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East Azarbaijan Science and Technology Park



AI-Enabled Airline Digital Core Modernization: A KPI-Governed Design Science Framework for Intelligent and Predictive Airline Operations

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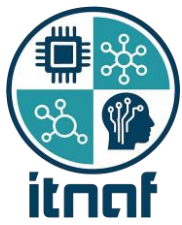
Abstract

Airline digital transformation is increasingly constrained not by the absence of technology projects, but by the absence of a governed digital core that connects enterprise architecture, trusted data, redesigned workflows, artificial intelligence (AI), cyber resilience, KPI accountability, and leadership execution. Existing airline studies have examined digital transformation, retailing, predictive maintenance, AI-supported disruption management, enterprise architecture, cybersecurity, and performance measurement, yet these streams often remain domain-specific. This paper develops ADCM-360 as a Design Science Research artifact for airline digital core modernization. The framework integrates seven layers: systems integration; data governance and intelligence; process modernization; AI and predictive operations; governance, risk, compliance, and AI assurance; performance and value realization; and leadership, transformation, capability, and adoption. It is grounded in the principle of Universal Core + Adaptive Execution: all airlines require a common modernization logic, but execution must be calibrated to airline type, digital maturity, fleet complexity, regulatory context, budget, data readiness, and strategic priorities. The paper contributes a theory-informed artifact, a KPI-governed maturity trajectory, a pilot-to-production AI governance logic, and a legacy-risk-to-control mapping. Because the paper is conceptual and design-science based, it does not claim completed empirical validation. Instead, it proposes a validation pathway through expert Delphi review, case demonstration, maturity assessment, KPI testing, and longitudinal value tracking. The contribution is relevant to information technology, AI governance, intelligent transport systems, cybersecurity, enterprise architecture, and technological futures studies.

Key words: airline digital transformation; digital core modernization; Design Science Research; aviation artificial intelligence; data governance; KPI governance; technological futures studies.

1. Introduction

1.1 Background and context



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The airline industry has historically competed through route networks, fleet scale, schedule reliability, cost efficiency, brand reputation, loyalty programs, and regulatory access. These factors remain important, but they no longer fully explain strategic resilience. The modern airline increasingly depends on whether it can connect operational, commercial, maintenance, financial, customer, workforce, and supplier data into a governed decision architecture. A large fleet can underperform when ERP, PSS, DCS, OCC, MRO, CRM, finance, procurement, BI, cyber controls, and AI pilots remain fragmented across vendors, departments, data domains, and workflows.

Why now? The urgency is created by the convergence of airline re-platforming, modern retailing, AI adoption, cybersecurity exposure, data governance demands, and the need to convert digital investment into measurable operational and financial value. The digital and data agendas of the International Air Transport Association (IATA) [1], [2], [3] point toward a shift from legacy processes to modern business architecture, while aviation AI guidance and AI risk frameworks emphasize assurance, human oversight, and accountable deployment [4], [5], [6], [7].

The central argument of this paper is that the future airline will not be defined by fleet size alone, nor by AI adoption alone, but by leadership's ability to govern the digital core. Fleet value is increasingly mediated by the ability to connect aircraft availability, maintenance planning, disruption recovery, crew resources, spare-parts readiness, revenue management, customer communication, procurement responsiveness, cybersecurity, and decision speed within one measurable operating model.

1.2 Statement of problem

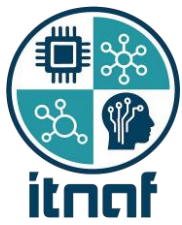
The operational problem is not that airlines lack digital initiatives. Many airlines already run ERP programs, passenger platforms, maintenance systems, dashboards, mobile applications, cloud projects, and AI pilots. The problem is that these initiatives often fail to become a digital operating model. Fragmented modernization creates duplicate master data, inconsistent KPIs, manual exception handling, weak ownership, vendor dependency, cyber exposure, limited AI readiness, and dashboards that are not trusted by operational decision-makers.

For airline executives, the failure mode is practical: decision latency remains high, disruption recovery remains slow, procurement and MRO planning remain reactive, cost leakage is not fully visible, customer journey data are disconnected, and AI pilots do not scale into auditable production value. For researchers, the failure mode is conceptual: the literature has not sufficiently integrated systems architecture, data governance, process modernization, AI assurance, KPI ownership, and leadership control into one airline-specific Design Science artifact.

1.3 Research gap, purpose, and research questions

The research gap is not simply that few studies discuss airline digital transformation. The gap is that existing research tends to explain or optimize specific domains—passenger experience, disruption management, predictive maintenance, retailing, cybersecurity, enterprise architecture, or performance measurement—without operationalizing how these domains should be integrated into one governed airline digital core. The gap is therefore integrative, methodological, measurement-based, and governance-oriented.

The purpose of this paper is to develop ADCM-360 v1.1 as an airline-specific, KPI-governed, leadership-driven Design Science artifact for digital core modernization. The primary research question is: How can airlines modernize their digital core through an integrated, KPI-governed,



leadership-driven, and AI-enabled framework that connects systems, data, processes, AI, governance, performance, and transformation capability?

SRQ1: What layers are essential for modernizing the digital core of an airline?

SRQ2: How can ERP, PSS, DCS, MRO, OCC, CRM, finance, procurement, and BI be integrated into a unified digital operating model?

SRQ3: How do data governance and process modernization function as prerequisites for predictive and AI-enabled operations?

SRQ4: Which KPIs should measure integration, data quality, process modernization, AI scalability, cyber resilience, and value realization?

SRQ5: How should airlines govern the transition from AI pilots to production across operational, commercial, financial, and engineering functions?

SRQ6: How can maturity be assessed from fragmented legacy operations toward AI-assisted adaptive operations?

1.4 Contributions, scope, and article roadmap

This paper contributes by (1) conceptualizing the airline digital core as a governed enterprise decision infrastructure, (2) developing ADCM-360 as a Design Science artifact that integrates systems, data, process, AI, governance, KPI, and leadership logics, (3) adapting KPI-governance logic from prior indicator architecture work into an airline-specific measurement architecture, and (4) specifying a pilot-to-production governance pathway for human-governed AI scaling [8], [9].

