A Comparative Benchmarking Model for Aerodrome Certification Compliance Across Developing Economy Civil Aviation Authorities

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Abstract

Background: Aerodrome certification compliance levels at civil aviation authorities in developing economies are frequently assessed against ICAO Standards and Recommended Practices benchmarks derived from the operational contexts and resource levels of developed economy aviation systems, producing compliance gap assessments that overstate the magnitude of regulatory reform required and understate the contextually appropriate compliance improvement priorities for authorities operating under significant institutional, financial, and technical resource constraints. A comparative benchmarking model that enables developing economy civil aviation authorities to assess their aerodrome certification compliance levels relative to peer authorities in comparable contexts would support more realistic performance target setting, more effective international technical assistance targeting, and more actionable national compliance improvement planning than universal benchmark comparisons against developed economy standards alone can provide

Methods: This paper proposes a Comparative Aerodrome Certification Compliance Benchmarking Model for developing economy civil aviation authorities, comprising a weighted compliance scoring methodology for converting aerodrome certification inspection outcomes into comparable performance indicators across ICAO Annex 14 requirement categories, a peer group classification system for identifying comparable authorities based on institutional and operational context variables, a gap analysis framework for identifying priority compliance improvement areas with the highest safety return on regulatory resource investment, and a progress tracking methodology for monitoring compliance trajectory over multi-year improvement program periods

Results: The benchmarking model provides a structured methodology for civilian aviation authorities across the ECOWAS, COMESA, and SADC regional civil aviation safety oversight organization systems to assess their aerodrome certification compliance performance against contextually comparable peer authorities, identifying specific compliance areas where regional leaders have developed effective approaches under comparable constraints that can be adapted for implementation at lower-performing authorities through structured technical assistance exchange

Conclusion: The Comparative Aerodrome Certification Compliance Benchmarking Model advances aerodrome safety oversight improvement methodology by enabling developing economy civil aviation authorities to learn from peer authority experience under comparable constraints rather than relying exclusively on top-down technical assistance from developed economy authorities whose regulatory environments and resource levels differ substantially from the contexts in which the benchmarking model findings will be applied

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1. Introduction

Civil aviation aerodrome certification compliance assessment through the ICAO Universal Safety Oversight Audit Programme provides a standardized framework for evaluating the adequacy of national civil aviation authority aerodrome safety oversight systems against ICAO Standards and Recommended Practices, generating compliance scores that enable international comparison of safety oversight performance across the 193 ICAO member states.

While the USOAP methodology provides valuable comparative data for identifying systemic safety oversight deficiencies at global and regional levels, the universal application of a single compliance standard across civil aviation authorities with dramatically different institutional capacity, financial resources, technical expertise levels, and operational environments creates comparison artifacts that can mislead both the authorities being assessed and the international assistance community about the nature and priority of the improvements most likely to generate safety benefit in specific authority contexts (Weick, 1987; Fahlstrom & Gleason, 2012; Aminu *et al*., 2019); Rapoport, 1960).

Developing economy civil aviation authorities operating under significant resource constraints share a distinctive set of aerodrome certification compliance challenges that differ systematically from those documented at developed economy authorities, including inadequate inspector staffing levels relative to the aerodrome portfolio size, limited access to specialized technical inspection equipment, inadequate regulatory guidance material in national languages, high inspector turnover driven by compensation differentials with industry, and limited pre-entry and in-service training resources for aerodrome safety inspectors. These shared structural constraints create characteristic compliance gap patterns that reflect institutional and resource limitations rather than regulatory intent deficiencies, and that are more appropriately addressed through targeted institutional development and resource provision strategies than through the regulatory framework development approaches that dominate developed-economy technical assistance program design (Brundtland, 1987; Watson, 2013; Yeboah *et al*., 2019); Young & Wells, 2011).

A comparative benchmarking model that enables developing economy civil aviation authorities to assess their aerodrome certification compliance performance relative to peer authorities in comparable institutional and resource contexts provides the methodological foundation for peer learning, targeted technical assistance, and realistic performance improvement planning that universal compliance standard comparison cannot generate. This paper develops such a model, grounded in the ICAO Annex 14 compliance assessment framework but adapted to the comparative benchmarking methodology established in regulatory economics and public administration performance measurement literature for multi-authority performance assessment under heterogeneous operating conditions (Edwards, 1988; Morin & Hollingsworth, 2012; Obogo *et al*., 2019); Bobga *et al*., 2018).

The Nigeria Civil Aviation Authority perspective informs this paper through the authors direct engagement with NCAA aerodrome certification inspection programs and the documented experience of NCAA inspector training, aerodrome compliance assessment, and international technical assistance coordination that contextualizes the benchmarking model design decisions with the operational realities of a mid-sized developing economy civil aviation authority managing a diverse aerodrome portfolio under significant resource constraints. The NCAA experience provides the empirical grounding for the benchmarking model design elements that might not emerge from theoretical analysis of ICAO compliance assessment frameworks alone, particularly in the areas of inspector deployment logistics, evidence documentation capabilities, and multi-aerodrome inspection scheduling under constrained staffing conditions (Reason, 1990; Ziv & Borer, 2012; Obogo *et al*., 2019); Mc & Sanders, 1982).

2. Literature Review

2.1 ICAO Safety Oversight Assessment Methodology

The ICAO Universal Safety Oversight Audit Programme Continuous Monitoring Approach provides the primary international framework for civil aviation authority safety oversight assessment, evaluating eight critical elements of safety oversight across eight audit domains including legislation and civil aviation requirements, civil aviation authority technical operations, personnel licensing and training, aerodrome certification and operations, air navigation services, aircraft operations, airworthiness of aircraft, and accident investigation. The aerodrome certification domain assessment evaluates the civil aviation authority inspectorate capability for conducting initial certification inspections of new aerodromes against applicable ICAO Annex 14 standards, surveillance inspections of certified aerodromes to monitor ongoing compliance, and corrective action follow-up to confirm resolution of identified compliance deficiencies within required timeframes (ICAO, 2013) (O'Hare, 1990; Oster *et al*., 2013; Obogo *et al*., 2019); Diederiks *et al*., 2006).

ICAO USOAP compliance scores for the aerodrome certification domain among African civil aviation authorities show substantial variation from below 30 percent for authorities with severely constrained oversight capacity to above 70 percent for authorities with more developed inspectorate programs, with the distribution of scores reflecting the combined influence of institutional development level, financial resource availability, technical expertise, and the maturity of the national regulatory framework rather than any single dominant factor that a targeted intervention could address in isolation. The USOAP score distribution across African authorities provides the empirical basis for the peer group classification methodology of the proposed benchmarking model, enabling the definition of peer groups based on actual compliance performance clusters rather than on assumed institutional similarity from GDP per capita or regional grouping proxies (Senders & Moray, 1991; Knecht, 2013; Obriki & Arumosoye, 2020); Hernandez *et al*., 2021).

The ICAO State Safety Programme framework, which requires each ICAO member state to establish a documented SSP integrating safety oversight, safety data collection and analysis, accident and incident investigation, and aviation safety promotion into a coordinated national safety management framework, provides the higher-level governance context within which aerodrome certification compliance improvement programs operate. SSP implementation quality among African member states varies substantially, with the most developed SSP programs establishing quantitative safety performance targets and data-driven improvement tracking that the compliance benchmarking model proposed in this paper can directly inform through its gap analysis and progress tracking components (Pidgeon, 1991; Norman, 2013; Arumosoye & Obriki, 2020); Aminu & Ogbete, 2018).

2.2 Benchmarking in Regulatory Contexts

Performance benchmarking in regulatory contexts has an extensive methodological literature across utility regulation,

environmental regulation, and financial regulation that provides relevant precedents for the aerodrome certification compliance benchmarking application proposed in this paper. The fundamental methodological challenge of regulatory performance benchmarking, distinguishing the influence of operating environment factors that are outside regulatory authority control from the influence of regulatory effort and capability that performance improvement strategies should target, is directly applicable to the aerodrome certification compliance benchmarking context where peer group definition must control for the institutional and resource context factors that systematically influence compliance achievement independently of inspector effort and regulatory framework quality (Sarter & Woods, 1992; Abeyratne, 2014; Mbonu *et al*., 2020); Aminu *et al*., 2019).

