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A COMPREHENSIVE ANALYSIS OF COMPETENCY AND TRAINING PERSPECTIVES AMONG AIR TRAFFIC CONTROLLERS

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Abstract. The aim of the study was to examine air traffic controllers' perspectives on competency, performance, and training. Analysing data from 182 participants, the results revealed a strong focus on competency with the controllers actively evaluating their skills. Notably, the experienced controllers (19+ years) displayed a heightened commitment to continuous learning, reflected in their higher participation in individual training and perception of its value for their career goals and adaptation to the evolving aviation industry. Competency-based training programs also received positive feedback across experience levels, highlighting their potential effectiveness. Moreover, training was universally perceived as key to performance throughout careers. These results highlighted the importance of fostering a culture of continuous learning within air traffic control (ATC) communities. Aviation authorities can support this by providing diverse training opportunities, including individual and competency-based programs. Future research should continue investigating the impact of technological advancements and AI/machine learning on ATC competencies, the effectiveness of competency-based training programs, and the role of individual training in competency development, ultimately ensuring the vital role of air traffic controllers in aviation safety.

Keywords: air traffic controller, aviation, competency, training, performance.

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1. Introduction

Air traffic controllers play a crucial role in ensuring flight safety within the aviation industry (Kraut et al., 2011; Rahman et al., 2016). They are responsible for guiding the safe, fast, and efficient flow of air traffic in airspace and at airports (Dmochowski & Skorupski, 2019). Additionally, air traffic controllers contribute to reducing fuel consumption and emission levels by optimizing flight routes to the best possible extent (Jopson, 2012).

Under this critical role and responsibility, air traffic controllers working in aerodrome control, approach control, and area control units must possess high levels of competency to safely guide flights through complex airspaces and airports. Competencies are fundamental attributes that enable successful job performance (Burnett & Dutsch, 2006; Shavelson, 2010). A combination of knowledge, skills, and abilities in a particular field can be referred to as competency (Davis et al., 1979; Fukada, 2018). Furthermore, competency refers to the forms of behaviors that workers must acquire or demonstrate to perform at a high level under specific conditions and roles (Ellis & Abbott, 2011).

Competencies directly linked to the performance of air traffic controllers have been emphasized in various studies (Jha et al., 2011; Pilmannova et al., 2023; van Meeuwen et al., 2018). Therefore, the continuous monitoring of their competencies is essential to enhance controllers' performance, to adapt to market changes and to maintain existing job standards (Papathanassiou et al., 2013).

The awareness, assessment, sustaining, and development of competencies are of vital importance for air traffic controllers to effectively fulfil their duties (Hlihel et al., 2022; Kmita, 2013; Marmier et al., 2006; Urusova et al., 2021). Competency awareness is the ability to identify and understand one's own competencies to perform a job or a task (Kusumalatha & Gowda, 2020). Competency assessment compares an individual's competencies to a set of predetermined criteria (Curran et al., 2009; Whelan, 2006). Sustaining competencies involves consistently fostering and renewing competencies throughout one's career path (Stallman et al., 2013; Westera, 2001). Competency development means building your own special set of skills and strengths to overcome challenges and achieve the company's aims (Berge et al., 2002; Karpagam

& Sujatha, 2020; Mathur, 2012; Sharf, 1979). Comprising essential elements of professional development for air traffic controllers, these tools facilitate self-assessment, goal-setting, and progress tracking, ultimately enhancing performance. Given the complexity of their roles and the crucial importance of continuous improvement, targeted training, and regular refresher courses are essential for controllers to ensure they possess the necessary competencies (Soldatov et al., 2018; van Meeuwen et al., 2018). Throughout their careers, controllers go through an intensive training to become competent in their roles (Zhang & Jin, 2019). Training allows controllers to significantly enhance their skills and support their ongoing development (Soldatov et al., 2018). One program known as refresher training serves to support air traffic controllers in enhancing their proficiency and maintaining optimal flight safety and efficiency, particularly in response to escalating demands in air traffic (Dattel et al., 2020). It also enables them to practically handle emergency situations, thereby enhancing their ability to effectively respond in real scenarios (Dattel et al., 2019). Moreover, training supports controllers in adapting to new air traffic management systems and procedural changes (Rodrigues et al., 2018). Hence, refresher training programs should address all training needs to keep pace with technological advancements and procedures (Dattel et al., 2019). These programs should be built upon standard foundations, made effective and tailored to the evolving needs of air traffic management (Shamsiev, 2022a). However, a study revealed a significant gap between formal training requirements for air traffic controllers and operational demands (Malakis & Kontogiannis, 2012). Competency-based programs offer a promising solution to this challenge, optimizing performance through targeted training that addresses specific skill gaps. This approach aims to achieve peak performance in a shorter duration through a more effective program rather than completing specified training hours (Kearns et al., 2017; Oprins et al., 2011; Suzana et al., 2020). Competency-based training involves advanced training processes that enhance the acquisition of knowledge, skills, and abilities (Keller et al., 2020; Shamsiev, 2022b). This method offers a more efficient training experience compared to traditional programs (Oprins et al., 2006). Additionally, competency-based training programs can be customized to adapt to the changing needs of the aviation sector, ensuring that air traffic controllers are always informed of the latest developments and equipped to meet requirements (Kholostov & Goroshko, 2022). In 2016, the International Civil Aviation Organization (ICAO), the international aviation regulatory and oversight body, amended the Procedures for Air Navigation Services – Training (PANS-TRG) document 9868 to define the requirements for competency-based training for air traffic controllers. Concurrently, ICAO published guidance for contracting states in document 10056, titled "Competency-Based Training and Assessment for Air Traffic Controllers."