The unit of analysis is the airline digital core as an enterprise operating model, not a single software application, department, airline, or vendor platform. The paper is sector-focused on airlines and related aviation operating environments. It does not claim completed empirical validation, causal performance improvement, or universal implementation success. It develops a conceptual artifact, design logic, operationalization pathway, and validation protocol. The article proceeds from literature review and research gap to methodology, artifact design, design outputs, KPI architecture, validation logic, discussion, and conclusion.

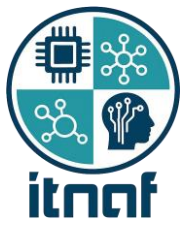
2. Literature Review and Research Gap

2.1 Search and selection logic

This study uses a narrative, integrative, and design-science-informed review strategy. The review synthesizes scholarly and authoritative sources on airline digital transformation, enterprise architecture, data governance, AI assurance, cybersecurity, KPI-based performance measurement, and Design Science Research. Its purpose is to identify the architectural, governance, and measurement gaps that justify the ADCM-360 artifact, not to claim systematic-review completeness. Sources were selected for their relevance to the research questions, methodological credibility, aviation-sector applicability, and contribution to artifact design.

2.2 Theoretical background and rival lenses

The primary theoretical lens is Design Science Research (DSR). DSR is appropriate when the research goal is to construct and communicate an artifact that addresses a relevant organizational problem [10], [11]. Gregor and Hevner [12] further emphasize that a design artifact should clarify the problem,



artifact, contribution type, and evaluation logic. ADCM-360 therefore treats airline modernization as an artifact-design problem rather than as a statistical causal test.

A rival lens is the Resource-Based View, which would interpret the digital core as a strategic asset. That lens is useful for explaining why digital capability may support advantage, but it does not specify how ERP, PSS, DCS, OCC, MRO, CRM, procurement, BI, data governance, and AI assurance should be architected together. Another rival lens is Technology-Organization-Environment logic, which explains adoption pressures but does not provide detailed artifact design. A sociotechnical systems lens explains the interaction of people, processes, and technology, but it requires a governance and KPI architecture to become operational. ADCM-360 therefore uses DSR as the main lens while incorporating sociotechnical, data-governance, and dynamic-capability logic as supporting lenses.

2.3 Airline digital core and enterprise architecture

Airline digital transformation literature shows that digital technologies reshape passenger experience, operations, maintenance, distribution, and management. Heiets et al. [13] analyze airline digital transformation as a multi-stage phenomenon, while Taneja [14], [15] argues for re-platforming airline business models beyond legacy operating assumptions. Aviation enterprise architecture work also supports the need for structured business, application, data, and technology views in an aviation-specific reference architecture [16]. API and microservice principles help explain how heterogeneous systems can be integrated without relying only on monolithic replacement [17]. Prior KPI-driven airline IT-solutions work also supports connecting IT initiatives to measurable governance and performance indicators [18].

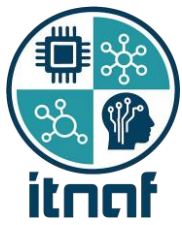
Airline heterogeneity also matters. Business-model convergence research shows that airline types cannot be treated as operationally identical, and this supports the ADCM-360 principle that a common digital-core architecture must still be executed through airline-specific pathways [19].

The unresolved issue is that technical integration alone does not produce a governed digital core. A system may be connected, but still lack master data governance, process ownership, business rules, decision rights, cyber controls, KPI ownership, and value-realization logic. This is where an airline-specific design artifact is needed. Airline modernization should therefore move beyond generic cloud, API, and AI language toward a governed digital operating model that integrates application modernization, master data management, AI/ML operations, cyber resilience, process re-engineering, and KPI-based value realization. In this sense, ADCM-360 positions the digital core not as a technology stack alone, but as a governed enterprise decision infrastructure.

This logic positions AI assurance as a digital-core governance issue rather than an isolated model-performance issue.

2.4 AI, predictive operations, and assurance

AI has clear airline use cases: predictive maintenance, disruption prediction, spare-parts forecasting, supplier-risk analysis, demand forecasting, dynamic pricing, customer personalization, fraud detection, and decision support. Geske et al. [20] show the relevance of AI-supported collaborative decision-making for disruption management. Pilon [21] documents emerging AI strategies in commercial aviation. The author's prior work on digital transformation and AI in airline management, predictive maintenance, and agentic AI also supports the need to connect AI to KPI governance rather than treating AI as an isolated tool [22], [23], [24].



However, AI raises an aviation-specific governance challenge. Aviation is safety-sensitive, time-critical, and regulation-intensive. EASA's AI Roadmap and AI concept paper emphasize human-centric assurance, ICAO's cybersecurity strategy places digital resilience within aviation-sector governance, and NIST AI RMF and ISO/IEC 42001 emphasize risk management and AI management systems [4], [5], [6], [7], [25], [26]. The implication for ADCM-360 is direct: AI should not scale from pilot to production unless data readiness, architecture fit, workflow ownership, human oversight, cyber controls, monitoring, and value evidence are satisfied.

The broader AI adoption literature also supports caution: rapid AI diffusion does not guarantee enterprise value, because value depends on workflow redesign, monitoring, talent, governance, and organizational capability rather than tool access alone [27].

2.5 Measurement, KPI, and operationalization review

Performance measurement literature warns that metrics without a governance logic can become decorative or even misleading. The Balanced Scorecard links performance indicators to strategy [28], while composite-indicator work highlights weighting, normalization, uncertainty, and sensitivity challenges [29], [30]. Aerospace digitalization KPI work further supports the need to connect digital transformation to measurable operational value [31].

Data-management practice is equally important because a KPI-governed digital core requires data definitions, stewardship, lineage, quality rules, and metadata governance. This is consistent with DAMA's data-management body of knowledge and with the ADCM-360 requirement that every KPI be traceable to source systems and accountable owners [32].

