

Review Article

Improved System-Wide Information Management for Aeronautical Data Chain Using Air Traffic Control Infrastructure: A Nigerian Perspective

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Abstract

The modernization of air traffic management (ATM) depends on how effective aviation stakeholders share accurate and timely information. System-Wide Information Management (SWIM) provides a unified digital framework that connects aeronautical, meteorological, and operational data across the aviation network. While many advanced regions have successfully adopted ICAO SWIM concept, Nigeria is still relying on fragmented and mostly manual systems that limit operational efficiency and data reliability. This study proposes the development of an improved SWIM-based framework that uses existing Air Traffic Control (ATC) infrastructure as the foundation for integrating aeronautical data. The research combined document analysis, system modelling, and iterative software design following Agile and Infrastructure-as-Code (IaC) principles. The proposed system prototype will be developed with C#.Net, ASP.Net, and SQL Server. It will also demonstrate how digital NOTAMs, electronic flight strips, ADR-16 reports, real-time weather data, and aerodrome operator's global reporting formats (GRF) can operate within a shared information environment. The results showed that the proposed framework will improve data consistency, reduce processing time, and enhance coordination among ICAO AFI Air Navigation Service Providers, meteorological agencies, airline operators and airport operators. It will also support real-time collaboration and aligns with ICAO's Global Air Navigation Plan (GANP). In conclusion, adopting SWIM framework through existing ATC infrastructure, which will be supported by sound policies, strong cybersecurity, and skilled personnel, will offer Nigeria a practical pathway toward a fully digital and globally connected air traffic management system.

Keywords

System-Wide Information Management (SWIM), Aeronautical Information Management (AIM), Aeronautical Data Chain (ADC), Air Traffic Management (ATM)

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1. Introduction

The rapid expansion of global air traffic, coupled with the growing complexity of aviation operations, has placed unprecedented demands on Air Traffic Management (ATM) systems [1-4]. Traditional information exchange models, often characterized by point-to-point communication and fragmented data silos, have proven inadequate for meeting modern aviation requirements [5-7]. The International Civil Aviation Organization (ICAO), recognizing the limitations of legacy systems, introduced System-Wide Information Management (SWIM) as a strategic framework to ensure timely, accurate, and interoperable information exchange among aviation stakeholders [8].

SWIM is a transformative enabler within modernization programs such as the Collaborative Action for Renovation of Air Traffic Systems (CARATS) in Japan, the China New Generation ATM System (CNAS), United States' Next Generation Air Transportation System (NextGen) and Europe's Single European Sky ATM Research (SESAR). By adopting service-oriented architecture (SOA), SWIM facilitates the integration of diverse information services including aeronautical, meteorological, and flight data, into a seamless, collaborative environment [9]. This approach enhances situational awareness, reduces redundancies, and supports data-driven decision-making across airlines, Air Navigation Service Providers (ANSPs), meteorological agencies, and airport operators [10, 11].

Despite global advancements, the African/Indian Ocean (AFI) region has made limited progress in implementing SWIM [12]. Financial constraints, lack of skilled manpower, policy inconsistencies, and infrastructural deficiencies continue to undermine its adoption [13]. Within this context, Nigeria which is a key regional aviation hub still faces persistent challenges [14, 15]. Its aeronautical data chain remains fragmented, reliant on manual processes, and constrained by outdated systems that impede interoperability and delay decision-making [16, 17]. Moreover, cybersecurity vulnerabilities further expose Nigerian aviation systems to risks of data loss, falsification, and unauthorized access [18].

The Nigerian Airspace Management Agency (NAMA), empowered through legislative amendments in 2022, has been tasked with adopting new technologies to modernize the nation's ATM infrastructure [19]. Yet, a clear roadmap for SWIM adoption remains absent, and the integration of existing ATC infrastructure into digital frameworks has been underexplored. This gap underscores the urgency of developing a context-specific SWIM model that addresses Nigeria's unique challenges while aligning with global aviation standards. This paper seeks to bridge that gap by proposing an improved SWIM-enabled framework for Nigeria's aeronautical data chain, leveraging ATC infrastructure as the backbone for integration. The objectives of the study include the following:

1) To survey and analyze the current state of aeronautical

information management in Nigeria, identifying gaps and inefficiencies.

- 2) To design a SWIM-enabled framework tailored to Nigeria's ATM environment, integrating key operational components.
- 3) To develop a software prototype implementing the proposed model using C#.Net and Microsoft SQL Server.
- 4) To evaluate the proposed system against existing frameworks and recommend strategies for national adoption.

2. Literature Review

2.1. Conceptual Framework of System-Wide Information Management (SWIM)

The concept of System-Wide Information Management (SWIM) emerged in response to the inefficiencies of fragmented Air Traffic Management (ATM) systems. It was initially introduced by Eurocontrol in the late 1990s and paralleled by the U.S. Federal Aviation Administration's (FAA) "NAS-Wide Information System" developed in 1998, SWIM was formally endorsed by the International Civil Aviation Organization (ICAO) in 2002. It was subsequently integrated into ICAO's Global Air Navigation Plan (GANP) and designated it as a pivotal element in multiple Aviation System Block Upgrades (ASBU) as a cornerstone of modern ATM [20, 21]. This was originally designated as a Block 1 initiative in the fourth and fifth editions of the GANP, the sixth edition has now repositioned SWIM to Blocks 2 and 3, extending its implementation timeframe to 2025 and beyond as shown in Figure 1 [22].