The increasing accessibility of training materials through technological advancements, such as online platforms and mobile learning apps, has driven the growth of individual training in the aviation sector (Kalbow, 2013). This trend, while not replacing traditional formal training programs, offers a flexible and personalized learning approach that meets individual needs. It can be delivered in a variety of ways, including one-on-one instruction, online courses, or blended learning. Individual training is often used to develop specific skills or knowledge, such as technical or soft skills (Read & Knoch, 2009).

Air traffic controllers rely on a dynamic interplay between training and real-world performance to ensure safe and efficient air traffic flow. Training equips them with essential knowledge and skills, like technical procedures and decision-making, through methods like competency-based training program and individual training efforts (Ogbeide, 2008; Singh, 2014; Tiwari et al., 2011). Applying these skills in real-time, adapting to unexpected situations under pressure, is crucial for effective performance (LeBleu & Sobkowiak, 1995). This continuous balance between training and performance is the core of professional air traffic control.

Standards are set by ICAO, and contracting states comply with these standards through regulations in aviation. Hence, there is a notable lack of literature, particularly in the field of air traffic control. Even though the ICAO introduced the competency-based training model in 2016, there are very few studies on competency-based training and the concept of competency. While recent works like Kesedzic et al.'s (2020) study on Air Traffic Control Competencies Measurements based on Functional Near-Infrared Spectroscopy, Wang and Ma's (2023) Analysis on the Competence Characteristics of Controllers in the Background of Air Traffic Control System with Man-machine Integration and Harris's (2021) Air Traffic Control Specialists' Perceptions of Simulation for Developing Job-Related Competencies have drawn attention to the field, there remains a significant gap in addressing competencies, competency-based training, individual training, and the training-performance relationship customized to experience and unit variables.

A positive correlation between experience and competency has been shown by research in air traffic control (Soldatov et al., 2018). Air traffic controllers working in different units (e.g., en-route, approach, tower) encounter distinct operational environments and tasks, necessitating unique competencies. For example, en-route controllers manage large airspace sectors and prioritize efficient traffic flow, while tower and approach controllers focus on precise aircraft sequencing and landing safety.

This study aims to explore how air traffic controllers approach the awareness, assessment, sustaining, and development of their professional competencies. Furthermore, it aims to comprehend how these controllers use individual training, competency-based training programs and the interplay between training and performance to

enhance and sustain their professional skills. This study focuses on air traffic controllers within a specific region, encompassing controllers with diverse experience levels and working in different units (e.g., en-route, approach, tower). While this provides valuable insights into their current approaches, it also highlights the need for further research as the air traffic control evolves rapidly. Technological advancements, such as increasing automation and the integration of artificial intelligence, are likely to transform the competencies and training needs of future controllers. Nevertheless, this research directly addresses a gap in the existing literature on competency and competency-based training in air traffic control. By examining air traffic controllers' experiences with competency, training, and the interplay between training and performance, the research offers valuable insights into this vital field of air traffic control. These insights can inform the design of future training programs and support systems, potentially fostering adaptability and resilience in the face of industry changes.

2. Methodology

This research employs a descriptive survey approach to explore air traffic controllers' perspectives on competency, training and the interplay between training and performance. Descriptive research aims to allow for a comprehensive description of the current situation and involves gathering data to answer specific questions (Koh et al., 2000; Nassaji, 2015). Choosing a survey over other methods, such as case studies or interviews, allows for a broader understanding of these crucial aspects among a diverse group of controllers distributed across different units and experience levels.

This study is guided by the following two research questions:

RQ1: How do air traffic controllers, having varying levels of experience and working in different units, approach the awareness, assessment, sustaining, and development of their professional competencies?

RQ2: How do air traffic controllers, having varying levels of experience and working in different units, approach individual training, competency-based training programs, and the interplay between training and performance in enhancing and sustaining their professional skills?

An online survey involving 182 professional air traffic controllers was conducted to gather data relevant to the research questions. The online survey comprised pre-determined seven questions for this purpose. The participants were provided with the opportunity to rate on a scale from 1 ('Strongly Disagree') to 5 ('Strongly Agree'). The collected data were analyzed using the SPSS (Statistical Package for the Social Sciences) software. Means and standard deviations were calculated based on the participants' responses using one-way Analysis of Variance (ANOVA). The results were individually assessed and interpreted for each section. The research was conducted following principles of participant confidentiality and data anonymity. The research hypotheses are presented in Table 1.

