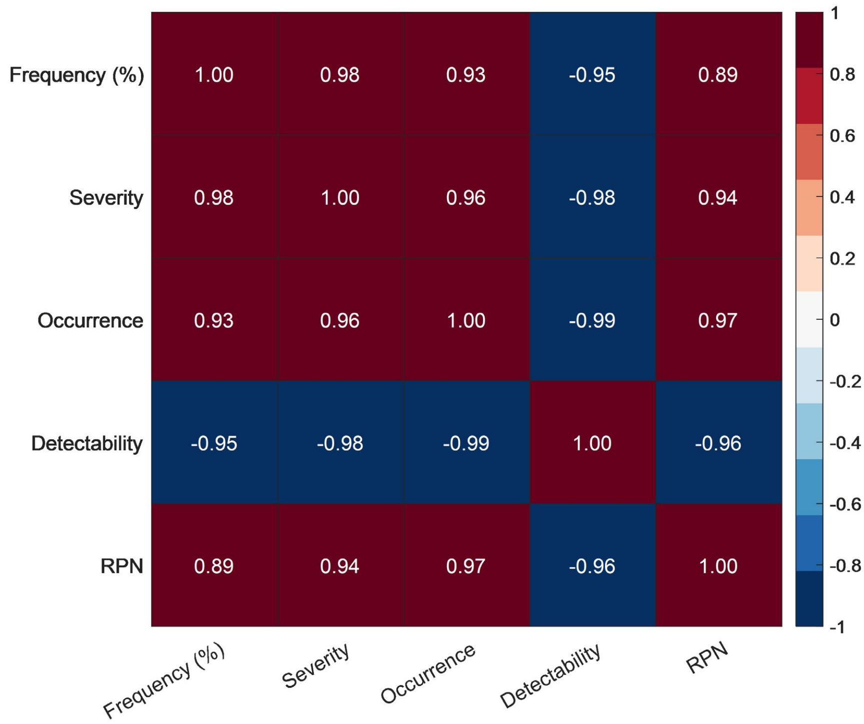

Figure 4. Correlation matrix heatmap between FMEA variables.

The analysis revealed strong positive correlations between Frequency and Severity (r = 0.98), as well as between Occurrence and RPN (r = 0.97). Conversely, Detectability was negatively correlated with all other variables, most notably with Occurrence (r = −0.99) and RPN (r = −0.96). These results confirm that incidents with high frequency and severity are not only more difficult to detect but also significantly elevate the overall risk. This supports the use of FMEA as a relevant tool in prioritizing actions to improve the reliability of BTS exam logistics.

3.1.4. Boxplot Analysis of Risk Variables

A box plot analysis was also performed to better understand the distribution of risk-related variables (**Figure 5**). The plot illustrates the spread and central tendency of five key FMEA variables: Frequency (%), Severity, Occurrence, Detectability, and RPN. It reveals that Severity, Occurrence, and RPN show relatively high median values, suggesting consistent and significant levels of these risk factors across observed failure modes. Detectability, on the other hand, exhibits the widest spread and contains potential outliers, indicating that detection capability is highly variable and less predictable. This variability underscores the need to standardize detection mechanisms to better manage exam logistics risks. The Frequency (%) distribution also shows some skewness, suggesting certain failure modes occur much more frequently than others. Overall, the box plot emphasizes the uneven distribution of risks and the importance of focusing efforts on improving detectability and managing high-frequency failure modes.

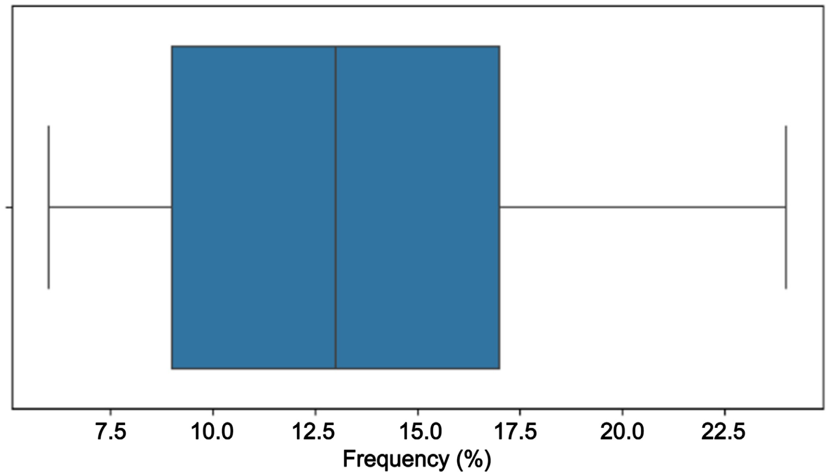

Figure 5. Boxplot of incident frequencies.