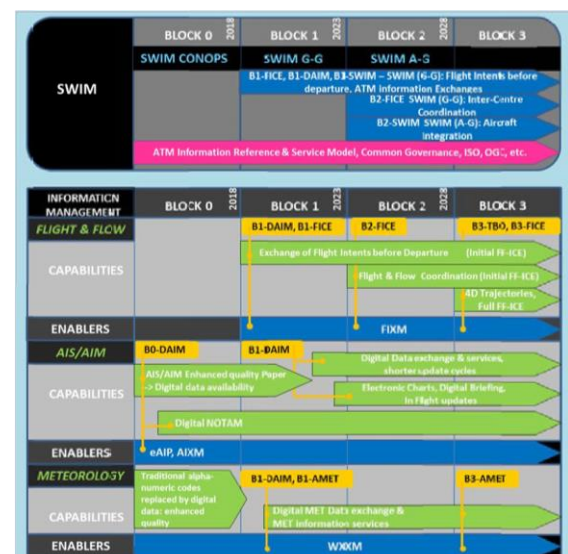


Figure 1. ICAO GANP Roadmap on SWIM [9].

The SWIM concept provides a service-oriented architecture (SOA) for information exchange, designed to overcome the limitations of point-to-point communication models. By allowing data to be published, discovered, and consumed dynamically, SWIM reduces redundancy and promotes collaboration [8, 23, 24]. SWIM's key benefits include interoperability, scalability, flexibility, and security [9]. The SWIM functional architecture as shown in Figure 2 can be divided into four categories [25, 26]:

- 1) Core Services: messaging, interface management, enterprise service management, and security.
- 2) Business Services: aeronautical, meteorological, and flight data.
- 3) Support Services: transformation, aggregation, and dissemination of data.
- 4) Technical Infrastructure: communication networks, computing platforms, and databases.

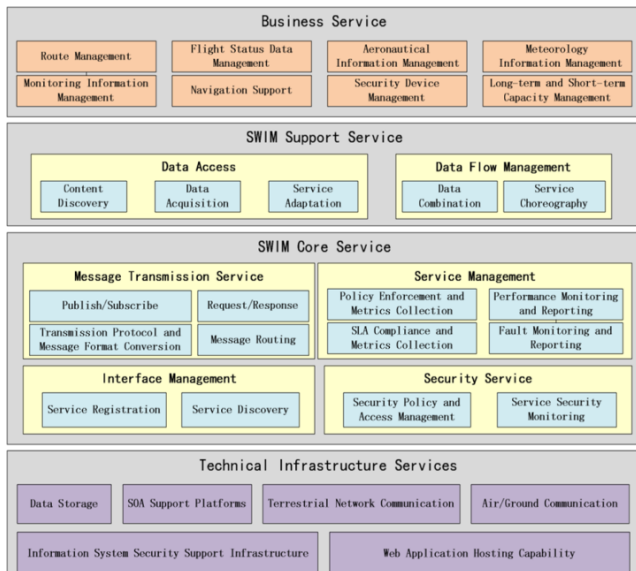


Figure 2. SWIM Functional Architecture [26].

However, the Global Interoperability Framework as shown in Figure 3 comprises the following layers:

- 1) Information Exchange Services: standardized services defined for each ATM domain and cross-domain interactions, governed by agreed specifications.
- 2) Information Exchange Models: subject-specific standards that establish the syntax and semantics of shared data.
- 3) SWIM Infrastructure: providing core services such as interface management, messaging (request-reply, publish-subscribe), security, and service management.
- 4) Network Connectivity: integrated telecommunications systems (private/public IP networks) connecting stakeholders worldwide.

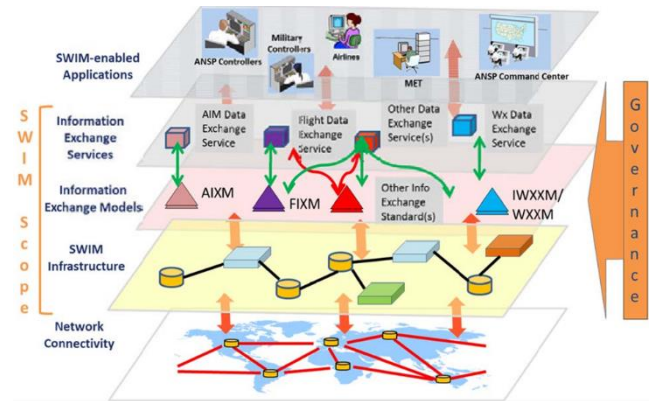


Figure 3. SWIM Global Interoperability Framework [9].

By embedding these modular services within a standardized governance framework, SWIM enables seamless interaction among stakeholders such as airlines, airports, ANSPs, and meteorological agencies. SWIM is the keystone for collaborative ATM and the integration of diverse projects into a coherent architecture [27].

