RESEARCH ARTICLE/ARAŞTIRMA MAKALESİ

# The air traffic control training process: A review of research

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**Abstract**

Air traffic control (ATC) is a complex part of the air transport system. Training in this activity takes more than one year and requires special qualities and abilities from all participants in this process. Recent studies consider the learning process as one of the determining factors that further influences the efficiency of aviation personnel. The purpose of this review article was to describe the available researches on the ATC training process and related areas, to analyze them, to identify gaps and areas where further research can be conducted. The studies were divided into several areas: studies analyzing ATC training programs (at the FAA Academy and other organizations); research related to simulator training; instructor methods in ATC training; related to ATC instructor competence; interaction between the instructor and the student, etc. In preparing this review, literature sources were used in publications included in Scopus, Web of Science, Google Scholar, Cyberleninka and Russian Science Citation Index. Preference was given to sources published in the last 17 years. The work can be useful for researchers of psychological, pedagogical aspects of the work of ATC instructors, students, as well as all those who are interested in finding methods to improve the efficiency of ATC and reduce the impact of the human factor on their work.

**Keywords:** ATC, Instructor, Training, Simulation, Literature review.

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# 1. INTRODUCTION

Air traffic control (ATC) is one of the significant elements of the air transport system, responsible for the safe and efficient regulation of the flow of aircraft. High rates of development of the aviation industry and the increasing volume of work lead to an increase in the risk of making mistakes. This affects the tightening of requirements for the professional level of aviation specialists, for the efficiency of their work, as well as for the selection and professional training of personnel. The work of an air traffic controller involves interaction with a variety of objects and subjects of the aviation system, their coordinated, efficient and safe interaction. His/Her activity is distinguished by high complexity, variety of individual actions, planning, verification and re-verification, as well as confidence in each step. The safety of work and, as a result, the state of the aviation system is influenced by a large number of factors, both acting at the moment, and latent, longer in time of their manifestation. One of the ways to reduce the human factor in the statistics of aviation incidents and accidents is continuous learning and advanced training of personnel.

"The efficiency of learning depends on teaching methods, content and presentation of material, attributes and motivation of the student and on whether the instruction is provided out by a human or machine" (Doc. 9683-AN/950. Human Factors Training Manual, 1998).

Ineffective training can contribute to a shortage of skilled controllers needed to operate airlines. Such a situation could eventually have disastrous consequences. According to researchers Tao Lyu, Wenbin Song, Ke Du, the top five most influential factors for ATC Performance are training, physical fatigue, mental state, ineffective monitoring and ATC software/hardware. "Obviously, training contributes the most to the performance of air traffic controllers" (Lyu et al., 2019).

"Important objectives of training are to instil good skills, knowledge and habits, and to reinforce them so that they are durable and retained" (Doc. 9683-AN/950. Human Factors Training Manual, 1998).

In our review, we were guided by the goal of analyzing the available research in areas related to the ATC training process and its elements, highlighting the main areas for which data have been published. Thus, to get an idea of what patterns and trends, problems and tasks exist in the process of training air traffic controllers over the past years. We are also interested in problems of studying the related fields.

# 2. METHODS

In preparing this review, we partially used literature sources in publications included in Scopus, Web of Science, Google Scholar, Cyberleninka, and Russian Science Citation Index. Preference was given to sources published in the last 17 years. For this review, articles and materials prepared by experts in their field, as well as governing aviation documents, were selected. Of particular interest was the consideration of the experience of researchers from different countries. Data retrieval was limited to the area of ATC training. In conclusion, the task was to highlight those areas in which there is still not enough information, and to make recommendations for new possible areas of research. The author sincerely hopes that this work will provide a clear technical roadmap for the study of available ATC data and tasks and will contribute to the research community.

# 3. DATA SOURCES

Analysis of literary sources revealed several areas that are in the focus of researchers. One of them concerns the analysis of the curriculum, the study of gaps in the program, the further development of the curriculum and assessment tools.