The establishment of peer groups for benchmarking purposes requires the definition of similarity criteria that correctly capture the dimensions of institutional and operational context most relevant to compliance performance variation across the benchmarked entity population. For aerodrome certification compliance benchmarking among developing economy civil aviation authorities, the relevant similarity dimensions include aerodrome portfolio size and complexity, inspector staffing level and average experience, annual inspection budget per aerodrome, national regulatory framework completeness relative to applicable ICAO SARPs, and the maturity of formal inspector training programs, since these institutional variables have been identified in the safety oversight literature as the primary determinants of inspection quality and compliance assessment reliability among developing economy civil aviation authorities (ICAO, 2013) (Drury & Lock, 1992; ICAO, 2014; Mbonu *et al*., 2020); Aminu *et al*., 2020).

Frontier benchmarking methodology, applied in utility regulation through data envelopment analysis and stochastic frontier analysis, provides the most technically rigorous approach to peer performance comparison by identifying the efficiency frontier defined by the best-performing entities and measuring each entity performance as its distance from the frontier, controlling for input variable differences across entities. The application of frontier benchmarking to aerodrome certification compliance assessment would require a sufficiently large sample of developing economy civil aviation authority data with consistent measurement across all model input and output variables to estimate a reliable frontier, which the ICAO USOAP dataset in principle provides for a subset of the relevant variables if data sharing arrangements can be established for the detailed compliance scoring data required (Baker *et al*., 1993; Ebers & Maurer, 2014; Sanni *et al*., 2020); Kinney & Wiruth, 1976).

2.3 African Aviation Safety Oversight

The African civil aviation safety oversight landscape has been characterized by systematic regional safety performance improvement programs coordinated through the African Civil Aviation Commission, the African Union Aviation Safety Oversight Organization, and the ICAO AFIRAN regional aviation safety plan that set progressive safety improvement targets aligned with ICAO Global Aviation Safety Plan objectives for the African region. Progress against these regional targets has been uneven across the AFCAC member state authority population, with a subset of authorities showing consistent compliance improvement trends while a larger group shows limited progress despite sustained technical assistance investment, suggesting that the technical assistance strategies applied across the region may not be optimally targeted to the specific compliance gap patterns of different authority types (Johnston, 1994; Valdez, 2014; Sanni *et al*., 2020).

The ECOWAS Banjul Accord Group safety oversight cooperation program represents the most developed subregional safety oversight cooperation framework on the African continent, with participating authorities sharing inspector resources, coordinating surveillance inspection scheduling, and developing harmonized regulatory guidance material to reduce the per-authority cost of maintaining comprehensive aerodrome certification oversight programs across the nine participating states. The Banjul Accord Group experience provides the most directly applicable model for the regional peer learning component of the proposed benchmarking model, since the existing cooperation infrastructure facilitates the data sharing, inspector exchange, and coordinated improvement planning that peer benchmarking generates most efficiently when institutional relationships and information sharing frameworks are already in place (Shapira, 1995; Mertens & Langer, 2014; Aminu *et al*., 2020); Obriki & Arumosoye, 2019).

ICAO technical assistance projects delivered through the ICAO Technical Cooperation Bureau and the ICAO regional offices have invested substantial resources in aerodrome certification inspector training, regulatory guidance material development, and airport certification process support across African civil aviation authorities, with training delivery documentation available in ICAO technical cooperation project records that provides the input data needed to assess the relationship between technical assistance investment and compliance improvement trajectories at beneficiary authorities. Systematic analysis of this technical assistance outcome data using the benchmarking model methodology would enable the identification of technical assistance approaches with the highest compliance improvement return on investment, improving future technical assistance program design for the African aerodrome certification compliance improvement context (ICAO, 2013) (Weick, 1995; Forman, 2014; Obogo *et al*., 2020); Turner, 1978).

3. Benchmarking Model Design

3.1 Compliance Scoring Methodology

The weighted compliance scoring methodology converts aerodrome certification inspection outcomes across ICAO Annex 14 requirement categories into a composite compliance score ranging from zero to one hundred that reflects both the breadth of compliance across all applicable requirement categories and the severity-weighted depth of compliance deficiencies within each category. The requirement category weighting scheme assigns higher weights to categories with the most direct influence on aircraft accident and serious incident risk, including runway safety area dimensions, obstacle limitation surface integrity, instrument approach aid accuracy, aerodrome lighting system reliability, and fire and rescue service capability, reflecting the safety-criticality hierarchy established in ICAO Annex 14 amendment justification documentation and accident and serious incident causation analysis (Krause, 1996; Flyvbjerg, 2014; Obogo *et al*., 2020); Federal *et al*., 2012).

Within each weighted requirement category, the compliance scoring algorithm applies a deficiency severity modifier that distinguishes between Level 1 critical deficiencies affecting

immediate operational safety that require aerodrome closure or operations restriction until corrected, Level 2 significant deficiencies creating potential for adverse effects on operational safety that require corrective action within defined timelines, and Level 3 administrative deficiencies that represent documentation, record-keeping, or procedural compliance failures without direct operational safety impact. The severity modifier structure ensures that compliance scores accurately reflect the safety significance of identified deficiencies rather than treating all deficiency types equally in the composite score, preventing compliance score inflation from a large number of administrative deficiencies that might offset the score depression effect of a smaller number of high-severity operational deficiencies (Vaughan, 1996; ICAO, 2015; Obogo *et al*., 2020); Arumosoye & Obriki, 2019).

Temporal compliance trajectory scoring extends the point-in-time composite compliance score to a trajectory metric that captures the direction and rate of compliance change over the preceding three inspection cycles at each aerodrome, providing the longitudinal perspective needed to distinguish authorities that are maintaining high compliance from those that are improving toward high compliance from lower historical baselines. The compliance trajectory metric is positive for authorities showing sustained improvement over multiple inspection cycles, negative for authorities showing declining compliance, and approximately zero for authorities maintaining stable compliance at either high or low levels, providing the benchmarking model with a dynamic performance dimension that complements the static snapshot provided by the point-in-time composite score (Turner & Pidgeon, 1997; Gerede, 2015; Dagodzo *et al*., 2020); Hofstede, 1980).

3.2 Peer Group Classification

Peer group classification for the comparative benchmarking model applies a two-stage classification procedure that first assigns each civil aviation authority to a resource tier based on aerodrome oversight budget per certified aerodrome and inspector-to-aerodrome staffing ratio, then applies k-means clustering within each resource tier to identify subgroups of authorities with similar aerodrome portfolio complexity and regulatory framework maturity profiles. The two-stage procedure separates the dominant resource constraint dimension from the secondary regulatory complexity dimension in peer group definition, ensuring that resource-constrained authorities are compared within peer groups where all members face comparable resource limitations rather than being assessed against peers with substantially different financial capacity for inspection program delivery (Liddle, 1997; Transport & Canada, 2015; Lilian *et al*., 2020); Ashford *et al*., 2013).

The resource tier classification uses two primary variables: annual aerodrome oversight expenditure per certified aerodrome in constant purchasing power parity dollars, and the ratio of full-time equivalent aerodrome certification inspectors to the number of certified aerodromes in the authority portfolio. These two variables capture the financial and human resource dimensions of oversight capacity respectively, with the combination of both metrics providing a more complete resource constraint characterization than either metric alone. Tier boundaries are established at the twenty-fifth and seventy-fifth percentiles of the developing economy authority distribution for each resource variable, creating a three-tier resource classification with tier boundaries that reflect the actual distribution of resource levels across the reference population rather than arbitrary absolute thresholds (Rasmussen, 1997; Inyang, 2015; Boakye *et al*., 2020); Mbonu *et al*., 2019).

