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# Understanding how Collaborative Communication and Competence-Based Educational Training Influence Runway Incursions

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The surge in air traffic caused by an increase in the number of people using the airports and cargo freights necessitates safety measures to reduce incidents and accidents with negative effects such as loss of lives, property damage, and economic implications. Runway incursions are among the incidents that negatively impact aviation safety. Several measures have been implemented to curb the runway incursions which have resulted in budget overruns. Therefore, the aim of the study was to understand how collaborative communication and competence-based educational training influence runway incursions. The research questions that guided the study are: (1) How does collaborative communication among aviation personnel influence mitigating runway incursion events? and (2) How does competence-based educational training influence safety by reducing runway incursions? Data were collected using interviews and focus groups from pilots, certified flight instructors, professors, and ground personnel. The thematic analysis performed resulted in identifying three themes: (a) Sharing safety strategies, (b) promotes coordinated ground operations, and (c) increases situational awareness. Collaborative communication among aviation personnel influence mitigating runway incursion events by supporting sharing safety strategies and promoting coordinated ground operations. Competence-based educational training promotes aviation personnels' situational awareness, which influences runway incursions. Accordingly, collaborative communication and competence-based educational training are essential in managing runway incursions.

*Keywords*: Runway incursions, collaborative communication, competence-based educational training, aviation

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# Understanding how Collaborative Communication and Competence-Based Educational Training Influence Runway Incursions

Safety in the aviation industry is prioritized to reduce the negative implications associated with accidents and injuries. Runway incursions, which are occurrences at airports involving the incorrect presence of a person, vehicle, or aircraft on the runway are among the issues that can negatively impact aviation safety (Federal Aviation Administration [FAA], 2024a). The prevalence of runway incursions has been varying with the incidence for 2019, 2020, 2021, 2022, and 2023 being 1,753, 1,261, 1,574, 1,730, and 1,760 (FAA, 2024b). Based on the trend, it can be identified that the prevalence of runway incursions in the past five years has been ranging between 1,261 and 1,760 (FAA, 2024b). In 2019, 2020, 2021, 2022, and 2023, there were 32, 28, 33, 32, and 33 runway incursions per one million takeoffs and landings (FAA, 2024a).

The causes of runway incursions can be clustered as pilot deviations or/and pedestrian/vehicle deviations (Federal Aviation Administration [FAA], 2017). In 2023, the causes of runway incursion were pilot deviations (60%), operational incidents (20%), and vehicle/pedestrian deviation (20%). The contributing factors to the pilot deviation-related runway incursions include distractions, training, confusion, expectation bias, communication, and inattention (FAA, 2017). Although runway incursion cannot be categorized as numerous, their occurrence negatively affects aviation safety, supporting the need for their elimination. In this qualitative study, the focus was exploring how collaborative communication and competence-based educational training can be applied to influence runway incursions.

Collaborative communication requires pilots, air traffic controllers (ATCs), and ground personnel to openly share information, with the purpose of improving situational awareness and enhancing collective efficiency. The concept of collaborative communication has been applied in fields such as marketing and education to promote reciprocal feedback (Chan & Cho, 2022; Vacheishvili, 2021). Collaborative communication is founded o dialogue, reflective practice, and social construction. The aspects related to collaborative communication include listening, climate building, thinking, questioning, acting, focusing, and facilitating (Seeley, 2023). In the aviation context, collaborative communication can allow pilots, ATCs, ground staff, and maintenance teams to seamlessly exchange information by being concise, listening actively, and comprehending current operational environment.

Competence-based educational training is an educational approach focused on developing specific skills, abilities, and knowledge that aviation staff require to be effective in their jobs (Mendonca et al., 2021). The International Civil Aviation Organization (ICAO) has a self-contained package to help aviation organizations and personnel implement competence-based training (ICAO, 2024). In the subsequent sections, the background, theoretical foundations, methodology, results, discussions, and recommendations are provided.

## Background

The aviation industry has grown with an increase in the number of planes and passengers in airports. It is expected that demand for air transport will increase by an average of 4.3% per annum in the next 20 years (International Civil Aviation Organization [ICAO], 2024). In addition, the ICAO (2019) reported that airline traffic is projected to rise as the number of passengers is expected to increase to 10 billion by 2040, with departure and landing being a few minutes away. The rising air traffic and airport activities are expected to increase the risk of runway incursions occurring.