2.2. Evolution from AIS to AIM

The transition from Aeronautical Information Services (AIS) to Aeronautical Information Management (AIM) represents a fundamental shift in the way aviation information is conceptualized and managed [28]. Traditionally, AIS focused on the manual preparation and dissemination of aeronautical publications, NOTAMs, and charts [29-31]. Between 1952 and 2000, AIS products have been largely paper-based and distributed through basic telecommunications, thereby creating delays and risks of inconsistency [31].

However, with the advent of digital technologies in the 1990s, ICAO recognized the need for a data-centric model. The 2009 Roadmap for Transition from AIS to AIM emphasized the shift from product-centric to data-centric management, advocating for proper automation, lifecycle management, and quality assurance [32]. AIM treats data as a strategic resource. It has been argued that this transformation expands AIS from a management information service (MIS) into an enterprise resource management system (ERMS), thereby enabling collaborative and real-time decision-making [33, 34]. AIM is not merely about digitalization but about embedding quality assurance and governance into the entire data lifecycle [35]; and SWIM builds directly on this AIM principles [36]. By extending AIM into a service-oriented, globally interoperable framework, SWIM also ensures that aeronautical data can be seamlessly integrated with meteorological, surveillance, and operational datasets to support net-centric ATM operations [8].

2.3. Aeronautical Data Chain and Information Management

The Aeronautical Data Chain (ADC) forms the foundation of Aeronautical Information Management (AIM), which is integral to System Wide Information Management (SWIM). It encompasses the processes of collecting, processing, managing, and disseminating aeronautical data, including airspace structures, flight procedures and meteorological inputs [29]. It

can also be referred to as the process of generating, managing, and disseminating critical aviation information, such as flight plans, NOTAMs, METARs, and surveillance data. Efficient information exchange enhances airspace management by ensuring real-time, reliable, accurate, and interoperable data sharing among aviation stakeholders, including Air Traffic Control (ATC), other Air Navigation Service Providers (ANSPs), airline operators, aerodrome operators, and meteorological services providers as shown in Figure 4.

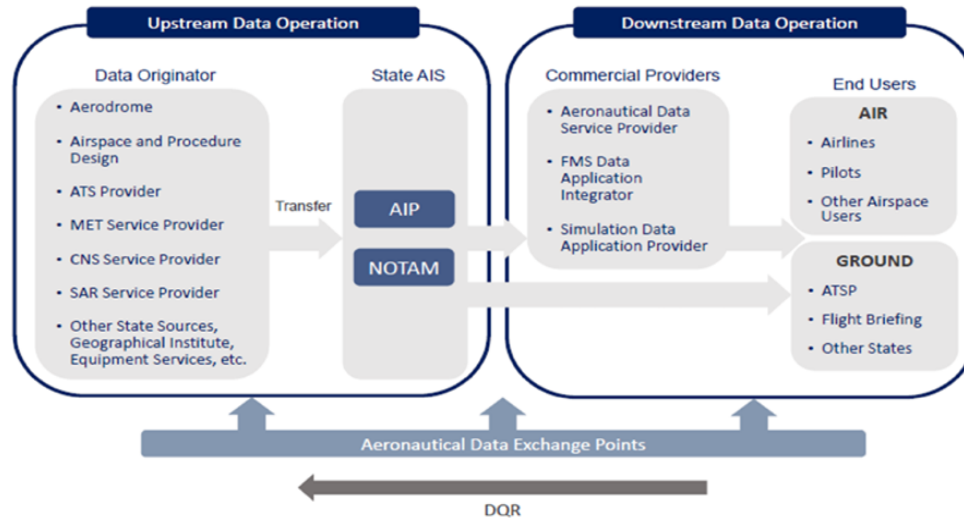


Figure 4. Aeronautical Data Chain [37].

Some of the Aeronautical Data and Aeronautical Information to be provided include Aerodrome data, Airspace data, ATS and other routes data, Instrument flight procedure data, Radio navigation aids/systems data, Obstacle data, Geographic data, and Terrain data [30]. However, these aeronautical data have been aggregated and streamlined for proper

data chain referencing into the following services, Aerodrome, Air Traffic Service Provider, Meteorological service provider, Communication Service Provider, Search and Rescue Service Provider and Procedure/ Airspace Designer as shown in Figure 5 [31, 38].