## 3.1. Research on The Analysis of ATC Training Programs.

In recent decades, due to the rapid development of computer technology, some educational institutions have begun to actively apply the practice of partial remote training in ATC activities. In addition, development and optimization of e-learning has been studied. As the air transport industry continues to grow, air traffic volume increases and there is a shortage

of qualified air traffic controllers, there is a need to speed up the training process, to partially replace the presence of an ATC instructor in the classroom, who in some cases can be replaced by pre-prepared scenarios of aircraft operations on simulators. The ideas of organizing an effective remote learning process have made a leap in their development in the era of the pandemic, and have been reflected in some studies. There are a number of advantages to be recognized in the use of such technologies. The emergence of modern types of simulators makes it possible to modernize the learning and retraining process. Similar ideas are described in a study by Updegrove J.A. and Jafer S. (Updegrove & Jafer, 2017a).

In January 2013, the FAA (US Federal Aviation Administration) conducted a review and evaluation of air traffic controller training at the FAA Academy.

One of the recommendations proposed following the FAA review, in light of the unstable global economic situation, was to develop and implement more courses using web-based materials and online learning solutions (Updegrove & Jafer, 2017a). General recommendations are reduced to a more economically beneficial reduction in the number of classrooms, the number of instructors and the very time of interaction between the instructor and the trainee through the use of computer simulation technologies and intelligent training systems, where possible, allowing recording and playback of work scenarios for trainee ATC controllers (Updegrove & Jafer, 2017a). One of the main areas of research was to determine the impact of simulation on the learning process. As a result, simulation was found to be a great advantage in the learning process. It allows students to bridge the gap between learning and reality. In addition, learning devices are cheaper, more accessible and safer to use than traditional hands-on teaching methods. Also, this method allows trainees to learn from their own mistakes, reproduce difficult and insufficiently learned training situations and increase trainees' confidence. The authors suppose that instructors will have more opportunities to improve the

quality and frequency of feedback during training by significantly reducing the number of tasks under the instructor control. This becomes possible due to technologies and leads to partial removal of the load from the instructor in those areas that can be trusted by the simulator. The recommendations made by Updegrove J.A. and Jafer S. as a result of the analysis of the training process indicate the addition of online training courses to the FAA Academy course catalogue that support self-study, independent of the location of the trainee.

In another study, Jafer S. (Updegrove&Jafer, 2017b) et al. propose an ATC scenario specification and exploration platform to easily create a variety of ATC scenarios.

The 2015 Darendia McCauley study focuses on the evaluation of the FAA's on-the-job training programme (McCauley, 2015). Among the list of recommendations was the use of simulation equipment for terminal or radar exercises where students and OJTI (instructors) can work together to better develop the necessary skills without the pressure and risk associated with control of live traffic. Of particular note is the recommendation to encourage OJTI trainers to share their past experiences at the ATC in order to ensure a more personal perception of the trainee's situation and thereby improve training. The authors also highlighted the fact that communication skills are crucial for OJTI.

The paper by Samuel R. Pavel explores the history of the Air Traffic Control (ATC) controller selection and training process, showing how the process has evolved in an attempt to select a highly qualified and diverse controller workplace (Pavel, 2012). The author's review covers information from before 1964 up to 2011.

The ideas outlined by Fox K.D. in "Prediction of Air Traffic Controller Trainee Selection and Training Success Using Cognitive Ability and Biodata", are to improve the FAA ATC controller selection system and training process by identifying which cognitive ability factors and BioData (biodata) can determine performance status, whether an ATC controller can successfully complete the Training Requirements and become

a certified professional ATC controller (Fox, 2014).

The article by M. Liang&N. Evans focuses on the introduction of an Air Traffic Control (ATC) Distance Learning Assistant (DLA) "E-tutoring" program via the Internet at the University of South Australia (Liang & Evans, 2021).

Also, the process of staff training, the theoretical and practical part of the internship is described by S.V. Gubenko, and Yu.A. Yurkin (Gubenko &Yurkin, 2013).