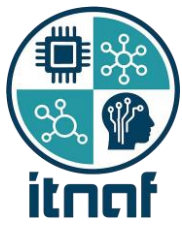
The author's 7S-360 Strategic Indicator Architecture is especially relevant because it deconstructs measurement into KPI, Diagnostic Indicator, Impact Indicator, Capacity-Building Indicator, Strategic Progress Indicator, Crisis Warning Indicator, and Master Convergence and Performance Index [8]. In the 7S-360 strategic indicator architecture, indicator integrity requires SMARTER definitions, normalization, AHP weighting, uncertainty bands, sensitivity checks, data lineage, and auditability. ADCM-360 adapts this logic to airline digital transformation: every modernization KPI should define owner, operational definition, source system, baseline, target, cadence, threshold, action rule, gaming risk, and escalation path.

2.6 Gap-to-RQ bridge

The literature supports five conclusions. First, airlines require digital transformation, but domain-specific projects do not automatically create enterprise-level modernization. Second, architecture and APIs are necessary but insufficient without data governance and process ownership. Third, AI creates value only when embedded into workflows, monitored through MLOps/LLMOps, and governed through human accountability. Fourth, KPI logic must move beyond reporting and become a control mechanism. Fifth, airline modernization requires adaptive execution because full-service, low-cost, regional, cargo, charter, legacy, and start-up airlines differ in fleet complexity, regulatory exposure, data maturity, and investment capacity.

These gaps justify the PRQ and SRQs by linking the literature problem to an artifact-design response. ADCM-360 is designed to answer what must be integrated, how it should be governed, which KPIs should be used, how AI should scale, and how maturity should be assessed.

3. Methodology



3.1 Research design and rationale

This study uses conceptual Design Science Research. The claim strength is design, integration, operationalization, evaluation logic, and future validation protocol. The study does not claim causal effects, statistical significance, completed expert consensus, or empirically measured improvement in OTP, CASK, AOG, revenue, customer satisfaction, or cyber resilience. Causal language is therefore avoided.

The artifact was developed through problem identification, literature-informed design, integration of prior author models, artifact construction, demonstration through figures and use-case logic, and evaluation planning. This follows the DSR logic that an artifact should be useful to practitioners while also contributing to scholarly understanding [12], [10], [11].

3.2 Study context, unit of analysis, and scope

The study context is airline digital transformation at the enterprise level. The unit of analysis is the airline digital core, defined as the governed enterprise architecture through which systems, data, processes, AI, controls, KPIs, and human decision rights are connected. The artifact is designed for airlines and airline units, including operations control, MRO, procurement, commercial, finance, customer experience, data, IT, cybersecurity, safety, and transformation offices. The study does not include direct empirical testing of a named airline, because its scope is conceptual artifact development rather than case-based evaluation.

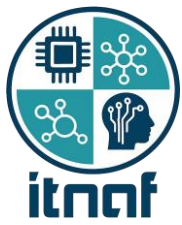
3.3 Design inputs and artifact development logic

The ADCM-360 artifact was developed from three categories of design inputs. The first category consists of airline-domain requirements, including enterprise system fragmentation, legacy application dependence, data-quality limitations, manual workflows, ungoverned dashboards, cybersecurity exposure, and the difficulty of scaling AI pilots into production value. The second category consists of theoretical and methodological inputs from Design Science Research, enterprise architecture, data governance, AI assurance, cybersecurity governance, KPI-based performance measurement, and airline digital transformation literature. The third category consists of the author's prior KPI-governed framework-development stream, including earlier work on airline performance analytics, airline IT solutions, AI-enabled airline management, and strategic indicator architecture.

The artifact was constructed through a layered design logic. Each layer was included only if it satisfied three criteria: it addressed a recurring airline modernization failure, it contributed to one or more research questions, and it could be operationalized through governance outputs, KPI evidence, or maturity assessment. The seven layers therefore respond to seven recurring failure modes: fragmented systems, weak data governance, inefficient workflows, AI pilots without readiness, unclear risk accountability, weak value evidence, and limited leadership-led adoption. The design principle of Universal Core + Adaptive Execution constrains the artifact by preventing overgeneralization: the core architecture is common across airlines, but implementation pathways must be calibrated according to airline type, fleet complexity, regulatory context, digital maturity, data readiness, budget, and strategic priorities.

3.4 Measures, instruments, and operationalization

Because this is a conceptual DSR paper, the measures are proposed rather than empirically populated. The KPI families are specified as part of the artifact's design outputs in Section 5, where they are



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linked to systems integration, data governance, process modernization, AI scaling, cyber assurance, value realization, and transformation adoption.

3.5 Evaluation protocol, validity, ethics, and replication package

The proposed evaluation protocol has four stages. First, a Delphi panel of airline CIOs, COOs, MRO leaders, data-governance experts, cybersecurity leaders, and digital transformation managers should evaluate clarity, completeness, feasibility, and relevance. Second, case demonstration should test the framework in one airline or airline unit. Third, maturity assessment should score the airline against the five maturity levels. Fourth, longitudinal KPI tracking should test whether modernization actions are associated with value realization.

Validity threats include author-model bias, conceptual overbreadth, limited empirical evidence, and sectoral heterogeneity. Mitigation requires transparent claim boundaries, expert validation, calibration by airline type, and explicit KPI data lineage. Ethics and compliance issues include privacy, cybersecurity, employee surveillance risk, passenger data protection, vendor lock-in, AI bias, and safety-critical decision rights. A replication package should include the design principles, KPI dictionary template, maturity scoring rubric, expert-review instrument, and synthetic example dashboard rather than confidential airline data.

4. ADCM-360 Artifact Design

4.1 Core definition and design principles

ADCM-360 is a KPI-governed and leadership-driven airline digital core modernization framework. It connects systems integration, data governance, process modernization, AI and predictive operations, governance/risk/compliance and AI assurance, performance and value realization, and transformation capability into one enterprise operating model. The artifact is not a software product, vendor blueprint, or generic digital transformation checklist. It is a reference model for diagnosing, designing, governing, and evaluating airline modernization.

