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**The Effectiveness of Crew Resource Management (CRM)
Training on On-Time Performance: A Case Study of Saudi
Arabian Airlines (Saudia), Jeddah, Saudi Arabia**

“A Case Study”

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Abstract

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1. Ch. 1: The Introduction

1.1. Background

Aviation captivates the imagination with speed, reach, and precision, yet day-to-day success is judged by disciplined delivery on schedule. Cirium (2021) defines on-time performance (OTP) as arriving within 15 minutes of the published schedule and treats it as a transparent, comparable benchmark across airlines and airports worldwide, turning punctuality into a public scorecard for reliability.

Building on this, Cirium (2025) shows how OTP rankings shape competitive positioning, reinforcing passenger expectations of consistency while signaling operational discipline to regulators and partners. From an industry standpoint, IATA (2025) frames punctual, dependable operations as integral to the sector's broader recovery and resilience narrative, linking on-time delivery to customer trust, network stability, and cost control in a capacity-constrained, disruption-prone environment. In short, OTP crystallizes the stakes of modern airline management: it is a headline KPI that translates operational precision into reputational capital and financial performance. Beyond headline metrics, punctuality reflects how well an airline orchestrates people, processes, and technology.

Airline punctuality emerges from a tightly coupled system where crews, aircraft, airports, and air traffic control interact in real time. EUROCONTROL's CODA Annual 2023 explains that delays rarely stem from a single cause; primary disruptions weather, ATC capacity, aircraft availability, or maintenance cascade into reactionary knock-on effects as late-arriving aircraft and crews propagate schedule slippage across the network. This propagation dynamic means a minor perturbation at one station can degrade performance across multiple downstream legs, especially under high utilization and limited buffer times. CODA's taxonomy and analytics further show how turnaround processes, gate conflicts, and ground-handling variances amplify or absorb shocks, making OTP a property of the whole operating

system rather than a timetable statistic. Cirium’s global benchmarking places these mechanisms in a competitive frame: carriers are compared on their ability to contain primary delays and prevent reactionary spread, turning operational discipline into measurable advantage. Because infrastructure and schedules cannot guarantee punctuality alone, outcomes hinge on human coordination.

At the core of airline reliability is the human element: decisions made under uncertainty, information exchanged under time pressure, and workload distributed across tightly choreographed teams. The FAA’s Pilot’s Handbook of Aeronautical Knowledge explains Aeronautical Decision-Making (ADM) as a systematic, risk-focused process that translates perception and judgment into safer, more consistent actions; it also highlights how hazardous attitudes, communication breakdowns, and poor workload management can erode performance when minutes matter (FAA, 2016). Building on this foundation, CAP 737 frames non-technical skills as explicit competencies leadership, teamwork, communication, situational awareness, and decision-making each with observable behavioural markers that can be trained, briefed, and evaluated within routine operations and time-critical turnarounds (UK CAA, 2023). Critically, these competencies map directly to the operational frictions that drive delays: unclear briefings, weak cross-checks, fragmented authority, and saturated cognitive load during gate, pushback, and taxi phases. By treating human performance as measurable and improvable not a residual after technology and schedules modern guidance positions non-technical skills as levers of consistency, resilience, and ultimately punctuality. These human-performance risks motivated the industry to formalize a training response.

In parallel, Cirium’s on-time reviews show that industry leaders distinguish themselves not merely by fleet or infrastructure, but by the ability to contain knock-

on delays and sustain consistent arrival performance an outcome that hinges on precise, repeatable crew processes under time pressure (Cirium, 2024/2025).

Taken together, these perspectives reposition CRM from a safety-only intervention to a performance lever: the same competencies it trains communication, situational awareness, leadership, and decision-making mirror the behaviours required for on-time turnarounds and network stability. Prior literature rarely models this pathway explicitly from CRM to OTP, leaving a practical, testable link at the heart of airline reliability. This under-examined link is especially relevant where punctuality is strategically salient.

Within the Middle East, carriers have become increasingly visible in global punctuality tables, with Cirium's annual reviews highlighting how the region's hubs and mainline operators compete on consistent schedule adherence amid rapid growth and network complexity. Cirium (2025) situates punctuality as a comparative yardstick across carriers in the Gulf and beyond, underscoring that competitive advantage in the region is now inseparable from disciplined, time-reliable operations. In parallel, IATA (2025) frames the sector's priorities around resilience, reliability, and data-driven improvement as traffic scales back to, and beyond, pre-pandemic levels an agenda that places day-to-day operational consistency at the center of airline strategy. Against this backdrop, Saudi Arabian Airlines (Saudia) operates as a flagship carrier within a national push to enhance connectivity and service quality, participating in the same benchmarking ecosystem that publicly compares OTP performance across markets. Cirium's coverage shows how regional leaders differentiate themselves by containing reactionary delays and sustaining repeatable arrival performance, a standard directly relevant to Saudia's competitive context (Cirium, 2025). This setting provides an opportunity to examine whether

CRM training translates into measurable punctuality, linking human-performance capabilities to a strategically salient outcome in Saudi airline operations.

A clear conceptual framework connects CRM training effectiveness to punctuality outcomes through measurable operational performance indicators. The independent variable in this study is Crew Resource Management (CRM) Training Effectiveness, which represents the overall quality and consistency of the training delivered to Saudia's flight crews. This includes the scope and frequency of recurrent training cycles, the use of scenario-based simulations, instructor qualifications, and performance assessments that evaluate behavioural competence. According to *CAP 737* (UK CAA, 2023), CRM is structured as a competency-based model encompassing four key dimensions decision-making, communication, leadership, and situational awareness each serving as an observable and assessable behavioural domain. These dimensions form the operational foundation through which CRM training is expected to influence On-Time Performance (OTP), measured in terms of departure punctuality, arrival punctuality, turnaround efficiency, and reactionary delay management. Thus, the conceptual model underpinning this study assumes a direct, positive relationship between CRM training effectiveness and the core components of OTP, aligning with the three hypotheses established for the research.

These competencies serve as mediators that connect training to day to day performance. The FAA's Aeronautical Decision Making framework supports measuring judgement, workload management, and communication under time pressure, which are precisely the behaviours that affect turnarounds and schedule adherence (FAA, 2016). The dependent variable is on time performance using the industry definition of arrival within fifteen minutes of schedule and tracked as a monthly percentage at the flight, route, and unit levels, which aligns with global benchmarking practices reported by Cirium in 2021 and 2025 (Cirium, 2021;

Cirium, 2025). To isolate the human factor pathway, the model controls for weather and air traffic constraints, maintenance events, fleet and station differences, and reactionary delay propagation, following EUROCONTROL's delay taxonomy and analytics in the CODA Annual 2023.

Managerial levers around turnaround discipline, cross functional coordination, and shock absorption buffers provide additional contextual variables as recommended in BCG's operational analyses from 2016 and 2025. Given this scaffold, the next section articulates the precise problem and gap.

Taken together, the background points to a dual imperative in modern aviation: sustaining the highest safety standards while delivering dependable punctuality as a visible marker of organizational maturity. Industry narratives frame OTP as a public test of operational discipline, where competitive carriers convert process precision into reliability and customer trust (Cirium, 2025; IATA, 2025). At the core of this capability sits the human system. FAA guidance and CAP737 both position non-technical skills decision-making, communication, leadership, and situational awareness as trainable levers that stabilize performance under time pressure, turning routine turnarounds into repeatable results (FAA, 2016; UK CAA, 2023). Decades of CRM research reinforce this premise by showing consistent gains in teamwork and safety-relevant behaviours, suggesting a credible behavioural pathway from training to schedule discipline (Salas et al., 2006; O'Connor et al., 2008). In the Saudi context, Saudia operates within a benchmarking ecosystem that openly compares punctuality, making it a practical lens for generating insights that managers and policymakers can generalize across similar network settings (Cirium, 2025; IATA, 2025). With this foundation, the next section specifies the problem and gap to be addressed in 1.2. Problem Statement. Top of Form

1.2. Research Problem

Modern commercial aviation defines success through two interdependent pillars: safety and operational reliability, particularly on-time performance (OTP). While *Crew Resource Management (CRM)* training has become a global standard to enhance teamwork and minimize human error, most academic and regulatory frameworks still conceptualize CRM primarily as a safety tool, not as a mechanism for improving operational efficiency. Global benchmarking platforms such as *Cirium* and *IATA* emphasize OTP as a key indicator of airline reliability, yet they rarely explore how effective crew coordination and communication core CRM outcomes translate into punctuality improvements.