3. Results

The results of the study are presented in Tables 2, 3, and 4. The research was conducted to examine the perspectives and perceptions of air traffic controllers regarding competency awareness, assessment, sustaining, development, individual training, competency-based training, and the relationship between training and performance. The results explain the levels of awareness, beliefs about possession and approaches toward sustaining and enhancing these critical competencies among air traffic controllers. Additionally, one-way ANOVA statistical analyses were performed to assess potential differences across various experience levels and air traffic control (ATC) units. To perform an ANOVA test, it is essential for the data to exhibit normal distribution. Tabachnick and Fidell (2013) state that skewness and kurtosis values between ±1.50 are generally considered to be indicative of a normal distribution. When the values in Table 2 is examined, it is evident that all variables demonstrate skewness and kurtosis values within the acceptable range. Consequently, the data for each variable is generally normally distributed.

Table 1. Research hypotheses

H1a: The approaches to competency awareness among air traffic controllers differ according to experience. H1b: The approaches to competency awareness among air traffic controllers differ according to unit.
H2a: The approaches to competency assessment among air traffic controllers differ according to experience. H2b: The approaches to competency assessment among air traffic controllers differ according to unit.
H3a: The approaches to sustaining competencies among air traffic controllers differ according to experience. H3b: The approaches to sustaining competencies among air traffic controllers differ according to unit.
H4a: The approaches to competency development among air traffic controllers differ according to experience. H4b: The approaches to competency development among air traffic controllers differ according to unit.
H5a: The approaches to individual training among air traffic controllers differ according to experience. H5b: The approaches to individual training among air traffic controllers differ according to unit.
H6a: The approaches to competency-based training program among air traffic controllers differ according to experience. H6b: The approaches to competency-based training program among air traffic controllers differ according to unit.
H7a: The approaches to training and performance among air traffic controllers differ according to experience. H7b: The approaches to training and performance among air traffic controllers differ according to unit.

Table 2. n, Mean, Std. Deviation & Normality of results

	n	Mean	Std. Deviation	Normality	
				Skewness	Kurtosis
Competency awareness	182	4.6429	.50295	–.863	–.647
Competency assessment	182	4.5440	.58124	–.742	–.481
Sustaining competencies	182	4.5440	.56190	–.856	–.251
Competency development	182	4.4341	.64246	–.699	–.514
Individual training	182	4.1813	.73212	–.297	–1.087
Competency-based training	182	4.4451	.63486	–.708	–.487
Training and performance	182	4.4560	.69389	–.894	–.440

Table 3. ANOVA results by experience

	Groups	n	Mean	Std. Deviation	Std. Error	F	Sig	Dif.
Competency awareness	0–2 years	13	4.5385	.66023	.18311	2.041	.110	
	3–10 years	73	4.6027	.52014	.06088			
	11–18 years	51	4.5882	.49705	.06960			
	19+ years	45	4.8000	.40452	.06030			
Competency assessment	0–2 years	13	4.3077	.75107	.20831	1.807	.148	
	3–10 years	73	4.4795	.57998	.06788			
	11–18 years	51	4.5882	.53578	.07502			
	19+ years	45	4.6667	.56408	.08409			
Sustaining competencies	0–2 years	13	4.4615	.66023	.18311	4.877	.003*	"3–10"– "19+"; "11–18"– "19+"
	3–10 years	73	4.4110	.59711	.06989			
	11–18 years	51	4.5294	.54233	.07594			
	19+ years	45	4.8000	.40452	.06030			
Competency development	0–2 years	13	4.5385	.51887	.14391	3.719	.013*	"3–10"– "19+"
	3–10 years	73	4.2603	.66724	.07809			
	11–18 years	51	4.4706	.61165	.08565			
	19+ years	45	4.6444	.60886	.09076			
Individual training	0–2 years	13	3.7692	.72501	.20108	6.296	.001*	"0–2"– "19+"; "3–10"– "19+"
	3–10 years	73	4.0000	.70711	.08276			
	11–18 years	51	4.2745	.75042	.10508			
	19+ years	45	4.4889	.62603	.09332			
Competency-based training	0–2 years	13	4.3077	.63043	.17485	1.011	.389	
	3–10 years	73	4.3699	.65631	.07682			
	11–18 years	51	4.5098	.57871	.08104			
	19+ years	45	4.5333	.66058	.09847			
Training and performance	0–2 years	13	4.3077	.75107	.20831	1.956	.122	
	3–10 years	73	4.3288	.76476	.08951			
	11–18 years	51	4.5686	.60844	.08520			
	19+ years	45	4.5778	.62118	.09260			

Note: *p < 0.05; F = One-Way Analysis of Variance (ANOVA); Difference = Tukey Test (<.05) Games Howell (>.05).