Based on the FAA (2024b), there were 1,760 runway incursions across all regions in the United States in 2023, which is an increase from the 1,730 that occurred in 2022. Runway

incursions are clustered into Category A, B, C, or D, which are based on the severity of the incidents (FAA, 2024a). Category A represents serious accidents where collisions are barely avoided. Category B refers to a situation where the separation decreases, creating a significant potential for collision that could cause a time critical response to mitigate a collision (FAA, 2024a; Ison, 2020). Category C can be assigned to incidents that are characterized by adequate time and/or distance to evade a collision. Category D refers to an incident that fulfills the definition of a runway incursion, without any immediate safety consequences (Ison, 2020). Categories A and B are regarded as more severe compared to C and D (FAA, 2022b). The severity of runway incursions incidents is dependent on influencing factors such as the distance between the aircraft and planes/ vehicles, collision geometry, corrective action, reaction time, environmental ambiance, and system performance determinants (FAA, 2022b).

In addition to pilot and vehicle/pedestrian deviation, operational incidents are considered causes of runway incursions (FAA, 2022b). For example, air traffic controllers (ATC) actions that might result in runway incursions include clearing a plane's takeoff on a closed runway or landing an aircraft with less than the minimum required distance between two airplanes or planes with other obstacles, such as vehicles, people, or equipment (FAA, 2022b). Pilot deviations account for many of the runway incursions at 61.9%, as opposed to operational incidents at 20.2% and vehicle/pedestrian at 17.5% (Wang et al., 2018). Therefore, the majority of runway incursions are attributed to human factors. According to Bhargava and Marais (2020), limited knowledge of the relationship between human error and runway accidents contributes to the rising incidents. There was a 24.82% increase in runway incursions between 2020 and 2021 (FAA, 2022a). Thus, it is important to incorporate mitigating activities that will help reduce the occurrence of runway incursion and ensure safety in the aviation industry as passenger traffic is projected to increase.

**Runway Incursion Economic Implications**

Runway incursions have a detrimental effect on the economy because of the cost associated with the damages, interruptions in normal operations, and causalities involved in the incident. According to Ison (2020), approximately $20 billion was spent on runway accidents between 2015 and 2018 globally. In the United States, the exact cost of runway incursions has not been reported in published literature. However, Fizza (2021) reported that the indirect costs associated with runway incursions are attributed to flight cancellations and compensation for extra employee work. The presence of foreign objects on the runway may result in destructive losses that increase the maintenance and operating cost of the airport if the debris is not immediately cleared (Fizza, 2021). Notably, neither Fizza (2021) or Ison (2020) directly assessed the economic implications of runway incursions, meaning that the reported information was based on secondary information.

Contrastingly, in a different study, researchers focused on performing an early cost safety assessment of runway incursions (Eekeren et al., 2018). It was identified that the occurrence of runway incursions can result in aircraft operation cost, which accounts for expenses such as flight delay, diversions, aircraft damage, and passenger compensation (Eekeren et al., 2018). Additionally, there are indirect safety costs, including insurance premiums, wreckage clearance, search and rescue, as well as accident investigation (Eekeren et al., 2018). Therefore, implementing runway incursions preventative measures can be essential in reducing the associated cost and expenses. The identified literature gap is the lack of quantitative-based publications, specific to the United States where the economic impact of runway incursions has

been assessed. Data on runway incursions are mainly reported by governing bodies such as the FAA.

### Mitigation Measures for Runway Incursions

There are techniques that could be applied to mitigate the economic impact of runway incursions (FAA, 2017). These include measures such as adopting better joint training, collaboration with other agencies, and employing additional personnel dedicated to airport events and emergency response. Different incursion mitigation measures have been recommended by diverse organizations such as the National Transportation Safety Board (NTSB) and FAA. The mitigation measures include research, technology, and training of the aviation personnel, while FAA initiated compulsory reporting of runway incursions and tracking the incidents in the Runway Incursion Database (RWS) (Ison, 2020). The initiatives by the FAA include training pilots, enhancing airport markings and signage, as well as investing in technology to improve environmental awareness and airplane monitoring (U.S. Department of Transportation Office of Inspector General, 2018). Despite the initiatives implemented, runway incursions still occur in the thousands annually in the United States (FAA, 2022b).

Ison (2020) posited that cost-benefit ratio analysis is essential in determining the total expenditure of preventative measures and its projected safety outcome. Additionally, the preventive measure should focus on the groups that are mostly associated with the incidences, regions, and airports with the highest incident report. Shahriari and Aydin (2018) recommended global safety audits based on a single definition of runway incursion to ensure accurate reporting of the incidents. The authors also recommended the separation of the runway from physical obstacles, signals installation, markings, and lighting, as well as frequent maintenance checks (Shahriari & Aydin, 2018). Additionally, mitigating measures can be applied at the managerial level, including training, collaboration with different stakeholders, and maintaining awareness of runway incursions incidences. Awareness campaigns can aid in emphasizing the severity and seriousness of the issue. Personnel training can be beneficial in reducing runway incursion incidents (Shahriari & Aydin, 2018). Overall, there is a lack of quantitative and qualitative literature on the mitigation measures of runway incursions, and their associated impact.