In the Saudi context, *Saudia Airlines* operates within an increasingly competitive and data-driven regional aviation ecosystem, where OTP is not only a performance metric but also a reflection of national service quality and operational discipline. However, there remains a significant lack of empirical understanding of whether the effectiveness of CRM training directly influences punctuality outcomes, and if the CRM dimensions of decision-making, communication, leadership, and situational awareness contribute to specific components of OTP, such as departure punctuality, arrival punctuality, turnaround efficiency, and reactionary delay management.

1.2.1. Theoretical Gaps

Theoretically, the existing literature predominantly situates CRM within the domain of safety management and human error reduction (Salas et al., 2006; O'Connor et al., 2008), providing limited explanation of its role in improving time discipline and operational consistency.

Although the *CAP737* framework defines CRM competencies including leadership, decision-making, communication, and situational awareness as measurable and

improvable skills (UK CAA, 2023), their connection to punctuality and turnaround efficiency remains under-theorized.

Furthermore, the *FAA's Aeronautical Decision-Making (ADM)* model identifies judgment, workload, and time management as core human-factor skills, but their link to managing reactionary delays and minimizing schedule deviation is not clearly modeled (FAA, 2016). Existing theories also overlook contextual moderators such as airport congestion, fleet configuration, and crew pairing frequency that shape how CRM competencies translate into operational outcomes (EUROCONTROL CODA, 2023; Hajko & Badánik, 2020).

Thus, there is a conceptual gap between CRM's established behavioral benefits and its potential to drive operational performance metrics like OTP.

1.2.2. Empirical Gaps

Empirically, very few studies directly examine the relationship between CRM training effectiveness and on-time performance at the airline level. Prior evaluations of CRM programs have focused almost exclusively on safety indicators, crew attitudes, and incident reduction (Salas et al., 2006; O'Connor et al., 2008), without assessing how these behavioral improvements affect punctuality outcomes.

Industry analyses from *EUROCONTROL* and *Cirium* primarily attribute delays to weather, ATC constraints, or maintenance issues, while giving limited attention to human coordination, communication, and workload management, which are central to CRM (EUROCONTROL CODA, 2023; Cirium, 2025). In the Saudi aviation context, public OTP benchmarks exist, but they are not correlated with CRM training records or competency evaluations, leaving the CRM→OTP pathway untested.

Methodologically, most available studies lack longitudinal or quasi-experimental designs that measure pre- and post-training differences in crew behavior and connect

these changes to delay patterns. This absence of integrated human-factor and operational datasets limits the ability to determine whether CRM training directly enhances departure and arrival punctuality, improves turnaround efficiency, or reduces reactionary delays (BCG, 2016; EUROCONTROL CODA, 2023).

❖ Main Research Question

To what extent does the effectiveness of Crew Resource Management (CRM) training at Saudia Airlines influence on-time performance (OTP), and how do CRM dimensions decision-making, communication, leadership, and situational awareness affect specific aspects of OTP such as departure punctuality, arrival punctuality, turnaround efficiency, and reactionary delay management?

1.3. Research Significance

This study contributes to aviation management and human-factors scholarship by establishing a direct empirical link between Crew Resource Management (CRM) Training Effectiveness and On-Time Performance (OTP) within *Saudia Airlines*. It reframes CRM from a traditional safety-centered concept into a strategic operational performance tool that can improve punctuality, reliability, and customer trust.

By integrating *human-factor theory* with *operational performance analytics*, this research explains how improved competencies in decision-making, communication, leadership, and situational awareness can stabilize departure and arrival times, enhance turnaround efficiency, and reduce reactionary delays the core dimensions of OTP.

Within the *Saudi aviation context*, where OTP is a national and reputational benchmark, this study provides a new analytical framework for understanding how training quality translates into measurable operational gains, thereby enriching both academic theory and industry practice.

1.3.1. Theoretical Significance

Theoretically, this research builds a conceptual bridge between human-factors training models and real-world operational performance.

Drawing from the *FAA's Aeronautical Decision-Making (ADM)* principles and the *CAP737 CRM Competency Model*, the study operationalizes non-technical skills decision-making, leadership, communication, and situational awareness as mediating variables that link training inputs to OTP outcomes (FAA, 2016; UK CAA, 2023).

While previous meta-analyses (Salas et al., 2006; O'Connor et al., 2008) confirmed CRM's role in improving teamwork and safety culture, this research extends the theoretical framework to include time discipline and delay control as measurable outputs of CRM competence.

By connecting behavioral theory with performance data, it introduces a performance-oriented CRM model:

CRM Training Quality → Enhanced Crew Competencies → Reduced Operational Delays → Improved On-Time Performance.

This positions CRM not only as a safety mechanism but also as a predictive model of reliability and operational stability within airline systems.

1.3.2. Empirical Significance

Empirically, this study develops a measurable framework that links CRM training effectiveness to on-time performance using Saudia Airlines as a case study.

It collects operational data on OTP indicators (departure and arrival punctuality, turnaround efficiency, reactionary delay containment) and relates them to training records and competency evaluations based on CAP737 benchmarks (UK CAA, 2023; Cirium, 2025).

By statistically controlling for external factors such as weather, ATC constraints, maintenance issues, and fleet type, the study isolates the human-performance contribution to airline punctuality (EUROCONTROL CODA, 2023).

The findings are expected to:

- Provide evidence-based recommendations for enhancing recurrent CRM training programs.
- Guide managers and regulators in aligning training investments with measurable OTP improvements.
- Offer practical insights for optimizing crew coordination and turnaround management.

Ultimately, this study enables *Saudia Airlines* and by extension other regional carriers to translate human-factor development into competitive operational reliability, enhancing both safety and customer satisfaction.

1.4. Research Questions:

Main Research Question

What is the relationship between Crew Resource Management (CRM) Training Effectiveness and On-Time Performance (OTP) at Saudi Arabian Airlines (Saudia)?

Sub-questions

1. How strongly does overall CRM Training Effectiveness relate to overall OTP at Saudia during the study period?
2. How do the CRM dimensions decision-making, communication, leadership, and situational awareness contribute to overall OTP?

3. To what extent does CRM Training Effectiveness influence each OTP dimension: departure punctuality, arrival punctuality, turnaround efficiency, and reactionary delay management?
4. Which CRM dimension shows the strongest association with OTP when compared across the four dimensions?

1.5. Research Objectives

1. Examine the overall influence of CRM Training Effectiveness on On-Time Performance (OTP) at Saudi Arabian Airlines (Saudia).
2. Identify the contribution of CRM dimensions decision-making, communication, leadership, and situational awareness to overall OTP and determine which dimension shows the strongest association.
3. Assess the impact of CRM Training Effectiveness on each OTP dimension: departure punctuality, arrival punctuality, turnaround efficiency, and reactionary delay management.
4. Evaluate the current implementation level of CRM training at Saudia (exposure, recency, scenario-based practice) to inform targeted improvements aligned with punctuality outcomes.

1.6. Research Hypotheses

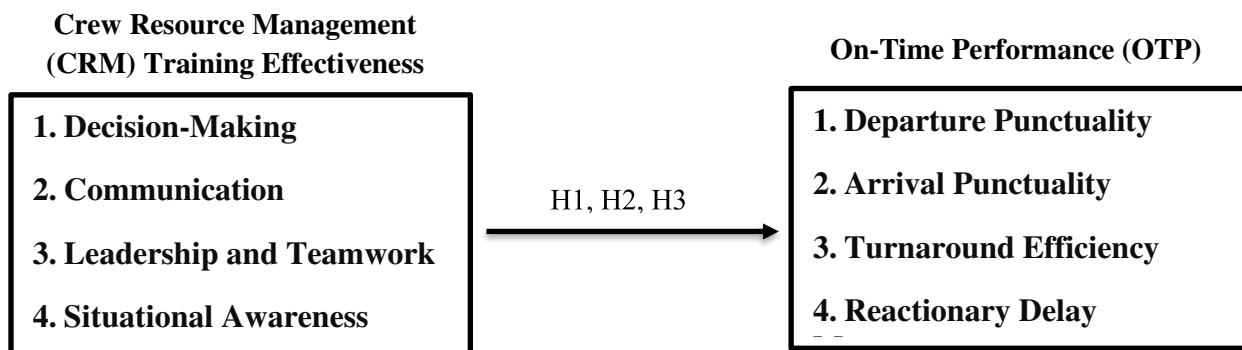
H1. There is a statistically significant positive relationship between Crew Resource Management (CRM) Training Effectiveness and On-Time Performance (OTP) at Saudia Airlines.