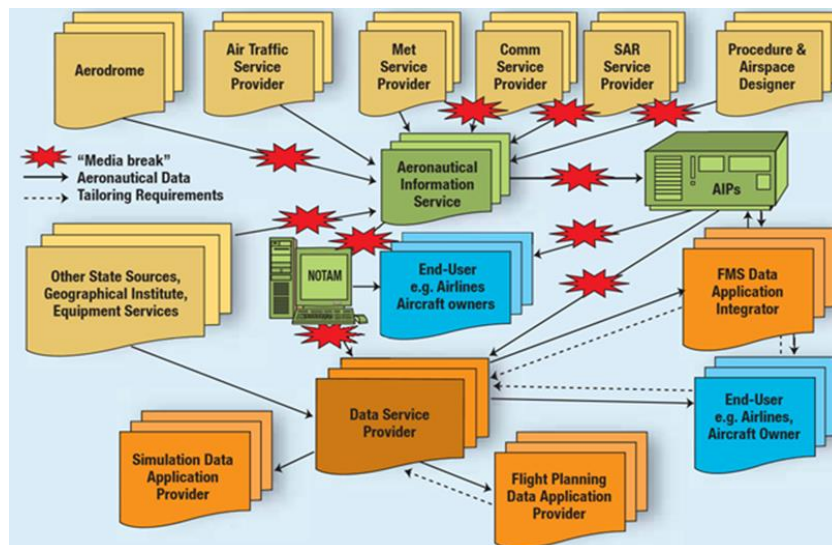


Figure 5. Aeronautical Data Chain Reference [31].

This chain is critical for aviation safety, as errors or delays in data dissemination can have operational consequences. These manual processes and multiple transaction points across stakeholders creates “media breaks” that result to increase of risk of human error [31]. These human errors are major factors in aviation incidents, which are further exacerbated by poorly designed data systems that fails to detect inconsistencies [39]. To address these challenges, EUROCONTROL launched the Controlled and Harmonized Aeronautical Information Network (CHAIN) in 2005, aimed at improving data traceability and compliance with ICAO standards [31, 40-42]. The Aeronautical Data Chain provides guidance on the processes involved in the origination, management, and distribution of aeronautical information. It emphasizes on the following [30]:

- 1) Origination of aeronautical data is from authorized sources.
- 2) Processing and maintenance are carried out according to ICAO standards.
- 3) Validation and quality control are done to ensure compliance with accuracy, integrity, and timeliness requirements.
- 4) Exchange of aeronautical data must use internationally agreed standards.
- 5) Provision of information to end-users in support of safe and efficient air navigation.

To align with the objectives of this study and to provide greater clarity, the Aeronautical Data Chain model as shown in Figure 4 has been remodified into a stepwise structured format as follows [30]:

- 1) Data Collection: from originators such as ANSPs, airports, airlines, and meteorological agencies.
- 2) Processing & Formatting: ensuring strict adherence to ICAO standards.
- 3) Quality Control: confirming accuracy, resolution, integrity, and completeness of data.
- 4) Storage: in centralized or distributed databases for easy

retrieval and redundancy.

- 5) Exchange: through standardized models (AIXM, FIXM, IWXXM) to guarantee interoperability.

- 6) Dissemination: by pilots or airline/ aircraft operators, aerodrome operators, controllers, and regulators for operational safety and decision-making.

SWIM enhances this chain by embedding automation, interoperability, lifecycle management, and ensuring that information is delivered accurately and on time to all authorized stakeholders through a unified interface with a streamlined access to a wide range of critical information, including Electronic Flight Strips, NOTAMs, METARs, flight plans, and surveillance data, fostering efficiency, reliability, and safety within the aviation ecosystem [9, 30].

2.4. ATC Infrastructure as a Backbone for SWIM-enabled Aeronautical Data Chain

ATC Infrastructure is one of the major components of ATM system that plays a central role in Aeronautical Data Management. This Infrastructure form the backbone of safe and efficient airspace operations [23]. It consists of physical, technical, and operational systems, including radar systems, communication networks, control tower electronic flight strip, and other composite systems which collectively forms the central cohesive source of support for the SWIM architecture and facilitates the safe and efficient management of airspace [43].

Among these Air Traffic Control (ATC) infrastructure, Electronic Flight Progress Strips (EFPS) represent one of the critical components of the broader ATM system as shown in Figure 6. Leveraging on the ATC Infrastructure for Aeronautical Data Integration can be carried out by Integrating Electronic Flight Progress Strips into the Aeronautical Data Chain of an ATM. This will make Electronic Flight Progress Strip system an Enabler of SWIM Integration.

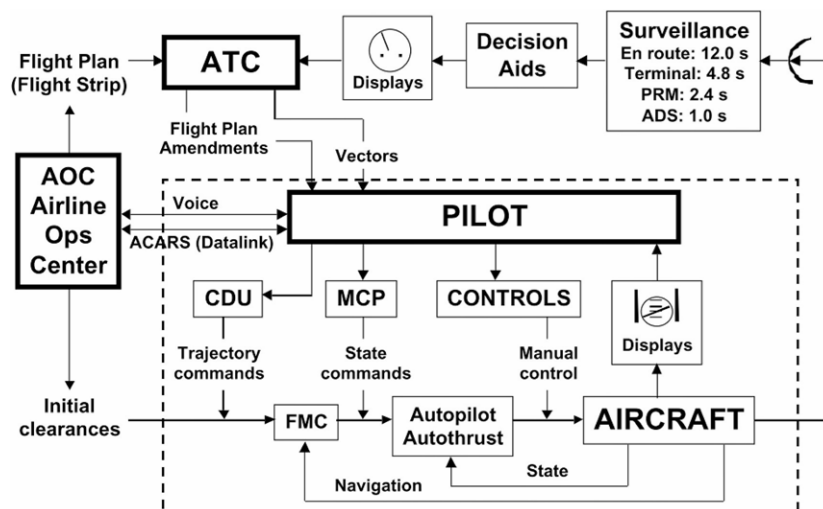


Figure 6. ATM control loops [44].