## Purpose of the Study and Research Questions

The purpose of this qualitative study was to understand how collaborative communication and competence-based educational training influence runway incursions. The study was guided by research questions that were applied to help understand how competence-based training and collaborative communication can help mitigate runway incursions. Over the years, different mitigation measures have been implemented but did not result in a reduction in runway incursions. For example, according to the Office of the Inspector General (2018), approximately 549.8 million was spent on the Airport Surface Detection Equipment (ASDE) program with an unexpected cost overrun of $100 million. Similarly, the funds allocated for runway status lights between 2014 and 2016 accounted for $101 million. However, despite the government and the FAA's efforts to curb the cases of runway incursions, the incidents still occur in the thousands.

After several unyielding efforts, strategies to enhance the awareness of aviation personnel on the importance of safe and effective global air transport were considered through education and training. According to Metallinos (2018), educating pilots on deviations and collaboration between pilots, ATC personnel, and ground vehicle individuals could enhance their awareness and reduce the prevalence of runway incursions. Also, collaboration entails effective information sharing between aviation personnel to attain a specific objective or solve problems in the

industry (Metallinos, 2018). Limitations of the findings on the effectiveness of education and training are that the results were reported in a dissertation publication, which is not subject to much peer-review, when compared to journal publications. However, the findings are consistent with those of other researchers who have indicated that collaboration among personnel in the aviation industry is effective in promoting innovation, creating value, strategic decision-making, and mitigating risk while economizing on cost (Pereira et al., 2021).

Effective collaboration entails developing relationships between the company participants and the stakeholders that necessitate governance, strategic decision-making, and resource utilization (Pereira et al., 2021). In fostering innovative collaboration, effective communication flow is essential in ensuring the development of technology and monitoring its progress. Among the leading causes of runway incursion is a lack of effective communication and collaboration (Maharaj, 2020). Therefore, collaborative communication and physical modifications of the environment could help mitigate runway incursions and enhance aviation safety (Maharaj, 2020). Similar to Metallinos (2018), the results reported by Maharaj (2020) were reported in a dissertation, which could mean that the findings were not subject to rigorous peer-review. Based on the conducted literature review, there is a gap in literature, which supports the need for a study conducted using a qualitative methodology. Thus, the first research question was: How does collaborative communication among aviation personnel influence mitigating runway incursion events?

Education and training have been recommended to improve safety in the aviation industry. The lack of educational and training skills contributes to the occurrence of runway incursions (Mahlman, 2019). Therefore, training aviation personnel on safety issues is essential for improving the industry. Most of the safety education and training are based on management and staff-related issues such as takeoff and clearing the runways (Mahlman, 2019). Therefore, the lack of training in specific jobs or roles in aviation contributes to aviation safety-related issues, especially vehicle deviation induced incidents such as runway incursions.

Staff-related educational programs should be timely, precise, and frequent, with follow-up meetings with the stakeholders on safety issues (Mahlman, 2019). Additionally, the quality of education the pilots receive is vital in the prevalence of runway incursion incidents. However, despite flight training and education improvement through the years, the rate of accidents, including runway incursions, involving experienced pilots and aviation personnel have been occurring (Mendonca et al., 2019). Incidents such as runway incursions have been attributed to poor teamwork, inadequate decision-making, and ineffective communication. Thus, a competence-based education could be effective in training technical and non-technical teams on safety and efficient flow of airport operations (Mendonca et al., 2019). The competence-based education entails knowledge acquisition, creating evaluation tools, and conducting a pilot assessment to identify shortcoming and enable employing airlines and training providers to increase the success rate in the prior training (Mendonca et al., 2019).

Competence-based education programs could help enhance the skills and competencies of the aviation team resulting in improved safety outcomes. According to Mendonca et al. (2019), competence-based training includes promoting technical excellence through leadership, collaboration, communication, decision-making, and resilience. The literature gap in the research on the impact of competence-based educational training on runway incursions is evident, especially because all the results identified were reported in dissertations (Mahlman, 2019; Mendonca et al., 2019). The lack of peer-reviews articles on competence-based training, relating specifically to runway incursions supported the need to conduct this study. The second research

question in this study is: How does competence-based educational training influence safety by reducing runway incursions?

## Theoretical Framework: High-Reliability Theory

The high-reliability theory (HRT) asserts that organizations significantly contribute towards accidents prevention (Roberts, 1993). Accordingly, organizations can mitigate catastrophic failures, even in highly perilous and complex environments. The HRT was conceptualized to understand complex organizations, such as aviation and ensure operational safety, despite the possibility of devastating accidents.