H2. There is a significant positive correlation between of decision-making, communication, leadership, and situational awareness and the overall On-Time Performance.

H3. There is a statistically significant positive relationship between Crew Resource Management (CRM) Training Effectiveness and of departure punctuality, arrival punctuality, turnaround efficiency, and reactionary delay management.

1.7. Research model:

Figure 1: Suggested project model



Source: Researcher

1.8. Research Methodology

1.8.1. Introduction

This section explains the methodology that was applied in the current project, in order to answer the study questions and test the study hypotheses. The following titles explain, the operational definitions for the research variables, and what has been applied, as follows:

1.8.2. Operational definitions for research variables

In research studies, operational definitions are key in clearly defining the variables being measured. An operational definition describes how a variable will be measured, observed, or manipulated. It helps researchers ensure that their studies are consistent, reliable, and valid.

1.8.2.1. Crew Resource Management (CRM) Training Effectiveness (The independent variable)

Operational Definition: CRM training effectiveness refers to the extent to which the airline's CRM program develops, assesses, and sustains non-technical skills that support safe, efficient, and time-reliable operations. This includes activities such as

recurrent CRM modules, scenario-based LOFT/LINE simulations, instructor-led briefings and debriefings, competency-based assessments using behavioral markers (e.g., communication, teamwork/leadership, situational awareness, decision-making, workload/automation management, and threat-and-error management), training recency/frequency tracking, and post-training follow-up (e.g., line checks, LOSA/TEM observations).

1.8.2.2. On-Time Performance (The dependent variable)

Operational Definition:

On-Time Performance (OTP) is the airline's operational measure of the punctuality of its flights, defined by the industry standard as arriving within 15 minutes of the scheduled time. It reflects the overall efficiency and coordination of flight operations. OTP includes factors such as departure punctuality, arrival punctuality, turnaround time efficiency, and the airline's ability to reduce or prevent reactionary delays. OTP is assessed from actual operational records and represents the final performance outcome experienced by passengers, crew, and the airline.

1.8.3. Research design

In this template, we'll present a structure that covers five important methodological matters (as outlined above). This structure is loosely based on "research onion".

1.8.3.1. Research Design:

Research Philosophy: Positivist

Research Approach: Deductive

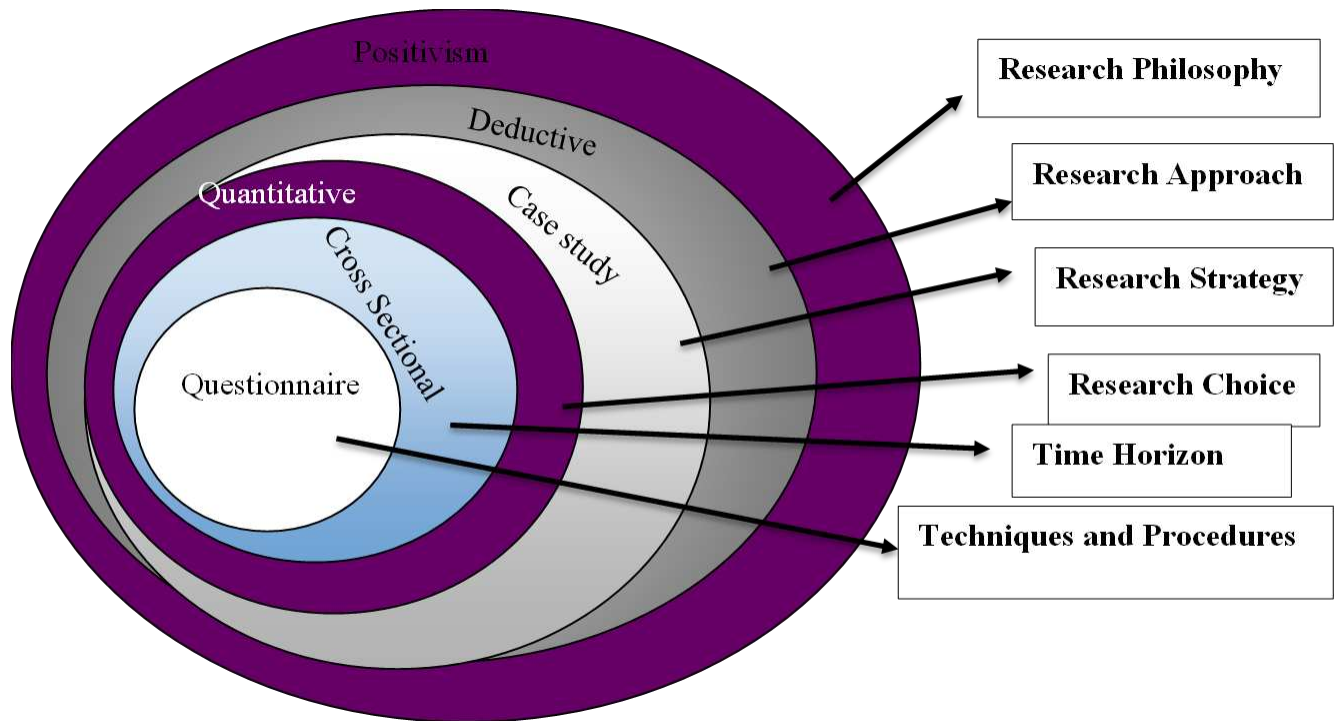
Research Strategy: Case study.

Research Choice: Quantitative

Time Horizon: Cross-sectional

Data Collection and Analysis Techniques : Questionnaire

Figure 2: Research Design



Source: Researcher

1.9. Scope of the Study

1.9.1. Introduction about Saudia Airlines

This study examines Saudi Arabian Airlines Saudia as a single case within the Saudi aviation context. The focus is on line operations that affect schedule adherence and on the training ecosystem that develops crew non-technical skills. The scope is limited to flights operated by Saudia during the defined study window and to crew groups who completed CRM training within the same period.

1.9.2. Vision

To provide evidence that strengthening human-factor competencies through CRM training can support reliable, punctual operations and visible improvements in on-time performance that matter to passengers, partners, and regulators.

1.9.3. Mission

To measure, analyze, and explain the link between CRM training effectiveness and on-time performance at Saudia by integrating training records, competency evidence, and operational punctuality indicators, and by producing actionable guidance for managers.

1.9.4. Operational and Training Domains Included

1.9.4.1. CRM Training Domain.

Coverage includes exposure and quality of CRM training. Examples include recurrent cycles, scenario based exercises, instructor standards, and assessment outcomes. Competency focus follows recognized guidance on decision making, communication, leadership, and situational awareness (FAA, 2016; UK CAA CAP737, 2023).

1.9.4.2. On-Time Performance Domain

Coverage includes departure punctuality, arrival punctuality, turnaround efficiency, and reactionary delay management, using the industry convention of arrival within 15 minutes of schedule for OTP benchmarking (Cirium, 2021; Cirium, 2025).

1.9.4.3. Controls and Context

Analysis controls for weather, air traffic constraints, maintenance events, fleet and station differences, and delay propagation, following established delay causality frameworks (EUROCONTROL CODA, 2023).

1.9.5. Population, Unit of Analysis, and Time Frame

- Population: Saudia flights and operating crews active within the study period.
- Unit of Analysis: Flight level and aggregated route or unit level, with crew level training linkages where data are available.

- Time Frame: A continuous window sufficient to observe pre and post training exposure and to compute reliable monthly OTP percentages. The exact dates will be set based on data availability and training cycles.

1.9.6. Geographic and Organizational Boundaries

- Geographic: Domestic and international stations served by Saudia that fall within the data window.
- Organizational: Flight operations and ground turnaround interfaces relevant to crew coordination. Third party providers are in scope only where their activities directly intersect with the crew processes under study.

1.9.7. Inclusion and Exclusion Criteria

- Included: Scheduled passenger services with complete records for CRM training variables and OTP indicators.
- Excluded: Charter or irregular operations if they lack comparable schedules, flights with missing core variables, and events dominated by extraordinary disruptions outside operational control.