Yushkova E.O. analyzes the stages of training air traffic service specialists in training institutions on control simulators, reveals the stages of training, the characteristics of work in each aerodrome sector, describes the criteria for the methodology of assessment by instructors of the trainees' task performance (Yushkova, 2015).

Nemliy L.S.'s research touches upon the issues of pedagogical competence of future air traffic control (ATC) instructors in the course of professional training, describing the process of organizing and conducting a pedagogical experiment to prepare controllers' cadets for pedagogical activity (Nemliy, 2014). The researchers tested the curriculum of the "Fundamentals of the pedagogical activity of the ATC instructor-controller" special course.

The 2022 Dwi Sanjaya, R., Prasetyo, I. & Rossydi A. study aims to evaluate the on-the job-training (OJT) curriculum organised by the Vocational Education Institute, with a focus on the Air Traffic Management (MLLU) curriculum of Makassar Aviation Polytechnic Institute (Sanjaya et al., 2023).

The improvement of the initial training of air traffic controllers is addressed by the author V.P. Kolotusha (Kolotusha, 2013). In his article he points out the need to individualise the training process, and also, taking into account the teamwork of air traffic controllers, considers it important to train future controllers for teamwork (as part of an ATC shift), and to "take into account the compatibility in professional-psychological indicators of individual individuals as part of an ATC shift"

(Kolotusha, 2013). In addition to the above, the author considers a wide range of issues: the exchange of experience and the best educational practices via the exchange of information through participation in international working groups, seminars, symposiums; wider use of modern technical teaching aids and information technologies; where possible, the introduction of a more student-centered training process; "applying a model of remote access of students to educational materials, with the possibility of self-assessment based on the use of the Internet and / or Intranet" (Kolotusha, 2013).

M. Lomakina and K. Surkova consider the problem of individualization of air traffic controller cadet training, using a cybernetic approach to training (Lomakina&Surkova, 2018). The purpose of the study was to highlight various aspects of the professional training of air traffic controllers, which will allow during the training session to decompose the activities of both the teacher and the cadets, providing a correction of the training on the simulator.

Gagloev E.P. and Yurkin Y.A. propose to focus on theoretical and practical training in conditions of increased traffic intensity (difficulties), as well as the development of air traffic control skills in uncertain situations with mandatory compliance with flight safety requirements using the method of random activity fragments (Gagloev& Yurkin, 2013).

Speaking about the evaluation of training programs, it is necessary to mention the 2015 Lisa M. Mercer study on air traffic controllers commissioned by the FAA (Mercer, 2015). The aim was to ascertain if the program facilitated the learning of critical ATC on-the-job training skills. An ad hoc expertise-oriented evaluation was conducted using the lenses of andragogy, experiential learning, and instructional system design (ISD).

In turn, neurophysiological studies can also make a tangible contribution to the effectiveness of the training process. For example, the article by Aricò et al. reviewed research on neurophysiological measures, also referred to as "neurometry", to show how effectively this method can address

some of the most important Human Factors (HF) needs in air traffic management (Aricò et al., 2017). Of particular interest is the authors' coverage of the issue of "Training Design and Competence Assessment" as one of the top five research and innovation priorities in human factors for flight safety arising from the OPTICS workshop. "Initial and ongoing training are important (and costly) activities to ensure efficiency and safety. There is an innovation gap in current approaches to learning: teachers have few tools to support their work and evaluation is based only on subjective assessment, self-reflection and few performance indicators. Both the development of new training methods and their purpose can greatly benefit from the use of methods that make it possible to understand what level of training operators have achieved and in which specific areas they need more practice» (Aricò et al., 2017).

S. Arbula and M. Capizzi et al. in their work analyzed the effects of real cognitive-enhanced training that air traffic controllers undergo on higher cognitive processes, and identified the specific components of this effect in order to modulate learning (Arbula et al., 2016).

