9 (2): 388-398 (2025)

Journal of Aviation

https://dergipark.org.tr/en/pub/jav

e-ISSN 2587-1676

Impact of Competency on Performance: An Application to Air Traffic Controller

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Article Info

Received: 13 February 2025
Revised: 22 May 2025
Accepted: 11 June 2025
Published Online: 25 June 2025

Keywords:
Aviation
Air traffic control
Air traffic controller
Competency
Performance

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RESEARCH ARTICLE

https://doi.org/10.30518/jav.1639476

Abstract

The aim of the study was to examine the differences in air traffic controllers' perceptions of competency and performance based on variables such as experience, units, and being an instructor, and to determine the impact of competency on performance along with its sub-factors. The study sample consisted of 397 air traffic controllers in Türkiye. In line with the aim of the study, the Air Traffic Control Competency Scale (ATCCS) and the Performance Scale (PEC), both utilizing a 5-point Likert rating, were used to measure the competencies and performances of air traffic controllers. The analyses revealed that the group with 0-5 years of experience have high perceptions of competency (*mean=4.5379*) and performance (*mean=4.3418*) and that perceptions do not differ according to being an instructor or the unit. It was found that 60.3% of the variation in the performance variable was dependent on the competency variable ($r=0.777$; $\beta=0.796$), and there was a positive and significant interaction among all sub-factors. Future research is recommended to adopt a broader and more dynamic approach by examining additional variables, tracking long-term changes, and considering diverse operational contexts to enhance competency and performance in air traffic control.

1. Introduction

The aviation industry has undergone a profound transformation since the inaugural powered flight in 1903, driven by the increasing mobility of people and goods across the globe (Fu, 2008; Spearman, 2006). This evolution has resulted in the development of a more diverse range of aircraft, enhanced performance, and increasingly complex airspace structures. Consequently, the role of air traffic controllers in ensuring aviation safety has become paramount. Air traffic controllers are responsible for ensuring the safe navigation of aircraft in all flight areas, including airports. They provide services at different flight stages through three units: aerodrome control (TWR), approach control (APP), and area control (ACC). TWR manages ground operations, APP organizes inbound and outbound traffic, and ACC handles en-route traffic, including military and unmanned aerial vehicles. This requires controllers to be highly attentive and multifaceted.

Air traffic controllers are responsible for the rapid performance of a range of tasks, including planning, monitoring, and controlling the air traffic flow, and the resolution of any issues that may arise. This is achieved through the utilization of appropriate coordination methods (Çınar, 2010). It is imperative that controllers be licensed, a process overseen by the International Civil Aviation Organization (ICAO) through Annex 1. This Annex delineates a competency model developed by the ICAO, which encompasses situational awareness, traffic and capacity management, separation and conflict resolution, communication, coordination, management of unexpected situations, problem-solving, decision-making, self-management, workload management, and teamwork (ICAO, 2020). These competencies guarantee that controllers are adequately prepared to fulfill their responsibilities.

Competency, as defined by Gonczi et al. (1993), is a construct inferred from performance that combines the underlying characteristics that contribute to that performance. It is of the significant importance that controllers maintain high performance standards in order to prevent loss of life, significant financial costs, or delays (Edwards et al., 2012). Factors affecting operational performance include age, experience, health, mental structure, working conditions, equipment, automation technologies, ergonomics, environmental factors, aircraft performance, and workload (Chang and Yeh, 2010; Edwards et al., 2012; Edwards et al., 2013; Hansen, 2004; Hilburn et al., 2006; Isaac and Ruitenberg, 2017; Mogford et al., 1995; Rothaug, 2004; Ruitenberg, 1997; Shafique, 2014; Stager and Hameluck, 1990; Turhan, 2009). Nevertheless, there is a paucity of empirical research examining the influence of competencies on performance in the context of air traffic control, which suggests a knowledge gap in this area.

The aim of the study is to determine the impact of competency on performance in air traffic control, evaluating competencies and performance based on experience, unit, and

instructor status. The recommendations are designed to enhance competencies and performance. The originality of the study lies in its comprehensive examination of the interrelationship between competencies and performance. It should be noted that the findings are limited to the attitudes of current air traffic control personnel and do not take into account other factors that may affect performance. Additionally, the evolving nature of competency represents a potential limitation. The study initially explains the concept of competency and its relationship with performance using existing literature, thereby providing a comprehensive understanding of the dynamics of air traffic control performance.