The design principles are: architecture before automation; governed data before AI; process redesign before digitization; human-governed autonomy before operational autonomy; KPI value realization before scale-up; cyber and AI assurance as built-in controls; and universal core with adaptive execution. These principles convert the paper from a general digital transformation discussion into a structured Design Science artifact.

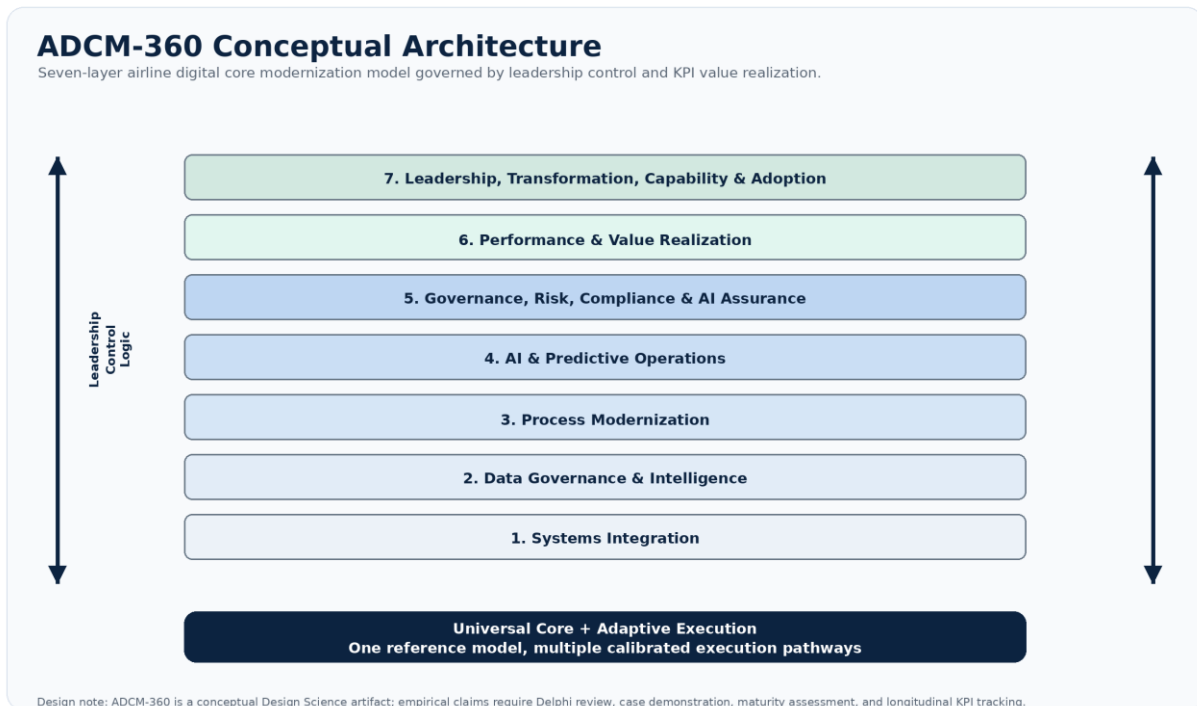


Figure 1. ADCM-360 conceptual architecture.

4.2 Seven layers of the framework

The ADCM-360 artifact is organized into seven interdependent layers. These layers are not independent modules; they define a staged modernization logic through which an airline moves from fragmented legacy operations toward integrated, predictive, and human-governed AI-enabled operations. The sequence is deliberate: systems and data must be governed before advanced automation is scaled, and AI production must be controlled through risk, KPI, and leadership gates.

Layer 1: Systems Integration. The first layer connects the core airline systems into an integrated digital architecture. It covers ERP, PSS, DCS, MRO/M&E, OCC, CRM, BI, finance, procurement, revenue management, crew management, loyalty/FFP, cargo systems, AODB where applicable, and airport or ground-handling interfaces where relevant. Its strategic function is to reduce digital fragmentation and ensure that operational, commercial, maintenance, financial, procurement, and customer systems do not operate as isolated islands. Key outputs include integrated enterprise architecture, API-based connectivity, legacy application mapping, critical system ownership, integration governance, system rationalization, legacy retirement planning, and interface monitoring.

Layer 2: Data Governance and Intelligence. The second layer transforms fragmented airline data into trusted, governed, and decision-ready intelligence. It includes master data management, data-quality management, data lineage, data catalogue, metadata governance, real-time data pipelines, data ownership, data stewardship, privacy, access control, certified datasets, and operational data products. Critical airline data domains include aircraft, flight, passenger, booking, revenue, route, maintenance, component, inventory, supplier, contract, crew, customer profile, cost center, safety, compliance, and regulatory data. This layer ensures that BI, dashboards, AI models, executive reports, and cross-functional decisions are based on reliable and auditable data.



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Layer 3: Process Modernization. The third layer redesigns airline processes before automation. It includes workflow redesign, process mining, approval governance, exception handling, SOP digitization, RPA where suitable, digital audit trails, process ownership, and process performance dashboards. Priority processes include procurement-to-pay, spare-parts ordering, AOG response, maintenance planning, repair-order management, contract approval, budget approval, disruption management, crew recovery, service recovery, inventory replenishment, safety occurrence reporting, commercial campaign approval, and route profitability review. Its purpose is to prevent airlines from digitizing inefficient processes and to create a workflow foundation for AI-enabled operational decision support.

Layer 4: AI and Predictive Operations. The fourth layer moves the airline from descriptive reporting to predictive, prescriptive, and human-governed AI-enabled decision support. Core use cases include predictive maintenance, disruption prediction, crew recovery optimization, aircraft recovery optimization, demand forecasting, dynamic pricing, customer personalization, ancillary revenue optimization, spare-parts forecasting, supplier risk prediction, fraud detection, no-show prediction, baggage disruption prediction, route profitability forecasting, fuel-efficiency analytics, and irregular-operations support. The layer explicitly avoids uncontrolled autonomy: in safety-critical, regulatory, ethical, financial, or customer-sensitive contexts, AI must remain subject to human oversight, escalation rules, lifecycle monitoring, explainability evidence, and risk classification.