The article by T.J. Wiltshire et al. presents the results of an empirical study of real-world trainee training and the strategies used by experienced instructors in the complex cognitive domain of air traffic controllers to improve trainee cognitive training (Wiltshire et al., 2014). The authors' work is based on a methodology for improving the cognitive transformation theory and adapting it to the field of ATC training.

Article by S. K. Soldatov et al., is devoted to the development of the basic skills of air traffic controllers (ATC) based on the analysis of their work professiograms, the relationship of professional skills with experience and the possibility of teaching these skills (Soldatov et al., 2018).

C. Malakis и T. Kontogiannis studied the extent to which advanced training in air traffic control can take into account the requirements of real emergencies (Malakis&Kontogiannis, 2012).

Research in this area is generally limited, as most of the focus is on normal operation and error taxonomy. The authors made recommendations for the analysis of learning needs to be guided by the CTA (Cognitive Task Analysis) methods in order to determine the cognitive and command strategies that will become a central element of the training program.

In reviewing the research related to ATC controller training, it is necessary to highlight the area of research related to simulator training, as it is an important part of the entire process in training ATC controllers.

### 3.2. Research Related to Simulator Training in ATC Training Process.

"Simulation is a training method that refers to the technology used to reproduce human-aircraft interaction for training purposes" (Gheorghiu, 2013).

"Among the many factors contributing to the widespread introduction of simulator training in the learning process is its effectiveness in terms of consolidating and developing skills" (Klimov & Zarechkin, 2019)

"Simulators eliminate operational risk present in live traffic and provide significant contributions to ATC training by their fidelity and realism" (Gheorghiu, 2013).

A study by D. Brudnicki, K. Chastain & B. Ethier, published in 2006, provides a detailed overview of the training technologies used at the FAA Academy and in the On-Job Training (OJT) during those years (Brudnicki, 2006). It describes the features of instructor support, including updated simulator features such as scenario recording and playback. The authors also gave recommendations for future applications of the technology. Researchers recorded a reduction in the workload of instructors and an improvement in real-time feedback from trainees.

According to the authors, this can bring ATC training one step closer to a more personalized learning experience for each student in a large classroom, allowing instructors to move more freely around the classroom and instruct each student individually.

A.N.Gorenkov's article gives an overview of the various categories of simulators and simulation systems used in the system of air traffic controller training (Gorenkov, 2016).

Several studies by Borisov V.Ye. also focus on the simulator training. One of them describes the process of developing complex air traffic services (ATS) skills, which, in turn, are divided into simpler skills (Borisov et al., 2020). As applied to the training of air traffic controllers, the authors distinguish three types of skills: motor, cognitive and metacognitive, which develop over time as they are practised.

Referring to WHO data on the increased likelihood of a new epidemic in the near future, V.Ye. Borisov et al. consider the possibility of using automated modular simulator systems for training air traffic controllers in remote access mode, and also points out the need to improve the methods of training and advanced training of aviation personnel using remote forms of training along with traditional training (Borisov et al., 2020).

A.V.Sannikov's study considers the possibilities of using statistical models to assess air traffic controllers' qualification level during simulator training and describes the methods developed by him for monitoring and assessing the training level of air traffic controllers (Sannikov, 2010).

X.Wu's article describes the development of an ATC simulator evaluation system architecture, an algorithm of evaluation indices, editing the base of rules knowledge, and an evaluation system reasoning mechanism to carry out automatic, objective, fair and efficient evaluation in accordance with the established rules for training and successful application in an ATC simulator (Wu, 2020).

Stepnova A.I. and her team of co-authors propose joint simulator training for cadets - air traffic controllers and pilots - as a means of optimising the training for both (Stepnova et al., 2019). The reason for this approach is to familiarise them with each other's work, as the cadets in both specialities are trained separately, and such a programme will allow them to practise "quick decision-making skills" together, giving them a direct insight into the intricacies of the related professions.