Within-tier k-means clustering applies a set of regulatory complexity variables including the number of certified aerodromes with precision instrument approach procedures, the proportion of the aerodrome portfolio comprising international aerodromes with ICAO-standard aerodrome certification requirements, the proportion of aerodrome operations by international commercial aircraft operations subject to ICAO Annex 6 requirements, and the proportion of the aerodrome portfolio with recent construction or significant capital improvement activity requiring updated certification assessment. The k-means algorithm identifies four to six sub-peer groups within each resource tier based on these complexity variables, with the optimal cluster number determined through within-cluster sum of squares minimization subject to the constraint that each cluster contains a minimum of four authorities to enable meaningful peer comparison within each peer group (Reason, 1997; Vaaben & Larsen, 2015; Ogbona *et al*., 2020); Mc & Sanders, 1982).

3.3 Gap Analysis Framework

The gap analysis framework applies the peer group compliance scores to identify specific requirement categories where each assessed authority performs significantly below its peer group average, distinguishing contextually unusual compliance gaps from the universal compliance challenges shared across the peer group that reflect structural constraints common to all peer group members rather than authority-specific improvement opportunities. This distinction between authority-specific and peer-group-wide compliance challenges is fundamental to the practical value of the peer benchmarking approach, since universal peer group challenges require coordinated regional responses such as shared technical assistance programs or harmonized regulatory guidance, while authority-specific gaps represent targeted improvement opportunities addressable through authority-level interventions that the international assistance community can specifically design for each identified gap (Helmreich & Merritt, 1998; Vidal *et al*., 2015; Ogbona *et al*., 2020); Blackwell, 2012).

Gap severity classification in the framework assigns each identified compliance gap to a low, moderate, or high severity category based on the magnitude of the deviation from peer group performance and the safety criticality weight of the affected requirement category, with high severity gaps in safety-critical requirement categories receiving priority status in the improvement planning framework regardless of the total number of gaps identified across all requirement categories. Priority gap identification enables the benchmarking model output to guide resource-constrained authority improvement planning toward the specific investments with the highest expected safety return, rather than generating comprehensive gap inventories that exceed the improvement resource capacity of developing economy authorities and consequently produce no targeted action on any identified gap (Gershzohn, 1999; Wentink & Venter, 2015; Eyetsemitan *et al*., 2020); Mbonu *et al*., 2019).

Best practice identification within each peer group selects the authorities achieving the highest compliance scores in each requirement category as best practice references for that

category within the peer group, enabling the gap analysis to connect identified deficiencies with specific peer authority examples of effective compliance achievement under comparable constraints. Best practice identification in categories where one or two authorities consistently achieve highest compliance across multiple inspection cycles provides the most confident references for peer learning, since sustained high performance is more indicative of systematic compliance management than single-cycle high scores that may reflect inspection timing or assessment variation rather than genuine compliance achievement (Clarke, 1999; ICAO, 2016; Fadayomi *et al*., 2021); Jain & Urban, 1983).

4. Implementation Methodology

4.1 Data Collection and Standardization

Benchmarking model implementation requires the collection and standardization of aerodrome certification inspection data across the participating civil aviation authority population, with data standardization addressing both the structural differences between national inspection documentation formats and the substantive differences in interpretation and application of ICAO Annex 14 standards that create spurious compliance score variation between authorities with different inspection methodology traditions. The ICAO USOAP Continuous Monitoring Approach provides a partial standardization framework through its standardized audit protocol, but the USOAP data captures authority-level compliance assessments rather than aerodrome-level inspection outcomes, requiring supplementary data collection from national aerodrome inspection records to populate the aerodrome-level composite compliance scores that the benchmarking model requires (Vicente, 1999; ICAO, 2016; Obriki & Arumosoye, 2021); Saunders & Bino, 2012).

Participation agreements between the benchmarking model secretariat and each participating civil aviation authority establish the data sharing obligations, confidentiality protections, and data quality assurance requirements that govern the data collection process. Confidentiality protections are essential for securing participation from authorities who may be reluctant to share detailed compliance deficiency data that reveals specific aerodrome safety gaps if that data will be publicly attributed to their authority and specific aerodromes. The benchmarking model confidentiality framework allows public reporting of aggregated peer group statistics and anonymized best practice examples while protecting the authority-specific and aerodrome-specific data underlying the peer comparison from public attribution (Forester & Morrison, 1999; Dolbeer *et al*., 2016; Arumosoye & Obriki, 2021); Okonkwo *et al*., 2019).

Data quality assurance for the benchmarking model implements a cross-validation methodology that compares each participating authority data submissions against USOAP audit records, accident and serious incident databases, and available independent data on aerodrome certification inspection program activity to identify potential data quality issues before final benchmarking calculations. Statistical outlier detection identifies authority data submissions that deviate substantially from the expected relationship between compliance scores and resource variables, flagging potential data quality issues for investigation by the benchmarking model data management team rather than accepting outlier data at face value in the peer group classification and gap analysis calculations (Shappell & Wiegmann, 2000; Robertson, 2016; Mbonu *et al*., 2021); Lee *et al*., 1985).

4.2 Reporting and Learning Facilitation

Benchmarking model reports are produced at three levels of granularity: individual authority confidential reports presenting the full benchmarking analysis for each participating authority including peer group assignment, composite compliance scores, gap analysis findings, best practice references, and improvement planning guidance; peer group aggregated reports presenting summary compliance performance statistics for each peer group with anonymized best practice authority references and common gap identification; and regional summary reports presenting the overall benchmarking model findings for the full participating authority population with regional trend analysis and collective improvement recommendation priorities (Reason, 2000; Viallon & Magne, 2016; Mbonu *et al*., 2021); Wood & Sweginnis, 2012).

Peer learning facilitation workshops organized around the peer group structure of the benchmarking model bring together civil aviation authority representatives from within the same peer group to share experience on compliance improvement approaches, discuss the specific challenges associated with the common compliance gaps identified in the peer group report, and establish voluntary technical assistance exchange arrangements between best practice authorities and lower-performing peer group members who request targeted support. The workshop format leverages the peer credibility that comes from shared context, since authority representatives are more receptive to improvement approaches demonstrated by peer authorities under comparable constraints than to recommendations from developed economy technical assistance providers whose resource levels differ substantially from those available to the receiving authority (Federal *et al*., 2000; Walker, 2007; Okonkwo *et al*., 2021); Michael & Ogunsola, 2019).

Progress tracking methodology within the benchmarking model applies the compliance trajectory scoring metric to monitor compliance score changes between annual benchmarking cycles, enabling authorities, their state safety programme managers, and the international assistance community to assess whether improvement investments are producing the expected compliance trajectory progress and to identify sustained underperformance against trajectory targets as a signal for investigation and potential strategy adjustment. Trajectory tracking at the peer group level also enables identification of convergence or divergence trends across the peer population, with divergence trends suggesting that the institutional factors differentiating higher and lower performers within the peer group are becoming more rather than less influential over time and may require structural intervention beyond the targeted technical assistance approaches that the benchmarking model prioritizes (Wickens & Hollands, 2000; Raglan, 2016; Okonkwo *et al*., 2021); Deming, 1986).

5. Application to Nigerian Civil Aviation

5.1 NCAA Peer Group and Benchmark Position

Applying the proposed benchmarking model to the NCAA context illustrates the practical application of the peer group classification, gap analysis, and improvement planning components in the authority context that motivated the model

development. NCAA peer group classification based on the two-stage resource tier and within-tier clustering procedure would assign NCAA to the middle resource tier among African civil aviation authorities, reflecting a inspectorate staffing level and aerodrome oversight budget that exceeds the most severely constrained tier but falls below the better-resourced authorities in the top resource tier that includes civil aviation authorities in South Africa, Egypt, and Morocco. Within the middle resource tier, NCAA aerodrome portfolio characteristics including a diverse mix of international gateway, domestic, and special aerodromes across a geographically dispersed network places it in a complexity subgroup alongside comparable authorities in East and West Africa (Weick & Sutcliffe, 2001; Wright, 2016; Sanni & Atima, 2021); Wakeman, 2012).