Flight progress strips were originally introduced as paper-based tracking tools in the 1940s to function essentially as external representations of aircraft under Air Traffic Control (ATC) [45]. These flight progress strips provide critical flight details and parameters such as callsign, altitude, and speed, to facilitate situational awareness, enable controllers to visualize air traffic and coordinate handovers effectively [46, 47]. Some of the inherent limitations of Paper strips include, Lack of System Integration, Time-Intensive Processing, Restricted Information Sharing, Risk of Misinterpretation, and Continuous Maintenance Requirements [46-49]. To address this challenge, the concept of Electronic Flight Strips (EFS) was introduced as tool to aid in representing the overall traffic situation and to allow seamless integration of ATC directives into digital systems and to streamline the routine tasks for Air Traffic Controllers [50]. However, it is clearly observed that the several developed EFS still lack proper standardization from the authorized prototype.

Consequently, the evolving and heterogeneous nature of Air Traffic Control systems still requires that this Electronic Flight Strip should be standardized and designed as a single system which will integrate every parameter with an interoperable capability such that each controller position will include 3 screens: airspace situation, flight progress strip, and other general information such as weather, ATIS, etc. [51]. The Electronic Flight Strips (EFS) system should also be designed to automate routine tasks such as loading, writing, placing, data entry, and as a decision support tool (DST) for air traffic controllers as shown in Figure 7.

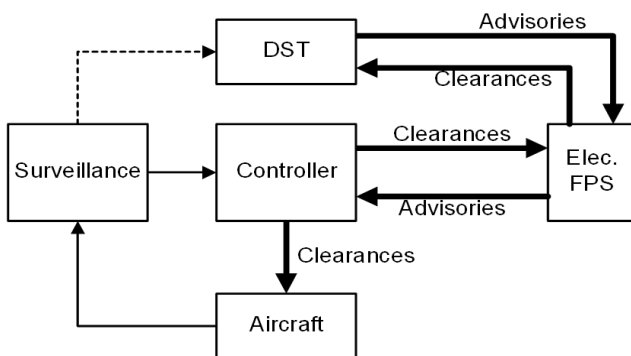


Figure 7. Air Traffic Control Loop with EFPS as DST Interface Flight Strip as DST Interface [52].

In this regard, the SWIM core services infrastructure which is referred to as the Hardware and software elements that provide the SWIM core services and its fundamental mechanisms should be designed to enable information sharing through Interface Management, Messaging, Enterprise Service Management (ESM) and Security [8]. This SWIM enterprise can be an ATM service provider (ASP), a group of ANSPs, an Airspace User, or an ATM support industry that

has full control of the implementation planning and execution within the enterprise [8]. If these enterprises are properly governed, structured and harnessed, SWIM will then ensure that aeronautical data can be seamlessly integrated within its unit structures and beyond with particular reference to meteorological, surveillance, and operational datasets to support net-centric ATM operations.

According to ICAO documentations on Global Air Traffic Management (ATM), Operational Concept envisions the application of System-Wide Information Management (SWIM) as essentially a new approach to information management that connects the entire ATM network through shared data rather than isolated systems [53]. This also marks a significant shift from the traditional one-to-one message exchange model toward a many-to-many information-sharing environment [8]. In this new paradigm, multiple geographically distributed sources collaboratively generate and update common datasets, while users across different locations maintain continuous situational awareness of any changes or updates to that information. This implies that many geographically dispersed sources (such as stations and units) collaboratively update the same piece of information, with many geographically dispersed destinations maintaining situational awareness regarding changes to that piece of information [8, 9, 53]. Electronic Flight progress strip console and its Information nodes is undoubtedly the most critical component of this information resource platform and serves as one of the most important component of Air Traffic Control and Aeronautical Information Management; the lack of its integration with the Airlines Daily Route Records (ADR-16) for Arrival and Departure messages, electronic flight plans, Global reporting format, CNS equipment and Aerodrome apparatus status, and its centralization to a common database has resulted to the further disintegration of ATS Message, Aeronautical, and Meteorological data exchange systems, thereby causing loss of revenue and proper data management and analysis.

2.5. Challenges of SWIM Implementation

Despite ICAO's promotion of SWIM, its adoption in the Africa-Indian Ocean (AFI) region remains limited. The following constraints explain why AFI states are still lagging behind its global peers, and it further underscores the need for incremental and context-sensitive frameworks:

- 1) **Infrastructural Gaps:** Many AFI states face deficits in communication networks, surveillance systems, and ICT infrastructure. Without a reliable communication network broadband, databases, and the existing redundant systems, real-time information sharing will still remain difficult [13, 54, 55].
- 2) **Financial Barriers:** Modernization initiatives such as electronic flight strips and e-NOTAM systems require significant investment. Many states rely on do-

nor-funded projects, which are often short-term and lack sustainability [54].