1.9.8. Measurement Overview aligned to the three hypotheses

- Independent Variable: CRM Training Effectiveness operationalized through exposure and quality indicators and mapped to competencies in decision making, communication, leadership, and situational awareness (FAA, 2016; UK CAA CAP737, 2023).
- Dependent Variable: On-Time Performance measured as monthly percentages and decomposed into departure punctuality, arrival punctuality, turnaround efficiency, and reactionary delay management (Cirium, 2021; Cirium, 2025).

- Model Context: Weather, ATC, maintenance, fleet and station differences, and reactionary delay chains are modeled as controls to isolate the human-performance pathway (EUROCONTROL CODA, 2023).

1.9.9. Importance of studying Saudia within this scope

- Strategic relevance: OTP is a public benchmark that differentiates carriers and shapes market confidence. Demonstrating a human-performance route to punctuality can guide training investment and operational design (IATA, 2025; Cirium, 2025).
- Generalizability: Findings from a high visibility, network carrier can inform similar operations where CRM training and punctuality are joint priorities.

1.9.10. Limitations and Delimitations

- Limitations: Potential constraints include incomplete linkage between training and operational records and unobserved external shocks.
- Delimitations: The study deliberately centers on CRM related behaviours and OTP outputs rather than broader commercial metrics.

1.9.11. Conclusion

The study scope aligns data, measures, and boundaries with the three hypotheses. It concentrates on Saudia's CRM training effectiveness as the independent variable and on-time performance as the dependent variable, while accounting for operational context. This setting enables a focused test of whether enhancing crew competencies can translate into measurable punctuality improvements.

1.10. The Project structure:



2. Ch. 2: literature review

2.1. Introduction

The literature on airline operations increasingly emphasizes that operational outcomes are not determined solely by technical systems or regulatory compliance, but rather by the quality of human performance within complex socio-technical environments. Early human factors research in aviation demonstrated that a significant proportion of incidents and operational disruptions were rooted in deficiencies in communication, decision-making, and teamwork rather than mechanical failure. Helmreich, Merritt, and Wilhelm (1999) argued that these human-related breakdowns highlighted the limitations of purely technical training approaches and necessitated structured interventions targeting non-technical skills. This perspective established the conceptual foundation upon which Crew Resource Management (CRM) training later evolved.

Building on this foundation, subsequent studies reframed CRM from a safety-centered initiative into a broader performance-oriented training system. Salas et al. (2006) emphasized that CRM should be understood as a systematic method for shaping team behaviors and coordination processes that directly influence operational effectiveness. Similarly, O'Connor et al. (2008) demonstrated through meta-analytic evidence that CRM training improves communication quality, leadership behaviors, and decision-making consistency, suggesting that its impact extends beyond accident prevention. This shift in the literature signals a critical transition: CRM is no longer viewed only as a defensive mechanism against errors, but as an enabler of reliable and efficient operations.

At the same time, airline performance research increasingly identifies On-Time Performance (OTP) as a central indicator of operational reliability and organizational effectiveness. Hajko and Badánik (2020) argued that OTP reflects the cumulative outcome of multiple interdependent processes, including crew

coordination, real-time decision-making, and delay recovery strategies. Importantly, these processes are deeply influenced by the same non-technical competencies targeted by CRM training. However, despite this conceptual overlap, the literature often treats CRM and OTP as separate domains, with CRM studies focusing predominantly on safety outcomes and OTP research emphasizing technical and external factors.

This fragmentation in the literature creates a critical analytical gap. While CRM research provides strong evidence of behavioral and cognitive improvements at the crew level, and OTP studies highlight the operational importance of coordination and decision-making, few studies explicitly integrate these two streams. As Kaynak (2024) noted, the real-world effectiveness of CRM can only be fully understood when its behavioral outcomes are examined within actual operational contexts. Consequently, this chapter reviews the literature on CRM training and On-Time Performance in an integrated manner, laying the theoretical and empirical groundwork for examining how CRM competencies may contribute to improved punctuality in airline operations. This integrated perspective directly informs the research framework and hypotheses developed in the subsequent chapters.

2.2. Crew Resource Management (CRM) Training

2.2.1. Introduction

Building on the recognition that human performance is a decisive determinant of airline operational outcomes, Crew Resource Management (CRM) emerged in the aviation industry as a structured response to recurrent deficiencies in communication, leadership, and decision-making within flight and operational crews. Helmreich et al. (1999) argued that many operational breakdowns and safety events were rooted not in technical malfunction but in predictable patterns of human

interaction, which exposed the limitations of traditional, technically focused training models. As airline operations became increasingly complex, CRM evolved beyond a safety-centered corrective tool into a comprehensive framework aimed at optimizing non-technical skills that support effective coordination and adaptive performance under operational pressure.

Salas et al. (2006) emphasized that CRM functions as a systematic team training strategy designed to shape observable behaviors, while O'Connor et al. (2008) demonstrated that its impact extends to consistent behavioral improvement rather than short-term attitudinal change. More recently, Kaynak (2024) highlighted that the practical value of CRM lies in its translation from training environments to real-life operational practice, reinforcing the need to examine CRM training through its conceptual foundations, objectives, evolutionary development, and effectiveness. Accordingly, this section provides a structured review of CRM training to establish a coherent analytical basis for assessing its role in airline operational performance.

2.2.2. Definition of Crew Resource Management (CRM)

Academic literature in aviation initially defined Crew Resource Management (CRM) as a response to the growing recognition that human error, rather than technical failure, was the dominant contributor to aviation accidents and operational breakdowns. Helmreich et al. (1999) conceptualized CRM as a training philosophy aimed at improving the use of interpersonal communication, leadership, and decision-making within the cockpit, emphasizing that effective crew performance depends on how individuals interact rather than on isolated technical competence. This definition marked a departure from traditional pilot-centric skill models by framing performance as a collective, socially constructed outcome. Building on this perspective, Salas et al. (2006) expanded the academic definition of CRM by positioning it as a structured team-training system designed to develop non-technical

skills that support coordination and adaptive performance in dynamic, high-risk environments. This shift reflects an important evolution in the literature, where CRM is no longer viewed merely as an error-reduction tool but as a mechanism for shaping reliable operational behavior.

While academic definitions emphasize theoretical and behavioral foundations, organizational and regulatory bodies have translated CRM into standardized operational frameworks. Aviation authorities such as national civil aviation administrations define CRM as a mandatory, competency-based training program focused on observable behaviors related to communication, teamwork, leadership, situational awareness, and decision-making. Regulatory guidance documents emphasize that CRM must be integrated into both initial and recurrent training cycles to ensure continuous behavioral reinforcement. O'Connor et al. (2008) highlighted that such regulatory definitions operationalize CRM by linking training objectives to measurable performance criteria, thereby reducing ambiguity between training intent and operational application. This alignment between regulatory expectations and airline training practices reflects an institutional recognition that CRM is essential not only for safety compliance but also for maintaining consistent operational performance.

Across both academic and organizational perspectives, CRM is consistently framed as a human factors and non-technical skills framework. Kaynak (2024) noted that CRM targets the cognitive and social dimensions of crew performance, including communication quality, teamwork dynamics, leadership distribution, decision-making processes, and situational awareness. These core components are not treated as independent skills but as interrelated competencies that collectively shape how crews manage workload, resolve conflicts, and respond to operational pressure. This integrated view supports the argument that CRM influences operational outcomes

through behavioral coordination rather than through procedural adherence alone. Consequently, the CRM concept has evolved from a cockpit-focused training initiative to an organization-wide framework encompassing flight crew, cabin crew, dispatchers, and ground operations personnel. This evolution reflects the systemic nature of airline operations, where performance reliability depends on coordinated action across multiple functional domains rather than isolated crew units.

2.2.3. Objectives of CRM Training

Following the definition of CRM as an integrated human factors and non-technical skills framework, the objectives of CRM training extend beyond compliance with regulatory requirements to address systematic patterns of crew behavior that influence operational performance. Helmreich et al. (1999) argued that one of the primary objectives of CRM training is to enhance communication and information sharing among crew members, as breakdowns in communication were repeatedly identified as precursors to both safety incidents and operational disruptions. By promoting open dialogue, assertiveness, and cross-checking behaviors, CRM training aims to reduce ambiguity and ensure that critical information is effectively transmitted and validated within the crew.

Closely linked to communication is the objective of improving decision-making under conditions of time pressure and uncertainty. Salas et al. (2006) emphasized that CRM training targets decision-making as a collective process rather than an individual cognitive act, enabling crews to integrate multiple perspectives and manage workload more effectively during high-demand operational phases. This objective reflects a shift from individual expertise to shared judgment, reinforcing the role of teamwork in managing complex operational scenarios.