The analysis reveals key insights into the logistics of BTS exam management, notably the high frequency of payment delays and regulatory issues. The Cronbach's Alpha indicates a good internal consistency among the variables used to assess risk, supporting the reliability of the data. The correlation matrix and boxplot analysis emphasize the relationship between high-risk factors and detection challenges, providing a clear direction for improving logistical processes and risk management practices.

3.2. Respondent Profiles

Understanding the demographic and professional profiles of respondents is essential to assess the credibility, relevance, and representativeness of the data collected. As illustrated in Figure 6, the participants were distributed across four main functional roles: 58 correctors (35.4%), 61 invigilators (37.2%), 27 secretariat members (16.5%), and 18 administrators (11%).

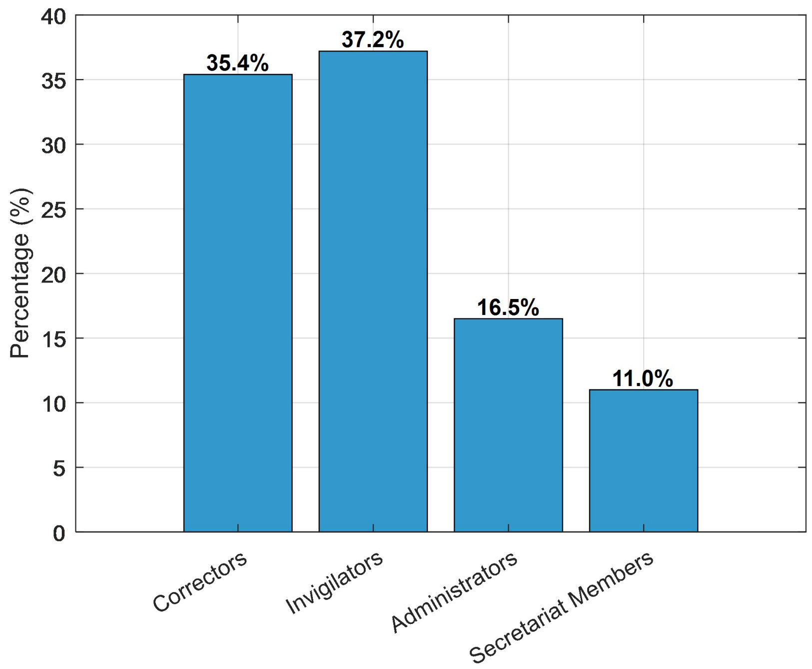

Figure 6. Role distribution.

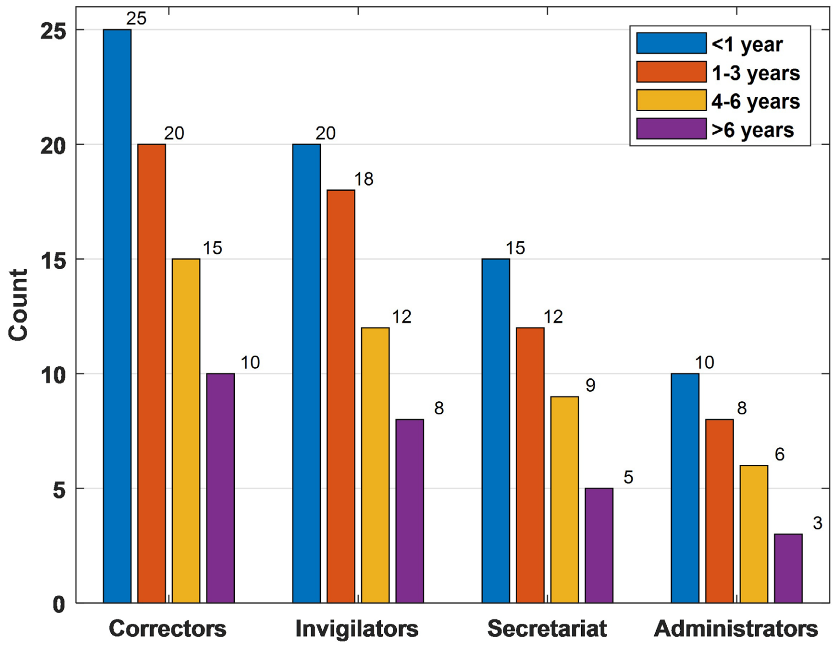

Figure 7. Professional experience distribution.