- 3) Policy Instability: Civil aviation authorities in the region still lack strong legal frameworks to mandate SWIM adoption. This leads to fragmented strategies and weak compliance with ICAO guidelines [56, 57].
- 4) Human Capacity Deficits: The shortage of ICT-trained aviation professionals limits the ability to implement and maintain SWIM-enabled systems. Most personnel remain trained in legacy AIS and ATC processes as mere technicians which is not sustainable [58, 59].
- 5) Organizational Resistance: Resistance to change, coupled with limited awareness of SWIM's benefits, slows its adoption. Most Stakeholders are still accustomed to manual systems, and they still perceive SWIM as disruptive concept rather than transformative.

Nigeria is a major aviation hub in the West African Region, and its aeronautical data chain reflects many of the ICAO AFI region's broader challenges. Some of the challenges observed include:

- 1) Fragmentation: AIS, ATC, and meteorological systems still operate in silos, leading to duplication and inefficiency.
- 2) Legislative Gaps: Although the 2022 amendments to the NAMA Act empower and encourages system modernization, there is currently no comprehensive national SWIM roadmap.
- 3) Technological Inequality: Major airports have limited digital systems, only four out of over twenty Airports in Nigeria are equipped with obsolete safe tower facilities, while other secondary airports still rely on outdated operational tools.
- 4) Human Resource Shortages: There is currently a limited number of ICT expertise within the aviation workforce which constrains IT modernization and innovative solutions.
- 5) Cybersecurity Risks: There is limited cybersecurity consciousness, and these weak protocols expose aviation systems and IT facilities to threats such as unauthorized access and denial-of-service attacks [18].

Despite these obstacles, Nigeria has opportunities to leverage on the existing ATC infrastructure as a backbone for SWIM adoption. Doing so could reduce costs and accelerate modernization while serving as a model for other AFI states. This review establishes SWIM as a transformative framework for ATM modernization in Nigeria.

3. Methodology

Since this project is adopting Air Traffic Control Infrastructure as Code (IaC) to improve the SWIM aeronautical data chain concept, the Agile Methodology becomes most suitable [60]. This approach focuses on rapid continuous support for IT service delivery and automation in the context of a system-oriented approach through the adoption of Agile

methodologies [61, 62]. Due to the increasing demand for efficient management and provisioning of infrastructure resources particularly in air navigation service provision and the entire civil aviation, Infrastructure as Code (IaC) tools have become indispensable in modern aviation IT environments [63]. Infrastructure as Code can also be referred to as Agile Infrastructure [64]. It adopts features which come from one of the Lean/Agile principles, and which stands for "Build incrementally with fast integrated learning cycles" [65]. This approach also reduces barriers and frictions between organizational silos development, operations, and other stakeholders involved in planning, building and running the developed software.

Infrastructure as Code (IaC) can also be described an approach for infrastructure automation which is based on practices originating from software development that emphasizes the use of consistent and repeatable routines for infrastructure provisioning [62, 66-69]. It is a technique of defining and deploying infrastructure, such as networks, virtual machines, load balancers, and connection topologies [63]. The idea behind the IaC approach is that of both writing and executing code in order to define, deploy and update the infrastructure [62].

Document analysis formed the main foundation of the research. Some of the key documents used in research include ICAO documents [8, 9, 21, 29, 30, 36, 70-73], and several Journal publications which were also reviewed alongside national policy papers, operational manuals, and technical reports from FAA, ICAO WACAF, Eurocontrol, SESAR, and South Africa [12, 13, 22, 34, 40-42, 59, 74-89]. Notable observations were also carried on the Nigerian Airspace Management Agency (NAMA) regarding the existing and operational procedures. This process helped identify current gaps, compliance levels, and infrastructural limitations within the existing Nigerian Air Traffic Management (ATM) environment.

4. Results and Discussion

In Nigeria, the current aeronautical information environment is characterized by fragmented systems which is largely operated independently with minimal data sharing capability between critical stakeholders. These limitations result in inefficiencies, delayed decision-making, and partial non-compliance with requirements [17, 29]. Though the existing system has some features of Service Oriented Architecture, it is proprietary and its software is written with outdated programming language. However, ICAO has provided a framework for bridging Legacy or proprietary System and its Integration with the SWIM Architecture as shown in Figure 8 [8, 9]. Most of the tools employed in the architectural development of the existing system in Nigeria which was developed by Frequentis and is currently deployed in only four major stations including, Murtala Muhammed International Airport, Nnamdi Azikiwe International Airport, Port Harcourt

International Airport, and Mallam Aminu Kano International Airport, are superannuated, redundant, lacks scalability, in-extensible, lack modular framework, lack global standardization, operated with Simple Object Access Protocol (SOAP)

architecture which slows parsing speed of XML, lacks standard interaction models, poor programmatic interfaces and cannot provide the necessary framework for ICAO mandatory interoperability.