2. Literature Review

2.1. Competency

Competency is defined as the ability to perform tasks or work successfully in a specific role through a combination of personal qualities (Chouhan and Srivastana, 2014). It is a key factor in achieving success (Spencer and Spencer, 1993) and has been adopted in a range of fields through competency-based approaches to the selection, training, evaluation and development of employees (Ennis, 2008). The literature offers a plethora of definitions of competency due to its diverse applications (Hoffman, 1999). Competency, as a proven ability in a specific area, can be assessed by the amount of knowledge applied to achieve successful outcomes (Haddouchane et al., 2017).

Competency is defined as observable behaviors encompassing the knowledge, skills, and attitudes deemed necessary for superior performance. Knowledge is defined as an understanding of rules, principles, concepts, or processes that have been acquired through learning and experience (Hoge et al., 2005). In contrast, skills are defined as the ability to utilize knowledge for specific purposes (Lawson et al., 2014). Finally, attitudes encompass attributes such as accuracy, honesty, responsibility, and ethical awareness (Roe, 2002). Competency is recognized as behaviors exhibited in a work context (McClelland, 1973; McClelland, 1998), reflecting the desired qualities within the job (Stewart and Brown, 2009). The concept of competency is utilized to predict successful job performance, which is manifested through behaviors observed under specific conditions (ICAO, 2020). It encompasses both routine and complex situations, with competencies developing as experience increases, becoming essential in decision-making and demonstrating individual performance (Nijveldt et al., 2005). Competencies are linked to individual performance and career development (Cernușca and Dima, 2007), and provide direction (Intagliata et al., 2000).

Competencies are comprehensive, trainable, measurable, job-related, and interconnected, encompassing knowledge, skills, and attitudes. Furthermore, competencies indicate not only job performance ability but also professional authority and judgment, which are crucial in high-competency jobs such as air traffic control (Ten Cate, 2005).

The term 'procedural competency' encompasses technical knowledge and skills that are perceived as being essential for task independence and success (Tran et al., 2018; Koch, 2023). In contrast, behavioral competencies define how individuals behave and interact in the workplace, and are therefore distinct from technical skills (Jackson and Chapman, 2012; Leme, 2012).

2.2. Performance

Performance can be defined as an employee's ability to fulfill the requirements of their role based on the skills, knowledge, and competencies they possess (Griffin et al., 2007; Sonnentag and Frese, 2002). Performance is associated with outcomes and incorporates both quantitative and qualitative elements within specified objectives (Campbell et al., 1990; Çöl, 2008). Motivation and desire are essential for high performance, as even with capacity and opportunity, a lack of these elements impedes achievement (Ivancevich et al., 1990). The presence of physical and emotional desire has been demonstrated to enhance performance outputs (Boles et al., 2004).

Performance appraisal is the process of evaluating an employee's task completion and contribution to organizational goals (Viswesvaran and Ones, 2008). Competency models, which are learnable and developable, facilitate this evaluation by focusing on observable behaviors and role responsibilities (McClelland, 1973). Performance management, which is distinct from performance appraisal, is a continuous, future-oriented process that establishes mutual expectations and fosters a culture of responsibility (Armstrong, 2006; Taylor, 2014).

Performance is influenced by a multitude of variables and factors, necessitating a comprehensive examination of these elements to enhance performance (Locke, 1966; Waldman, 1994). The concept is multidimensional, typically encompassing task and contextual performance (Ramawickrama et al., 2017; Varela and Landis, 2010; Viswesvaran and Ones, 2008). Task performance encompasses job-specific tasks that contribute to organizational goals, including procedural knowledge and skills (Borman and Motowidlo, 1997; Van Scotter and Motowidlo, 1996; Ramawickrama et al., 2017). Contextual performance encompasses social interactions and voluntary behaviors that facilitate organizational success, including cooperation and voluntary participation (Borman and Motowidlo, 1997; Van Scotter and Motowidlo, 1996; Jawahar and Carr, 2007). In a study of air traffic controllers conducted by Griffin et al. (2000), it was found that both task and contextual performance contribute to perceived efficiency. Task performance in air traffic control encompasses situational awareness, control actions, communication tasks, and facility use, each of which is subject to a standardized minimum performance level. Contextual performance, on the other hand, is characterized by teamwork, professionalism and the ability to support organizational goals. Borman et al. (2014) concluded that overall performance is constituted by both task and contextual performance, with cognitive ability predicting task performance and personality predicting contextual performance.