Layer 5: Governance, Risk, Compliance, and AI Assurance. The fifth layer ensures that digital modernization is safe, compliant, accountable, auditable, and strategically governed. It covers digital governance, decision rights, cybersecurity, privacy, vendor governance, risk registers, auditability, safety alignment, portfolio governance, steering committees, escalation rules, investment governance, and AI assurance. In ADCM-360, this layer aligns AI governance with recognized risk-management and AI management-system principles while requiring consistency with aviation safety, cybersecurity, regulatory, and airline-specific operational controls. Its outputs include governance charters, decision-rights matrices, digital and AI risk registers, cybersecurity dashboards, vendor governance, privacy controls, AI system inventory, model registries, compliance mapping, audit trails, human oversight protocols, and risk-acceptance procedures.

Layer 6: Performance and Value Realization. The sixth layer connects digital transformation to measurable airline performance and financial value. It covers operational performance, financial performance, customer value, maintenance reliability, procurement efficiency, cyber resilience, process efficiency, data quality, AI effectiveness, employee adoption, and digital transformation ROI. The layer prevents transformation from being measured only by system go-live dates, cloud migration, software deployment, or number of AI pilots. Each initiative should have a baseline, target, owner, benefit hypothesis, tracking cadence, threshold, action rule, and scale/revise/retire decision logic.

Layer 7: Leadership, Transformation, Capability, and Adoption. The seventh layer converts ADCM-360 from a conceptual architecture into an executable transformation roadmap. It includes executive sponsorship, transformation office, change management, digital roadmap, capability building, training, digital culture, adoption management, portfolio governance, legacy retirement, communication planning, role redesign, AI literacy, data literacy, and leadership review cadence. This layer embeds leadership into execution and ensures that digital modernization becomes an operating model rather than only a technology deployment programme.

Together, the seven layers define ADCM-360 as a governed digital modernization method. The framework begins with systems integration and data trust, progresses through process modernization and AI-enabled prediction, and is controlled through governance, KPI value realization, and leadership-led adoption. This sequence is important because advanced AI should not be scaled before minimum integration, data quality, process ownership, cyber resilience, human oversight, and KPI value evidence are established.

4.3 Maturity trajectory

ADCM-360 defines five maturity levels: fragmented legacy airline, digitally aware airline, integrated digital airline, predictive airline, and AI-assisted adaptive airline. The maturity trajectory is deliberately staged: advanced AI should not be moved into production before minimum integration, data quality, governance, cyber resilience, human oversight, and KPI value evidence exist.

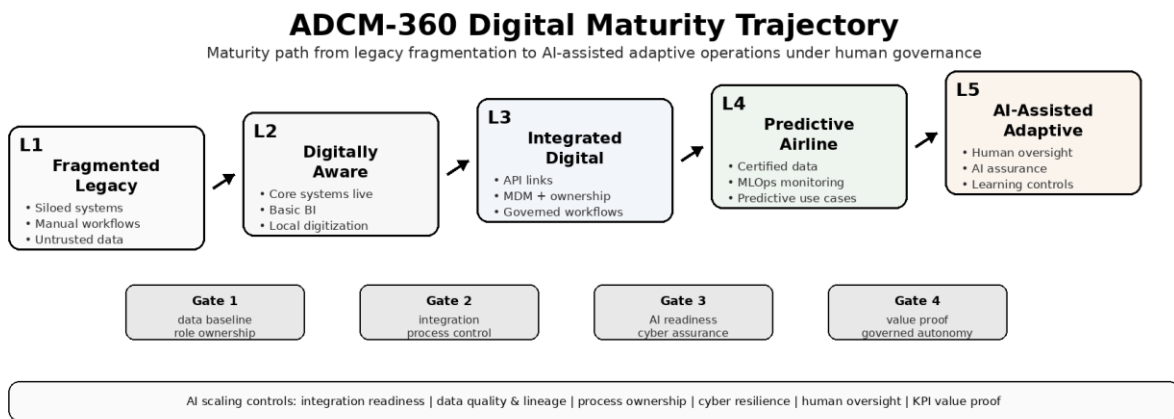


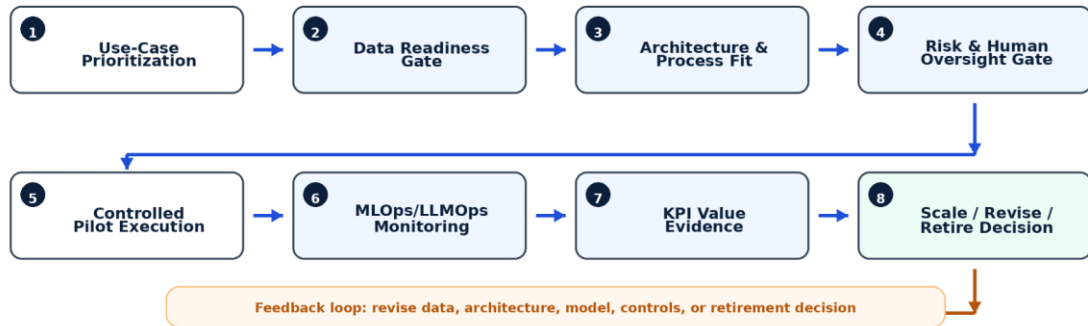
Figure 2. ADCM-360 digital maturity trajectory.

4.4 Pilot-to-production governance logic

AI scaling is one of the most important contribution areas of ADCM-360. The framework requires use-case prioritization, data readiness, architecture and process fit, risk and human oversight, controlled pilot execution, MLOps/LLMOps monitoring, KPI value evidence, and scale/revise/retire decision logic. This pathway reframes AI scaling as a governance problem rather than merely a model-performance problem.

ADCM-360 Pilot-to-Production Governance Logic

Human-governed AI scaling from controlled pilot to auditable production value



Leadership gates and production controls

Strategic priority | business case | funding approval |
operational owner
Risk acceptance | safety/compliance clearance | human
oversight | production control

Minimum KPI evidence: owner | definition | source system |
baseline | target
Refresh cadence | threshold | action rule | gaming risk |
escalation path

Design logic: select → certify readiness → assure risk → test → monitor → prove value → scale, revise, or retire

Detailed formulas, owners, thresholds, and escalation paths should be explained in the text or appendix, not inside the figure.