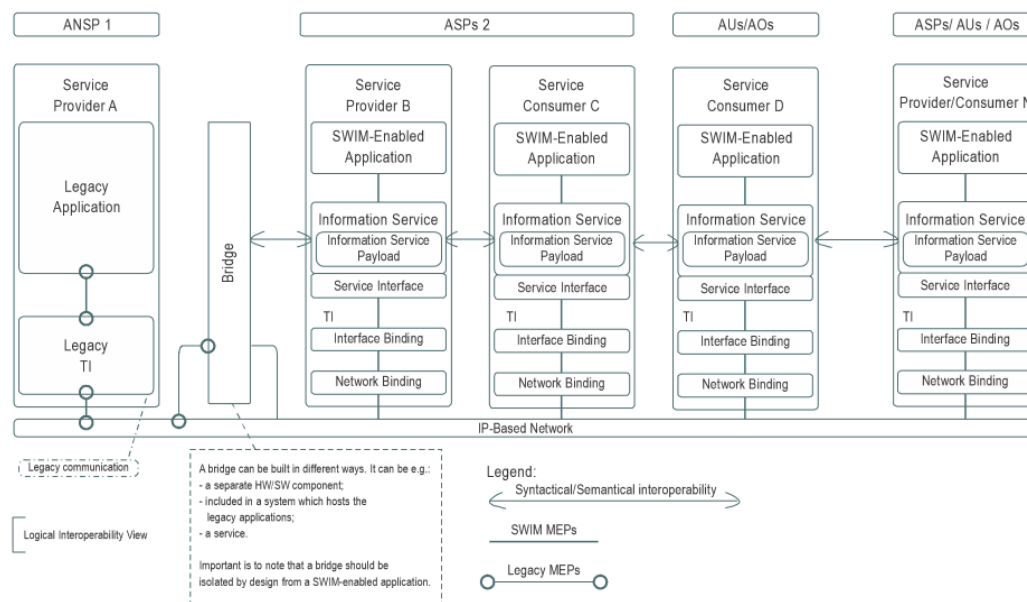


Figure 8. Mixed-mode environment with bridge [8].

Beyond these challenges, the existing system used for Electronic Flight Progress Strip Console and as shown in Figure 9 was observed to be very user - friendly though with a small repository system. It also has an improved situational awareness capability, and a capacity to search and retrieve

items by using the basic search options with a user interface that clearly simplified the work flow of traffic which is also fully customized as shown in Figure 9. It is also integrated with ATIS and has limited weather and CNS systems interoperability.

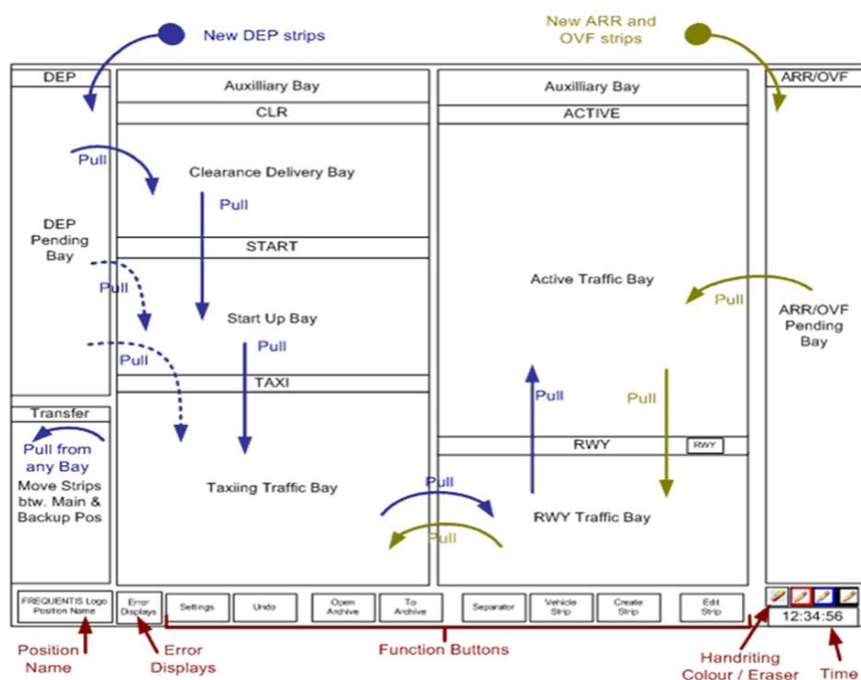


Figure 9. Frequentis SmartStrips - Workflow Interface [90].

The proposed framework leverages on ATC infrastructure as the backbone of a SWIM-enabled ecosystem. By embedding a service-oriented architecture (SOA), the framework will ensure that aeronautical, meteorological, and surveillance data are accessible to all authorized stakeholders in real time. The proposed system will also engage REST (Representational State Transfer) in what is referred as RESTful Web service which can use URI (Uniform Resource Protocol) to respond to different document format such as XML (Extensible Markup Language), HTML (Hypertext Markup Language), JSON (JavaScript Object Notation) and other light weight data-interchange defined formats. By adopted ICAO's structured data models such as AIXM, FIXM, IWXXM, the proposed system will be integrated with all the stakeholders, units, centers and all the stations within the Nigerian ANSP, and it is expected that the result will lead to the interoperability of the following Core components:

- 1) A standardized Electronic Flight Strips (EFS): Digital replacement of paper strips and the unstandardized Frequentise Electronic Smart Strip.
- 2) Electronic Flight Plan: with will be integrated with the Electronic Flight Strip and will also serve as a digital replacement of paper strips and the current unintegrated automated flight plan system.
- 3) Digital NOTAMs and AIPs: This will be transitioned into machine-readable formats that will be integrated and easily accessible from all the necessary information nodes.
- 4) Meteorological Data Integration: Real-time ingestion of IWXXM-compliant weather data will be integrated with the Electric Flight Strip and Pilot's information briefing platform.
- 5) ADR-16 Digitization: Automated daily airline route records linked to SQL databases and also integrated with the Electronic Flight Strip and Electronic Flight Plan.
- 6) Global report Format: Runway condition report status will be integrated to the Electronic Flight Strip Console and Digital NOTAM and SNOWTAM for promulgation when necessary.
- 7) Equipment Serviceability Monitor: Automated navigational and Landing aid serviceability status will also be integrated with Electronic Flight Strip Console and Digital NOTAM for promulgation when necessary.
- 8) Surveillance/ Communication Data Fusion: Integration of radar monitor will be implemented on the Electronic Flight Strip Console, with VHF/HF communications frequencies and other Coordination links.

5. Conclusion

SWIM adoption in Nigeria is not merely a technological upgrade; it is a strategic necessity for safety, efficiency, and competitiveness in global aviation [2, 91]. By embracing this proposed framework, Nigeria can position itself as a leader in

digital aviation within the AFI region, setting a benchmark for modernization and interoperability. This proposed system will demonstrate seamless integration of AIS, ATC, and meteorological datasets. Unlike the existing siloed system, the proposed prototype will enabled real-time data exchange across different aviation stakeholders, thereby improving collaborative decision-making. The entire ATM system will also be improved in terms speed and accuracy. For example, NO-TAM dissemination delays will be exceedingly reduced to near real time, and the ADR-16 compilation errors will also be reduced by thereby improving accuracy. The proposed system framework will align with all the necessary ICAO global and regional documents and initiatives by adopting structured data models such as AIXM, FIXM, IWXXM [8, 9, 21, 29, 30, 71, 92-96]. It will also support and align with the ICAO Global Air Navigation Plan (GANP) Aviation System Block Upgrades (ASBU), particularly the B1-SWIM and B2-SWIM modules. When this proposed system framework is fully implemented and deployed, the improved and standardized electronic flight progress strip will enhance ATC situational awareness, reduce operational workload, enhance revenue generation, improve safety and speedy decision-making capacity, and enable trajectory-based operations [97]. By providing this functional prototype, it will assist policymakers to craft a national SWIM roadmap for SWIM deployment and this framework can also serve as a replicable model for neighboring ICAO AFI states thereby promoting harmonization and interoperability across the region.

Abbreviations

ACARS	Aircraft Communications Addressing and Reporting System
ADC	Aeronautical Data Chain
ADR-16	Airlines Daily Route Records
ADS	Automatic Dependent Surveillance
AFI	Africa-Indian Ocean
AIM	Aeronautical information management
AIP	Aeronautical Information Publication
AIS	Aeronautical Information Service
AIXM	Aeronautical Information Exchange Model
ANSP	Air Navigation Service Provider
ASBU	Aviation System Block Upgrades
ATC	Air Traffic Control
ATFM	Air Traffic Flow management
ATM	Air Traffic Management
ATS	Air Traffic Services
CARATS	Collaborative Action for Renovation of Air Traffic Systems
CDU	Control Display Unit.
CHAIN	Controlled and Harmonized Aeronautical Information Network
CNAS	China New Generation ATM System
DST	Decision Support Tool

EFPS	Electronic Flight Progress Strips
EFS	Electronic Flight Strips
ERMS	Enterprise Resource Management System
ESM	Enterprise Service Management
FIXM	Flight Information Exchange Model
FMC	Flight Management Computer
GANP	Global Air Navigation Plan
GRF	Global Reporting Formats
HTML	Hypertext Markup Language
IaC	Infrastructure-as-Code
ICAO	International Civil Aviation Organization
IWXXM	ICAO Meteorological Information Exchange Model
JSON	JavaScript Object Notation
MCP	Mode Control Panel
METAR	Meteorological Aerodrome Report
MIS	Management Information Service
NAMA	Nigerian Airspace Management Agency
NextGen	Next Generation Air Transportation System
NOTAM	Notice to Airmen
PRM	Precision Runway Monitor
REST	Representational State Transfer
SOA	Service-Oriented Architecture
SESAR	Single European Sky ATM Research
SWIM	System-Wide Information Management
URI	Uniform Resource Protocol
WACAF	ICAO Western and Central African Region
XML	Extensible Markup Language

Author Contributions

Obinna Banner Aliche: Conceptualization, Methodology, Writing – original draft

Asagba Prince Oghenekaro: Supervision

Fubara Egbono: Supervision

Matthew Lawrence Pwajok: Investigation, Resources, Writing – review & editing

Hyelni Haruna Bassi: Investigation, Resources, Writing – review & editing

Conflicts of Interest

The authors declare no conflict of interest.

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