2.3. The relationship between competency and performance

The relationship between competency and performance is complex and significantly influenced by specific knowledge, technical skills, and job-related competencies. The existing literature is in agreement that the definition of competencies is intended to improve workplace performance. This encompasses the utilization of tools such as knowledge, skills and attitudes, as well as the outcome of task performance (Chyung et al., 2006). Competency has a direct impact on performance (Locke, 1991). Although performance can be observed, competency is a complex concept that cannot be directly observed. Performance is structured within competencies, which define the criteria by demonstrating the

requisite knowledge, skills, and abilities (Hambrick and Mason, 1984).

The "Effective Job Performance Model", as proposed by Boyatzis, suggests that effective performance is contingent upon the alignment of three key factors: the organizational environment, job demands, and individual competencies. A lack of alignment between the individual, the organizational environment and the demands of the job results in ineffective performance (Boyatzis, 1982). The development of competencies has been shown to enhance job performance, with studies indicating a significant relationship between competency and performance (Yıldırım et al., 2019). However, high competency alone is insufficient; individual and situational factors such as motivation and the availability of tools also influence performance (Roe, 2002).

Competencies delineate both the abilities and the aspirations of an individual, and are thus fundamental to the evaluation of job performance (Ryan et al., 2009). They are predictive of job performance through the observation of observable behaviors (Cardy and Selvarajan, 2006; Zaim et al., 2013). Competencies are performance standards that specify the requisite knowledge and skill levels (Hoffmann, 1999). Job success is contingent upon the alignment of individual competencies with the demands of the job (Abraham et al., 2001; Boyatzis, 2007). Competencies are defined as the combination of knowledge, skills, attitudes, and other characteristics that form the basis for the behaviors necessary for effective job performance (Hoffmann, 1999; Mansfield, 1996; Mirabile, 1997; Rodriguez et al., 2002; Shippmann et al., 2000). It has been demonstrated that observable behaviors strongly associated with high performance manifest competencies (Athey and Orth, 1999).

The relationship of an individual to knowledge, skills, behavior, competency, and performance has been confirmed through various studies. In a study conducted by Rosman et al. (2022), it was found that competencies affect performance. The findings of the study showed that the integrated effect of knowledge, skills, and ability was sufficient to predict individual performance. In a field study conducted in the service industry by Zaim et al. (2013) to analyze the impact of competency on performance, a positive relationship was found between competencies and performance. This positive relationship was also noted in the research by Levenson et al. (2006). Similarly, various studies clarify the relationship between competencies and employee performance. In the study conducted by Ryan et al. (2009), it was found that competencies were consistently linked to performance, while Ahadzie et al. (2009) observed the potential benefits of competency in reflecting performance in their study. In another study focusing on the relationship between competency and performance, Dainty et al. (2004) identified competencies that support effective performance. Qiao and Wang (2009) found in their study that competencies such as team building, communication, coordination, execution, and continuous training were critical for the success of managerial employees. Kolibacova (2014) demonstrated in her three-year study on competency and performance evaluation that when the competency ratio of an employee was one unit higher than that of another employee, the performance ratio could be assumed to be 7% to 12.5% higher. In a study involving 40 tennis players by Barling and Abel (1983), it was found that all correlations between competency and performance were positive and significant. Gist et al. (1989) observed in field experiments involving 108 university administrators that performance increased as competencies increased. Bandura (1986), who made significant contributions to the competency literature, concluded in his studies that low levels of competency lead individuals to avoid all tasks except routine tasks resulting in low-level performance. Empirical studies covering areas such as career choice, coping with challenging career tasks, learning and success, and adaptation to new technologies have consistently yielded results regarding the relationship between competency and performance (Gist and Mitchell, 1992).