Runway incursions are avoidable, a concept congruent with the HRT. According to the HRT, organizations should not just acknowledge accidents as normal aspects of high-risk environments (Teske & Adjekum, 2022). Rather, the organizations should focus on better understanding how they can avoid accidents, ensuring that operations are almost error-free (Scott et al., 2023). The HRT supports the need for continuous risk monitoring, assessment, and mitigation. It is essential for organizations to react to and learn from the occurrence of adverse incidents as an initiative for avoiding catastrophic events and outcomes in the future. It is important to decrease the level of performance variance by decreasing errors (Scott et al., 2023; Teske & Adjekum, 2022).

Based on the HRT, incidents occur when reliability in organizations fails, which is mainly attributed to noncompliance with recommended practices. A characteristic of high-reliability organizations is continuous training, which is often delivered through simulation. Consequently, applying the HRT enabled in explaining how the aviation industry can apply collaborative communication and competence-based education can promote in creating high reliable teams that ensure safe operations.

## Methodology

A qualitative methodology involves collecting data in words to understand a natural phenomenon (Busetto et al., 2020). In this study, a qualitative descriptive research design was applied to understand how collaborative communication and competence-based educational training influence runway incursions. A qualitative methodology was selected because it allowed the researcher to collect data using interviews and focus groups. The use of open-ended semi-structured interviews supported the collection of in-depth data on participants' perceptions (Knott et al., 2022). A semi-structured interview was applied (Appendix A) as it allowed interviews to be centered, while still allowing the investigator freedom to explore relevant and essential ideas that arose during data collection, which enhanced the comprehension of the phenomenon of focus (Evans & Lewis, 2018). The semi-structured interview protocol was created to support the collection of data on collaborative communication and competence-based educational training concerning runway incursion. Additionally, a single focus group protocol (Appendix B) was also used to collect data. A focus group was suitable as it was essential for obtaining a comprehensive understanding of the phenomenon by providing a platform for diverse opinions and perceptions (Busetto et al., 2020).

A basic qualitative research design was applied, which supported performing a thematic analysis of the collected data. The collected data were inductively analyzed, which promotes the results' trustworthiness because the findings were based on teachers' verbatim responses (Bingham, 2023). A purposive sampling technique was applied in the study as it entails recruiting participants with the experience and knowledge to answer the interview and focus group questions, achieving the purpose of the research (Campbell et al., 2020). The purposive sampling process involved sending recruitment messages via emails to aviation personnels from

airports in New York and New Jersey. Individuals were considered eligible for inclusion in the study if they had at least five years of experience and held the positions of pilot, ground personnel, airport administrators, and ATCs. Applying a purposive sampling technique resulted in the recruiting of 25 participants. The study participants were aviation personnel including pilots, certified flight instructors ATCs, ground personnel, and airport administrators. Conversely, data saturation was achieved at the 18th participant.

Thematic analysis was performed in a five-step process (Creswell & Creswell, 2018). First, the researcher read and re-read the responses obtained from the interview and focus group to gain a general idea. Reading the transcripts supported identifying the main ideas discussed by participants, which supported in the inductive coding process. Second, the researcher performed inductive coding. Codes of the recurrent and interesting concepts discussed by participants were identified during the process. Inductive coding involved retrieving *in vivo* terms from participants' verbatim responses. Identifying and naming the core concepts and patterns in data support the themes development. Third, the identified codes were combined to generate themes. The generated themes were related to the respective research questions, ensuring the findings' relevance. The fourth involved reviewing the themes retrieved from the thematic analysis. Reviewing the themes supported determining whether the findings addressed the study purpose. Fifth, the respondents' verbatim responses were coded to the respective themes. The researcher ensured that each theme was supported by adequate verbatim responses to underpin the results' trustworthiness.

The findings trustworthiness was promoted by ensuring credibility, transferability, dependability, and confirmability (Ahmed, 2024). Credibility was achieved by collecting in-depth data from participants, using interviews and focus groups. The data collection proves supported in retrieving adequate responses to answer the research questions. Transferability was promoted by explaining the purposive sampling strategy applied (Ahmed, 2024). Dependability was achieved by describing the data collection and analysis processes, which promoted transparency, enabling the replicability of the study. Confirmability was achieved through peer debriefing, where the results in this study were reviewed and validated by experts, helping decrease personal bias that could have affected the study findings (Ahmed, 2024).

The study was conducted per the research guidelines. Data collection commenced after obtaining institutional review board (IRB) approval, which ensured that the methodology and design of the study were ethical, viable, and applicable. The ethical considerations observed in the study included privacy and confidentiality, informed consent, and data management regulations. Before commencing the data collection process, the participants were briefed about the purpose of the study, its risks, and what the study entailed before issuing the informed consent forms. Enough information is important in ensuring that the respondents make an informed decision (Emma et al., 2019). Additionally, participants were informed that being part of the study was voluntary and were allowed to withdraw at any time without repercussions.