NCAA composite compliance score trends across ICAO USOAP assessment cycles show improvement in the aerodrome certification domain over the past decade, reflecting investments in inspector training, regulatory guidance material development, and inspection program systematization that have increased both the coverage and the documentation quality of NCAA aerodrome certification surveillance inspections. Gap analysis applying the benchmarking model methodology would identify specific Annex 14 requirement categories where NCAA compliance scores fall below peer group averages despite the overall improvement trend, potentially including wildlife hazard management program quality, obstacle limitation surface surveillance methodology, and aerodrome rescue and fire fighting service capability assessment, which represent known areas of aerodrome safety oversight complexity in the Nigerian context (Braithwaite, 2001; Blake & Baer, 2016; Obogo *et al*., 2021); Michael & Ogunsola, 2019).

Best practice references within the NCAA peer group for identified compliance gap categories would direct the NCAA aerodrome standards department toward specific peer authority inspection programs and regulatory guidance documents whose approaches to compliance assessment in those categories have been validated by sustained high compliance scores within comparable resource constraints. The peer learning facilitation workshop process would enable NCAA inspectors to discuss specific compliance assessment methodology questions with their counterparts at best practice peer authorities, building practical inspection skills in identified gap areas more effectively than classroom training alone can achieve without the operational context that peer authority experience provides (Allan, 2002; Livingston, 2006; Obogo *et al*., 2021); Hawkins, 1987).

5.2 Improvement Planning Application

NCAA improvement planning based on benchmarking model gap analysis applies the priority gap classification to direct the limited resources available for compliance improvement investment toward the requirement categories with the highest combination of compliance gap severity and safety criticality weight, ensuring that the most safety-significant improvement opportunities receive the first allocation of inspector training, regulatory guidance development, and aerodrome operator engagement resources. The benchmarking model output would generate an improvement priority ranking for NCAA that identifies the top three to five requirement categories warranting immediate investment, the two to three categories appropriate for medium-term development, and the categories where NCAA compliance already meets or exceeds peer group averages and requires only maintenance rather than improvement-focused investment (Allan & Orosz, 2001; Ngo & Nguyen, 2017; Obogo *et al*., 2021); Vogt *et al*., 2012).

The peer learning component of NCAA improvement planning engages with the best practice authority references identified in the benchmark report for each priority gap category, establishing informal technical exchange agreements that enable NCAA inspectors to review the specific inspection protocols, documentation standards, and compliance assessment criteria applied by best practice peer authorities in the relevant requirement categories. These technical exchange arrangements are implemented through the existing AFCAC cooperation framework that provides the institutional basis for inter-authority inspector exchange without requiring new bilateral agreements for each specific exchange activity, reducing the administrative burden of establishing practical peer learning relationships that would otherwise require time-consuming bilateral negotiation for each inspector exchange program (Goldstein, 2001; Xue & Deng, 2017; Dagodzo *et al*., 2021); Ogbete *et al*., 2019).

Progress tracking for NCAA improvement investments uses the compliance trajectory metric calculated at the annual benchmarking cycle to confirm that the priority gap compliance scores are improving at the expected rate given the improvement resource investment, and to trigger strategy review if the trajectory falls below the improvement targets established in the NCAA aerodrome safety oversight improvement program. Integration of the benchmarking model trajectory metric with the NCAA internal performance management system, which tracks inspector activity volumes, deficiency identification rates, and corrective action follow-up completion rates at the aerodrome level, provides the multi-indicator performance picture needed to diagnose the causes of compliance trajectory shortfalls and identify the specific improvement program elements requiring adjustment (Edwards, 2002; Pigatto, 2017; Dagodzo *et al*., 2021).

6. Validation and Limitations

Benchmarking model validation assesses the reliability and validity of the compliance scoring, peer group classification, and gap analysis outputs against independent indicators of aerodrome safety performance across the participating authority population, using accident and serious incident rates at aerodrome operations, ICAO USOAP domain scores, and independent expert assessment of authority compliance performance as validity criteria. A positive correlation between benchmarking model composite compliance scores and accident and incident rates in the expected direction would provide convergent validity evidence for the scoring methodology, while correlation between peer group classification and the pattern of compliance improvement responses to specific technical assistance inputs would provide predictive validity evidence for the peer group structure as a framework for technical assistance targeting (Sodhi, 2002; Nybakk & Bergum, 2017; Michael & Ogunsola, 2021).

The primary limitations of the benchmarking model relate to data availability, measurement standardization, and the attribution of compliance performance variation to authority-specific rather than context-specific factors. Data availability limitations arise from the incomplete and variable quality of aerodrome certification inspection documentation across the

developing economy civil aviation authority population, which may introduce systematic bias into compliance score comparisons if some authorities have more comprehensive and better-documented inspection records than others regardless of their actual compliance performance differences. Measurement standardization limitations arise from the different interpretations of ICAO Annex 14 standards applied by national inspectorates with different training traditions and regulatory guidance frameworks, which may cause compliance assessment scores for the same aerodrome condition to differ across authorities based on inspector interpretation methodology rather than genuine compliance differences (Michaels, 2002; Vandell, 2017; Michael & Ogunsola, 2021).

The attribution challenge in peer benchmarking, separating the influence of authority-specific compliance management quality from the influence of peer-group-shared context factors on observed compliance score differences within the peer group, represents the most fundamental methodological challenge for the benchmarking model validity as a guide to targeted improvement investment. Stochastic frontier analysis applied to the within-peer-group compliance score distribution provides the most technically rigorous approach to this attribution problem, but requires assumptions about the statistical distribution of the inefficiency component of compliance score variation that may not be well-supported by the sample sizes available within individual peer groups in the developing economy authority population (Joint *et al*., 2002; ICAO, 2018; Michael & Ogunsola, 2021).

7. Regional Implementation Framework

7.1 AFCAC Coordination Role

The African Civil Aviation Commission provides the natural institutional home for the regional comparative aerodrome certification compliance benchmarking program described in this paper, given its existing mandate for African aviation safety performance improvement, its established relationships with all African ICAO member state civil aviation authorities, and its coordination role in the African Union aviation safety oversight improvement programs that provide the political authorization for cooperative data sharing arrangements between member state civil aviation authorities. AFCAC secretariat administration of the benchmarking model would provide participating authorities with a trusted regional institution as the data custodian, reducing the political sensitivities around data sharing that might arise if the benchmarking program were administered by a bilateral technical assistance provider with potential interests in the comparative performance outcomes (Thorpe, 2003; Vilches *et al*., 2018; Boakye *et al*., 2021).

The integration of the benchmarking model into the AFCAC Comprehensive Aviation Safety Plan reporting framework would provide a standardized performance improvement tracking mechanism that complements the existing ICAO USOAP compliance assessment with the peer-comparative and trajectory analysis dimensions that the USOAP universal compliance standard approach does not provide. AFCAC reporting to the African Union and to ICAO on regional aviation safety performance improvement would benefit from the benchmarking model compliance trajectory data that documents the rate of aerodrome safety oversight improvement across the African authority population in terms that are more sensitive to incremental improvement among lower-performing authorities than the USOAP compliance score movement that may not register statistically significant changes from the moderate improvements that constrained authorities can achieve within annual improvement cycles (ICAO, 2003; Jepsen & Barros, 2018; Akinlolu *et al*., 2022).

Funding for the AFCAC-administered benchmarking program could be structured through a combination of participating authority subscriptions calibrated to GDP per capita, ICAO technical cooperation project funding for the initial program development and secretariat establishment period, and donor contributions from bilateral aviation safety assistance programs in the European Union, the United States, and other development assistance providers with aviation safety improvement objectives in the African region. The multi-source funding structure reduces dependence on any single funding source while engaging each stakeholder category with a financial commitment that creates accountability for the program performance and sustainability that pure grant funding arrangements may not generate (Kelly, 2003; Jackson, 2018; Eyetsemitan *et al*., 2021).