This breakdown reflects a balanced representation across the key actors involved in the BTS examination logistics chain, ensuring that diverse operational perspectives were captured. In addition to roles, the survey also considered the professional experience of respondents. As shown in Figure 7 below.

In terms of professional experience, 41% of participants reported having between 4 to 6 years of experience, 32% had 1 to 3 years, 18% had more than 6 years, while 9% were relatively new with less than one year of engagement. The diversity in experience levels allowed the study to capture both historical and recent perspectives on logistical challenges.

3.3. Pareto Analysis of Incidents

To identify the most impactful disruptions within the BTS examination logistics system, a Pareto analysis was conducted, drawing from the frequency of reported incidents across all twelve logistical phases. In accordance with the 80/20 principle, the objective was to isolate a small set of incidents responsible for the majority of systemic disruptions, thereby enabling strategic and prioritized intervention.

From the complete list of incidents reported in the dataset, six critical incidents emerged as accounting for 82% of total disruptions observed by the 164 respondents. These incidents, along with their frequencies and associated phases, are presented in Table 4.

Table 4. Top six incidents identified via Pareto analysis.

Rank	Incident	Frequency (%)	Cumulative (%)	Logistics Phases
1	Payment delays and remuneration disparities	24%	24%	Phase 6
2	Regulatory weaknesses and inconsistencies	18%	42%	Phases 6, 11
3	Improper geographical assignment of staff	14%	56%	Phase 5
4	Errors or missing examination documents	12%	68%	Phases 2, 4, 9
5	Under enforced invigilator to candidate ratio	8%	76%	Phase 7
6	Inadequate incident response mechanisms	6%	82%	Phase 10

These six incidents alone represent the most recurrent and disruptive failures in the BTS logistics chain. As shown in Figure 8, the Pareto chart confirms the principle of disproportionate impact, whereby a small number of incident types account for the majority of operational disruptions. In this case, the top six incidents represent 82% of the reported issues, making them prime targets for corrective and preventive actions.

The most recurrent issues are payment delays and remuneration disparities (24%), followed by regulatory weaknesses (18%) and improper geographical assignment of staff (14%). These top three incidents alone represent 56% of all reported disruptions, highlighting the need for urgent attention to financial, regulatory, and planning aspects of the process.