Strengthening leadership and teamwork dynamics represents another central objective of CRM training. O'Connor et al. (2008) highlighted that effective CRM programs encourage adaptive leadership behaviors, where authority is balanced with inclusiveness and task delegation is responsive to situational demands. Teamwork objectives focus on fostering mutual support, role clarity, and coordination, ensuring that crews function as cohesive units rather than hierarchical structures. These leadership and teamwork outcomes are critical for maintaining operational continuity, particularly during abnormal or disrupted operations.

In parallel, CRM training seeks to increase situational awareness and enhance threat and error management capabilities. Kaynak (2024) noted that situational awareness enables crews to perceive and anticipate operational risks, while threat and error management provides structured strategies for detecting, mitigating, and recovering from potential failures. This objective underscores the preventive function of CRM, whereby crews are trained to recognize emerging threats before they escalate into operational breakdowns.

Beyond individual crew performance, CRM training also aims to reduce human error and prevent operational failures at the system level. Helmreich et al. (1999) argued that CRM contributes to error reduction not by eliminating human fallibility, but by creating behavioral defenses that limit the consequences of inevitable errors. This systemic objective aligns CRM with broader organizational reliability goals rather than isolated safety outcomes.

Finally, CRM training promotes standardized behavioral practices across flight and ground operations, supporting organizational safety culture and operational consistency. Salas et al. (2006) and O'Connor et al. (2008) emphasized that standardized non-technical behaviors facilitate coordination across functional

boundaries, ensuring that CRM principles are embedded throughout the organization. Kaynak (2024) further highlighted that such standardization strengthens safety culture by aligning individual behavior with organizational values and operational expectations. Collectively, these objectives position CRM training as a strategic tool for enhancing both safety and operational performance, thereby setting the foundation for examining its effectiveness in subsequent sections.

2.2.4. Evolution of CRM Training Programs

The evolution of CRM training programs reflects a progressive response to the changing understanding of human performance in aviation operations. Early generations of CRM training were primarily safety-driven and emerged in direct response to accident investigations that identified human error as a dominant causal factor. Helmreich et al. (1999) described these early CRM initiatives as corrective interventions aimed at reducing accidents by addressing authority gradients, communication failures, and decision-making deficiencies within the cockpit. At this stage, CRM was largely framed as a defensive safety mechanism, with limited attention to broader operational performance outcomes.

As research on human factors advanced, CRM training gradually shifted from classroom-based theoretical instruction toward more applied and behavior-focused approaches. Salas et al. (2006) argued that purely didactic training was insufficient to produce sustained behavioral change, leading to the incorporation of experiential learning techniques. This transition marked a critical turning point, as CRM training began to emphasize practical skill application rather than abstract knowledge acquisition. O'Connor et al. (2008) reinforced this shift by demonstrating that training effectiveness was significantly enhanced when CRM principles were practiced in realistic operational contexts.

The integration of simulation-based and scenario-based training methods further accelerated the evolution of CRM programs. Simulation allowed crews to rehearse complex, time-pressured situations in controlled environments, facilitating the transfer of non-technical skills to real-world operations. Kaynak (2024) highlighted that scenario-based CRM training enhances emotional regulation, communication quality, and adaptive decision-making, thereby strengthening the practical relevance of CRM. This methodological evolution supported the alignment of CRM training with the dynamic and unpredictable nature of airline operations.

In parallel with methodological advancements, the scope of CRM training expanded beyond flight crews to include cabin crew, dispatchers, and ground staff. Helmreich et al. (1999) noted that early CRM models underestimated the interdependence of operational roles within airline systems. Subsequent research recognized that coordination failures often occur at the interfaces between functional units rather than within isolated teams. Salas et al. (2006) argued that extending CRM principles across organizational boundaries was essential for achieving systemic performance improvements.

This expansion coincided with a broader conceptual shift from safety-centered CRM to performance-oriented CRM. While accident prevention remained a core objective, CRM increasingly became associated with operational reliability, efficiency, and consistency. O'Connor et al. (2008) observed that modern CRM programs are designed to support routine operations as much as abnormal situations, reflecting the growing emphasis on everyday performance outcomes. This shift laid the groundwork for the emergence of competency-based CRM training models, which define specific behavioral competencies and link them to observable performance indicators.

The adoption of competency-based CRM represents the most recent phase in the evolution of CRM training. Kaynak (2024) emphasized that competency-based models enable standardized assessment, targeted feedback, and continuous performance improvement. By aligning CRM training with contemporary airline operational demands—such as high traffic density, tight scheduling, and network complexity—these models position CRM as an integral component of organizational performance management rather than a standalone safety initiative.

2.2.5. CRM Training Effectiveness

The concept of training effectiveness in the context of CRM has evolved alongside the development of CRM programs themselves. As CRM shifted from an awareness-based safety intervention to a competency-oriented performance framework, the question of how to evaluate its effectiveness became increasingly central. Salas et al. (2006) argued that CRM training effectiveness should not be assessed solely by participant satisfaction or knowledge acquisition, but by its capacity to produce sustained improvements in non-technical skills and operational behavior. This perspective reflects a broader understanding that CRM effectiveness is inherently multi-level, encompassing individual, team, and organizational outcomes.

At the individual level, early evaluations of CRM training primarily focused on short-term outcomes such as knowledge gain, attitude change, and perception of safety. O'Connor et al. (2008) noted that many studies reported positive immediate reactions to CRM training, including increased awareness of human factors and improved attitudes toward teamwork and communication. While these outcomes are important indicators of training acceptance, the authors cautioned that attitudinal change alone does not guarantee behavioral transfer to operational settings. This limitation prompted a shift toward more behaviorally anchored evaluation models.

Behavioral change represents a more robust indicator of CRM training effectiveness. Helmreich et al. (1999) emphasized that the true value of CRM lies in observable changes in crew interaction, such as improved communication clarity, assertive behavior, shared decision-making, and effective workload management. Empirical findings summarized by O'Connor et al. (2008) demonstrated that CRM training can lead to measurable improvements in teamwork and leadership behaviors, particularly when reinforced through recurrent training and operational feedback mechanisms. These findings support the argument that behavioral indicators provide a stronger link between CRM training and real-world operational performance.

Beyond the crew level, CRM training effectiveness also manifests at the organizational level. Kaynak (2024) highlighted that effective CRM contributes to improved coordination across operational units, more consistent adherence to procedures, and enhanced safety culture. Such organizational outcomes suggest that CRM effectiveness extends beyond individual crews to influence how airlines manage routine operations and respond to disruptions. However, Salas et al. (2006) argued that organizational benefits are often indirect and mediated by factors such as leadership support, training quality, and organizational culture, making them more difficult to measure empirically.

Given this complexity, a variety of methods have been employed to evaluate CRM training effectiveness. Quantitative approaches commonly include surveys, behavioral rating scales, and performance indicators, while qualitative methods rely on observations, interviews, and field reports. O'Connor et al. (2008) emphasized that mixed-method approaches are particularly valuable, as they capture both measurable behavioral changes and contextual factors influencing training transfer. Nevertheless, the authors noted that many evaluation studies suffer from

methodological limitations, including small sample sizes, short follow-up periods, and reliance on self-reported data.

These limitations highlight a persistent challenge in CRM research: the difficulty of linking training outcomes directly to operational performance indicators. Helmreich et al. (1999) acknowledged that while CRM training demonstrably improves non-technical skills, its impact on concrete operational metrics is rarely examined in a systematic manner. Kaynak (2024) similarly argued that the effectiveness of CRM can only be fully understood when behavioral improvements are connected to real operational outcomes. This gap underscores the need for research that explicitly links CRM training effectiveness to performance indicators such as operational reliability and punctuality, providing a clear rationale for examining CRM in relation to On-Time Performance in subsequent sections.

2.3. On-Time Performance (OTP) in Airline Operations

2.3.1. Introduction

Following the discussion of CRM training as a performance-oriented human factors framework, the concept of On-Time Performance (OTP) emerges as one of the most critical indicators through which airline operational effectiveness is evaluated. Hajko and Badánik (2020) argued that OTP is not merely a scheduling metric, but a comprehensive reflection of how well an airline manages the interaction between planning, execution, and real-time operational control. From this perspective, punctuality represents the observable outcome of complex coordination processes that involve crews, aircraft, airports, and air traffic management systems, thereby positioning OTP as a central bridge between human performance and operational results.