Table 4. ANOVA results by unit

	Groups	n	Mean	Std. Deviation	Std. Error	F	Sig	Dif.
Competency awareness	TWR	101	4.6139	.52859	.05260	1.166	.314	
	APP	40	4.7500	.43853	.06934			
	ACC	41	4.6098	.49386	.07713			
Competency assessment	TWR	101	4.5149	.61015	.06071	.516	.598	
	APP	40	4.6250	.54006	.08539			
	ACC	41	4.5366	.55216	.08623			

End of Table 4

	Groups	n	Mean	Std. Deviation	Std. Error	F	Sig	Dif.
Sustaining competencies	TWR	101	4.5347	.57558	.05727	1.149	.319	
	APP	40	4.6500	.53349	.08435			
	ACC	41	4.4634	.55216	.08623			
Competency development	TWR	101	4.4158	.62076	.06177	.534	.587	
	APP	40	4.5250	.71567	.11316			
	ACC	41	4.3902	.62762	.09802			
Individual training	TWR	101	4.1188	.73874	.07351	.913	.403	
	APP	40	4.2250	.73336	.11595			
	ACC	41	4.2927	.71568	.11177			
Competency-based training	TWR	101	4.4455	.60787	.06049	.037	.964	
	APP	40	4.4250	.71208	.11259			
	ACC	41	4.4634	.63630	.09937			
Training and performance	TWR	101	4.3960	.70823	.07047	.850	.429	
	APP	40	4.5250	.64001	.10119			
	ACC	41	4.5366	.71055	.11097			

Note: $*p < 0.05$; *F* = One-Way Analysis of Variance (ANOVA); TWR = Aerodrome Control Tower; APP = Approach Control Unit; ACC = Area Control Center.

3.1. Competency awareness

The participants' level of awareness regarding competencies required to ensure safe air traffic control services was found to be 4.6429 with a standard deviation of 0.50295. This outcome indicates that air traffic controllers possess a high awareness of the competencies necessary to provide safe air traffic control services. The low standard deviation suggests a consensus among participants regarding this matter.

According to the ANOVA results shown in Table 3 and Table 4, there was no statistically significant difference in the level of the competency awareness among the controllers with different levels of experience and those working in different ATC units. The test results related to competency awareness hypothesis are shown in Table 5. Despite formulated hypotheses (H1a and H1b) anticipating differences, both were ultimately rejected. These results suggest that the air traffic controllers across all experience levels and units demonstrate a high level of self-awareness regarding the competencies necessary for safe and effective air traffic control. This implies that they can identify and understand their own strengths and limitations in relation to the critical skills and knowledge required for their demanding profession, regardless of individual or unit-specific factors.

3.2. Competency assessment

The participants rated the level of competency assessment as 4.5440 with a standard deviation of 0.58124. This result indicates a positive attitude among the air traffic controllers towards assessing their competencies.

According to the ANOVA results shown in Table 3 and Table 4, there was no statistically significant difference in the perspectives of the competency assessment among the controllers with different levels of experience and those working in different ATC units. The test results related to competency assessment hypothesis are shown in Table 6. Despite formulated hypotheses (H2a and H2b) anticipating differences, both were ultimately rejected. These results suggest that the air traffic controllers across all experience levels and units consistently engage in high-level competency assessment, actively comparing their own skills and knowledge to established criteria for safe and efficient air traffic control.

3.3. Sustaining competencies

The average assessment level of the participants regarding the sustaining competencies was 4.5440 with a standard deviation of 0.56190. This result indicates a positive attitude among the air traffic controllers towards maintain-

Table 5. The test results related to competency awareness hypothesis

H1a: The approaches to competency awareness among air traffic controllers differ according to experience.	Rejected.
H1b: The approaches to competency awareness among air traffic controllers differ according to unit.	Rejected.

Table 6. The test results related to competency assessment hypothesis

H2a: The approaches to competency assessment among air traffic controllers differ according to experience.	Rejected.
H2b: The approaches to competency assessment among air traffic controllers differ according to unit.	Rejected.

ing their competencies. Similarly, the moderate standard deviation implies a consensus on this matter.

According to the ANOVA results shown in Table 3 and Table 4, there was no statistically significant difference in the perspectives of the sustaining competencies among the controllers working in different ATC units. However, there was a notable difference among the experience groups. Particularly, a significant difference was observed between the air traffic controllers with 19+ years of experience and those with less experience ($F = 4.877$; $p < 0.05$). This outcome suggests that experience influences the air traffic controllers' perceptions of sustaining competencies. The controllers with higher experience emphasize more on sustaining competencies, indicating that the knowledge and experience gained over the years might significantly impact this perception. The test results related to sustaining of competencies hypothesis are shown in Table 7.

3.4. Competency development

The participants showed an average assessment level of 4.4341 regarding the continual development of their competencies, with a standard deviation of 0.64246. These positive attitudes indicate the air traffic controllers' keenness to advance in their careers. However, the slightly higher standard deviation suggests potential diversity in opinions on this matter.

According to the ANOVA results shown in Table 3 and Table 4, there was no statistically significant difference in the perspectives of the competency development among the controllers working in different ATC units. However, there was a notable contrast in the experience levels. Particularly, a significant difference was observed between the air traffic controllers with 19+ years of experience and those with 3–10 years of experience ($F = 3.719$; $p < 0.05$). This outcome indicates that the controllers with higher experience are more willing to engage in the continual development of competencies, consistent with the results related to competency sustaining. The test results related to competency development hypothesis are shown in Table 8.

3.5. Individual training

The participants expressed a focus on individual training alongside refresher courses for enhancing their competencies in the evolving aviation sector. The mean assessment level of the participants was 4.1813 with a standard deviation of 0.73212.