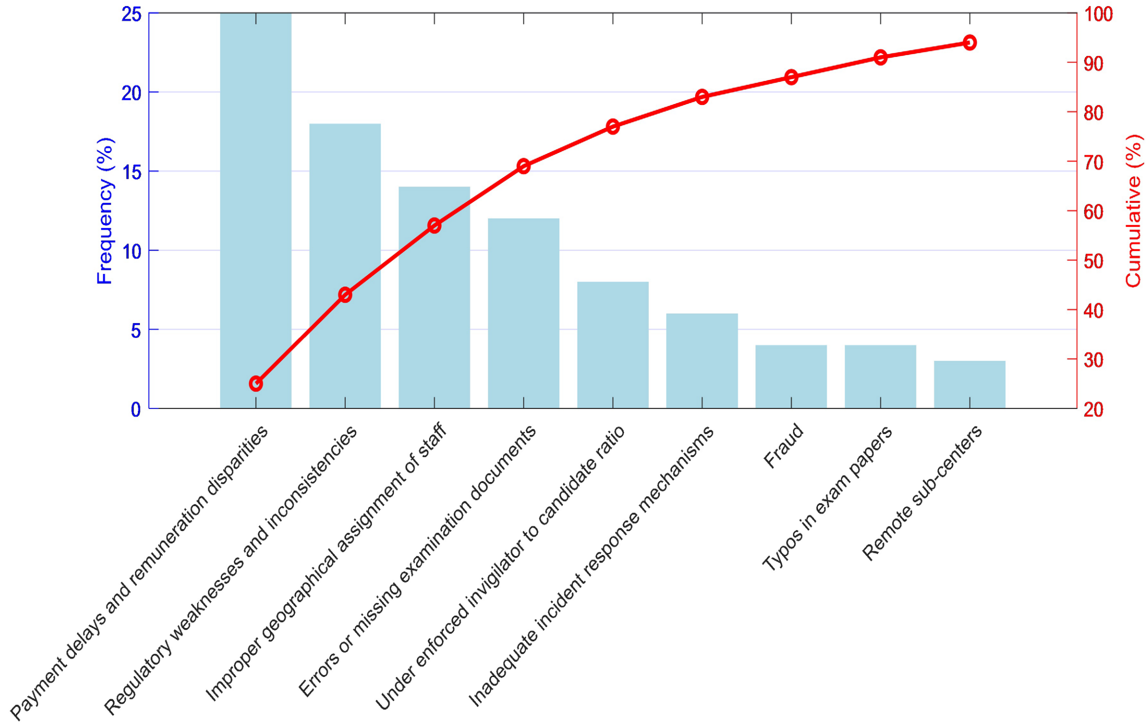

Figure 8. Pareto chart of critical and secondary incidents in the BTS logistics chain.

Secondary incidents, including fraud (4%), typos in exam papers (4%), and remote sub-centers (3%), though less frequent individually, collectively represent 18% of issues and are non-negligible. Their inclusion helps to provide a comprehensive view of the logistical vulnerabilities across different phases, such as surveillance, material preparation, and administrative coordination.

The concentration of high-impact failures in financial management, regulatory clarity, staff deployment, and incident response mechanisms reveals significant vulnerabilities at both the planning and operational stages of the logistics chain. Moreover, the presence of secondary incidents, such as fraud, typographical errors in exam materials, and the remoteness of certain sub-centers, highlights the need for continuous quality control across all phases.

These insights justify the application of structured analytical tools, such as the Ishikawa diagram and Failure Mode and Effects Analysis (FMEA) in the following sections, to systematically identify root causes and prioritize risks based on their severity, occurrence, and detectability.

3.4. Root Cause Analysis (Ishikawa)

Having identified six major incidents through Pareto analysis, a structured root cause analysis was conducted using the **Ishikawa Diagram** (also known as the

Fishbone Diagram), based on the **5M framework**: *Manpower*, *Methods*, *Materials*, *Machines*, *and Milieu* (Environment). This method is particularly relevant for logistics systems involving multiple stakeholders and operational tiers. Each major incident was deconstructed to identify its underlying causes, which were then categorized according to the 5M dimensions. Table 5 summarizes the leading root causes associated with each of the six critical incidents.

Table 5. Summary of root causes per major incident.

Major Incident	Manpower	Method	Material	Machine	Milieu
Payment delays and remuneration disparities	Lack of training, delayed reporting, poor communication	No standard process, centralized decisions	Unclear roles, manual errors	No e-payment, paper-based workflows	Budget delays, legal voids
Regulatory weaknesses and inconsistencies	Inconsistent understanding of policies	Vague or conflicting regulations	Outdated or missing procedural manuals	Lack of digital regulation database	Overlapping jurisdictions, political interference
Improper geographical assignment of staff	Poor HR planning, favoritism	Lack of assignment criteria	Missing deployment data	No allocation software	Demographic imbalances, local constraints
Errors or missing examination documents	Untrained staff, low attention to detail	No quality control in document validation	Poor printing quality, missing templates	Manual handling of sensitive materials	Time pressure, inadequate funding
Under-enforced invigilator-candidate ratio	Staff shortages, absenteeism	Weak planning guidelines	Misestimated candidate numbers	No attendance tracking tools	Rural deployment challenges, late approvals
Inadequate incident response mechanisms	Lack of emergency training	No incident management plan	Incomplete contact directories	No hotline or alert system	Lack of contingency budget, unstable networks