Industry-based analyses further reinforce the strategic importance of punctuality in airline operations. OAG (2023) emphasized that OTP has become a key benchmark for service quality, customer trust, and competitive positioning in the aviation market. Airlines with consistently high OTP are perceived as more reliable, which directly influences passenger satisfaction and brand reputation. This industry focus suggests that OTP functions not only as an internal performance indicator but also as an external signal of organizational competence, linking operational discipline with market performance.

At the system level, punctuality is increasingly viewed as a shared responsibility across multiple stakeholders rather than an outcome controlled solely by airlines. EUROCONTROL, FAA, and the European Commission (2024) demonstrated that arrival and departure punctuality are strongly influenced by air traffic management capacity, airport congestion, and network-level constraints. This systemic perspective highlights that OTP reflects the effectiveness of coordination across organizational boundaries, aligning closely with the principles underpinning CRM training discussed earlier. As such, punctuality becomes an integrative performance outcome shaped by both human and structural factors.

Recent empirical research further illustrates that maintaining high OTP is operationally complex and involves trade-offs between efficiency, robustness, and cost. van Schilt et al. (2024) showed that schedule reliability and OTP are directly affected by buffer allocation decisions, where excessive buffering may reduce network connectivity while insufficient buffering increases delay propagation. This finding underscores that punctuality is not an isolated objective but part of a broader operational optimization challenge. Consequently, understanding OTP requires a multidimensional analysis that goes beyond simple time thresholds, providing a

foundation for examining its definition, dimensions, and determinants in the following sections.

2.3.2. Definition of On-Time Performance (OTP)

Building on the understanding of punctuality as an integrative operational outcome, On-Time Performance (OTP) is commonly defined as the proportion of flights that arrive or depart within a specified time threshold relative to their scheduled time. Hajko and Badánik (2020) defined OTP as a key performance indicator that captures the reliability of airline operations by measuring adherence to published schedules. This definition emphasizes that OTP reflects not only timekeeping accuracy but also the effectiveness of operational planning, coordination, and execution across the airline system. Consequently, OTP serves as a quantifiable expression of operational discipline rather than a purely temporal measure.

Industry standards have further refined the definition of OTP by establishing widely accepted measurement criteria. OAG (2023) and Cirium (2025) defined an on-time flight as one that arrives or departs within 15 minutes of its scheduled time, a threshold that has become the global benchmark for airline and airport performance comparison. This standardized definition enables cross-airline and cross-regional benchmarking, reinforcing OTP's role as a comparative performance metric. However, van Schilt et al. (2024) critically noted that while the 15-minute rule provides consistency, it may obscure underlying operational variability, particularly in tightly scheduled or hub-and-spoke networks where small delays can propagate rapidly.

At the system level, regulatory and air traffic management bodies adopt OTP definitions that integrate network performance considerations. EUROCONTROL, FAA, and the European Commission (2024) emphasized that OTP should be

interpreted within the broader context of air traffic management constraints, airport capacity, and flow regulation policies. From this perspective, OTP is not solely an airline-controlled outcome but a system-level indicator shaped by interactions among multiple stakeholders. This interpretation aligns with empirical findings by Abdillah et al. (2025), who demonstrated that changes in airport operations and traffic distribution can significantly alter OTP outcomes even when airline schedules remain constant. Collectively, these definitions highlight that OTP represents a standardized yet multidimensional construct, providing the conceptual basis for examining its underlying dimensions in the following section.

2.3.3. Dimensions of On-Time Performance

Building on the standardized definition of OTP as adherence to scheduled times, the literature emphasizes that punctuality is not a single outcome but a multidimensional construct reflecting performance across different operational phases. Hajko and Badánik (2020) argued that aggregating punctuality into a single indicator may mask underlying inefficiencies occurring at specific stages of airline operations. Consequently, OTP is more accurately understood by examining its key dimensions, which collectively explain how delays originate, propagate, or are absorbed within the operational system.

2.3.3.1. Departure Punctuality

Departure punctuality represents the initial operational dimension of OTP and reflects the airline's ability to execute planned schedules at the point of origin. OAG (2023) highlighted that departure delays are often the earliest indicators of operational disruption, frequently linked to ground handling coordination, crew readiness, and aircraft availability. From an operational perspective, EUROCONTROL et al. (2024) noted that departure punctuality is particularly sensitive to airport congestion and air traffic flow management measures, indicating

that early-stage delays often emerge from interactions between airline processes and system-level capacity constraints. This suggests that departure punctuality functions as a gateway dimension through which inefficiencies can enter the operational network.

2.3.3.2. Arrival Punctuality

Arrival punctuality constitutes the most visible dimension of OTP and is commonly used in industry benchmarking and public performance reporting. Cirium (2025) defined arrival punctuality as the primary reference point for evaluating airline reliability, as it directly affects passenger experience and network connectivity. However, van Schilt et al. (2024) argued that arrival punctuality reflects the cumulative outcome of multiple upstream decisions, including buffer allocation, en-route management, and delay recovery strategies. Thus, arrival punctuality should not be interpreted independently but rather as the result of how effectively earlier disruptions are managed or mitigated across the flight trajectory.

2.3.3.3. Turnaround Efficiency

Turnaround efficiency forms a critical intermediate dimension linking departure and arrival punctuality across flight legs. Hajko and Badánik (2020) emphasized that inefficient turnaround processes increase the likelihood of delay propagation, particularly in tightly scheduled aircraft rotations. Empirical evidence from Abdillah et al. (2025) demonstrated that improvements in turnaround coordination can lead to measurable gains in overall OTP, even under constrained operational environments. This highlights turnaround efficiency as a key control point where airlines can actively influence punctuality outcomes through process optimization and coordination.

2.3.3.4. Reactionary Delay Management

Reactionary delay management represents the dynamic dimension of OTP that captures an airline's capacity to contain and recover from delays once they occur. EUROCONTROL et al. (2024) described reactionary delays as secondary delays that propagate through the network due to resource interdependencies involving aircraft, crews, and airport slots. van Schilt et al. (2024) further showed that insufficient buffer time and weak recovery strategies amplify reactionary delays, undermining both punctuality and network stability. This dimension underscores that OTP is not solely determined by initial schedule adherence, but by the airline's ability to respond adaptively to operational disturbances.

Taken together, these dimensions demonstrate that OTP emerges from a sequence of interrelated operational processes rather than isolated punctuality events. Understanding departure punctuality, arrival punctuality, turnaround efficiency, and reactionary delay management as interconnected dimensions provides a structured basis for analyzing the factors that influence OTP, which are examined in the following section.

2.4. Factors Affecting On-Time Performance

Building on the multidimensional nature of On-Time Performance outlined in the previous section, the literature indicates that OTP is influenced by a complex interaction of operational, human, and external factors. Hajko and Badánik (2020) argued that these factors do not operate independently; rather, they interact across different phases of flight, shaping how delays emerge, propagate, or are mitigated. Understanding these factors within an integrated framework is therefore essential for explaining variations in departure punctuality, arrival punctuality, turnaround efficiency, and reactionary delay management.

A. Operational Factors

Operational factors represent the structural and procedural elements that directly influence airline punctuality. Hajko and Badánik (2020) emphasized that scheduling practices, aircraft rotations, and turnaround planning play a decisive role in determining OTP outcomes, particularly in high-utilization networks. van Schilt et al. (2024) further demonstrated that buffer allocation within flight schedules critically affects the airline's ability to absorb delays, where insufficient buffers increase delay propagation while excessive buffers reduce network efficiency. From a system-level perspective, EUROCONTROL et al. (2024) highlighted that airport capacity constraints, air traffic flow management measures, and en-route congestion significantly affect both departure and arrival punctuality. These findings indicate that operational factors form the structural backbone within which punctuality performance is either enabled or constrained.

B. Human Factors

Closely intertwined with operational structures are human factors, which shape how procedures are executed in real-time operations. Abdillah et al. (2025) noted that crew coordination, situational awareness, and task prioritization during ground and flight operations can significantly influence turnaround efficiency and delay recovery. This observation aligns with industry analyses by OAG (2023), which emphasized that crew readiness and coordination failures are recurrent contributors to departure delays. Moreover, EUROCONTROL et al. (2024) argued that human decision-making under time pressure plays a critical role in managing congestion and recovery actions, particularly during disrupted operations. These findings reinforce the link between human performance and OTP dimensions, suggesting that punctuality is not solely determined by plans and procedures but by how effectively individuals and teams adapt to operational constraints.