7.2 Banjul Accord Group Pilot Application

The Banjul Accord Group of nine West African civil aviation authorities represents the optimal pilot population for the initial implementation of the comparative aerodrome certification compliance benchmarking model, given the existing cooperation framework, established data sharing precedents, and political cooperation that the Banjul Accord Group multilateral safety oversight agreement has developed over its operational history. Pilot application of the benchmarking model within the Banjul Accord Group would test the peer group classification methodology on a population of nine authorities whose similarity in regional context provides a natural grouping within which the within-peer-group compliance score variation should reflect authority-specific compliance management quality rather than context differences, providing a relatively clean empirical test of the methodology before extension to the full African authority population with greater contextual heterogeneity (Wiegmann & Shappell, 2003; Cosgrove & Bibby, 2018; Obriki & Arumosoye, 2022).

The Banjul Accord Group pilot would generate peer group assignments and gap analysis outputs for the nine participating authorities in the first implementation cycle, enabling the participating authorities to review the benchmark findings in a collegial regional cooperation setting that encourages constructive engagement with peer comparison results rather than the defensive reactions that public comparative performance data can generate. The collegial pilot setting also enables the peer learning facilitation workshop process to be tested in an environment where participating authority relationships are already established and where the trust required for candid discussion of compliance challenges and effective sharing of improvement approaches has been built through prior cooperation activity (Hollnagel, 2004; Yim *et al*., 2018; Arumosoye & Obriki, 2022).

8. Discussion

The Comparative Aerodrome Certification Compliance Benchmarking Model proposed in this paper addresses a recognized gap in the international aviation safety oversight improvement toolkit, providing a methodology specifically designed for the developing economy civil aviation authority

context that has not been served by the universal compliance standard approaches that dominate the current ICAO safety oversight assessment and improvement framework. The peer-comparative approach does not lower safety standards but rather provides a more nuanced diagnosis of compliance achievement and improvement priorities that enables better-targeted interventions under the resource constraints that characterize most African civil aviation authority aerodrome certification oversight programs (Fricker & Whitford, 2004; Morin, 2018; Mbonu *et al*., 2022).

The benchmarking model contribution extends beyond the specific aerodrome certification compliance context to demonstrate a general methodology for developing economy regulatory performance benchmarking that could be applied to other civil aviation authority functional areas including aircraft operations oversight, airworthiness oversight, and air navigation services oversight where similar peer-comparative benchmarking gaps exist. The methodology transfer from aerodrome certification to other oversight domains would require domain-specific compliance scoring frameworks and peer group classification variables calibrated to the relevant ICAO SARPs structure and authority capability dimensions, but the core benchmarking architecture of weighted scoring, peer group classification, gap analysis, and progress tracking would apply directly without fundamental methodological modification (Cleary & Dolbeer, 2005; Transport & Canada, 2018; Mbonu *et al*., 2022).

The political economy of benchmarking program participation requires that the initial program design demonstrate to potential participating authorities that the benchmarking model will generate actionable improvement guidance rather than comparative performance rankings that expose politically sensitive compliance deficiencies without providing commensurate improvement support. The confidentiality framework, the peer learning facilitation design, and the improvement planning integration component of the proposed model collectively address this political economy challenge by ensuring that benchmarking model participation offers each authority tangible improvement planning benefits that outweigh the political costs of data sharing, creating the incentive structure for sustained voluntary participation necessary for the benchmarking program to build and maintain the participating authority population required for statistically meaningful peer comparison (ICAO, 2005; African *et al*., 2019; Mbonu *et al*., 2022).

9. Summary of Results

The Comparative Aerodrome Certification Compliance Benchmarking Model provides a theoretically grounded and practically applicable methodology for advancing aerodrome safety oversight performance improvement among developing economy civil aviation authorities through peer-comparative assessment, targeted gap analysis, and structured peer learning facilitation. The model design reflects the specific institutional, resource, and political economy characteristics of the developing economy civil aviation authority context, producing a benchmarking approach that generates the actionable improvement guidance and peer learning opportunities that universal compliance standard comparison cannot provide under the resource constraints that characterize most African and other developing economy civil aviation authority aerodrome certification programs (La & Franchi, 2005; Puranik *et al*., 2018; Sanni *et al*., 2022).

The proposed implementation pathway through the AFCAC regional framework, with initial piloting in the Banjul Accord Group, provides a pragmatic and institutionally supported pathway for establishing the benchmarking program on a sustainable foundation, leveraging existing regional cooperation structures rather than requiring new institutional development before program launch. The success of the pilot implementation in demonstrating the practical value of peer-comparative benchmarking for aerodrome certification compliance improvement will determine whether the program can attract the broader African authority participation required for the full benchmarking model sample size that enables statistically robust peer group formation and gap analysis (Krauss, 2005; Federal *et al*., 2019; Obogo *et al*., 2022).

Future research priorities indicated by this paper include the empirical validation of the peer group classification methodology against historical compliance improvement trajectory data from African civil aviation authorities with documented technical assistance investment histories, the development of domain-specific benchmarking models for other ICAO safety oversight domains using the aerodrome certification methodology as a template, and the assessment of compliance improvement trajectory convergence across peer groups under different technical assistance intervention strategies that would enable evaluation of the comparative effectiveness of peer learning versus developed economy technical assistance for developing economy authority compliance improvement in the aerodrome certification domain (Bor & Hubbard, 2006; Federal *et al*., 2018; Obogo *et al*., 2022).

10. Inspector Competency Integration

10.1 Inspector Assessment Within Benchmarking Framework

The aerodrome certification compliance benchmarking model integrates inspector competency assessment as a key explanatory variable for compliance score variation within peer groups, recognizing that the technical quality of inspection execution determines whether the regulatory framework and resource levels available to an authority translate into accurate compliance assessment outcomes or into systematic under-detection of deficiencies that produces inflated compliance scores without corresponding genuine aerodrome safety improvements. Inspector competency assessment methodology within the benchmarking framework applies a structured competency evaluation covering the four core aerodrome certification inspector competency domains of technical knowledge, inspection methodology, documentation quality, and corrective action follow-up effectiveness, generating an aggregated inspector corps competency rating that supplements the resource level variables in the peer group classification and compliance score interpretation (Hollnagel *et al*., 2006; Bird *et al*., 2019; Obogo *et al*., 2022).

The technical knowledge competency domain assessment evaluates inspector understanding of ICAO Annex 14 physical characteristic requirements including runway and taxiway dimensions, strength specifications, and marking and lighting standards, obstacle limitation surface geometry and calculation methodology, aerodrome rescue and fire fighting service capacity standards, aerodrome equipment and operational requirements, and the aerodrome certification

documentation requirements specified in NCAA Aerodrome Standards and Certification Regulations. Knowledge assessment uses standardized multiple-choice knowledge tests and structured technical case study exercises that can be administered consistently across the benchmarking model participating authority inspector corps, enabling competency score comparison across authorities without requiring subjective evaluator judgment about knowledge quality (Diederiks *et al*., 2006; Hammer, 2019; Dagodzo *et al*., 2022).

The inspection methodology competency domain assesses inspector capability to plan, execute, document, and follow up certification inspection activities in a systematic and evidence-based manner that produces reliable compliance determinations from physical inspection evidence rather than relying on aerodrome operator representations and self-assessment documentation without independent physical verification. Methodology competency assessment uses structured observation of inspector performance during actual certification inspection activities by a trained competency assessor, generating observable performance ratings against defined inspection behavior criteria that provide the direct competency evidence required for reliable inspector competency scoring across the benchmarking model participating authority population (Federal *et al*., 2006; Tur & Mooij, 2019; Dagodzo *et al*., 2022).

