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Pilot Acceptance of Reduced Crew Operations in Commercial Aviation: An Empirical Analysis of Human Factors, Trust, and Perceived Safety

Melanie Kranich[1], Sumona Sen[2], and Patrick Pötters[2]

[1]Hamburger Fern-Hochschule (HFH), Business Administration and Engineering (B.Eng), Hamburg, Germany
[2]Laboratory for Human Factors Engineering & Production Management, Department of Industrial Engineering, Hochschule Niederrhein, Krefeld, Germany

ABSTRACT

The ongoing advancement of cockpit automation and the increasing shortage of qualified pilots have intensified discussions on Reduced Crew Operations (RCO) in commercial aviation. RCO comprises two main concepts: Extended Minimum Crew Operations (eMCO), which temporarily reduce cockpit crew during cruise, and Single Pilot Operations (SiPO), which envisage a single pilot on board throughout the entire flight. While technological progress suggests growing feasibility, pilot acceptance remains a critical human factors challenge. This paper investigates pilot acceptance of RCO from a human factors perspective, with a particular focus on trust in automation, perceived safety, and job-related concerns. An empirical mixed-methods study was conducted using an online survey among active, former, and prospective commercial pilots. Quantitative data were analyzed using descriptive and inferential statistical methods, while qualitative responses were examined through structured content analysis. The results indicate an overall low level of acceptance toward RCO, with particularly strong rejection of SiPO. Safety concerns, increased workload, and the perceived irreplaceability of a second pilot were identified as dominant barriers. Acceptance of eMCO was moderately higher but strongly conditional on reliable automation, transparent system behavior, and robust organizational safeguards. Statistical analyses reveal a significant positive relationship between trust in automation and acceptance of RCO, as well as a significant negative relationship between age and acceptance. Other factors, including flight experience, professional position, aviation sector, and perceived job insecurity, showed no significant effects. The findings highlight pilot acceptance as a decisive prerequisite for the implementation of RCO concepts and emphasize the importance of human-centered automation design, trust calibration, and transparent safety strategies in future cockpit systems.

Keywords: Human factors in transportation, Human systems integration, Aviation, Trust in automation

INTRODUCTION

Commercial aviation is currently undergoing a period of profound transformation driven by increasing system automation, digitalization, and growing personnel constraints. Technological progress has continuously

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reshaped cockpit design and task allocation, resulting in a gradual reduction of cockpit crew size over the past decades. Early commercial aircraft were operated by crews of up to five members, whereas modern transport aircraft rely on two pilots supported by highly automated flight management, navigation, and monitoring systems (Schuivens, 2015; Lüdtke, 2015). This development has fundamentally shifted the pilot's role from direct manual control toward system supervision and decision-making (Lüdtke, 2015).

Against this background, the concept of RCO has gained increasing attention within the aviation industry. RCO refers to operational concepts aiming to further reduce cockpit crew size while maintaining a safety level equivalent to current two-pilot operations (Radke, 2024; EASA, 2025). Two principal approaches are currently discussed: eMCO, in which one pilot temporarily leaves the cockpit during cruise while the other remains on duty, and SiPO, which envision a single pilot on board throughout all flight phases (Bade, 2024; Radke, 2024). Regulatory authorities, aircraft manufacturers, and research institutions are actively assessing the feasibility of these concepts, supported by advances in automation, artificial intelligence, and ground-based assistance systems (Bilimoria et al., 2014; Zinn et al., 2023).

Despite growing technical maturity, RCO remains highly controversial. While proponents emphasize potential benefits such as increased operational flexibility, economic efficiency, and mitigation of the forecasted pilot shortage (Myers & Starr, 2021; ICAO, 2021), pilot associations and safety stakeholders express substantial concerns. In particular, safety risks related to workload management, system reliability, and resilience in abnormal and emergency situations are emphasized, alongside the loss of redundancy traditionally provided by a second pilot (ALPA, 2024; IFALPA, 2025). These concerns underline that the feasibility of RCO cannot be evaluated solely from a technological perspective but must be examined within a comprehensive human factors framework.