C. External Factors

External factors represent conditions largely beyond the direct control of airlines but with substantial influence on OTP. EUROCONTROL et al. (2024) identified adverse weather, airspace restrictions, and air traffic control staffing limitations as primary external drivers of delays across both U.S. and European systems. OAG (2023) similarly highlighted that weather-related disruptions remain the dominant cause of large-scale punctuality degradation, particularly at congested hub airports. Abdillah et al. (2025) demonstrated that airport infrastructure characteristics and traffic distribution patterns can further amplify the impact of external disruptions on OTP outcomes. These external influences often trigger initial delays that, if not effectively managed, evolve into reactionary delays across the network.

Taken together, these operational, human, and external factors collectively shape On-Time Performance as a systemic outcome rather than an isolated metric. The interaction between structural constraints, human performance, and environmental conditions explains why punctuality varies across airlines, airports, and operational contexts. This integrated understanding of OTP determinants provides a critical foundation for examining how organizational interventions—such as CRM training—may influence operational performance, thereby setting the stage for analyzing the relationship between CRM and OTP in the following section.

2.5. The Relationship Between CRM Training and On-Time Performance

Although Crew Resource Management (CRM) training and On-Time Performance (OTP) are often examined within separate research streams, a closer analytical reading of the literature suggests a strong theoretical interconnection between them. Helmreich et al. (1999) argued that operational breakdowns frequently originate from failures in communication, leadership, and decision-making rather than from

technical deficiencies, implying that CRM training inherently influences operational outcomes beyond safety. Salas et al. (2006) conceptualized CRM as a team-based performance framework aimed at enhancing coordination and adaptive behavior in complex operational environments, competencies that closely align with the mechanisms governing punctuality and delay recovery.

O'Connor et al. (2008) further demonstrated that CRM produces measurable behavioral changes but noted that these outcomes are rarely linked to concrete operational performance indicators. At the same time, OTP research has increasingly recognized punctuality as a product of real-time coordination and recovery strategies rather than schedule design alone, as highlighted by Hajko and Badánik (2020) and van Schilt et al. (2024). Despite this conceptual overlap, empirical studies seldom integrate CRM training as an explanatory factor in OTP analysis, creating a notable gap in the literature. This section addresses this gap by examining the theoretical relationship between CRM training and operational performance, analyzing how specific CRM dimensions may influence OTP mechanisms, and reviewing prior empirical studies to highlight limitations and research opportunities.

2.5.1. CRM Training and Operational Performance

The theoretical relationship between CRM training and operational performance is grounded in the recognition that airline performance outcomes are shaped by human coordination and decision processes rather than technical capability alone. Helmreich et al. (1999) argued that many operational failures originate from predictable breakdowns in communication, leadership, and crew coordination, suggesting that interventions targeting these behaviors can influence routine operational outcomes as much as safety events. From this perspective, CRM training functions as a mechanism for stabilizing operational processes by reducing

variability in human performance, thereby supporting consistent execution under normal and disrupted conditions.

Expanding this argument, Salas et al. (2006) conceptualized CRM as a team performance system designed to enhance coordination, adaptability, and workload management in complex operational environments. These capabilities are directly aligned with the demands of airline operations, where crews must continuously balance efficiency, safety, and time constraints. O'Connor et al. (2008) further demonstrated that CRM training leads to observable behavioral changes, particularly in teamwork and decision-making, but emphasized that these changes are rarely evaluated in relation to operational performance indicators. This observation implies that CRM's contribution to operational performance is theoretically well-founded but empirically underexplored.

From an applied perspective, Kaynak (2024) emphasized that the effectiveness of CRM should be assessed through its reflection in real operational practices rather than through attitudinal measures alone. This view aligns with operational research by Hajko and Badánik (2020), who argued that performance indicators such as punctuality and delay recovery are outcomes of coordinated decision-making and task execution across operational units. When interpreted together, these strands of literature suggest that CRM training influences operational performance indirectly by shaping the behavioral processes that govern efficiency, coordination, and resilience. Accordingly, CRM can be theoretically positioned as an enabling factor for improved operational performance, providing a conceptual bridge to examining its specific relationship with On-Time Performance in the following subsection.

2.5.2. CRM Dimensions and On-Time Performance

Building on the theoretical link between CRM training and operational performance, the literature suggests that the influence of CRM on On-Time Performance (OTP) is not direct, but mediated through specific non-technical skill dimensions that shape day-to-day operational behavior. Salas et al. (2006) argued that CRM effectiveness manifests through improved decision-making, communication, leadership, teamwork, and situational awareness, which collectively determine how crews manage time-critical tasks and operational disruptions. O'Connor et al. (2008) further emphasized that these dimensions produce observable behavioral changes, particularly under conditions of time pressure, where operational performance is most vulnerable.

In parallel, OTP research has shown that punctuality outcomes depend heavily on how delays are anticipated, communicated, and managed rather than on schedule design alone, as highlighted by Hajko and Badánik (2020) and van Schilt et al. (2024). This convergence indicates that CRM dimensions correspond closely to the operational mechanisms governing departure punctuality, turnaround efficiency, and reactionary delay management. Accordingly, the following subsections examine how each core CRM dimension—decision-making, communication, leadership and teamwork, and situational awareness—can theoretically influence OTP outcomes within airline operations.

A. Decision-Making and On-Time Performance (OTP)

Decision-making is consistently identified in the CRM literature as a core determinant of operational outcomes in time-critical environments. Salas et al. (2006) argued that effective decision-making within CRM frameworks enhances crews' ability to prioritize tasks, allocate resources, and adapt plans under

uncertainty, which are all central to maintaining operational continuity. From an OTP perspective, Hajko and Badánik (2020) emphasized that delays often escalate when decisions regarding sequencing, recovery actions, or buffer utilization are delayed or poorly coordinated. van Schilt et al. (2024) further demonstrated that suboptimal decision-making during disruptions increases delay propagation across flight networks, particularly in tightly scheduled operations. When these findings are considered together, they suggest that CRM-driven decision-making competencies influence OTP indirectly by improving the quality and timeliness of operational choices that determine whether initial delays are absorbed or amplified.

B. Communication and On-Time Performance (OTP)

Closely linked to decision-making is communication, which functions as the primary mechanism through which operational decisions are shared and executed. Helmreich et al. (1999) highlighted that communication breakdowns are a recurring source of operational inefficiencies, as incomplete or delayed information transfer undermines coordinated action. In the context of punctuality, OAG (2023) identified communication failures between crews, ground staff, and operations control as frequent contributors to departure delays. EUROCONTROL et al. (2024) further noted that effective information exchange across organizational boundaries is critical for managing congestion and implementing flow control measures. These studies collectively indicate that communication quality directly affects OTP by shaping how quickly and accurately operational responses are aligned across multiple actors, reinforcing the role of CRM communication competencies in supporting punctuality.

C. Leadership and Teamwork and On-Time Performance (OTP)

Leadership and teamwork extend the effects of communication by structuring how crews coordinate and execute tasks under pressure. O'Connor et al. (2008) argued that CRM training promotes adaptive leadership and collaborative teamwork, enabling crews to respond flexibly to changing operational demands. Hajko and Badánik (2020) emphasized that inefficient teamwork during turnaround processes significantly increases the risk of delay propagation, particularly in high-frequency operations. Empirical evidence from Abdillah et al. (2025) showed that improved coordination among operational teams can lead to measurable improvements in overall OTP, even in constrained airport environments. These findings suggest that leadership and teamwork competencies support punctuality by enhancing task integration and reducing coordination friction during critical operational phases.