Zuluaga-Gomez, J.& Prasad A. propose a new virtual pilot simulator mechanism to accelerate ATC controller training by integrating various state-of-the-art AI (Artificial Intelligence)-based tools (Zuluaga-Gomez et al., 2023).

**3.3. A Study of Instructor Methods in ATC Training.**

An overview of research on the training process would not be complete without mentioning the authors' many years of research, including the methods used by ATC instructors in training trainees.

Researchers Arminen, I.; Koskela, I.; Palukka, H. in their paper analysed the temporal and sequential organization of the trainer's prompt–trainee's multimodal response adjacency pairs, identified the interrelation of actions and incentives in air traffic control training, and concluded that trainees reply either to the scenario itself or to the instructor prompt (Arminen et al., 2014).

The article "The Embedded Evaluations in Air Traffic Control Training" focuses on assessing the trainee's performance during practical training (Koskela & Arminen, 2012). The authors analyse the multimodal learning activities that develop from moment to moment between trainee and instructor during simulator training exercises, applying the principles of ethnomethodology (EM), multimodal conversation analysis (CA) and ethnography (observations, interviews and discussions with instructors and trainees.

I.Koskela and H.Palukka studied the guidance and control methods used by trainers when training ATC controllers on a simulator (Koskela&Palukka, 2011). They found that the instructors used five different training strategies to guide and supervise the trainees in the simulator. Instructors gave commands, asked control questions, supplemented speech production (speech formation), gave instructions and provided information. The aim of the researchers was to show how these methods make it easier for trainees to participate in the

main activity and to improve their involvement in the work process.

### 3.4. Concept of ATC Instructor Competence in Tthe Works of Researchers.

Another direction is related to the concept of ATC instructor competence. This is particular relevant following the publication in 2020 of Amendment 7 of Doc.9868 "Procedures for Air Navigation Services — Training. Third Edition. 2020" (Procedures for Air Navigation Services — Training. Doc 9868, 2020). It concerns the introduction of new definitions, regulations for ATC controller on-the-job training instructors, and minor clarifications to existing provisions. Significant changes also include the introduction of new ICAO competency frameworks. Instructor competence includes: Situational Awareness; Safety and Efficiency Management; Mentoring; Teaching, Instructing and Coaching; Communication; Assessment; Collaboration; Self-assessment; Ethics and integrity.

The issues of developing the pedagogical competence of an ATC instructor are also considered in the works of Olkhovsky D.V. (Olkhovsky, 2016; Olkhovsky, 2017)

The article by Sonhaji I, Jatmoko D. is devoted to the study of ICAO Document 9868 "Procedures for Air Navigation Services — Training", its comparison with the Indonesian curriculum for on-the-job ATC training (Sonhaji&Jatmoko, 2021). In their paper, the authors identify three main competencies that need to be included in the training of Indonesian trainers, namely: the acquisition of skills in mentoring and teamwork, as well as ethics and integrity skills.

The author Atmia, K. formulates the problem of the role of an ATC controller, a flight manager and an ATC instructor in accordance with the Civil Aviation Safety Regulations at the Mopah Merauke Airport (Indonesia), and considers the issues of training of ATC personnel on ATM (air traffic management) audit for implementing the performance audit rating and for training of ATC controllers-instructors (Atmia, 2020).

### 3.5. Study of Instructor-Trainee Interaction.

In reviewing the various aspects of the ATC training process, we approach its direct participants - the instructor and the trainee. Even with good psycho-physiological qualities, a high level of development of cognitive processes, the ability to quickly make decisions, both instructors and trainees are individuals with their own individual traits of character, temperament, level of worldview, and characteristic features. Accordingly, there is no guarantee that their interaction will be perfect. It is possible that their personal qualities may hinder effective teamwork, and this is confirmed by research. There are often a number of problems with the interaction between the instructor and the trainee. They may be related partly to the personality of the instructor himself, the lack or low level of development of the qualities necessary for this work. The study by Maria Lundahl describes the problem of the significant dependence of the learning climate on the instructors involved (Lundahl, 2009). "If an instructor/a group of instructors create the kind of climate where the students feel they are being listened to, are welcome to say their opinion, where they are given all available resources and where they are encouraged to think solutions out for themselves during training, then those students could be considered to be treated fairly" (Lundahl, 2009).