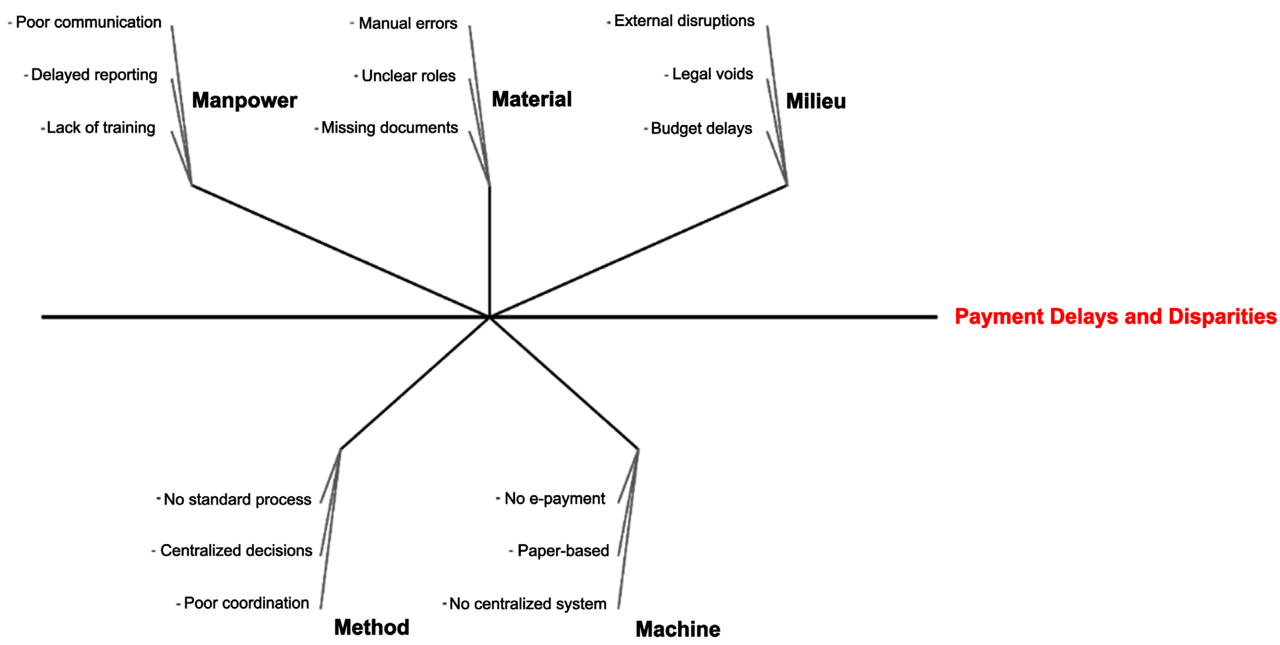

Figure 9. Ishikawa diagram of root causes for payment delays and remuneration disparities.

To visually illustrate the multi-factor causes of the most critical incident, Payment delays and remuneration disparities, an Ishikawa diagram was developed (see Figure 9).

This Ishikawa analysis reveals that process inefficiencies, weak coordination, and lack of digital tools are key contributors to payment delays.

3.5. Risk Prioritization with FMEA

Following the Ishikawa root cause analysis, a Failure Modes and Effects Analysis (see Table 6 below)was conducted to prioritize risks associated with each of the six critical incidents identified in the BTS logistics chain. FMEA is a systematic method used to evaluate the potential failure points in a process, assess their impact, and guide decision-makers toward mitigation strategies.

Table 6. FMEA results.

Incident	S	O	D	RPN	Priority
Payment delays and remuneration disparities	4	3	4	48	Very High
Regulatory weaknesses and inconsistencies	3	3	4	36	High
Improper geographical assignment of staff	3	2	3	18	Moderate
Errors or missing examination documents	3	2	3	18	Moderate
Under-enforced invigilator to candidate ratio	3	2	2	12	Moderate
Inadequate incident response mechanisms	4	2	4	32	High

The FMEA used a 1-to-4 scale for each of the three standard dimensions:

- **Severity (S):** Impact of the failure on the logistics chain, where:
  - 1 = Minor (little to no disruption)
  - 2 = Moderate (localized or recoverable issue)
  - 3 = Significant (affects major logistics nodes or outputs)
  - 4 = Critical (jeopardizes overall system performance or credibility)
- **Occurrence (O):** Likelihood of the failure happening again, where:
  - 1 = Rare (less than once per year)
  - 2 = Occasional (1 - 2 occurrences per year)
  - 3 = Frequent (happens in most sessions)
  - 4 = Systematic (happens each session or structurally embedded)
- **Detection (D):** Ability to detect the failure before impact, where:
  - 1 = High (clear monitoring and control systems)
  - 2 = Moderate (manual checks, some automation)
  - 3 = Low (ad hoc controls or inconsistent detection)

○ 4 = Very Low (no detection system in place)

Each incident's Risk Priority Number (RPN) was calculated as:

$$\text{RPN} = \text{Severity} \times \text{Occurrence} \times \text{Detection}$$

3.6. Analysis of Secondary Incidents

While the top six incidents identified through Pareto analysis and evaluated via FMEA account for over 80% of observed disruptions in the BTS logistics chain, several secondary incidents, though less frequent, pose residual vulnerabilities that can compromise specific phases of the process. These incidents, summarized in Table 7, tend to be episodic or context-specific, but remain strategically significant. They were consistently reported through open-text survey responses and interviews with examination coordinators, highlighting their relevance in field operations.