3. Methodology

3.1. Survey instrument

Since competencies are defined as job-specific and no competency scale was found in the literature review conducted in air traffic control, an air traffic control competency scale (ATCCS) was developed. The steps of item pool formation, expert opinion, factor analysis, and reliability test were followed in the development process of scale (Carpenter, 2018; Çelik, 2013; DeVellis, 2003). Through semi-structured interviews and content analysis, an initial item pool was established. Expert evaluations ensured content validity, resulting in a CVR value of 0.901. Exploratory factor analysis revealed a structure comprising 19 items distributed across two factors: "Procedural Competencies (PC)" and "Behavioral Competencies (BC)". Confirmatory factor analysis further validated this structure, with factor loadings ranging from 0.63 to 0.80. The reliability of the scale was tested through Cronbach's alpha, item-total correlations, and comparisons between the upper and lower 27% groups. The Cronbach's alpha coefficient for the ATCCS PC, consisting of 13 items, was 0.939, while for the ATCCS BC, with 6 items, it was 0.884. Acceptable item-total correlation, ranging from 0.580 to 0.786, was observed. Furthermore, the comparison of mean scores between the upper and lower 27% groups demonstrated significant differentiation in individuals' attitudes as measured by the scale. Significant correlations, ranging from 0.351 to 0.758, were identified between the items through Pearson correlation analysis. This statistically valid and reliable scale was used to calculate the competency score in the study.

The second scale used in the study is the "Performance Scale (PEC)". PEC was developed by Karakurum (2005) to measure employee performance. It is based on "Contextual Performance (CP)" by Borman and Motowidlo (1993) and "Task Performance (TP)" by Beffort and Hattrup (2003). PEC TP consists of 6 items with a Cronbach's alpha of 0.95. PEC CP consists of 5 items with a Cronbach's alpha of 0.68, making a total of 11 items. Both scales use a 5-point Likert rating from “(1) strongly disagree” to “(5) strongly agree”.

3.2. Study population & Data collection

A power analysis was conducted using G*Power 3.1.9.7 (Faul et al., 2020) to determine the sample size required for the study. Using a medium effect size (f = 0.25), alpha level of 0.05, and power level of 0.80, the analysis indicated that a minimum of 178 participants were required to detect significant differences across demographic groups (e.g., experience levels, unit types). However, 397 air traffic controllers from Türkiye were included in the study, exceeding the recommended sample size, thus further strengthening the validity and generalizability of the findings.

Moreover, Türkiye was chosen for its strategic role in global and European air traffic management. As a founding member of the International Civil Aviation Organization (ICAO), Türkiye has adhered strictly to international aviation standards. Turkish air traffic controllers are licensed in accordance with ICAO's Annex 1, which mandates competency standards, ensuring alignment with global aviation safety practices. Türkiye is one of the most significant countries contributing to high traffic volumes in the region

(EUROCONTROL, 2024a, 2024b). The airspace of Türkiye, with its major airports and high-volume traffic routes, is considered a critical junction between continents, making it a key player in maintaining the flow, safety, and efficiency of air travel in one of the busiest air corridors worldwide. Therefore, this carefully selected sample of Turkish controllers provides a representative basis for generalizing findings related to competency and performance in air traffic control, ensuring that the results align with the aim of the study to evaluate these attributes within a complex and demanding airspace.

Demographic information of participants is shown in Table 1. To reach all air traffic controllers working in different regions of Türkiye on a 24/7 basis, the survey was conducted online. In the study, the criteria of n>30 were met for each group in the unit, experience, and OJTI variables. It is observed that the highest participation at the unit level in the study was from the Aerodrome Control Unit (TWR) (46.6%), followed by the Approach Control Unit (APP) (26.2%) and the Area Control Centre (ACC) (27.2%). As for the experience and OJTI groups, it can be said that there is an equal distribution.

Table 1. Socio-demographic profile

		n	%
Gender	Female	135	34.0
	Male	262	66.0
Unit	TWR	185	46.6
	APP	104	26.2
	ACC	108	27.2
Title	Assistant Air Traffic Controller	22	5.5
	Air Traffic Controller	357	89.9
	Senior Air Traffic Controller	18	4.5
Age	21-30 years old	100	25.2
	31-40 years old	141	35.5
	41-50 years old	111	28.0
	> 51 years old	45	11.3
Experience	0-5 years	100	25.2
	6-10 years	83	20.9
	11-20 years	111	28.0
	> 20 years	103	25.9
OJTI	Authorized	186	46.9
	Not authorized	211	53.1
Total		397	100.0

3.3. Research question and hypotheses

The working unit, being an on-the-job training instructor, and experience are important factors in air traffic control. Although the primary goal of air traffic control services is to provide effective and safe air traffic services, methodological differences may exist across different units. There may be differences in the tools used in approach and area control compared to tower control services, leading to various dimensions. Being an on-the-job instructor is associated with experience and requires authorization. As experience increases, there is an improvement in competencies such as knowledge and skills, which are superficially expressed and learnable. It is assumed that these variables, along with competency, have a positive impact on performance. In this context, the research problem is defined as: "To what extent do the factors of being an on-the-job trainer, the working unit, and experience cause differences in perceptions of competency and performance in air traffic control, and what is the level of the effect of competency on performance along with its sub-factors?". The hypotheses related to the research problem are shown in Table 2.