Avoidance of harm to the participants is essential in conducting a study. Harm includes physical injuries, emotional, damage to career prospects, and indulgence in reprehensible actions (Emma et al., 2019). Notably, this study did not expose participants to any kind of harm. Also, the participant's personal information such as names and employment identification were not used, instead, pseudocodes were applied to protect their identity. During the briefing, all the information was unveiled to the participants and no form of deception was used in the study.

Data management activities such as storage and sharing were considered. The hardcopy data were stored in a sealed cabinet in the researcher's home, while softcopy data were recorded

in a password-protected laptop accessible by the researcher only. Also, the laptop that was used was scanned for viruses and malware, and an antivirus application was installed before recording the data to avoid data breaches and corruption. Data will not be shared with any third parties without obtaining the proper authorization. The data collected will be permanently destroyed three years after study publication. An eraser application such as BitRaser file eraser will be installed to permanently delete softcopy data while the hardcopy data will be shredded.

## Results

In this section, the results are categorized according to the demographic data and thematic findings. In the demographics section, participants either participated in the interviews or focus group. Demographic information was presented to support the study findings' transferability. In the thematic findings, the results for each research question were provided.

### Demographic Findings

Table 1 and 2 contains participants' demographic information. Interviews were conducted with 11 participants who held the roles of pilots, ATC, professors, flight instructors, ground personnel, and senior tower planner. Participants' experience ranged from 15 to 40 years, in commercial, general, corporate, and military aviation sectors. The focus group contained seven participants who were pilots, a mechanic, ATCs, a professor, and instructors. Participants' experiences ranged from 15 to 49 years.

**Table 1**

*Interview Participants' Demographic Information*

| Participants | Role | Years of Experience | Aviation Sector |
|---|---|---|---|
| P1 | Pilot | 20 | Commercial and general |
| P2 | Pilot | 25 | Corporate, military, and general |
| P3 | Pilot and ATC | 34 | Commercial and general |
| P4 | Check pilot and instructor | 40 | General |
| P5 | Pilot | 30 | General |
| P6 | Pilot | 15 | General |
| P7 | Pilot and flight instructor | 40 | General |
| P8 | Ground personal | 40 | General |
| P9 | Senior tower planner operations and pilot | 28 | General |
| P10 | Professor and pilot | 40 | Military |
| P11 | Ground personnel | 25 | General |

**Table 2**

*Focus Group Participants' Demographic Characteristics*

| Participants | Role | Years of Experience |
|---|---|---|
| FGP1 | Pilot, mechanic, and professor | 40 |
| FGP2 | ATC and private pilot | 15 |

| | | |
|---|---|---|
| FGP3 | Certificated flight instructor and professor | 25 |
| FGP4 | Jet and instructor pilot | 40 |
| FGP5 | Pilot | 42 |
| FGP6 | Pilot and instructor | 49 |
| FGP7 | ATC | 30 |

**Thematic Results**

The thematic analysis performed resulted in the identification of three themes. The themes are (a) sharing safety strategies, (b) promoting coordinated ground operations, and (c) increasing situational awareness. In the subsequent section, the themes were supported by participants' verbatim responses. Verbatim responses from participants were included to support the results' confirmability.

***Research Question One: Collaborative Communication***

The first research question was: How does collaborative communication among aviation personnel influence mitigating runway incursion events? Based on the performed analysis, it was identified that collaborative communication among aviation personnel influences mitigating runway incursion events by supporting in sharing safety strategies and promoting coordinated ground operations.

**Sharing Safety Strategies.** It was identified that collaborative communication promotes sharing safety strategies for mitigating runway incursions. Sharing safety strategies involved maintaining open communication channels, allowing aviation personnel to exchange information on best practices and lessons learned. For instance, P1 explained that "collaborative meetings enable us to review and discuss safety strategies and procedures, which promotes continuous improvement to mitigate the risks and vulnerabilities that cause runway incursions."

Another respondent, P2, added to the discussion by emphasizing the importance of collaborative communication among aviation personnel, particularly pilots in avoiding incursion events. P2 in the interview supported that collaboration communication supports open discussions that promote knowledge sharing and clarification of ambiguity, collectively promoting an understanding of critical safety information. P2 said "collaborations enable us to discuss safety with other pilots. We have open discussions on runway incursions. Hotspots on airport diagrams are not always clear and expecting pilots to read every word published is nearly impossible, making collaboration important."

Collaborative communication enables aviation personnel to share experiences, recommendations, and insights, promoting an understanding of effective strategies to prevent runway incursions. The regular meetings promote disseminating safety standards and guidelines across the aviation community, fostering consistency in mitigating runway incursion risks. P3 indicated that "open communications help us in maintaining a commitment to adhere to guidelines and safety standards."