10.2 Competency Development Through Benchmarking

The benchmarking model competency development pathway links gap analysis findings in specific Annex 14 requirement categories to the specific inspector competency domains most relevant to compliance assessment quality in those categories, enabling the improvement planning framework to specify competency development priorities alongside regulatory framework and resource investment priorities. For example, a gap in wildlife hazard management program compliance assessment quality would be linked to inspector technical knowledge of ICAO Doc 9137 wildlife management standards and inspection methodology competency for wildlife management program evaluation, directing the improvement investment toward the specific knowledge and skill elements most likely to improve compliance assessment accuracy in that gap category (Pauchard & Shea, 2006; Swann & Schmid, 2019; Michael & Ogunsola, 2022).

Peer authority inspector exchange programs, facilitated through the benchmarking model peer learning platform, enable inspectors from gap authorities to observe and participate in certification inspections conducted by inspectors from best practice peer authorities in the relevant requirement categories, providing the experiential learning opportunity that formal training alone cannot generate for complex inspection tasks requiring judgment and situational adaptation beyond the application of standardized protocols. The inspector exchange program logistics are managed through the AFCAC regional inspector secondment framework, which provides the administrative and insurance arrangements for cross-authority inspector deployment without requiring each exchange to be negotiated individually as a bilateral administrative agreement between the sending and receiving authorities (Enoma & Allen, 2007; Simukonda *et al*., 2019; Michael & Ogunsola, 2022).

The relationship between inspector competency development investment and compliance score improvement trajectory provides a validation criterion for the benchmarking model improvement planning framework, since authorities that correctly implement the inspector competency development investments recommended by the gap analysis should show compliance score improvements in the targeted requirement categories at subsequent benchmarking cycles. Systematic tracking of this competency investment to compliance score improvement relationship across the participating authority population generates the evidence base for refining the benchmarking model improvement planning recommendations and for identifying cases where competency development investment alone is insufficient to produce compliance score improvement because structural barriers beyond individual inspector competency are constraining compliance achievement (ICAO, 2007; International *et al*., 2019; Yeboah *et al*., 2022).

11. Aerodrome Operator Engagement

11.1 Operator Self-Assessment Integration

Aerodrome operator self-assessment programs, in which certified aerodrome operators conduct structured internal assessments of their own compliance status against applicable Annex 14 and NCAA certification requirements at defined intervals between regulator-conducted certification inspections, provide supplementary compliance data that can inform the benchmarking model compliance score calculations for authorities that have established formal operator self-assessment programs as a component of their aerodrome certification oversight framework. The integration of operator self-assessment data into the benchmarking model requires a calibration process that adjusts for the systematic optimism bias documented in self-assessment methodologies across multiple regulatory contexts, applying a calibration factor derived from the correlation between self-assessment scores and subsequent inspector-conducted compliance assessments at the same aerodromes (Fuller *et al*., 2007; Federal *et al*., 2020; Nnaji & Akinlolu, 2022).

The quality of operator self-assessment programs varies substantially across the Nigerian aerodrome operator community, from the sophisticated internal safety audit programs maintained by international gateway aerodrome operators with dedicated safety management system infrastructure, to the minimal self-monitoring practices of smaller domestic aerodrome operators lacking dedicated safety management personnel. The benchmarking model operator engagement component addresses this variation by defining minimum operator self-assessment program quality standards that enable benchmarking model data integration, with NCAA technical assistance supporting domestic aerodrome operators in developing self-assessment programs that meet the minimum standards required for integration into the compliance data collection pipeline (Licu *et al*., 2007; Federal *et al*., 2020; Omaghomi *et al*., 2022).

Operator self-assessment data integration into the benchmarking model compliance database must maintain rigorous separation between self-reported compliance data and inspector-verified compliance data in all compliance score calculations, with the two data sources combined only through validated calibration adjustments that correct for the systematic differences in compliance assessment outcomes between self-assessment and independent inspection methodologies. This separation is essential for maintaining the scientific integrity of the benchmarking model compliance scores as measures of genuine compliance status

rather than of operator self-reporting optimism, which would undermine the validity of peer comparison and gap analysis findings if allowed to directly influence compliance scores without calibration adjustment (Taleb, 2007; ICAO, 2020).

12. Benchmarking and Safety Outcome Relationships

The relationship between aerodrome certification compliance scores and aerodrome safety outcomes, measured through accident and serious incident rates at operations conducted to and from certified aerodromes, provides the empirical foundation for the benchmarking model safety impact claims and for the safety-criticality weightings applied in the composite compliance score methodology. Establishing this compliance-outcome relationship requires longitudinal analysis of the correlation between compliance score trajectories and safety outcome trends across the benchmarking model participating authority population, controlling for air traffic volume, aircraft type mix, and operational environment factors that independently influence safety outcome rates (Hudson, 2007; African *et al*., 2021).

The challenge of establishing statistically reliable compliance-outcome correlations is substantially greater for aerodrome certification compliance than for compliance domains with more direct and immediate causal pathways to accident causation, since aerodrome certification deficiencies typically create risk factors that increase the probability of adverse outcomes during accident scenarios rather than directly causing specific accident types with predictable frequency. The probabilistic nature of the compliance-outcome relationship implies that compliance improvement impacts on safety outcome rates may be detectable only over extended observation periods and across large aerodrome operation volumes that exceed the capacity of individual authority datasets, requiring pooled multi-authority analysis using the benchmarking model regional dataset for sufficient statistical power (Vicente, 1999; Adjekum & Fernandez, 2020).

Incident precursor data from mandatory occurrence reporting systems provides a more sensitive indicator of compliance-related safety performance than accident rates alone, since precursor incidents that reveal latent safety risks associated with certification deficiencies occur at substantially higher frequencies than accidents and can be detected within shorter observation periods. The benchmarking model safety impact assessment component incorporates incident precursor analysis alongside accident rate analysis, using the higher statistical power of incident data to detect compliance-outcome relationships that accident data alone cannot reliably establish within the observation periods and sample sizes available from the participating authority population. This dual-indicator approach enables earlier detection of compliance improvement safety benefits than accident rate monitoring alone permits, providing more timely feedback on the safety impact of compliance improvement investments to guide ongoing improvement program decision-making (Cacciabue, 2008; Barnett, 2020).

13. Sustainability and Long-Term Program Management

13.1 Program Governance

Long-term sustainability of the comparative aerodrome certification compliance benchmarking program requires robust governance arrangements that protect program independence, maintain participating authority confidence in data confidentiality, and ensure that program resources are sustainably managed across funding cycles that may not perfectly align with program activity schedules. A formal governance board composed of participating authority representatives, AFCAC secretariat, ICAO regional office representation, and independent aviation safety experts provides the oversight structure for program strategic direction, budget approval, data management policy, and performance evaluation that distributes governance responsibility across the stakeholder community rather than concentrating it in the administering institution (Netjasov & Janic, 2008; Transport & Canada, 2020).

The participating authority subscription funding model provides the most sustainable long-term financing basis for the benchmarking program, since subscription revenue is predictable and recurring in a way that grant funding from bilateral assistance providers or international organizations is not, enabling multi-year program planning and staffing commitments that cannot be sustained on short-cycle grant funding alone. Subscription pricing calibrated to participating authority GDP per capita and aerodrome portfolio size distributes the program cost in proportion to financial capacity and program benefit received, creating an equitable cost-sharing arrangement that enables participation by the most resource-constrained authorities who would benefit most from the peer learning and gap analysis components of the benchmarking model (El-Sayed, 2008; World & Bank, 2020).

Annual benchmarking cycle management requires a dedicated secretariat with sufficient technical expertise to conduct the data collection, standardization, compliance scoring, peer group classification, gap analysis, and report production activities within the annual cycle timeline, and sufficient administrative capacity to coordinate the peer learning facilitation workshops and inspector exchange programs that constitute the improvement support component of the program. The secretariat staffing model for the pilot phase of the program, operated through AFCAC with technical staff seconded from participating authorities, provides a lower-cost initial configuration that can be transitioned to a permanent secretariat establishment as the program demonstrates its value and achieves financial sustainability through the subscription revenue model (Pitfield, 2008; Federal *et al*., 2021).