Table 2. Research hypotheses

H1a	Competency perceptions among air traffic controllers are significantly influenced by their level of experience.
H1b	Performance perceptions among air traffic controllers are significantly influenced by their level of experience.
H2a	Competency perceptions among air traffic controllers are significantly influenced by working unit.
H2b	Performance perceptions among air traffic controllers are significantly influenced by working unit.
H3a	Competency perceptions among air traffic controllers are significantly influenced by being an on-the-job training instructor.
H3b	Performance perceptions among air traffic controllers are significantly influenced by being an on-the-job training instructor.
H4a	Competency positively and significantly impacts performance in air traffic control.
H4b	Procedural competency positively and significantly impacts task performance in air traffic control.
H4c	Behavioral competency positively and significantly impacts task performance in air traffic control.
H4d	Procedural competency positively and significantly impacts contextual performance in air traffic control.
H4e	Behavioral competency positively and significantly impacts contextual performance in air traffic control.

3.4. Statistical analysis

The investigation into the relationship between competency and performance commenced with an initial assessment concerning the assumption of normality. Subsequently, linear regression models were developed following the confirmation of an association among the variables (Pardo et al., 2021). For this purpose, the relationship between the variables was initially examined using Pearson correlation, followed by the application of Linear Regression Models since a linear relationship between the variables was questioned. The aim of linear regression is to understand and quantify the relationship between variables, as well as to make predictions based on this relationship (James et al., 2013; Shahrel et al., 2021). The regression equation presents the mathematical representation of the relationship between variables (He et al., 2021). It demonstrates how the dependent variable changes for each one-unit increase in the independent variables. Additionally, the coefficients in the regression equation indicate the magnitude and direction of the effect of each independent variable on the dependent variable. These coefficients can be associated with a one-unit change in the dependent variable while holding all other variables constant. The results of linear regression analysis also include statistical measures such as the R-squared value, which indicates the proportion of variation in the dependent variable explained by the independent variables (Salinas et al., 2021).

To detect differences in competency and performance perceptions according to variables with scales that meet the assumption of normality, Independent Samples t-Test and One-Way Analysis of Variance (ANOVA) were used. The

gender variable of demographic characteristics was not included in the analysis process due to the assumption that it does not have an effect on competency and performance perceptions in air traffic control. Similarly, the age variable was not included in the analyses due to the use of the experience variable in the process. IBM SPSS (Statistical Package for Social Science) V26 program was used for the analyses in the study.

4. Results

4.1. Competency and performance with respect to experience

Differences in competency and performance scores with respect to the experience of air traffic controllers are shown in Table 3. It was observed that there were statistically significant differences in competency and performance scores among different experience groups. Upon examination of competency scores, a significant difference was found between the group with 0-5 years of experience (*mean= 4.5379, Sd.=0.38528*) and the group with 6-10 years of experience (*mean= 4.3576, Sd.= 0.47694*) (*F = 3.076, p = 0.028*). Similarly, when looking at performance scores, a significant difference was observed between the group with 0-5 years of experience (*mean= 4.3418, Sd.= 0.41006*) and the group with 6-10 years of experience (*mean= 4.1172, Sd.= 0.45488*) (*F = 4.170, p = 0.006*). Based on these results, hypotheses H1a and H1b were accepted.

4.2. Competency and performance with respect to units

Differences in competency and performance scores with respect to units of air traffic controllers are shown in Table 4. It was observed that there were no differences in competency and performance scores based on duty units. In unit groups where there was no statistically significant difference, it was found that air traffic controllers working in TWR had higher competency (*mean = 4.5255, Sd.= 0.43638*) and performance scores (*mean = 4.2747, Sd.= 0.46422*) compared to other units. Based on these results, hypotheses H2a and H2b were rejected.

4.3. Competency and performance with respect to authorized/ not-authorized instructor

Differences in competency and performance scores among air traffic controllers with respect to authorized/ not-authorized instructors are shown in Table 5. It was observed that there were no differences in competency and performance scores based on being an instructor. In groups where there was no statistically significant difference, it was found that air traffic controllers authorized as instructors had higher competency (*mean = 4.5040, Sd.= 0.44769*) and performance scores (*mean = 4.2370; Sd.= 0.46635)* compared to those not authorized as instructors. Based on these results, hypotheses H3a and H3b were rejected.