These results highlight the air traffic controllers' strong emphasis on continual learning and personal development. This attitude reflects their willingness to adapt to rapid changes in the industry and to advance their careers. However, the high standard deviation suggests a potential significant diversity in perspectives on this matter.

According to the ANOVA results shown in Table 3 and Table 4, there was no statistically significant difference in the perspectives of the individual training among the controllers working in different ATC units. Hence, the controllers across different units similarly value training and development. However, in comparisons based on experience levels, a significant difference was noted between the air traffic controllers with 19+ years of experience and those with less experience ($F = 6.296$; $p < 0.05$). This outcome indicates that the controllers with higher experience participate more in individual training throughout their careers. It suggests that these controllers consider individual training more instrumental in sustaining and enhancing their careers. The test results related to individual training hypothesis are shown in Table 9.

3.6. Competency-based training program

The process and learner-focused competency-based training model was assessed as a suitable model by the participants, with an average evaluation level of 4.4451 and a standard deviation of 0.63486. This outcome indicates a positive reception among the air traffic controllers toward competency-based training, while the moderate standard deviation suggests a consensus on this approach.

According to the ANOVA results shown in Table 3 and Table 4, there was no statistically significant difference in the perspectives of the competency-based training program among the controllers having different experiences

Table 7. The test results related to sustaining competencies hypothesis

H3a: The approaches to sustaining competencies among air traffic controllers differ according to experience.	Accepted.
H3b: The approaches to sustaining competencies among air traffic controllers differ according to unit.	Rejected.

Table 8. The test results related to competency development hypothesis

H4a: The approaches to competency development among air traffic controllers differ according to experience.	Accepted.
H4b: The approaches to competency development among air traffic controllers differ according to unit.	Rejected.

Table 9. The test results related to individual training hypothesis

H5a: The approaches to individual training among air traffic controllers differ according to experience.	Accepted.
H5b: The approaches to individual training among air traffic controllers differ according to unit.	Rejected.

Table 10. The test results related to competency-based training hypothesis

H6a: The approaches to competency-based training program among air traffic controllers differ according to experience.	Rejected.
H6b: The approaches to competency-based training program among air traffic controllers differ according to unit.	Rejected.

Table 11. The test results related to training and performance hypothesis

H7a: The approaches to training and performance among air traffic controllers differ according to experience.	Rejected.
H7b: The approaches to training and performance among air traffic controllers differ according to unit.	Rejected.

and working in different ATC units. Thus, the training model preferences of the air traffic controllers seem not to be correlated with their experience levels or the units they are assigned to, indicating an overall positive evaluation of this competency-based training model. The test results related to competency-based training hypothesis are shown in Table 10. Despite formulated hypotheses (H6a and H6b) anticipating differences, both were ultimately rejected. These results highlight the widespread approval of this competency-based training model among the air traffic controllers, regardless of individual or unit-specific factors.

3.7. Training and performance

The participants rated the average assessment level of how training throughout their careers enhanced job performance at 4.4560, with a standard deviation of 0.69389. This outcome reflects the perception among the controllers of the positive effects of training on job performance.

Despite the relatively high standard deviation above the average, the ANOVA results shown in Table 3 and Table 4 indicated no statistically significant difference in the perspectives of the training and performance among the controllers having different levels of experience and those working in different ATC units. Thus, the air traffic controllers, regardless of varying experiences or units, share a similar belief in the enhancing impact of training on job performance. The test results related to training and performance hypothesis are shown in Table 11. Despite formulated hypotheses (H7a and H7b) anticipating differences, both were ultimately rejected. These results support the idea that the air traffic controllers see training and performance as an ongoing cycle. Continuous development through training programs and personal efforts helps them adjust, make important decisions, and handle the challenges of their demanding job. This ongoing connection between training and performance highlights the need to encourage a culture of lifelong learning in the air traffic control community for the utmost safety and efficiency in aviation.

4. Conclusions

This study explored the air traffic controllers' perspectives on competency awareness, assessment, sustaining, development, individual training, competency-based training programs, and the interplay between training and performance. The results provide valuable insights into how these critical professionals approach their careers and maintain the high standards required for safe and efficient air traffic flow.

Key takeaways from the study include:

High awareness and assessment of competencies: Air traffic controllers demonstrate a strong awareness of the competencies necessary for their demanding role and actively engage in assessing their own skills and knowledge against established criteria.

Experience matters for sustaining and development: The research results revealed the willingness of the air traffic controllers to sustain and develop their existing competencies. While some differences emerged based on experience, the controllers generally placed significant individual emphasis on their development in this domain. Especially, the experienced (19+ years) air traffic controllers showed a stronger commitment to maintaining and improving their skills, suggesting an ongoing desire to learn and grow throughout their careers.

Individual training valued across experience levels: The group of 19+ years of experience participates in individual training beyond administrative requirements more frequently than those with less experience. They also view individual training as more instrumental in maintaining their skill sets and adapting to the evolving aviation industry, potentially due to its ability to address both specific career goals and knowledge gaps identified through self-assessment.