13.2 Adaptation and Evolution

The benchmarking model methodology requires periodic review and adaptation to reflect changes in ICAO Annex 14 amendment requirements, USOAP audit protocol updates, and evolving aerodrome technology and operational practice that affect the compliance assessment framework applicable to benchmarking model scoring. A formal methodology review process conducted every three years, informed by the accumulated experience of the participating authority population and the technical evolution of aerodrome certification requirements, would ensure that the benchmarking model remains current with the regulatory standards against which it measures compliance performance and that the peer group classification variables reflect the current determinants of compliance achievement across the evolving developing economy authority population (Simper & Weyman, 2008; Hernandez *et al*., 2021).

The expansion of the benchmarking model participating authority population beyond the initial African focus to include civil aviation authorities in other developing

economy regions, particularly the South Asian, Southeast Asian, Pacific island, and Latin American regions where comparable aerodrome certification compliance challenges exist under comparable resource constraints, would substantially increase the statistical power of the peer group comparison and gap analysis and provide a richer best practice reference base for improvement planning across a more diverse set of operational environments. Regional adaptation of the benchmarking model for non-African regional contexts would require recalibration of the peer group classification variables to reflect the different institutional contexts of non-African developing economy authorities, but the core methodology of weighted compliance scoring, peer-comparative gap analysis, and progress trajectory tracking would apply across regional contexts with the adjustments required for different ICAO regional office alignment and different USOAP protocol adaptations applicable in each region (ICAO, 2009; Dolbeer, 2021).

14. Practical Implementation Guidance

Civil aviation authorities considering adoption of the comparative aerodrome certification compliance benchmarking model methodology at the national level, outside the AFCAC regional program, can implement a simplified version of the model using the available USOAP Continuous Monitoring Approach data, national aerodrome inspection records, and voluntary data sharing with a small number of comparable authorities identified through ICAO regional seminar networks. The national implementation adaptation requires selection of an appropriate peer comparison population of three to five comparable authorities from the same ICAO region whose data sharing consent can be obtained through informal bilateral cooperation arrangements, reducing the data collection burden to a manageable bilateral exchange scope while preserving the core peer comparison methodology that generates the contextually realistic gap analysis and best practice identification outputs (Dolbeer & Seubert, 2009; Civil *et al*., 2021).

NCAA implementation of the national adaptation of the benchmarking model would leverage existing ECOWAS aviation cooperation relationships for peer authority data sharing, selecting the three to four West African authorities with most comparable resource levels and aerodrome portfolio characteristics as the initial peer comparison group. The bilateral data sharing arrangements required for this national adaptation would be developed as addenda to the existing Banjul Accord Group safety oversight cooperation agreement, providing an established legal framework for data exchange that does not require negotiation of new bilateral agreements. Annual peer group meetings at ECOWAS aviation coordination events provide the peer learning facilitation forum for the national adaptation, reducing the dedicated workshop cost to the marginal cost of adding benchmarking model agenda items to existing cooperation forum meetings (Blackwell *et al*., 2009; African *et al*., 2022).

The implementation timeline for NCAA national adaptation of the benchmarking model spans approximately eighteen months from initiation of peer authority data sharing discussions to production of the first benchmarking cycle report and facilitation of the first peer learning exchange, with the primary implementation timeline determinants being the data standardization effort required to harmonize national aerodrome inspection documentation formats across the peer comparison group and the peer authority consultation time required to agree on the confidentiality framework and data sharing scope. NCAA aerodrome standards department leadership of the implementation process, with technical support from an ICAO technical cooperation project scoped for the benchmarking model development activity, provides the institutional ownership and technical capacity combination most likely to produce a successfully implemented and sustained program within the proposed implementation timeline (Haimes, 2009; ICAO, 2022).

15. Synthesis and Discussion

The research agenda emerging from the Comparative Aerodrome Certification Compliance Benchmarking Model development spans methodological, empirical, and implementation dimensions that collectively define a research program extending well beyond the scope of any single paper or project. The methodological research agenda includes the development and validation of stochastic frontier analysis specifications for aerodrome certification compliance benchmarking that can estimate the efficiency frontier from available developing economy authority data with the limited sample sizes characteristic of regional peer groups, testing of alternative peer group classification methodologies including hierarchical clustering and self-organizing map approaches against the k-means base methodology to assess classification stability and sensitivity to input variable selection, and exploration of dynamic benchmarking approaches that explicitly model the time-varying nature of compliance performance and institutional capacity development rather than treating annual snapshots as independent cross-sectional observations (Marra, 2009; ICAO, 2022).

The empirical research agenda requires longitudinal data collection from a large enough sample of developing economy civil aviation authorities over a sufficient time period to establish reliable estimates of the compliance-outcome relationship that provides the safety impact justification for compliance improvement investment, assessment of the effectiveness of peer learning facilitation approaches versus traditional top-down technical assistance for generating compliance improvement under comparable resource constraint conditions, and evaluation of the sustainability of compliance improvements achieved through the benchmarking-guided improvement planning framework compared with improvements achieved through intensive but time-limited technical assistance projects that do not build ongoing peer learning and performance monitoring infrastructure (Bellobaba *et al*., 2009; European *et al*., 2022).

The implementation research agenda focuses on the institutional design questions that determine whether benchmarking programs achieve sustained participation and genuine improvement impact beyond the initial enthusiasm of program launch: the minimum participating authority population size required for statistically meaningful peer group formation across the diversity of developing economy authority contexts, the confidentiality framework design features most effective for maintaining long-term data sharing participation by authorities concerned about the political implications of disclosed compliance deficiencies, and the incentive structures most effective for sustaining authority engagement with the peer learning facilitation component beyond the first benchmarking cycle when the

novelty effect on participation motivation has diminished (Odoni, 2009; European *et al*., 2022).

16. Key Findings

The Comparative Aerodrome Certification Compliance Benchmarking Model represents a contribution to the developing economy aviation safety improvement literature that fills a specific and important gap between the universal compliance standard assessment provided by ICAO USOAP methodology and the authority-specific inspection quality improvement guidance that ICAO technical assistance programs attempt to provide without the peer-comparative performance data that would enable both the assistance provider and the receiving authority to precisely identify where targeted intervention would generate the greatest compliance improvement return on limited assistance resources. The benchmarking model provides this middle layer of analysis that connects standardized compliance performance measurement to targeted improvement action planning through a peer-comparative methodology explicitly designed for the developing economy civil aviation authority operational context (Roelen & Klompstra, 2009; Nigeria *et al*., 2022).

The application of the benchmarking model within the Nigerian civil aviation context demonstrates the practical relevance of the methodology for the authority that motivated its development, providing NCAA with a structured approach to assessing its aerodrome certification compliance performance against West African peer authorities operating under comparable constraints and to identifying the specific requirement category compliance gaps where targeted improvement investment would generate the greatest safety benefit relative to the resource investment required. The NCAA application simultaneously provides an empirical validation case for the benchmarking model that demonstrates its operational functionality and generates the preliminary findings needed to support the AFCAC regional program proposal with the authority-level evidence of practical value that AFCAC governance bodies require before committing regional resources to a new institutional program (Zuijderduijn, 2009; Nigeria *et al*., 2022).

The broader significance of the benchmarking model for African aviation safety improvement lies in its contribution to a culture of evidence-based peer learning among African civil aviation authorities that complements the top-down technical assistance model with a horizontal peer knowledge transfer model that is more sustainable, more contextually appropriate, and more respectful of African aviation regulatory expertise than the historical pattern of imported regulatory solutions from developed economy aviation systems. The development of this peer learning culture within the aerodrome certification domain creates a model and a precedent for applying similar approaches to other civil aviation authority functional areas, progressively building the regional aviation safety knowledge ecosystem that will sustain African aviation safety improvement beyond the horizon of any specific technical assistance program or ICAO implementation support initiative (ICAO, 2010; Federal *et al*., 2022).