Figure 3. ADCM-360 pilot-to-production governance logic for human-governed AI scaling.

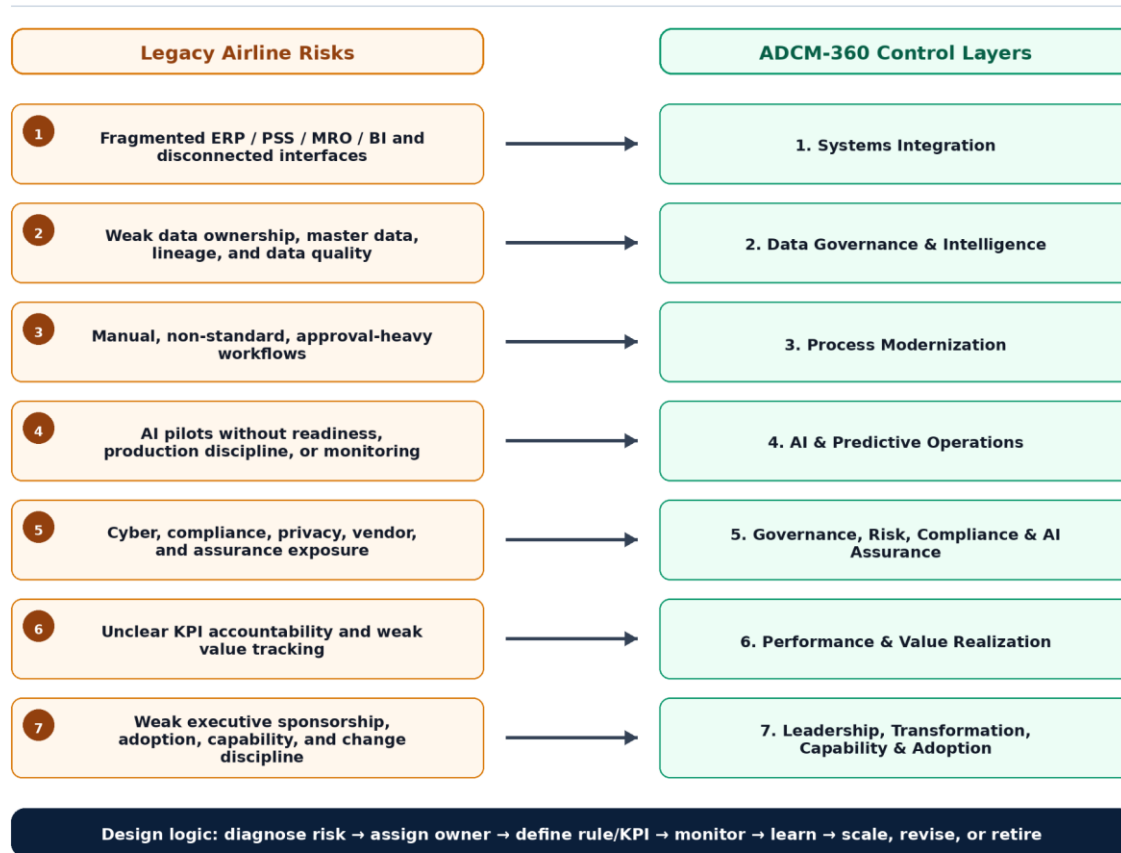
Figure 3. ADCM-360 pilot-to-production governance logic for human-governed AI scaling.

4.5 Legacy airline risk-to-control mapping

Traditional airlines may already own digital systems but still suffer from fragmented interfaces, weak master data, manual workflows, AI pilots without readiness, cyber and vendor exposure, weak KPI accountability, and change resistance. Figure 4 maps these risks to corresponding ADCM-360 control layers. The mapping is not a statistical result; it is a design output that helps practitioners translate diagnosis into governance action.

ADCM-360 Legacy Airline Risk-to-Control Mapping

Recurring legacy-airline risks mapped to the seven ADCM-360 control layers



Detailed formulas, owners, thresholds, and escalation paths should be explained in the text or appendix, not inside the figure.

Figure 4. ADCM-360 legacy-airline risk-to-control mapping.

Figure 4. ADCM-360 legacy-airline risk-to-control mapping.

5. Findings and Results: Design Outputs

Because this paper is conceptual Design Science, the findings are presented as artifact outputs rather than empirical performance results. The ADCM-360 outputs answer the research questions through the seven-layer architecture, SRQ-based design mapping, KPI-governed control logic, maturity trajectory, pilot-to-production governance pathway, and legacy-risk-to-control mapping. Accordingly, the KPI and maturity architecture is treated as part of the artifact's design results, not as a separate empirical measurement outcome.

5.1 SRQ-Based Design Outputs

For SRQ1, the essential layers are systems integration, data governance and intelligence, process modernization, AI and predictive operations, governance/risk/compliance and AI assurance, performance and value realization, and leadership/transformation/capability/adoption. For SRQ2, integration is not treated as a single IT interface project; it is an enterprise architecture problem connecting operational, commercial, engineering, financial, and customer systems through APIs, data ownership, workflow rules, and governance. For SRQ3, data governance and process modernization



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are prerequisites because predictive and AI-enabled operations require trusted data, defined decision rights, controlled workflows, and auditable source systems.

For SRQ4, the KPI architecture includes integration KPIs, data quality KPIs, process KPIs, AI scaling KPIs, cyber-assurance KPIs, value-realization KPIs, and transformation-adoption KPIs. For SRQ5, the transition from AI pilot to production is governed through readiness gates, human oversight, MLOps/LLMOps monitoring, KPI value evidence, and scale/revise/retire rules. For SRQ6, maturity is assessed through a five-level trajectory that prevents premature AI scale-up before foundational controls are established.