Positive reception of competency-based training: The learner-focused approach of competency-based training programs is met with approval by the controllers across experience levels and units, highlighting its potential as an effective training model.

Training seen as key to performance: The air traffic controllers view training throughout their careers as instrumental in enhancing their job performance, regardless of their specific experience or unit assignment.

These results highlight the importance of fostering a culture of continuous learning and development within the air traffic control community. By providing access to diverse training opportunities, including individual training and competency-based programs, aviation authorities can support controllers in sustaining and enhancing their skills, ultimately contributing to the continued safety and efficiency of aviation.

Future research should continue to investigate competency development, individual training preferences, and competency-based training programs to ensure that air traffic controllers possess the requisite skills and knowledge for effectively managing air traffic flow. This is crucial, especially considering the rapid changes in the aviation environment. Researchers should research the impact of technological advancements and AI/machine learning on air traffic controller competencies. Understanding how these advancements alter the skills and knowledge required by air traffic controllers is imperative for adapting training programs to meet evolving demands. Additionally, there is a need to assess the effectiveness of competency-based training programs. Research should focus on designing these programs to align with the specific needs of air traffic controllers within a dynamically changing environment. Examining their efficacy will contribute to optimizing training strategies. Exploring the role of individual training in competency development is another key area for future research. Understanding how individual training can be customized to support air traffic controllers in acquiring essential skills and knowledge will enhance their overall competency. The outcomes of such research will play an important role in supporting air traffic controllers for aviation safety.

Authors' contribution

First Author: Conceptualization, Methodology for the Review, Data Screening, Analysis, Writing – original draft, Validation of Concept and Methodology, Validation of Screened Data, Review of Results, Validation of Analysis, Data Screening, Results, and Review of the original draft.

Second Author: Conceptualization, Methodology for the Review, Data Screening, Analysis, Writing – original draft, Validation of Concept and Methodology, Validation of Screened Data, Review of Results, Validation of Analysis, Data Screening, Results, and Review of the original draft.

Disclosure statement

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Conflict of interests

Hereby, the authors declare that there have been no potential conflicts of interest concerning the research, authorship, and/or publication of this article.

References

Berge, Z., Verneil, M., Berge, N., Davis, L., & Smith, D. (2002). The increasing scope of training and development competency. *Benchmarking: An International Journal*, *9*, 43–61. https://doi.org/10.1108/14635770210418579

Burnett, M., & Dutsch, J. V. (2006). Competency-based training and assessment center: Strategies, technology, process, and issues. *Advances in Developing Human Resources*, *8*(2), 141–143. https://doi.org/10.1177/1523422305279687

Curran, V., Casimiro, L., Banfield, V., Hall, P., Lackie, K., Simmons, B., Tremblay, M., Wagner, S., & Oandasan, I. (2009). Research for interprofessional competency-based evaluation (RICE). *Journal of Interprofessional Care*, *23*(3), 297–300. https://doi.org/10.1080/13561820802432398

Dattel, A. R., Henry, A., D'Souza, G., Zhang, T., Perini, R. L., Tagoe, B., Song, J. Y., Babin, A. K., & Lim, B. L. (2019). Analog and digital clock refresher training for improvement in identifying aviation traffic. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 63, No. 1, pp. 131–135). SAGE Publications. https://doi.org/10.1177/1071181319631163

Dattel, A. R., Wang, H., Padilla, C., Gao, P., Song, K., Zhang, Z., Henry, A. P., Zhang, T., & Agha, R. D. (2020). Using relevant time clock refresher training for improvement in identifying aviation traffic. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 64, No. 1, pp. 2023–2024). SAGE Publications. https://doi.org/10.1177/1071181320641490

Davis, C. M., Anderson, M. J., & Jagger, D. (1979). Competency: The what, why, and how of it. *Physical Therapy*, *59*(9), 1088–1094. https://doi.org/10.1093/ptj/59.9.1088

Dmochowski, P. A., & Skorupski, J. (2019). A method of evaluating air traffic controller time workload. In *Development of Transport by Telematics: 19th International Conference on Transport System Telematics, TST 2019, Selected Papers 19* (pp. 363–376). Springer International Publishing. https://doi.org/10.1007/978-3-030-27547-1_26

Ellis, P., & Abbott, J. (2011). Managing difficult people: Competence vs competency. *Journal of Renal Nursing*, *3*(2), 88–92. https://doi.org/10.12968/jorn.2011.3.2.89

Fukada, M. (2018). Nursing competency: Definition, structure, and development. *Yonago Acta Medica*, *61*(1), 001–007. https://doi.org/10.33160/yam.2018.03.001

Harris, C. A. (2021). *Air traffic control specialists' perceptions of simulation for developing job-related competencies*. The University of West Florida.