From a human factors perspective, pilot acceptance represents a decisive prerequisite for the successful implementation of RCO. Acceptance is influenced by multiple psychological factors, including trust in automation, perceived safety, workload expectations, and concerns regarding professional roles and job security (Lucke, 1995; Hoffmann et al., 2018). Research on highly automated systems consistently shows that even technically reliable solutions may fail in practice if operators perceive them as unsafe, opaque, or misaligned with their mental models (Lee & See, 2004; Körber, 2019). Trust in automation, in particular, plays a central role in determining whether operators appropriately rely on automated systems or resist their use (Ghazizadeh et al., 2012; Dautzenberg & Voß, 2022).

Although a growing body of research addresses the technical and operational feasibility of RCO, empirical studies focusing on the pilot perspective remain limited. Moreover, few investigations explicitly differentiate between eMCO and SiPO when examining acceptance-related factors (Bailey et al., 2017). To address this gap, the present study investigates pilot acceptance of RCO concepts with a specific focus on automation, trust, and perceived safety. By empirically analyzing attitudes, acceptance determinants, and underlying concerns, this paper contributes to a human-centered understanding of future

cockpit concepts and supports evidence-based decision-making in aviation system design.

BACKGROUND AND THEORETICAL FRAMEWORK

Cockpit Automation in Commercial Aviation

The evolution of commercial aviation is closely linked to continuous advances in cockpit automation. Since the early stages of civil aviation, technological developments have progressively transformed flight deck design and task allocation. Whereas early commercial aircraft required cockpit crews of up to five members, including navigator, flight engineer, and radio operator—technical innovations gradually rendered these roles obsolete (Schuivens, 2015). Improvements in navigation systems, communication technologies, and engine monitoring enabled a systematic reduction of crew size, culminating in today's two-pilot cockpit as the standard configuration in commercial air transport (Schuivens, 2015; Lüdtke, 2015).

Modern cockpits are characterized by a high degree of automation, with systems such as the Flight Management System (FMS), autopilot, and automated flight envelope protections supporting or replacing manual control tasks (Lüdtke, 2015). As a result, pilots' responsibilities have increasingly shifted from direct aircraft control toward system monitoring, supervision, and decision-making. While automation has been shown to reduce physical workload and fatigue, it also introduces new cognitive demands related to system understanding, mode awareness, and trust calibration (Causse et al., 2025).

Recent developments demonstrate that automated systems are already capable of performing safety-critical flight phases. Test programs have successfully demonstrated automated taxiing, take-off, and landing procedures, as well as autonomous emergency landing systems in smaller aircraft classes (Airbus, 2021; Garmin, 2021). These advancements form a technological foundation for further reductions in cockpit crew size and provide the basis for the ongoing discussion on RCO.

Reduced Crew Operations: eMCO and SiPO

RCO encompass operational concepts aimed at further reducing cockpit crew size while maintaining a safety level equivalent to current two-pilot operations (Radke, 2024; EASA, 2025). Two primary concepts are distinguished: eMCO **and** SiPO.

The eMCO concept is a temporary reduction of cockpit crew during cruise flight. One pilot remains on duty while the second pilot leaves the cockpit for rest, returning for safety-critical phases such as approach and landing (EASA, 2025). The primary objective of eMCO is to optimize crew resource utilization on long-haul flights and potentially reduce the need for augmented flight crews, while compensatory measures such as enhanced automation and ground-based support are intended to maintain safety (Radke, 2024).

SiPO represents a more radical approach, envisioning a single pilot on board throughout all flight phases. To achieve an equivalent safety level, extensive

compensatory measures are required, including advanced automation, intelligent assistance systems, and potential remote support from ground-based operators (Bilimoria et al., 2014). While single-pilot operations are already established in military aviation and parts of general and business aviation, their application to commercial passenger transport remains highly controversial (Puca & Guglieri, 2025).

Acceptance, Trust in Automation, and Job Insecurity

From a human factors perspective, the implementation of RCO is fundamentally dependent on pilot acceptance. Acceptance is understood as the result of a dynamic evaluation process shaped by individual attitudes, contextual factors, and perceived consequences of a technological or organizational change (Lucke, 1995; Hoffmann et al., 2018). In the context of RCO, acceptance is not limited to general approval or rejection but reflects pilots' willingness to operate under reduced crew conditions. A key determinant of acceptance in highly automated systems is trust in automation. Trust describes the extent to which operators are willing to rely on an automated system under conditions of uncertainty and potential vulnerability (Lee & See, 2004). Empirical models of automation acceptance indicate that trust directly and indirectly influences acceptance by shaping perceptions of system reliability, predictability, and safety (Ghazizadeh et al., 2012). In aviation, insufficient or inappropriate trust may result either in overreliance on automation or in active resistance, both of which can compromise system safety (Körber, 2019).