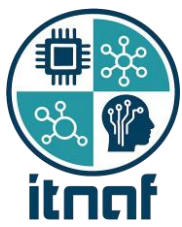
5.2 KPI Architecture as Decision-Control Output

The KPI architecture functions as the control system of ADCM-360. In this framework, a KPI is not a decorative reporting number; it is a decision-control mechanism with an accountable owner, operational definition, source system, baseline, target, reporting cadence, threshold, action rule, gaming risk, and escalation path. This logic extends the author's prior KPI-governed airline analytics and 7S-360 strategic indicator architecture into the specific context of airline digital core modernization [8], [33]. The purpose is to ensure that digital transformation is not judged only by system go-live dates, cloud migration, software deployment, dashboard production, or the number of AI pilots, but by measurable improvements in integration, data trust, process performance, AI readiness, cyber resilience, financial value, and organizational adoption.

ADCM-360 distinguishes seven KPI families aligned with the seven layers of the framework. Systems KPIs assess integration coverage, critical-system availability, interface error rate, API coverage, and legacy retirement progress. Data KPIs assess completeness, validity, duplication, lineage coverage, master-data compliance, certified dataset availability, and data-quality escalation closure. Process KPIs assess cycle time, automation rate, workflow compliance, approval lead time, exception resolution, rework reduction, and digital audit-trail coverage. AI and predictive-operation KPIs assess production readiness, model drift, model monitoring coverage, AI recommendation adoption, false positive rate, human override rate, incident escalation closure, and value evidence from AI use cases. Cyber and assurance KPIs assess mean time to detect, mean time to respond, access violations, vendor-risk closure, audit findings, privacy-control compliance, and AI assurance evidence. Value-realization KPIs assess OTP improvement, CASK reduction, aircraft availability, AOG avoidance, disruption recovery time, procurement efficiency, revenue uplift, customer value, and digital ROI. Transformation and adoption KPIs assess training completion, user adoption, roadmap delivery, capability maturity, executive review cadence, change resistance, and legacy-retirement progress.

The KPI architecture must also control measurement quality. Each KPI should be traceable to a governed data source and should be assigned to a business owner rather than treated as a purely IT-owned metric. Without data lineage, KPI definitions, and escalation rules, dashboards may create the appearance of control without improving decision quality. ADCM-360 therefore requires every high-priority KPI to be accompanied by minimum evidence: definition, source system, data owner, calculation logic, baseline, target, threshold, reporting frequency, responsible executive, and corrective-action rule. This prevents KPI gaming, reduces metric conflict between departments, and supports auditability.

5.3 Maturity Architecture and Readiness Gates



The maturity model provides sequencing discipline for digital modernization. L1 airlines are fragmented and retrospective: systems are siloed, workflows are manual, and data are not fully trusted. L2 airlines are digitally aware but locally optimized: core systems may exist, but integration, data ownership, and process governance remain partial. L3 airlines are integrated digital airlines: key systems are connected, master data and ownership are established, and governed workflows support cross-functional visibility. L4 airlines are predictive airlines: certified data, monitored models, and KPI evidence support predictive use cases. L5 airlines are AI-assisted adaptive airlines: AI supports decision-making under human governance, assurance controls, learning mechanisms, and value-realization discipline.

Progression across maturity levels should be treated as a gate-based assessment rather than a symbolic label. An airline should not move from L2 to L3 without evidence of integration coverage, data ownership, and process control. It should not move from L3 to L4 without data quality, lineage, workflow ownership, cyber resilience, and model-monitoring capability. It should not move from L4 to L5 without human oversight, AI assurance, value proof, escalation rules, and scale/revise/retire decision logic. The model therefore avoids the unsafe claim that airlines should become fully autonomous without human governance. In ADCM-360, autonomy is not the removal of human responsibility; it is the disciplined use of AI-assisted decision support under accountable human, operational, regulatory, and KPI-based control.

The proposed KPI and maturity architecture remains conceptual at this stage. The selection, weighting, and aggregation of KPIs should be validated in future work through expert Delphi review, AHP-based weighting, case demonstration, sensitivity testing, and longitudinal KPI tracking. This limitation is important because different airline types may require different KPI priorities. A low-cost carrier, full-service network airline, cargo operator, charter airline, regional carrier, and state-owned legacy airline may share the same digital-core logic but require different thresholds, sequencing, investment priorities, and value-realization measures.

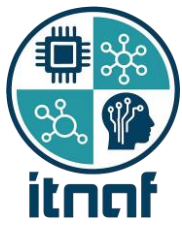
Implementation of ADCM-360 should begin with an As-Is diagnostic rather than immediate AI deployment. The diagnostic should assess system fragmentation, data quality, master data, process bottlenecks, KPI ownership, dashboard trust, cyber exposure, vendor dependency, RACI clarity, and AI readiness. Implementation can then proceed through staged waves: business and data readiness, technology enablement, and controlled AI scaling. This sequencing is intentionally conservative because premature AI scale-up can amplify poor data, weak processes, and unclear decision rights.

6. Discussion

6.1 Summary of principal design findings

The paper produces six principal design findings. First, airline modernization should be conceptualized as digital core modernization, not a set of isolated digital projects. Second, the digital core is a decision infrastructure connecting systems, data, processes, AI, governance, KPIs, and people. Third, AI scaling is unsafe and economically weak without data readiness, workflow integration, human oversight, and monitoring. Fourth, KPI governance must be embedded into modernization rather than appended as reporting after implementation. Fifth, airline modernization requires a universal architecture but adaptive execution. Sixth, legacy airline risks can be translated into control layers, owners, KPIs, and maturity gates.

6.2 Interpretation and mechanisms



Evidence-supported mechanism: fragmentation weakens decision quality because airline decisions depend on interdependent data from operations, maintenance, commercial, finance, procurement, customer, and external systems. This mechanism is consistent with aviation enterprise architecture, airline digital transformation, and re-platforming literature [13], [16], [14], [15].

Interpretive but plausible mechanism: leadership control logic determines whether digital investments become operating-model capabilities. The artifact assumes that executive sponsorship, governance cadence, ownership, and KPI escalation convert technology into sustained organizational routines. This is plausible because AI and digital value require workflow redesign, data quality, accountability, and adoption, not only tool availability.