Another factor that has a significant impact on the interaction between the instructor and the trainee is the style of pedagogical communication of the ATC controller-instructor, i.e. a system of techniques and methods used by the instructor in the training process. With regard to ATC instructors, there is a study that has been reflected in the article "Styles of pedagogical communication in the work of air traffic control instructor" **(**Estrova, 2023**)**.

The personality of the instructor, his pedagogical skill, which is a synthesis of professional psychological and pedagogical knowledge, abilities and qualities of the teacher's personality, occupies a special place in the training process of ATC controllers-trainees. Arminen et al. note: "In ATC training, a complex joint project is transformed into an object of pedagogy"

(Arminen et al., 2014). At the same time, the ATC instructor must have sufficient knowledge in the field of psychology and pedagogy to understand the personality traits of the trainee-controller.

The article "Professiographic analysis of activity of ATC instructor" presents the results of a study on the analysis of the professional activity of an ATC controller-instructor, including a professiogram of this specialty which has been compiled based on the analysis of the available literature, guidance documents, expert assessments and observation (Estrova, 2023). The publication also provides basic information about the profession, describes the dominant activities, outlines the areas of knowledge required for the effective work of the instructor, etc. To clarify the list of professionally important qualities of an ATC controller-instructor, the authors developed an expert assessment questionnaire "Suitability for work as an ATC controller-instructor". Proceeding from the fact that modern computer simulation technologies are beginning to take an increasing place in the ATC controller training process, thereby reducing the time of joint interaction between the trainee and the instructor, every action and communicative act of the ATC instructor in this process are becoming increasingly important, and the personal, psychological component of their interaction and communication in the learning process acquires greater significance and value. And this provides a wide area for further research.

## 4. CONCLUSION

Historical and theoretical analysis of the problem of studying the ATC training process, including various aspects of the activity of an ATC controller-instructor and a trainee in the learning process, shows the availability of information in the field of the existing process of ATC controller training in different countries, conducting a pedagogical experiment and approbation of the curriculum to train students-ATC controllers for pedagogical activities, the problems of advanced training of existing operators, specialists and managers associated with the development of new types of aircraft and automated air traffic control systems, improvement of the FAA

selection system for ATC controllers and learning process. Numerous studies on various aspects of the simulator training for ATC controllers are also known.

For clarity, we present a classification of various areas of research published in the last 17 years (see Table 1).

**Table 1.** Areas of research in ATC training

| | Areas of research in ATC training | Quantity of studies | Percentage of the total amount |
|---|---|---|---|
| 1 | Research on the analysis of ATC training programs | 19 | 47,5% |
| 2 | Research related to simulator training in ATC training process | 11 | 27,5% |
| 3 | A study of instructor methods in ATC training | 3 | 7,5% |
| 4 | The concept of ATC instructor competence in the works of researchers | 3 | 7,5% |
| 5 | Study of instructor-trainee interaction | 4 | 10% |

In conclusion, having analysed the literature provided by resources from around the world and summing up, it is important to note that despite the importance of the effect of the ATC training process on the working efficiency of ATC controllers, many areas have not been studied yet. In particular, we can mention the study of personality traits of current instructors and their influence on the learning process, as well as gaps in gender research in ATC training, professional burnout of instructors and many other issues. Also, programs and strategies have not been developed to overcome the problems and barriers of educational interaction between an ATC controller-instructor and trainees that arise in the pedagogical activities of ATC controllers-instructors. Accordingly, as well as programs to

research and improve the competency qualities of instructors

Considering the new requirements of guidance aviation documents and a more in-depth approach to the personal qualities of specialists involved in aviation personnel training, conduct more psychological and pedagogical research in this area.

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