In addition to trust, perceived job insecurity has been identified as a relevant psychological factor in the context of automation-driven change. Job insecurity refers to the perceived threat to employment continuity or professional role stability and has been shown to negatively affect openness toward organizational and technological change (De Witte, 2005; Babalola, 2013). As RCO concepts imply fundamental changes to pilots' roles and responsibilities, concerns about long-term career prospects and professional identity may further influence acceptance.

Despite the relevance of these factors, empirical research addressing pilot acceptance of RCO remains limited, and few studies systematically differentiate between eMCO and SiPO. This study therefore integrates acceptance theory, trust in automation, and job insecurity into a unified human factors framework to empirically examine pilots' attitudes toward reduced crew concepts.

METHOD

Study Design

The study followed an empirical, cross-sectional research design using an online survey. A mixed-methods approach was applied, combining quantitative and qualitative elements to obtain a comprehensive understanding of pilot acceptance RCO. Quantitative data were used to test predefined hypotheses (acc. to Table 1) regarding acceptance and its determinants, while qualitative

responses provided additional insight into underlying attitudes, concerns, and contextual factors.

Table 1: Hypothesis.

Designation	Hypothesis
H1	Pilot acceptance of Reduced Crew Operations (RCO) is generally low.
H2	There is no correlation between the age of the pilots and the acceptance of RCO.
H3	There is no correlation between the pilots' flight experience and their acceptance of RCO.
H4	There is no correlation between the pilots' position and the acceptance of RCO.
H5	There is no correlation between trust in automation and acceptance of RCO.
H6	There is no correlation between perceived job insecurity and acceptance of RCO.
H7	There is no connection between the aviation sector and the acceptance of RCO.
H8	There is no difference in acceptance compared to eMCO and SiPO.

Participants

The target population comprised active commercial pilots, former professional pilots, and prospective pilots currently in training. The focus was exclusively on fixed-wing aircraft in civil aviation. Military aviation and non-commercial recreational flying were excluded. A total of 125 valid responses were included in the final analysis. Incomplete questionnaires and responses from individuals outside the defined target group were excluded based on predefined filter criteria. The sample consists of 18 female (14.4%) and 107 male (85.6%) participants.

Questionnaire Development

As no validated questionnaire specifically addressing acceptance of RCO was available, a dedicated survey instrument was developed for this study. Wherever possible, established and validated measurement instruments from the literature were adapted to the aviation context. The questionnaire was administered in English to ensure international accessibility and to increase sample diversity.

The survey consisted of four main sections:
(1) introductory and filter questions assessing prior knowledge of RCO,
(2) demographic and professional background variables (e.g., age, flight experience, position, aviation sector),
(3) standardized scales measuring acceptance-related constructs, and
(4) open-ended questions allowing participants to elaborate on perceived risks, conditions, and potential benefits of RCO.

Trust in automation was measured using a validated multidimensional framework, while perceived job insecurity was assessed using an established

scale capturing subjective employment-related concerns. Acceptance of RCO was operationalized via items reflecting willingness to operate under eMCO and SiPO conditions.

Data Collection Procedure

The survey was distributed online over a defined data collection period. Participation was voluntary and anonymous. Prior to participation, respondents were informed about the study's purpose, data protection measures, and estimated completion time. A pretest was conducted to ensure clarity, comprehensibility, and appropriate survey length.

RESULTS

Sample Characteristics

The final dataset comprised 125 valid responses from active, former, and prospective commercial pilots. Participants represented a broad range of ages, flight experience levels, professional positions, and aviation sectors, including passenger transport, cargo aviation, and business aviation. This heterogeneity allowed for the examination of acceptance patterns across different pilot subgroups.

Quantitative Hypothesis Testing

Overall acceptance of RCO was low. Descriptive statistics (Table 2) revealed a mean acceptance score for RCO of M = 1,85 (SD = 0,83) on a five-point Likert scale. Acceptance differed between the two RCO concepts: eMCO showed higher acceptance (M = 2,12, SD = 0,99) compared to SiPO (M = 1,59, SD = 0,78). A frequency analysis showed that 80.8% of respondents rejected RCO (n = 101 of 125). A binomial test confirmed that this proportion differed significantly from an equal distribution (50%), $p < 0,001$, thus supporting the hypothesis of a general rejection of RCO.