Hlihel, F. B., Chater, Y., & Boumane, A. (2022). Maintenance 4.0 employees' competencies: Systematic literature review. In *2022 2nd International Conference on Innovative Research in Applied Science, Engineering and Technology (IRASET)* (pp. 1–14). IEEE. https://doi.org/10.1109/IRASET52964.2022.9737840

Jha, P. D., Bisantz, A. M., Parasuraman, R., & Drury, C. G. (2011). Air traffic controllers' performance in advance air traffic management system: Part I – performance results. *The International Journal of Aviation Psychology*, *21*(3), 283–305. https://doi.org/10.1080/10508414.2011.582456

Jopson, I. (2012). The role of air traffic control in improving aviation's environmental performance. In O. Inderwildi & D. King, *Energy, transport, & the environment: Addressing the sustainable mobility paradigm* (pp. 469–478). Springer. https://doi.org/10.1007/978-1-4471-2717-8_25

Kalbow, M. (2013). Does airbus training cope with the evolution of the new aircraft generation? In *Proceedings of the 31st European Conference on Cognitive Ergonomics* (pp. 1–1). ACM Digital Library. https://doi.org/10.1145/2501907.2505350

Karpagam, K., & Sujatha, R. (2020). Competency development – A literature review. *Solid State Technology*, *63*(2), 8335–8341.

Kearns, S. K., Mavin, T. J., & Hodge, S. (2017). *Competency-based education in aviation: Exploring alternate training pathways*. Routledge. https://doi.org/10.4324/9781315563220

Keller, J., Mendonca, F., Cutter, J., Suckow, M., & Dillman, B. (2020). Justification and development of competencies to transform a

collegiate aviation flight program. *The Journal of Competency-Based Education*, *5*(3), Article e01216. https://doi.org/10.1002/cbe2.1216

Kesedzic, I., Bozek, J., Rados, M., Popovic, S., & Cosic, K. (2020). Air traffic control competencies measurements based on functional near-infrared spectroscopy. In *2020 43rd International Convention on Information, Communication and Electronic Technology* (*MIPRO*) (pp. 243–248). IEEE. https://doi.org/10.23919/MIPRO48935.2020.9245242

Kholostov, K. M., & Goroshko, I. V. (2022). Optimal planning of professional training for air traffic controllers. *Russian Engineering Research*, *42*(1), 85–88. https://doi.org/10.3103/S1068798X22010087

Kmita, E. (2013). Professional competence of air traffic controller in the sphere of subject-activity approach. *Edukacja-Technika-Informatyka*, *4*(1), 204–209. https://www.ceeol.com/search/article-detail?id=32034

Koh, E. T., Owen, W. L., Koh, E. T., & Owen, W. L. (2000). Descriptive research and qualitative research. In *Introduction to nutrition and health research* (pp. 219–248). Springer. https://doi.org/10.1007/978-1-4615-1401-5_12

Kraut, J. M., Kiken, A., Billinghurst, S., Morgan, C. A., Strybel, T. Z., Chiappe, D., & Vu, K. P. L. (2011). Effects of data communications failure on air traffic controller sector management effectiveness, situation awareness, and workload. In G. Salvendy & N. J. Smith, *Human Interface and the Management of Information. Interacting with Information. Human Interface. Lecture Notes in Computer Science* (Vol. 6772, pp. 493–499). Springer. https://doi.org/10.1007/978-3-642-21669-5_58

Kusumalatha, D., & Gowda, N. (2020). Job competence of agricultural officers in Southern zone of Andhra Pradesh, India. *International Journal of Current Microbiology and Applied Sciences*, *9*(3), 2394–2398. https://doi.org/10.20546/ijcmas.2020.903.273

LeBleu, R., & Sobkowiak, R. (1995). New Workforce Competency Models getting the IS staff up to warp speed. *Information Systems Management*, *12*(3), 7–12. https://doi.org/10.1080/07399019508962980

Malakis, S., & Kontogiannis, T. (2012). Refresher training for air traffic controllers: Is it adequate to meet the challenges of emergencies and abnormal situations? *The International Journal of Aviation Psychology*, *22*(1), 59–77. https://doi.org/10.1080/10508414.2012.635127

Marmier, F., Varnier, C., & Zerhouni, N. (2006). Maintenance activities scheduling under competencies constraints. In *2006 International Conference on Service Systems and Service Management* (Vol. 2, pp. 1217–1222). IEEE. https://doi.org/10.1109/ICSSSM.2006.320682

Mathur, A. (2012). Building a robust organisation through competency framework. *The Indian Journal of Public Administration*, *58*(3), 451–454. https://doi.org/10.1177/0019556120120315

Nassaji, H. (2015). Qualitative and descriptive research: Data type versus data analysis. *Language Teaching Research*, *19*(2), 129–132. https://doi.org/10.1177/1362168815572747

Ogbeide, G. (2008). A case study of restaurant training motivations and outcomes. *Anatolia. An International Journal of Tourism and Hospitality Research*, *19*(1), 172–177. https://doi.org/10.1080/13032917.2008.9687063

Oprins, E. A. P. B., Burggraaff, E., & Roe, R. (2011). *Analysis of learning curves in the on-the-job training of air traffic controllers.* Ashgate Publishing Company.