Speculative and requiring future research: airlines that achieve L4 or L5 maturity may demonstrate measurable improvements in OTP, CASK, aircraft availability, disruption recovery, procurement efficiency, and customer value. This cannot be claimed from the current evidence; it must be tested through case demonstration and longitudinal KPI tracking.

6.3 Comparison with prior literature

ADCM-360 agrees with airline digital transformation literature that digital infrastructure and electronic applications are increasingly important [13]. It extends that literature by arguing that infrastructure must be governed as a cross-functional digital core. It agrees with Taneja's re-platforming logic that airlines need platform-level transformation, but it adds KPI ownership, data governance, AI assurance, and pilot-to-production controls as explicit model components [14], [15]. It agrees with AI-supported disruption-management literature that AI can support airline decision-making, but it places AI within a larger readiness and assurance system [20], [21].

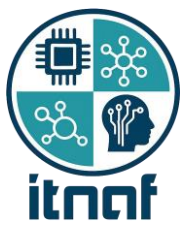
The model also extends KPI and performance measurement literature. Balanced Scorecard logic links metrics to strategy, while 7S-360 emphasizes indicator taxonomy, normalization, weighting, and governance integrity [28], [8]. ADCM-360 adapts these ideas to airline digital modernization by specifying KPI families for integration, data, process, AI, cyber, value, and transformation. The boundary condition is clear: this measurement architecture remains a proposed framework until calibrated with airline data.

6.4 Alternative explanations and rival mechanisms

One rival explanation is that vendor-led modernization is sufficient: airlines can buy integrated platforms, cloud migration, ERP upgrades, or AI tools and thereby solve fragmentation. This explanation is incomplete because vendor platforms do not automatically create data ownership, decision rights, KPI accountability, workflow redesign, or human oversight. A second rival explanation is that AI maturity alone will define future airline competitiveness. This is also incomplete because AI depends on trusted data, integrated systems, operational workflows, cyber controls, and managerial adoption. A third rival explanation is that airline type matters so much that no common framework is possible. ADCM-360 addresses this by separating Universal Core from Adaptive Execution.

6.5 Theoretical implications

Theoretically, the paper changes how airline digital transformation can be framed. Instead of treating digital transformation as technology adoption or isolated capability development, it conceptualizes the airline digital core as a governed enterprise decision infrastructure. This refines Design Science application in aviation by specifying how an artifact can integrate architecture, data governance, AI



assurance, KPI measurement, and leadership control. It also introduces a boundary condition: AI-assisted adaptive operations are only credible when maturity gates, human oversight, and value evidence are present.

6.6 Practical and policy implications

For airline executives, the implication is to govern digital transformation through a digital core steering model rather than a list of IT projects. The action is to appoint owners for systems, data domains, KPIs, and AI use cases; the enabling systems are ERP/PSS/DCS/MRO/OCC/CRM/finance/procurement/BI integration and data governance; the monitoring metrics are API coverage, data quality score, workflow compliance, AI readiness, cyber MTTD/MTTR, and digital ROI; the risk is transformation becoming dashboard theater without operational control.

For CIOs and data leaders, the implication is to build data products and certified datasets before AI scale-up. The action is to define lineage, MDM, data dictionary, metadata catalog, data SLA, and access controls; the KPIs are certified dataset coverage, lineage coverage, duplicate rate, invalid format rate, and source-system reliability; the risk is AI models being trained or deployed on inconsistent data. For COOs, MRO leaders, and procurement leaders, the implication is to redesign workflows before automation; the KPIs are cycle time, exception closure, AOG response, repair TAT, supplier OTD, spare-parts forecast accuracy, and workflow compliance. For regulators and policymakers, the implication is that aviation AI guidance should be connected to enterprise architecture, data governance, cybersecurity, and human accountability, not only algorithmic performance.

6.7 Boundary conditions, limitations, and responsible use

The paper has clear limitations. It is not an empirical airline case study. It does not include interviews, survey data, process-mining logs, operational records, or validated KPI outcomes. It does not demonstrate that ADCM-360 improves OTP, CASK, AOG, revenue, or customer value. It is a conceptual DSR artifact and should be read as a model for validation, not as validated evidence. Generalizability is bounded by airline type, regulatory environment, fleet complexity, IT maturity, data availability, budget, and workforce capability.

Responsible use requires that AI use cases remain under human-governed autonomy, especially in safety-sensitive or high-consequence contexts. Privacy, bias, passenger-data protection, cybersecurity, vendor dependency, and model auditability must be treated as design requirements. The model should not be used to justify automation that removes accountable human decision-making from safety-critical airline operations.

7. Conclusion

7.1 Summary of key findings

This paper developed ADCM-360 v1.1 as a KPI-governed and leadership-driven Design Science artifact for airline digital core modernization. It argued that the future airline will not be defined by fleet size alone or AI adoption alone, but by the maturity of the governed digital core. The paper identified a high-value research gap: existing airline digital transformation streams remain too fragmented to explain how systems, data, processes, AI, governance, KPIs, and leadership execution should be integrated into one operating model.



7.2 Scholarly contributions and recommendations

Scholarly contributions include a new artifact definition of the airline digital core, a seven-layer modernization architecture, a maturity trajectory, a pilot-to-production AI governance logic, and a KPI architecture adapted from prior indicator-governance work. Practitioners should begin with an As-Is diagnostic, establish data and KPI ownership, modernize workflows before automation, implement AI only through readiness gates, and track value realization through operational, financial, customer, cyber, and transformation KPIs.

7.3 Future research directions

Future research should conduct Delphi validation with airline executives and technical experts; apply ADCM-360 in at least one airline unit as a case demonstration; develop a maturity scoring rubric; create a synthetic or anonymized KPI dashboard; test sensitivity of KPI weights using AHP and robustness checks; compare full-service, low-cost, cargo, regional, and legacy airline implementation pathways; and examine how AI assurance controls interact with aviation safety and cybersecurity requirements.

7.4 Final payoff sentence

This paper changes airline digital transformation from a technology-project narrative into a governed Design Science artifact and enables airline decision-makers to translate digital core modernization into accountable systems integration, AI readiness, KPI value realization, and human-governed adaptive operations.

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