Consistent with the pilots' responses, an ATC, FGP2 supported that collaborative communication is essential in sharing safety strategies, an argument that was seconded by FGP7. FGP2 indicated that "collaborative communication crates a shared network the promoted awareness, assisting in informed decision making." Additionally, a ground personnel P11 explained that "collaborative communication can allow us to share safety information with ATCs if we notice any runway obstruction." Accordingly, collaborative communication is an essential

component in supporting the mitigation of runway incursions, because it supports the free flow of best practices among aviation personnel.

**Promotes Coordinated Ground Operations.** Participants in the focus groups and interviews posited that collaborative communication promotes coordinating activities and movements of different ground assets, such as support vehicles, aircraft, and personnel operating on airport surfaces. For instance, in the focus group, FGP1 explained that "collaborative communication that supports training on the ground and plane is essential." FGP2 added to the discussion by saying that "concise and standardized communication, including read-back/hear-back procedures, ensure instructions and information are accurately exchanged and understood by ATC, pilots, and ground personnel." FGP3's response related to the theme was that "collaboration between pilots, airport tower controllers, and ground can be helpful and so can listening in the chart supplement."

In the interviews, participants supported that collaborative communication promotes coordinated ground operations, helping mitigate potential runway incursion. P2 provided a perfect scenario of the efficacy of collaborative communication. P2 said:

> I remember an instance where collaborative communication worked. We were looking to takeoff at runway 34 which is mostly a hotspot, and we received an instruction from the air traffic control that we could take off "at our own risk" without an explicit clearance. The ambiguous situation could have resulted in confusion or miscommunication, increasing the risk of runway incursions, but through collaborative communication and seeking clarification, we were able to understand the reason behind the air traffic control instruction. The tower's line of sight was obstructed in the hotspot area, preventing them from providing a takeoff clearance.

Collaborative communication promotes coordinated ground operations by supporting the development of clear and concise instructions. Another respondent, P6, offered insights into the manner collaborative communication among aviation personnel promotes coordinated ground operations and mitigates runway incursion risks. P6 mentioned how the use of controller-pilot data link communications (CPDLC) promotes collaborative communication. P6 said "We have done a lot of work with CPDLC because it allows text messages between controllers and aircraft. It is only used enroute and not for taxi instructions. Perhaps taxi instructions via the same method can be used to help reduce the chance for miscommunication." In essence, collaboration communication is essential in leveraging digital communication technologies to promote coordinated ground operations. Improved coordinated ground operations can consequently result in mitigating runway incursions from occurring.

***Research Question Two: Competence-Based Educational Training***

The second research question was: How does competence-based educational training influence safety by reducing runway incursions? After the thematic analysis, it was identified that competence-based educational training influences safety by increasing participants' situational awareness. The theme of increased situational awareness was discussed in the subsequent section.

**Increases Situational Awareness.** Participants in the focus groups and interviews indicated that competency-based education increases situational awareness. The training programs include exercises and modules that simulate different scenarios, enabling participants to practice identifying possible hazards and anticipating risks to promote making informed decisions in real time. In the focus groups, FGP2 said that "education can help avoid mistakes."

Another participant FGP4 added that "training promotes situational awareness and continuous education on runway incursion avoidance and best practices, which are vital."

In the interviews, participants offered valuable insights into the manner competence-based educational training can promote safety by improving situational awareness, which decreases runway incursions. For instance, P1 indicated that "the use of real-life scenarios such as electronic flight bags provide realistic simulations, which improves our situational awareness." Another respondent P2 supported the essence of making training relevant and applicable to the local airports and operating environments that pilots frequently encounter. The localized approach can improve training efficacy in fostering situational awareness of the pilots' context. P2 said that "training needs to apply to local airports for the pilots. Discussing runway incursion issues about an airport in Texas when one mostly flies in New York or California could make it less appealing." Also, it is indispensable to ensure that the educational training delivered is easily consumable, appealing, and accessible to enhance retention and application.

Incorporating real life in competency-based training can promote situational awareness by exposing aircraft personnel to realistic scenarios. P3 acknowledged that "current training/ resources are adequate but incorporating more real-life cases and examples would help enhance training. More emphasis on human factors and error management could promote situational awareness." Another participant, P6 supported the value of providing data on trends, statistical information, and best practices in promoting situational awareness. P6 explained that "data on trends, statistical data, and best practices for maintaining situational awareness and techniques for mitigating read back errors are promote by training." Another respondent P7 added more evidence by indicating that "discussing the causal factors and mitigation techniques associate to runway incursions such as distractions, lack of familiarity with airports improper radio usage by pilot or controller, and confusing airport layout and/or markings through training promotes situational awareness." Hence, competence-based training that is focused on hotspots, communication practices, and sterile cockpit procedures can improve situational awareness of high-risk areas and reinforce effective information exchange.