The acceptance scales demonstrated excellent internal consistency (RCO: $\alpha = 0,96$; eMCO: $\alpha = 0,94$; SiPO: $\alpha = 0,94$). Trust in automation showed good reliability ($\alpha = 0,80$). The initial scale for perceived job insecurity yielded a lower reliability ($\alpha = 0,58$); after removal of one item, reliability increased to an acceptable level ($\alpha = 0,69$). Spearman rank correlations revealed a significant negative relationship between age and acceptance of RCO ($r = -0,207$, $p = 0,021$), indicating decreasing acceptance with increasing age. A significant positive relationship was found between trust in automation and acceptance of RCO ($r = 0,320$, $p < 0,001$), representing a moderate effect. No significant relationships were observed between acceptance of RCO and flight experience ($r = -0,085$, $p = 0,345$) or perceived job insecurity ($r = -0,073$, $p = 0,420$).

Group comparisons using a Kruskal–Wallis test showed no significant effect of professional position on acceptance of RCO ($H = 8,09$, $df = 4$, $p = 0,088$). Similarly, a Mann–Whitney U test indicated no significant difference between pilots with and without Business Aviation experience ($U = 1231$, $p = 0,193$).

A Wilcoxon signed-rank test revealed a highly significant difference between acceptance of eMCO and SiPO (Z = –7,307, p < 0,001). The effect size was large (r = –0.654), indicating substantially higher acceptance of eMCO compared to SiPO.

Table 2: Results of the descriptive an alysis.

Designation	r	p
H1		< 0,001
H2	–0,207	0,021
H3	–0,085	0,345
H4		0,088
H5	0,320	< 0,001
H6	–0,073	0,420
H7		0,193
H8	–0,654	< 0,001

Qualitative Findings

Qualitative content analysis of open-ended responses revealed several recurring themes that provide deeper insight into the quantitative findings. Safety concerns emerged as the dominant issue across both RCO concepts, particularly regarding abnormal and emergency situations. Respondents frequently emphasized the importance of human redundancy and mutual cross-checking between pilots.

In relation to SiPO, participants highlighted workload overload, fatigue, and limited resilience as critical risks. Many respondents explicitly stated that automation was perceived as a valuable support tool but not as a replacement for a second pilot.

For eMCO, respondents articulated conditional acceptance, emphasizing prerequisites such as highly reliable automation, transparent system behavior, effective ground-based support, and clear operational procedures. Overall, automation was described as beneficial when supporting pilots but problematic when perceived as substituting essential human functions.

CONCLUSION

The findings of this study demonstrate that pilot acceptance represents a decisive human factors barrier to the implementation of RCO in commercial aviation. Overall acceptance was low, with a clear distinction between the two investigated concepts. SiPO were largely rejected, whereas eMCO received moderately higher but strongly conditional acceptance. This differentiation highlights that RCO concepts must be evaluated individually rather than as a uniform approach.

Trust in automation emerged as a key determinant of acceptance. Pilots reporting higher trust levels were more inclined to accept reduced crew concepts, particularly eMCO, underscoring the central role of trust calibration in highly automated aviation systems. At the same time, trust alone was insufficient to ensure acceptance, as safety concerns and perceived loss of human redundancy remained dominant barriers. The significant negative relationship between age and acceptance suggests generational differences in attitudes toward automation, while the absence of significant effects for flight experience, professional position, aviation sector, and perceived job insecurity indicates that acceptance is primarily driven by subjective safety evaluations rather than structural or career-related factors.

Qualitative results reinforce these findings by revealing persistent concerns regarding workload, fatigue, and system resilience in abnormal or emergency situations. Automation was consistently perceived as a valuable support tool but not as a replacement for a second pilot. This reflects established safety principles in aviation and emphasizes the importance of maintaining human redundancy in future cockpit concepts.

Several limitations must be acknowledged. The study relies on self-reported survey data and a cross-sectional design, which restrict causal inference. Additionally, the sample, while heterogeneous, does not fully represent all segments of the global pilot population. Despite these limitations, the results provide valuable insights into pilot perspectives on RCO and highlight the necessity of human-centered automation design, transparent system behavior, and trust calibration as prerequisites for future reduced crew concepts.

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