Table 3. Analysis results of competency and performance with respect to experience

	Groups	n	Mean	Sd.	F	p	Dif.
Competency	0-5 years	100	4.5379	0.38528	3.076	0.028*	0-5 years & 6-10 years
	6-10 years	83	4.3576	0.47694			
	11-20 years	111	4.4585	0.47625			
	> 20 years	103	4.5278	0.45122			
Performance	0-5 years	100	4.3418	0.41006	4.170	0.006*	0-5 years & 6-10 years
	6-10 years	83	4.1172	0.45488			
	11-20 years	111	4.1802	0.48524			
	> 20 years	103	4.2515	0.47412			

*p < 0.05

Table 4. Analysis results of competency and performance with respect to units

	Groups	n	Mean	Sd.	F	p	Dif.
Competency	Aerodrome Control Unit (TWR)	185	4.5255	0.43638	2.333	0.098	-
	Approach Control Unit (APP)	104	4.4514	0.43436			
	Area Control Centre (ACC)	108	4.4128	0.48820			
Performance	Aerodrome Control Unit (TWR)	185	4.2747	0.46422	2.028	0.133	-
	Approach Control Unit (APP)	104	4.2002	0.42666			
	Area Control Centre (ACC)	108	4.1684	0.49103			

Table 5. Analysis results of competency and performance with respect to authorized/ not-authorized instructor

	Groups	n	Mean	Sd.	t	p
Competency	Authorized	186	4.5040	0.44769	1.182	0.238
	Not authorized	211	4.4502	0.45543		
Performance	Authorized	186	4.2370	0.46635	0.436	0.663
	Not authorized	211	4.2167	0.46184		

*p < 0.05

4.4. Impact of competency on performance

The strength and direction of the correlation between competency and performance are shown in Table 6. The correlation coefficient between competency and performance is 0.777. This value indicated a positive and strong relationship between competency and performance. In other words, as competency increases, performance tends to increase, and conversely, as competency decreases, performance tends to decrease. A high level of competency may reflect the capacity to possess specific skills and knowledge and to effectively carry out tasks, which can contribute to higher performance.

The strength and direction of the correlation between procedural competencies, behavioral competencies, task performance, and contextual performance, which are sub-factors of competency and performance, are shown in Table 7. These results indicated a positive and generally moderate relationship between procedural competencies, behavioral competencies, task performance, and contextual performance. It can be inferred that these variables are related to each other and share similarities. The correlation coefficient between procedural competencies and task performance was found to be 0.769, which was identified as the strongest relationship among the sub-factors. Procedural competencies involve the accurate execution of particular procedures and instructions. When these procedures are executed correctly, the actions of controllers align with the requirements of the task, thereby enhancing their performance.

Upon examining the regression values in Table 8, it is observed that there is a positive relationship between competency and performance, and this relationship is statistically significant (*t=24.504; p=0.000*). The R-squared value was found to be 0.603. This value indicates that 60.3% of the variation in the performance variable is accounted for by the competency variable. The linear regression model is formulated as "y = a + βx", where "y" is the dependent variable, "x" is the independent variable, "β" is the coefficient of the model, and "a" is the constant. The regression model between competency and performance was established as "Performance = 0.66 + 0.8 * Competency".

Upon examining the regression values in Table 9, positive relationships between task performance and contextual performance variables and procedural competency and behavioral competency variables were identified. In other words, as procedural competencies increased, both task performance (*y = 0.7 + 0.83 * x; R-squared = 0.592*) and contextual performance (*y = 0.86 + 0.67 * x; R-squared = 0.255*) also increased. Similarly, as behavioral competency levels increased, both task performance (*y = 2.09 + 0.56 * x; R-squared = 0.473*) and contextual performance (*y = 1.33 + 0.6 * x; R-squared = 0.364*) increased. Based on these regression coefficients, it was concluded that procedural competency and behavioral competency variables had a positive and statistically significant effect on task performance and contextual performance (*p < 0.001*). Accordingly, hypotheses H4a, H4b, H4c, and H4d were accepted. Hypothesis test results are shown in Table 10.