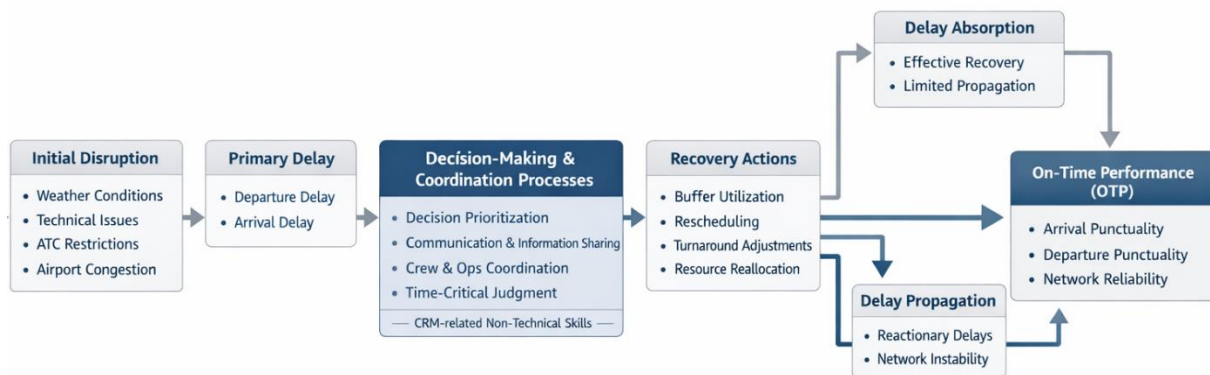
D. Situational Awareness and On-Time Performance (OTP)

Situational awareness integrates decision-making, communication, and teamwork by enabling crews to perceive, comprehend, and anticipate operational conditions. Helmreich et al. (1999) emphasized that loss of situational awareness often precedes both safety incidents and operational breakdowns. In OTP-related research, van Schilt et al. (2024) demonstrated that poor anticipation of downstream disruptions increases reactionary delays, while effective anticipation supports proactive recovery strategies. EUROCONTROL et al. (2024) similarly highlighted that situational awareness at the system level is essential for managing congestion and mitigating the impact of external disturbances. These studies indicate that situational awareness influences OTP by allowing crews and organizations to act preemptively rather than reactively, thereby limiting delay escalation.

Taken together, the literature suggests that CRM dimensions influence On-Time Performance not through direct causality, but by shaping the behavioral and

cognitive processes that govern operational execution and recovery. Decision-making, communication, leadership and teamwork, and situational awareness operate as interdependent mechanisms that determine how effectively airlines manage time pressure, coordination demands, and disruptions. This integrated interpretation reinforces the theoretical expectation that CRM training can contribute to improved OTP outcomes, while also highlighting the need for empirical studies that explicitly link these dimensions to punctuality metrics.

Figure 3: Delay Propagation and Recovery Model in Airline Operations



Source: Researcher, based on van Schilt et al. (2024) and Hajko & Badánik (2020)

The Figure presents a conceptual representation of the delay propagation and recovery process in airline operations, illustrating how on-time performance emerges from a sequence of interconnected operational and human processes rather than from isolated disruptions. Consistent with the work of Hajko and Badánik (2020), the model begins with initial disruptions such as weather conditions, technical issues, or air traffic control restrictions, which generate primary departure or arrival delays. These initial delays interact with operational interdependencies, including aircraft rotations, crew assignments, and airport resource constraints, creating the potential for delay propagation across the network.

At the core of the model lies the decision-making and coordination layer, which functions as a mediating mechanism between disruptions and operational outcomes. This layer reflects CRM-related non-technical skills, such as communication, coordination, prioritization, and time-critical judgment, through which operational responses are shaped. As emphasized by van Schilt et al. (2024), recovery actions—such as buffer utilization, rescheduling, and turnaround adjustments—determine whether delays are absorbed or propagate further as reactionary delays. The bifurcation between delay absorption and delay propagation highlights that on-time performance is not determined solely by the presence of disruptions, but by the effectiveness of coordinated recovery processes.

By conceptualizing OTP as the final outcome of these dynamic interactions, the figure provides a theoretical bridge between CRM training and operational performance without implying direct causality. Instead, it demonstrates how CRM competencies influence punctuality indirectly by shaping the quality of decision-making and coordination processes that govern delay recovery. This integrative perspective supports the analytical framework of the current study and justifies the examination of CRM training effectiveness in relation to on-time performance indicators.

2.5.3. Prior Empirical Studies on CRM and On-Time Performance

Empirical studies on Crew Resource Management (CRM) have predominantly focused on evaluating its impact on safety-related behaviors and non-technical skill development rather than direct operational performance outcomes. Helmreich et al. (1999) provided early empirical evidence demonstrating that CRM training improves communication patterns, leadership behaviors, and decision-making quality within flight crews, emphasizing its role in reducing human error. However, their findings were largely interpreted through a safety lens, with limited

consideration of how these behavioral improvements translate into routine operational performance.

Extending this line of research, Salas et al. (2006) reviewed a wide range of CRM training programs and concluded that CRM is effective in enhancing teamwork, coordination, and adaptability in complex operational environments. Despite these positive findings, the authors highlighted that most empirical evaluations relied on self-reported attitudes, classroom assessments, or simulated scenarios, rather than real operational data. O'Connor et al. (2008), through a meta-analysis of CRM effectiveness studies, reinforced this conclusion by demonstrating statistically significant behavioral improvements while simultaneously noting the scarcity of studies linking CRM outcomes to organizational performance indicators. Collectively, these studies confirm CRM's behavioral effectiveness but reveal a narrow empirical focus that limits its operational interpretation.

2.5.3.1. Empirical Studies on On-Time Performance Determinants

In contrast to CRM research, empirical studies on On-Time Performance (OTP) have concentrated primarily on structural, operational, and system-level determinants. Hajko and Badánik (2020) examined airline OTP through the lens of scheduling practices, turnaround processes, and network constraints, identifying operational design and resource allocation as key drivers of punctuality outcomes. Similarly, van Schilt et al. (2024) analyzed delay propagation and recovery mechanisms, demonstrating that buffer allocation and recovery strategies significantly influence OTP and network stability.

Industry-oriented analyses further support these findings. Reports by OAG (2023) and EUROCONTROL et al. (2024) consistently identify coordination failures, delayed decision-making, and information flow breakdowns as recurring contributors to delays across airline networks. However, these studies tend to treat

human performance factors descriptively, without integrating formal human factors training frameworks such as CRM. As a result, while OTP research acknowledges the importance of coordination and decision processes, it rarely operationalizes these factors in relation to structured training interventions.

2.5.3.2. Identified Gaps and Limitations in the Literature

A critical synthesis of the empirical literature reveals several persistent limitations that justify further investigation. These limitations can be summarized as follows:

1. Separation of Research Streams

CRM studies focus primarily on safety, attitudes, and behavioral change, while OTP studies emphasize scheduling, capacity, and system-level efficiency, with minimal integration between the two domains (Helmreich et al., 1999; Hajko & Badánik, 2020).

2. Limited Use of Operational Performance Indicators

Most CRM effectiveness studies stop at intermediate outcomes and rarely examine concrete operational metrics such as punctuality or delay recovery (Salas et al., 2006; O'Connor et al., 2008).

3. Descriptive Treatment of Human Factors in OTP Research

OTP studies frequently acknowledge human coordination and decision-making as contributors to delays but do not systematically link these factors to CRM training or non-technical skill development (OAG, 2023; EUROCONTROL et al., 2024).

4. Lack of Integrated Empirical Models

Few empirical studies adopt integrative frameworks that examine how CRM dimensions influence OTP mechanisms such as turnaround efficiency and reactionary delay management (van Schilt et al., 2024).

Kaynak (2024) explicitly highlighted this disconnect, arguing that the real effectiveness of CRM can only be assessed when behavioral improvements are evaluated through their impact on everyday operational performance. Taken together, these gaps indicate a clear need for empirical research that bridges CRM training effectiveness and On-Time Performance, providing the analytical foundation for the current study.

2.6. Conclusion

This chapter reviewed the literature on Crew Resource Management (CRM) training, on-time performance (OTP) in airline operations, and the theoretical relationship between the two constructs. The review demonstrated that CRM has evolved from a safety-focused training approach to a comprehensive framework targeting non-technical skills such as decision-making, communication, leadership, teamwork, and situational awareness, which are essential for managing complex operational environments. In parallel, the OTP literature conceptualizes punctuality as a multidimensional and dynamic outcome shaped by departure and arrival punctuality, turnaround efficiency, and reactionary delay management rather than by scheduling practices alone. Despite this conceptual alignment, the literature reveals a clear gap: empirical CRM studies predominantly assess safety and behavioral outcomes, while OTP studies focus on operational and system-level factors, with limited integration of structured human factors training frameworks. Consequently, there remains insufficient empirical evidence linking CRM training effectiveness to measurable operational performance indicators such as OTP. Addressing this gap, the current study adopts an integrative perspective that examines how CRM training effectiveness may influence on-time performance through operational decision-making and coordination processes. This synthesis provides the foundation for the research design and methodological approach

presented in Chapter Three, which outlines the data collection, measurement, and analytical techniques used to empirically investigate this relationship.

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