## Discussion

In this study, it was identified that collaborative communication among aviation personnel influences mitigating runway incursion events by supporting in sharing safety strategies and promoting coordinated ground operations. Collaborative communication enables aviation personnel to share safety strategies, which allows the exchange of best practices, information, and lessons learned from past incidents. Similar to the study findings, Metallinos (2018) found that collaboration among pilots, ATC personnel, and ground vehicles promotes information sharing. Another researcher Maharaj (2020) reported that collaborative communication helps in mitigating runway incursions. The research findings advance existing literature by supporting that collaborative communication provides open channels for collective knowledge sharing. Collaborative communication can be applied to promote information sharing, which enhances understanding, situational awareness, and continuous improvement.

It was also identified that collaborative communication promotes coordinating ground operations. The findings advance existing literature by supporting that collaborative communication supports in development of clear and standardized communication approaches. Collaborative communication promotes the coordination of ground operations by supporting the timely exchange of information about taxiway closures, runway occupancy, and any other related updates that could affect ground operations or result in runway incursions. Collaborative communication fosters the coordination of ground operations, ensuring that aircraft, vehicles,

and personnel adhere to their designated routes, decreasing the peril of inadvertent runway incursions. Consistent with the HRT, participants supported that collaborative communication could help mitigate runway incursions by promoting sharing safety strategies and fostering coordinated ground operations.

Competence-based educational training was identified to increase aviation personnel situational awareness, which can decrease runway incursions. In the published literature, the efficacy of competence-based training in enhancing the skills of the aviation team and by extension fostering safety outcomes has been supported (Mahlman, 2019; Mendonca et al., 2019). The results advance existing studies by supporting that competence-based training programs support promoting aviation personnel situational awareness because they involve the simulation of various scenarios. Competence-based training was identified to promote situational awareness by assisting participants in identifying the factors that contribute to runway incursions, such as ambiguous procedures, ineffective communication, and confusing airport layouts. Notably, the need for competency-based training to be specific to participants' context, consumable, applicable, and visually appealing has been supported as essential. Accordingly, the study findings supported that competence-based educational training enables aviation personnel to assess situations from different perspectives, anticipate conflicts, and formulate strategies to mitigate risks proactively. Competence-based educational training supports the need to emphasize core elements such as hotspots, supporting on providing data-driven insights.

The findings can be applied in general aviation to promote the increased adoption of online learning, mentorship programs, and personalized learning paths. Online learning platforms can provide aviation personnel with resources, that are flexible and convenient to promote training among pilots, ATCs, and ground personal. The mentorship programs can allow experienced pilots to impart knowledge to novice peers. Personalized learning paths can be created based on pilots' needs and experiences, ensuring that they are provided with the most relevant instruction. Also, in alignment with the HRT, competence-based education provides opportunities to learn firm incidents, underpinning in the mitigation of practices that result in runway incursions.

## Conclusion

Collaborative communication was identified to decrease runway incursions, support aviation personnel in sharing safety strategies, and promote coordinated ground operations. Competence-based educational training increases aviation personnel's situational awareness, which could result in a reduction in runway incursions. Based on the findings, it is essential to prioritize investment in communication training programs. The training programs can promote collaborative communication among aviation personnel. It is indispensable for aviation organizations to promote the development of a culture that encourages open communication, knowledge sharing, and collaboration among ATC, pilots, and ground crew.

Creating an environment where aviation personnel feel empowered to share their experiences, insights, and concerns related to safety and promote the development and improvement of safety strategies. Based on the findings, aviation competency-based training programs should focus on developing personnel situational awareness skills and the practical application of safety procedures. The programs need to incorporate realistic scenarios to help aviation personnel in real-world situations enhance their ability to identify and mitigate the potential risk of runway incursions occurring.

Three practice recommendations are associated with the findings in this study. The first practice recommendation is for aviation organizations to encourage collaborative communication

among pilots, ATC, and ground workers because it supports the sharing of safety strategies. Sharing safety strategies, specifically information on best practices, risks, and vulnerabilities can promote mitigating runway incursions. The second practice recommendation is for aviation organizations to promote collaborative communication because it enhances coordinated ground operations, support in mitigating miscommunication or confusion, and consequently promotes the management of runway incursions. The third recommendation is for aviation organizations to provide competency-based education training because it improves situational awareness. Improved situational awareness helps in mitigating the factors that result in runway incursions.

A policy change recommendation is for aviation authorities to manage the introduction of collaborative communication training programs for all aviation personnel, The programs can emphasize on active listening and situational awareness. Another recommendation is foe aviation organizations to invest in competency-based training programs that focus on improving aviation personal safety procedures and situational awareness skills. The programs should contain realistic case studies and simulations to prepare personnel for real-world situations.