Table 6. Pearson correlation results of competency and performance

	Competency	Performance
Competency	1	
Performance	0.777**	1

** p<0.01

Table 7. Pearson correlation results of competency and performance sub-factors

	PC	BC	TP	CP
PC	1			
BC	0.715**	1		
TP	0.769**	0.688**	1	
CP	0.505**	0.604**	0.566**	1

** p<0.01; PC= Procedural Competency; BC=Behavioral Competency; TP=Task Performance; CP= Contextual Performance

Table 8. Regression models for performance and competency

			Regression Coefficients (β)	Std. Regression Coefficients	Std. Err.	t	p
Performance	<<<	Competency	0.796	0.777	0.032	24.504	0.000
F=600.470; R-square= 0.603; Constant = 0.662							

Table 9. Regression models for performance and competency sub-factors

			Regression Coefficients (β)	Std. Regression Coefficients	Std. Err.	t	p
TP	<<<	PC	0.832	0.769	0.035	23.928	0.000
F=572.557; R-square = 0.592; Constant = 0.702							
CP	<<<	PC	0.669	0.505	0.058	11.629	0.000
F=135.238; R-square = 0.255; Constant = 0.864							
TP	<<<	BC	0.557	0.688	0.030	18.825	0.000
F=354.386; R-square =0.473; Constant t=2.091							
CP	<<<	BC	0.598	0.604	0.040	15.044	0.000
F=226.332; R-square = 0.364; Constant =1.331							

PC= Procedural Competency; BC=Behavioral Competency; TP=Task Performance; CP= Contextual Performance

Table 10. Test results of research hypotheses

No	Research hypotheses	Results
H1a	Competency perceptions among air traffic controllers are significantly influenced by their level of experience.	Accepted
H1b	Performance perceptions among air traffic controllers are significantly influenced by their level of experience.	Accepted
H2a	Competency perceptions among air traffic controllers are significantly influenced by working unit.	Rejected
H2b	Performance perceptions among air traffic controllers are significantly influenced by working unit.	Rejected
H3a	Competency perceptions among air traffic controllers are significantly influenced by being an on-the-job training instructor.	Rejected
H3b	Performance perceptions among air traffic controllers are significantly influenced by being an on-the-job training instructor.	Rejected
H4a	Competency positively and significantly impacts performance in air traffic control.	Accepted
H4b	Procedural competency positively and significantly impacts task performance in air traffic control.	Accepted
H4c	Behavioral competency positively and significantly impacts task performance in air traffic control.	Accepted
H4d	Procedural competency positively and significantly impacts contextual performance in air traffic control.	Accepted
H4e	Behavioral competency positively and significantly impacts contextual performance in air traffic control.	Accepted

5. Discussion

The study found that performance and competency perceptions among air traffic controllers varied according to experience groups. Particularly, it was found that controllers with 0-5 years of experience had higher performance and competency perceptions compared to other experience groups. This situation arises from the higher dedication and motivation of newly recruited controllers to their jobs, their enthusiasm for and willingness to acquire knowledge about the profession, and the performance and competency-enhancing effects of intensive training and evaluation processes such as initial and unit training.

However, it was observed that competency and performance perceptions did not differ according to variables such as being an instructor and unit. The presence of similar working conditions and continuous evaluation processes among air traffic controllers indicates significant similarities in performance and competency perceptions. However, the absence of statistical differences does not imply the complete absence of individual differences.

The simultaneous differentiation and non-differentiation of competency and performance perceptions among groups indicated the relationship between competency and performance. Regression results, along with correlation outcomes, also concluded that competency significantly and positively influences performance. It was determined that 60.3% of the variation in the performance variable within air traffic control is dependent on the competency variable. In a study conducted on various service sectors such as banking, cargo, communication, food and catering, finance, publishing, retail, IT, and tourism, this variation was found to be 45% (Zaim et al., 2013). In another study, this rate was found to vary between 7% and 12.5% (Kolibacova, 2014). The high proportion of performance explained by competency in the field of air traffic control is considered to be due to the complexity of the work and the magnitude of the risks involved.

Similar results were obtained in sub-factors. It emerged that procedural and behavioral competencies have a higher level of influence on task performance and that there is a significant relationship between behavioral competency and contextual performance. Procedural knowledge and skills, including cognitive abilities, are associated with task performance, whereas personality, an important element of teamwork in air traffic control, is associated with contextual performance (Borman et al., 2014). The research confirmed this observation with the high-level impact of procedural competency on task performance and behavioral competency on contextual performance.