Table 7. Notable secondary incidents by phase.

Phase	Secondary incident	Observed risk	Strategic concern
Phase 2	Typos in printed examination subjects	Risk to credibility and fairness	Could trigger disputes or annulments
Phase 4	Inaccessibility of sub-centers	Equity delay risk	Disadvantages for remote candidates and staff
Phase 6	Untrained support staff	Payment processing delay	May exacerbate delays and disparities
Phase 7	Lax oversight by invigilators	Increased risk of fraud	Undermines exam integrity
Phase 10	Lack of escalation protocol	Response delays	Slow mitigation of disruptions

These incidents may not cross the Pareto frequency threshold, but they demonstrate amplified contextual severity under certain conditions, such as during last-minute staff substitutions, exam center overloads, or high-stakes subject areas. Their presence can lead to:

- Compounded effects when co-occurring with major incidents (e.g., typos combined with late document delivery),
- Revealing latent control gaps in internal logistics systems,
- Eroding stakeholder trust, particularly among exam candidates and local coordinators.

To ensure a resilient and quality-driven logistics chain, these secondary incidents must not be overlooked. Instead, they should be:

- Incorporated into routine monitoring and internal audits,
- Addressed via scenario-based training for operational staff,
- Tracked using feedback loops from field actors.

While primary mitigation efforts rightly focus on high-impact issues identified through FMEA, a robust quality assurance framework also requires proactive management of secondary incidents, not because of their frequency, but because of their disruptive potential and reputational risk.

4. Discussion

4.1. Key Findings and Theoretical Implications

The integrated application of Pareto analysis, Ishikawa diagrams, and Failure Modes and Effects Analysis (FMEA) in this study provides a coherent framework to map the distribution, origin, and criticality of logistical disruptions across the BTS examination chain. Beyond empirical findings, this section synthesizes interpretive insights that inform logistics theory, risk management, and educational governance.

The analysis confirms the Pareto principle, with approximately 20% of incident types accounting for over 80% of operational disruptions. This observation aligns with established logistics theory, which suggests that failure points tend to cluster around a few recurrent vulnerabilities rather than being evenly distributed. In the BTS logistics system, six major incident categories dominate the risk profile, revealing systemic inefficiencies rather than isolated events.

The Ishikawa-based root cause exploration emphasizes that logistical failures are not just operational accidents but arise from interconnected organizational weaknesses:

- Manpower issues (e.g., unclear roles, undertraining) reinforce errors across multiple phases.
- Process gaps (e.g., non-standard payment protocols) highlight weaknesses in institutional governance.
- Technological constraints (lack of digitized tools) exacerbate delays and data mismanagement.

These findings reinforce systems theory in logistics and public administration, which posits that disruptions often emerge and propagate through interconnected nodes in complex, multi-actor systems.

By adapting industrial-grade tools like FMEA and Ishikawa diagrams to the education sector, this study introduces a methodological innovation that bridges logistics engineering and public service delivery. Traditionally used in manufacturing, aerospace, and healthcare, these tools prove highly effective in diagnosing and prioritizing risks in examination logistics. This reflects a transdisciplinary convergence between logistics risk modeling and educational process engineering.

The study also underscores the importance of organizational learning theory. Actors across the logistics chain, correctors, invigilators, examiners, and secretariat staff contributed critical observations that enabled the surfacing of latent failures. When these insights are systematically gathered through diagnostic tools and feedback mechanisms, they establish a knowledge loop essential for continuous quality improvement. In the context of expanding candidate volumes and increasing complexity, such knowledge-driven processes are vital for building institutional resilience, ensuring that the BTS logistics system evolves in a sustainable and responsive manner.

A critical cross-cutting theme identified in this study is the insufficiency of formal staff training programs across multiple logistics phases. While actors such as invigilators and secretariat staff play pivotal roles in documentation control and fraud prevention, most operate without standardized induction or simulation-based training. Particularly in Phases 7 (Surveillance), 9 (Secretariat), and 10 (Incident Management), the absence of structured training contributes directly to human error, procedural inconsistency, and poor response capability. Institutionalizing modular, competency-based training curricula—aligned with each logistics phase—would significantly enhance preparedness, accountability, and adherence to regulatory protocols.