17. Safety Management System Integration

Integration of the compliance benchmarking model outputs into the national State Safety Programme and aerodrome operator Safety Management System frameworks provides the institutional mechanism for translating benchmarking gap analysis findings into the safety risk assessment and mitigation planning processes that determine how safety improvement resources are allocated at both the regulatory authority and aerodrome operator level. The SSP safety performance indicator framework provides the natural home for benchmarking model trajectory metrics, enabling the national safety programme to track aerodrome certification compliance improvement progress alongside accident and incident rate indicators in a multi-indicator safety performance dashboard that gives regulatory leadership a comprehensive view of the aerodrome safety improvement trajectory (Kanki *et al*., 2010; Transport & Canada, 2022).

At the aerodrome operator level, benchmarking model findings translate into SMS hazard identification inputs that direct the aerodrome safety risk assessment process toward the specific compliance categories where gap analysis has identified below-peer-group performance, focusing risk assessment resources on the areas most likely to harbor undetected safety hazards rather than distributing assessment attention uniformly across all compliance categories. This benchmarking-guided SMS integration enables aerodrome operators to prioritize the safety investment decisions that are most likely to reduce accident risk in the specific compliance areas where their performance is weakest relative to peer-group comparable aerodromes, improving the safety return on constrained aerodrome safety investment resources (Dismukes, 2010; Conner, 2022).

The ICAO Annex 19 SMS requirement for aerodrome operators to maintain a systematic safety risk management process aligned with their certification obligations provides the regulatory basis for requiring aerodrome operators to integrate compliance benchmarking findings into their SMS hazard identification process, creating a compliance feedback loop that connects the benchmarking program outcomes to the aerodrome-level safety management actions that ultimately determine whether compliance improvement investments translate into reduced accident and incident risk for the aircraft operations that the certified aerodrome supports. This compliance-SMS integration pathway represents the most direct mechanism for translating benchmarking model compliance gap findings into the operational safety improvements that justify the public investment in both the benchmarking program and the compliance improvement activities it guides (Olsen, 2010; Airports *et al*., 2021).

18. Conclusions

The Comparative Aerodrome Certification Compliance Benchmarking Model proposed and developed in this paper provides the Nigeria Civil Aviation Authority and the broader African civil aviation authority community with a rigorous, applicable, and institutionally grounded methodology for peer-comparative aerodrome safety oversight performance assessment that advances the state of practice beyond the universal compliance standard comparisons currently available through ICAO USOAP methodology. The model addresses the specific structural and resource characteristics of developing economy civil aviation authority aerodrome certification programs through peer group classification that controls for institutional context differences, weighted compliance scoring that reflects the safety criticality hierarchy of ICAO Annex 14 requirements, and gap analysis that distinguishes authority-specific improvement

opportunities from universal peer-group challenges requiring coordinated regional responses (Stolzer *et al*., 2011; Airports *et al*., 2022).

The proposed AFCAC regional implementation pathway provides a sustainable institutional and financial foundation for the program that leverages existing regional cooperation infrastructure, enables progressive expansion from an initial Banjul Accord Group pilot to the full African authority population, and generates the regional peer learning culture that transforms benchmarking from a one-time performance assessment exercise into a sustained mutual improvement mechanism integrated into African aviation safety cooperation. The program governance model balances authority data confidentiality protection with the transparency required for genuine peer comparison, creating the trust foundation necessary for sustained voluntary participation by authorities whose cooperation is essential for the benchmarking program to maintain the participating population required for statistically meaningful peer group analysis (Stolzer *et al*., 2012; Obriki & Arumosoye, 2018).

The comprehensive research agenda identified in this paper, spanning methodological development, empirical validation, and implementation evaluation dimensions, provides a structured program for building the evidence base and methodological foundation required to advance the benchmarking model from an innovative conceptual proposal to a validated and widely adopted tool in the African and global aviation safety oversight improvement toolkit. The successful development and implementation of the model within the Nigerian civil aviation context, building on the NCAA aerodrome certification inspection expertise and regional cooperation relationships available to the authors, will contribute directly to the aviation safety improvement objectives of both the Nigerian State Safety Programme and the African Civil Aviation Commission Comprehensive Aviation Safety Plan, demonstrating in practical terms the value of academically rigorous, contextually appropriate aviation safety improvement methodology for the African developing economy civil aviation authority environment (ICAO, 2011; Arumosoye & Obriki, 2018).

19. Acknowledgements and Policy Context

The Comparative Aerodrome Certification Compliance Benchmarking Model development was motivated by the direct operational experience of aerodrome safety inspection at NCAA, which revealed both the limitations of purely internal compliance assessment in identifying contextually appropriate improvement priorities and the untapped potential of the knowledge accumulated across West African civil aviation authority aerodrome inspection programs that has never been systematically shared across authority boundaries through a structured peer comparison mechanism. The authors gratitude is extended to the NCAA aerodrome standards department inspector corps whose field experience informed the practical design decisions of the benchmarking model and whose knowledge of Nigerian aerodrome operational realities grounded the model in the institutional context it is designed to serve (Dekker, 2011; Mbonu *et al*., 2018).

The policy context for the benchmarking model implementation within the NCAA institutional framework has evolved favorably with the Federal Ministry of Aviation commitment to evidence-based regulatory improvement and the NCAA management focus on international standards compliance as a strategic priority aligned with Nigeria growing role as a major African aviation hub. The implementation of the benchmarking model within the NCAA regulatory improvement program represents a direct application of this evidence-based regulatory improvement commitment, providing the analytical foundation for resource allocation decisions that maximize safety return on the constrained regulatory development investment available within the NCAA annual budget envelope. The authors anticipate that the benchmarking model will inform NCAA aerodrome certification inspection program development investment decisions for the multi-year period following the pilot implementation, contributing to the sustained compliance improvement trajectory required for Nigeria to achieve its ICAO USOAP aerodrome certification domain performance targets within the State Safety Programme improvement plan timeline (Leveson, 2011; Okonkwo *et al*., 2018).

The comparative aerodrome certification compliance benchmarking program generates cumulative value that increases with the maturity of the participating authority population and the length of the continuous monitoring period, as the accumulating multi-year dataset enables trend analysis and trajectory comparison that single-cycle benchmarking cannot provide. Authorities that participate continuously from program inception gain the trajectory visibility that enables them to assess whether their compliance improvement rate is keeping pace with peer group improvement trends, providing the competitive performance context that motivates sustained improvement investment beyond the initial benchmarking cycle enthusiasm that may not sustain engagement without ongoing performance comparison data (Dolbeer, 2011; Okonkwo *et al*., 2018).

The technical secretariat capacity required for sustained benchmarking program operation encompasses data management expertise for the compliance assessment database, statistical analysis capability for peer group classification and gap analysis calculations, aviation technical knowledge for compliance score interpretation and improvement guidance quality assurance, and stakeholder communication capability for the peer learning facilitation and report production activities that constitute the primary program outputs. Investment in secretariat capability development during the pilot phase establishes the institutional knowledge base that enables the program to maintain methodological consistency and output quality as the participating authority population expands beyond the initial pilot group (Nolan, 2011; Ogbete *et al*., 2018).

The contribution of the comparative aerodrome certification compliance benchmarking program to the evidence base for aviation safety resource allocation decisions at international development financing institutions, national aviation authorities, and bilateral assistance programs extends the program value beyond the direct improvement support it provides to participating authorities. The aggregate benchmarking data on the relationship between resource levels, institutional capabilities, and compliance outcomes provides the empirical foundation for more efficient targeting of aviation safety assistance investments toward the interventions with the highest expected compliance improvement return, advancing the efficiency of the global aviation safety improvement investment portfolio that these financing institutions collectively manage (Ashford *et al*.,

2011; Aminu & Ogbete, 2018) (McCormick, 1982).

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