In the world driven by technology today, the aviation sector is undergoing a significant transformation with the use of unmanned aerial vehicles. It is predicted that with advancing technology, there will be increased use of automation and artificial intelligence applications in the aviation field (Zaoui et al., 2024). Significant assumptions are made about how these developments may affect the roles and responsibilities of air traffic controllers. Air traffic controllers play a critical role in managing air traffic, ensuring the safety and order of airspace. However, rapidly advancing technology and increasing automation will bring new requirements for the competency and performance levels of controllers. This indicates the need for controllers to undergo technology-focused competency development programs and performance evaluations to provide effective and safe services in the aviation sector.

Performance evaluation can be defined as a systematic method that involves setting work standards, assessing the actual performance of the employee based on these standards, and providing feedback to address performance deficiencies, achieve organizational goals, and enhance employee motivation (Dessler, 2008). However, performance evaluation of air traffic controllers can be a complex process involving a range of factors. This process may include competencies such as response time, decision-making ability, stress management, adaptation to automation, and communication. While air traffic controllers manage air traffic through radar systems and other advanced technologies, human skills and decision-making ability also play a significant role. Performance evaluation can assess controllers' ability to perform specific tasks, how they respond in emergencies, and their ability to work effectively as a team. Therefore, performance evaluation not only serves as a tool to measure operational effectiveness but also functions as a developmental mechanism to guide continuous improvement and ensure safety within dynamic airspace environments. The evaluation process can be an important tool for training controllers based on technology-focused competency, maintaining and enhancing their competencies. Additionally, performance evaluation can contribute to the continuous improvement of air traffic control systems and enhance safety. Therefore, objectively evaluating the performance of air traffic controllers considering competencies can be seen as one of the cornerstones of the aviation sector.

6. Conclusion

The study concluded that there were no statistically significant differences in competency and performance levels among air traffic controllers, except for differences based on experience groups. The findings revealed that competency has

a meaningful influence on performance, highlighting its vital role in ensuring operational effectiveness in air traffic control. This relationship underscores the importance of competency-based approaches in the development and evaluation of air traffic controllers, especially in the context of increasing technological complexity and safety demands in the aviation sector. The study offers a valuable contribution to the understanding of how individual competencies shape job performance in this highly specialized domain.

Despite these contributions, certain limitations should be acknowledged. The findings are limited to the current attitudes and conditions experienced by air traffic controllers, which may not fully capture changes across different organizational or technological contexts. Moreover, the analysis was restricted to competency as the central variable affecting performance, while other important factors such as organizational culture, leadership style, stress levels, and job satisfaction were excluded from the scope. Additionally, the concept of competency itself is dynamic and subject to continuous evolution, particularly within technology-driven professions such as air traffic control. This evolving nature may affect the long-term applicability and generalizability of the results.

Building on these limitations, several directions for future research can be proposed. Longitudinal studies could be conducted to observe how the relationship between competency and performance evolves over time, especially in response to advancements in automation and digital systems. Incorporating other performance-related variables may offer a more comprehensive understanding of the factors influencing controller effectiveness. Moreover, continuous updates to competency frameworks and training models are recommended to ensure alignment with emerging operational requirements. Comparative and cross-cultural studies could also provide valuable insights into how differing institutional and cultural contexts impact competency development and performance outcomes in air traffic management systems around the world.

In conclusion, the study provides an important foundation for advancing competency-based strategies in air traffic control. By recognizing both its current contributions and areas for further research, it serves as a relevant reference for improving safety, efficiency, and adaptability in aviation operations through more informed human resource development practices.

Ethical approval

Yes, the study was reviewed by the Eskişehir Technical University Social and Human Sciences Scientific Research and Publication Ethics Committee and found to be ethically appropriate according to the "Ethical Committee Decision No. 3/1 dated 10/03/2023". Informed consent was obtained from each participant.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Acknowledgement

The paper was derived from Arif TUNCAL's doctoral research titled "Competency and performance in air traffic control" conducted at the Eskişehir Technical University, Institute of Graduate Programs. The authors would like to extend their gratitude to Suat USLU and V. Onur ÇELİK for their invaluable guidance throughout the doctoral research process.

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Cite this article: Tuncal, A., Cinar, E. (2025). Impact of Competency on Performance: An Application to Air Traffic Controller. Journal of Aviation, 9(2), 388-398.