4.2. Practical Recommendations

Table 8 below presents a synthesis of actionable and phase-specific recommendations derived from the integrated diagnostic analysis using Pareto, Ishikawa, and FMEA tools. Each recommendation targets a critical weakness identified in the BTS examination logistics chain and proposes concrete measures aimed

Table 8. Recommendations for strengthening BTS examination logistics in Cameroon.

Recommendation Area	Phases Concerned	Main Action	Expected Impact	Support Measures
Financial Transparency & Payment Systems	Phase 6 & 11	Implement a centralized digital payroll system integrated with mobile money or Orange money platforms. Introduce blockchain-based audit trails for traceability. Geo-tag work to align payment with services rendered	Reduces delays and inconsistencies, enhaces fairness, builds trust across examination centers.	- Standardize contracts. Integrate staff verification with geo-location data-train finance teams on digital tools. - Align with national pay scales. - Provide user tracking portals.
Regulatory inconsistencies	Phase 1 & 11	Develop and disseminate a unified logistics regulation manual.	Reduces ambiguities, Standardized procedures, enforces consistency across exam centers.	- Create a regulatory oversight body. - Train stakeholders on updated protocols.
Staff allocation errors	Phase 5	Use GIS-based assignment tools factoring proximity and availability.	Enhances timeliness, reduces costs, ensures fair distribution of duties, efficient deployment.	- Maintain geolocation database. - Integrate availability into the platform.
Documentation and Data Control	Phase 2, 4, 9	Deploy a three-tier QC system for subjects, lists, and records.	Prevents errors and strengthens confidence in logistics documents.	- Train staff in document auditing. - Establish archival protocols.
Surveillance & Anti-Fraud Enforcement	Phase 7	Set invigilator-to-candidate ratios and conduct pre-deployment briefings.	Reduces fraud, Reduced malpractice, enhances procedural compliance.	- Mobile-based monitoring apps. - Conduct supervision quality audits.
Incident Management & Institutional Learning	Phase 10	Implement structured incident reporting with escalation paths.	Improves response speed and builds institutional memory.	- Train actors on reporting. - Monitor incidents via dashboard tools.

at improving system resilience, equity, and operational efficiency. For clarity, the recommendations are grouped according to the dominant incident categories and their respective logistics phases.

In response to the systemic weaknesses identified across the BTS logistics chain, particularly regarding payment delays, staff allocation, and document processing, the integration of digital technologies emerges as a strategic imperative. Several tools are proposed:

- A centralized digital payroll system with real-time tracking would ensure transparent, automated disbursement of compensation to correctors, invigilators, and secretariat members. Integration with mobile money platforms can overcome banking infrastructure limitations in remote areas.
- GIS-based staff assignment platforms would enable the fair and proximity-based deployment of human resources. This would optimize travel time, reduce costs, and prevent geographical mismatches in staff placement.
- Digital dashboards for incident tracking could facilitate real-time monitoring and rapid escalation of logistical disruptions. These tools would integrate field reports, enabling early detection and corrective action.
- E-documentation systems, including the digitization of exam scripts, attendance sheets, and correction records, would improve traceability and reduce the risk of material loss or manipulation.

These technologies can significantly improve coordination, accountability, and resilience across the logistics chain and should be prioritized in upcoming reform cycles.

4.3. Study Limitation and Future Perspectives

4.3.1. Limitations

Despite offering a robust and original diagnosis of logistical dysfunctions in the organization of national examinations in Cameroon, this study presents several limitations that must be acknowledged for a balanced interpretation of its findings. The analysis was conducted exclusively in the city of Douala. While Douala is a critical examination hub due to its high candidate volume and logistical intensity, the findings may not fully capture the specific constraints and operational realities of rural, remote, or less centralized regions. Moreover, the empirical focus was limited to the BTS examination, selected for its strategic significance and complexity. However, other national exams, such as the Baccalauréat, BEPC, or HND, follow different logistical architectures, which may involve distinct dysfunctions, thereby limiting the generalizability of the conclusions across the broader education system.