Oprins, E., Burggraaff, E., & van Weerdenburg, H. (2006). Design of a competence-based assessment system for air traffic control training. *The International Journal of Aviation Psychology*, *16*(3), 297–320. https://doi.org/10.1207/s15327108ijap1603_4

Papathanassiou, N., Pistofidis, P., & Emmanouilidis, C. (2013). Competencies development and self-assessment in maintenance management e-training. *European Journal of Engineering Education*, *38*(5), 497–511. https://doi.org/10.1080/03043797.2013.811475

Pilmannova, T., Hanakova, L., Socha, V., Freigang, M., & Schmidt, S. (2023). Student air traffic controllers' performance under conditions of increased workload. In G. Praetorius, Ch. Sellberg, & R. Patriarca (Eds), *Human Factors in Transportation*. *AHFE* (*2023*) *International Conference* (Vol. 95, pp. 539–548). AHFE International. https://doi.org/10.54941/ahfe1003839

Rahman, S. A., Borst, C., van Paassen, M. M., & Mulder, M. (2016). Cross-sector transferability of metrics for air traffic controller workload. *IFAC-PapersOnLine*, *49*(19), 313–318. https://doi.org/10.1016/j.ifacol.2016.10.561

Read, J., & Knoch, U. (2009). Clearing the air: Applied linguistic perspectives on aviation communication. *Australian Review of Applied Linguistics*, *32*(3), 21.1–21.11. https://doi.org/10.2104/aral0921

Rodrigues, S., Paiva, J. S., Dias, D., Aleixo, M., Filipe, R., & Cunha, J. P. S. (2018). A wearable system for the stress monitoring of air traffic controllers during an air traffic control refresher training and the trier social stress test: A comparative study. *The Open Bioinformatics Journal*, 11(1), 106–116. https://doi.org/10.2174/1875036201811010106

Shamsiev, Z. Z. (2022a). Organizational factors affecting the effectiveness of the educational process of training air traffic controllers. *Heliyon*, *8*(11), Article e11801. https://doi.org/10.1016/j.heliyon.2022.e11801

Shamsiev, Z. Z. (2022b). Improving the process of training air traffic controllers based on the formation of an electronic educational environment. *Journal of Airline Operations and Aviation Management*, *1*(2), 1–6. https://doi.org/10.56801/jaoam.v1i2.5

Sharf, R. S. (1979). A career development model. *Journal of College Placement*, *40*(1), 43–49.

Shavelson, R. J. (2010). On the measurement of competency. *Empirical Research in Vocational Education and Training*, *2*(1), 41–63. https://doi.org/10.1007/BF03546488

Singh, G. (2014). Impact of training on job performance at diesel locomotive work. *Journal of Management Research and Analysis*, *1*(*1*), 27–41.

Soldatov, S., Zasyad'ko, K., Bogomolov, A., Vonarshenko, A., & Solomka, A. (2018). Professionally important skills of air traffic controllers. *Human Physiology*, *44*, 775–778. https://doi.org/10.1134/S0362119718070150

Stallman, R., Moran, K., Brenner, R., & Rahman, A. (2013). Swimming and water survival competence. In *Drowning: Prevention, rescue, treatment* (pp. 197–206). Springer. https://doi.org/10.1007/978-3-642-04253-9_30

Suzana, A., Wibowo, S. N., Rudiantono, Y., & Indrayanti, I. (2020). Measuring the effect of competence and training program on employees performance. In *Proceedings of the 1st International Conference on Accounting, Management and Entrepreneurship* (*ICAMER 2019*) (pp. 25–28). Atlantis Press. https://doi.org/10.2991/aebmr.k.200305.007

Tabachnick, B. G., & Fidell, L. S. (2013). *Using multivariate statistics* (6th ed.). Allyn & Bacon.

Tiwari, R., Sharma, M., Singh, B., & Dutt, T. (2011). Impact of trainings on the gain in knowledge of the field veterinary professionals. *Journal of Community Mobilization and Sustainable Development*, *6*, 112–116.

Urusova, Z. B., Kozlova, L. Y., & Elkanova, B. D. (2021). Competencies as the equivalents of the individual's professional development. *SHS Web of Conferences*, *113*, Article 00039. https://doi.org/10.1051/shsconf/202111300039

van Meeuwen, L. W., Brand-Gruwel, S., Kirschner, P. A., de Bock, J. J., & van Merriënboer, J. J. (2018). Fostering self-regulation in training complex cognitive tasks. *Educational Technology Research and Development*, *66*, 53–73. https://doi.org/10.1007/s11423-017-9539-9

Wang, Y., & Ma, W. (2023). Analysis on the competence characteristics of controllers in the background of air traffic control system with manmachine integration. In *International Conference on Human-Computer Interaction* (pp. 264–275). Springer. https://doi.org/10.1007/978-3-031-35392-5_21

Westera, W. (2001). Competences in education: A confusion of tongues. *Journal of Curriculum Studies*, *33*(1), 75–88. https://doi.org/10.1080/00220270120625

Whelan, L. (2006). Competency assessment of nursing staff. *Orthopaedic Nursing*, *25*(3), 198–202. https://doi.org/10.1097/00006416-200605000-00008

Zhang, Y., & Jin, S. (2019). Research on the allocation of control position in domestic air traffic control units. *IOP Conference Series: Materials Science and Engineering*, *688*(4), Article 044035. https://doi.org/10.1088/1757-899X/688/4/044035