Similar to any other study, this research is associated with limitations. One limitation is that only qualitative data which is considered as subjective when compared to quantitative data were collected. As such, future researchers can apply a quantitative methodology to mitigate the limitation. In quantitative methodology, researchers can assess the impact of collaborative communication and competence-based education on runway incursions. Another limitation is that data triangulation was not achieved because there were only two sources of data: Focus groups and interviews. Future researchers can mitigate the limitation by adding a third data source such as observations or document analysis. Participants' responses in the interviews and focus groups might have been influenced by social desirability. Social desirability might have been influenced by the fear of providing information that creates a negative reputation in the aviation industry. The occurrence of social desirability could have negatively affected the findings' trustworthiness. In the future, the use of document analysis or observations can help mitigate any social desirability bias. Despite the limitations, collaborative communication has been supported to promote knowledge sharing and coordination of ground operations. Competence-based training increases aviation personnel's situational awareness. Overall, leveraging collaborative communication and competence-based training can support decreasing the risk of runway incursions, creating a safer and more efficient aviation environment.

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# Appendices

## Appendix A: Semi-Structured Interview Questions and Protocol

Hello, I am Bill Metallinos from York College. Thanks for accepting to participate in this interview which is part of my doctoral research. I will begin by verifying the consent form and your permission to allow the documentation and use of this interview. I would also like to remind you that this interview is voluntary, and you are free to discontinue participation at any time or avoid responding to any question you deem inappropriate. May we proceed with the interview? [If YES, welcome the participant and ensure he/she is comfortable before starting the interview. If NO, thank the participant for coming and inform him/her that they will not face any consequences due to their decision to withdraw]. Please note, in the interview aviation personnel is used to describe pilots, vehicle drivers, pedestrians, and air and ground controllers. This interview contains three sections: (a) demographic questions, (b) education and training, and (c) collaboration questions.

**Demographic Questions**

1. Please specify your
   a. Gender
   b. Age
   c. Area of expertise (profession)
   d. Education level
   e. Years of experience
   f. Is your experience mostly with general aviation or commercial aviation? (please describe)

**Collaboration and Communication**

**i.** Have you ever received or issued complex instructions on runway clearance/ landing protocol?

**ii.** How do you perceive the level of communication among aviation personnel on runway safety?

**iii.** Do you talk to aviation personnel about runway incursions?

**iv.** Do you think aviation personnel communicate/collaborate regarding the use or non-use of runways?

**v.** Do you think that lack of communication and collaboration among aviation personnel is a cause of runway incursions?

**vi.** How is your relationship with the aviation personnel?

**vii.** How can the collaboration between aviation personnel be improved to ensure the prevention of runway incursions?

**Education and Training**

1) Have you ever received educational training on runway incursions?
2) Have you ever received educational training on runway incursions prevention or mitigation?
3) How do you report runway incursions?
4) Do you think there is a better way of reporting the incidents?
5) Will attending educational training on runway incursions be effective in preventing and reducing runway incursions?
6) What should be included in an educational training program on runway incursions?

7) Do you think a multi-professional team training can be a solution to reducing runway incursions?
8) Do you think that training on effective communication and collaboration among aviation personnel can help reduce runway incursions?
**9)** In your area of expertise, what are some of the factors associated with communication and collaboration do you think should be incorporated in an educational training program?

**Appendix B: Focus Group Protocol**

Hello, I am Bill Metallinos from York College. Thank you once again for accepting to participate in this focus group meeting which is part of my research. I will begin by verifying the consent form and your permission to allow the documentation of this interview. I would also like to remind you that this interview is voluntary, and you are free to discontinue participation at any time or avoid responding to any question you deem inappropriate. Due to the nature of open communication in focus groups, if you feel that information you would like to share is too personal, please feel free to speak generally about the experience. I will keep your information confidential, however, I cannot guarantee that all participants will keep that information in confidence. I, therefore, encourage you to speak generally and use pseudo names if you must mention names.

a. First, we can introduce ourselves and what we do in the aviation industry.
b. What do you think of education as a strategy to minimize runway incursions?
c. What do you think of training as a strategy to minimize runway incursions?
d. What do you think about collaboration as a strategy to minimize runway incursions?
e. What is your opinion about training on communication competencies to reduce runway incursions?
f. In your opinion, what is missing in either education and training or/and collaboration as strategies to minimize runway incursions?
g. How often do you think the training should be conducted?
h. Do you think the aviation personnel should meet after a runway incursion incident?
i. Do the aviation personnel receive a financial statement of the runway incursion cost?
j. Do you think a briefing on the financial implication of runway incursion can be helpful in increasing runway safety measures by aviation personnel?
k. Closing (ask any other question needing clarification that arose during the individual interviews).

Thank you for your participation!