In terms of methodology, although triangulated approaches were employed, including questionnaires and interviews, the data may be subject to recall bias or social desirability effects, especially when dealing with sensitive topics such as payment irregularities or procedural non-compliance. Analytical tools borrowed from industrial diagnostics, such as Pareto analysis, Ishikawa diagrams, and FMEA, were effectively adapted to the educational context. Nevertheless, these tools may not fully capture the behavioral and institutional complexities that often underpin public service delivery outcomes.

Finally, while the study draws on insights from multiple examination cycles, its retrospective nature represents a further limitation. The absence of continuous or real-time monitoring mechanisms restricts the capacity to detect emerging risks dynamically or assess the long-term impact of any reforms implemented.

4.3.2. Furture Perspectives

Building on the insights and methodological innovations of this study, several avenues for future research and institutional improvement are proposed.

First, future studies should expand their geographic scope to include rural, border, and conflict-affected areas in order to capture a more comprehensive and representative picture of logistical challenges nationwide. Similarly, analyzing other major national examinations, such as the Baccalauréat or BEPC, could help identify exam-specific logistical risks and allow for comparative analysis across examination types.

Second, the development of digital dashboards and continuous data collection systems is recommended to facilitate real-time monitoring of logistics performance, enhance predictive analytics, and support timely corrective interventions during examination periods.

- Extend the methodology to other national examinations (e.g., Baccalauréat, BEPC) for comparative insights.
- Explore the integration of advanced analytics and AI tools for predictive and adaptive exam logistics management.

In addition to extending geographic scope and digitizing current systems, future research should explore the integration of machine learning and artificial intelligence into the examination logistics ecosystem. Historical data collected through FMEA scoring and incident logs provide a fertile foundation for developing predictive models. These models can be trained to forecast payment delays, absenteeism, or document mismanagement based on prior incident patterns, stakeholder roles, and exam phases. AI can also power adaptive logistics dashboards, capable of reallocating staff or resources dynamically in response to predicted failures. Integrating such intelligent systems would transform current logistics governance from reactive to predictive, enhancing resilience in real-time.

5. Conclusions

This study has provided a systematic analysis of logistical failures in the administration of Cameroon's Brevet de Technicien Supérieur examinations, with particular focus on the high-volume testing center of Douala. Through the novel application of an integrated Pareto-Ishikawa-FMEA analytical framework, the research has identified that approximately 80% of operational disruptions stem from six core systemic weaknesses: payment processing delays, regulatory inconsistencies, inefficient staff allocation, documentation errors, insufficient supervision ratios, and inadequate incident management protocols.

The methodological innovation of this work lies in its successful adaptation of industrial quality control tools to the education sector, demonstrating their efficacy in diagnosing complex public service delivery challenges. The findings not only validate the Pareto principle's applicability to educational logistics but also reveal the interconnected nature of logistical failures, where human resource factors, procedural gaps, and technological limitations collectively undermine system performance.

From a theoretical perspective, this research makes significant contributions by bridging the domains of operations management and educational administration. It establishes a proof of concept for applying manufacturing sector quality assurance methodologies to public sector contexts, particularly in developing economies where institutional weaknesses often mirror those found in underperforming production systems.

Practically, the study provides education policymakers with empirically grounded priorities for intervention. The identified dysfunction areas demand immediate attention through targeted measures, including digital transformation of payment systems, standardization of operating procedures, implementation of geospatial staff allocation tools, and establishment of robust quality control mechanisms for examination documents. Furthermore, the research underscores the necessity of developing institutional learning systems to enable continuous improvement in examination logistics.

While the study's findings are particularly relevant to Cameroon's BTS examinations, the methodological framework and many of the identified solutions possess transferability to other national examinations and similar contexts in developing nations. Future research should explore the framework's application to other high-stakes testing environments and investigate the potential of emerging technologies, such as artificial intelligence and blockchain, to further enhance the resilience and transparency of examination logistics systems.

Furthermore, this work advocates for the progressive digitization of logistics operations and the use of machine learning models to enable predictive management of exam logistics. These technologies offer an opportunity to transition from fragmented manual workflows to an intelligent, data-driven ecosystem capable of preempting failures and dynamically reallocating resources based on real-time constraints.

In conclusion, this study offers both a diagnostic tool and a reform roadmap for educational authorities seeking to strengthen the integrity and efficiency of national examination processes. By addressing the systemic weaknesses identified through this research, education systems can better ensure equitable access, maintain academic standards, and preserve public confidence in national certification mechanisms - all of which are fundamental to human capital development and socioeconomic progress.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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