Modern Technologies & Human Performance Taxonomy in Air Traffic Management Development.

Polish and Georgian Case Studies

Nika Tikanashvili
Faculty of Engineering, Georgian Aviation University, Tbilisi, Georgia
Antoni Kopyt
Faculty of power and Aeronautical engineering, Warsaw University of Technology, Warsaw, Poland

Abstract— The Global Air Navigation Plan (GANP) is a flexible global engineering approach that allows all States to advance their Air Navigation capacities based on their specific operational requirements. One of the most important problematic part for successful implementation of the GANP is innovative air traffic management system and aircraft on-board technologies effective interrelationship taking into consideration human factors.

The research work is focused on the creation of methodology for comparison gap between Air Traffic Management (ATM), aircraft modern on-board systems and aviation professionals' competencies. One of the problem in the implementation of the new technologies is that, there are currently no unified requirements for all categories of ATM, and on the other hand, the development of modern trends requires new competencies from operational and maintenance personnel. This problem becomes even more noticeable in countries that have just started an active modernization of ATM systems.

This paper examines the expertise of human performance specialists and the tools they use have been recognized as key ingredients to advance ATM infrastructures in the process of modernizing the national air traffic control systems. Research oriented to the Polish and Georgian case studies, as in both counties quickly improves the ATM technologies the development of personnel skills is critical. As a result, taxonomy of key human performance issues for the design and integration of large-scale future ATM programs is proposed.

Keywords— Air Traffic Management, Avionics, Human Performance, New Technologies.

Introduction

Any national airspace system is dedicated to ensuring the safe, and reliable flow of air traffic through the integrated largest, most complex air navigation system in the world. The system encompasses a vast array of air navigation facilities, equipment, and services; airports or landing areas; aeronautical charts, information, and services; rules, regulations, and procedures; technical information; human performance and materials. Human factor, in the context of Air Traffic Management (ATM), refers to the performance of jobs, tasks, and activities by operational personnel–individually and together. Human factor, as a domain, focuses on optimizing the

people element in complex work systems such as air traffic management. It covers all aspects of integrating people into systems.

The GANP represents a strategic methodology which leverages existing technologies and anticipates future developments based on State/industry agreed operational objectives (ICAO, GANP 2016-2030). The GANP explores the need for more integrated aviation planning at both the regional and State level and addresses required solutions by introducing the consensus-driven Aviation System Block Upgrades (ASBU) systems engineering modernization strategy. The Block Upgrades will enable aviation to realize the global harmonization, increased capacity, and improved environmental efficiency that modern air traffic growth now demands in every region around the world. The GANP also outlines implementation issues involving the near-term performance-based navigation and Block 0 Modules and the Planning and Implementation Regional Groups (PIRGs) that will be managing regional projects.

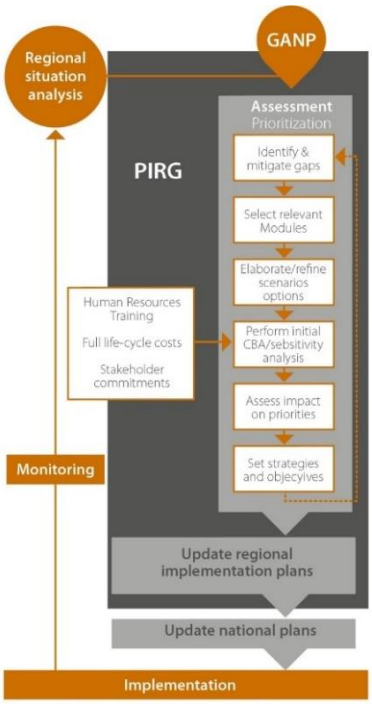

Figure 1. Regional planning process

Investing in human performance will help to reduce industry costs, and improve overall organizational performance by:

- improving system design, development & implementation processes and outcomes;
- improving selection, recruitment, staffing;
- improving work organization;
- improving procedures and training;
- improving system safety;
- improving transition into operations and the social acceptance of changes.

It is therefore critical that the concepts being developed within the GANP take into account the strengths and weaknesses of existing and future skilled personnel at every juncture. All actors with a stake in a safe air transportation system will need to intensify efforts to manage risks associated with human performance and the sector will need to proactively anticipate interface and workstation design, training needs and operational procedures while promulgating best practices.

Key problem in the implementation of the GANP is that, on the one hand, there are currently no unified requirements for all categories of ATM personnel, and on the other hand, the development of ATM technologies is far ahead of the pace of training of personnel of appropriate qualifications. This problem becomes even more noticeable in countries that have just started an active modernization of ATC systems. In particular, Poland and Georgia are among the countries mentioned. The figure below shows the progress made so far, per SESAR Essential Operational Changes, in the implementation of the SESAR phases based on the official statistics of the European Organization for the Safety of Air Navigation (EUROCONTROL, LSSIP 2021 – Local Single Sky Implementation, Poland, Georgia).

Georgia	Poland	Essential Operational Changes
100 %	95%	ATM Interconnected Network
23 %	81%	Airport and TMA performance
80 %	97 %	CNS Infrastructure and Services
100 %	46 %	Digital AIM and MET Services
100 %	95%	Fully Dynamic and Optimised Airspace
100 %	100%,	Trajectory Based Operations
60 %	70%	Virtualisation of Service Provision

Table 1. SESAR Essential Operational Changes (Georgia, Poland)

At the same time official investigation reports of aviation accidents and incidents during previous years shows that, there are several aviation incidents, which have the direct connection with the human insufficient competencies in ATM during the operation.

An additional problem under these conditions is that it is difficult to identify competencies of personnel that require development in order to meet the requirements of modern ATM technologies and in the same time it is difficult to understand the gap between the training curricula outcome and the industry requirements.

The paper is focused on the creation of a novel methodology for the partial automation of the comparison competences of ATM personal and synthesis of training courses and modules, using a formal, taxonomy and ontology-based approach as a tool to solve these problems.

Research Methodology

Human competency gap analysis in ATM and for gap analysis between the university curricula outcome and the ATM requirements.

The main objectives of the research are as follows:

1. To create ontology for the formal representation of an educational course, its modules, learning outcomes and keywords.
2. To propose a methodology for the partially automated population of the ontology based on program specifications and module templates.
3. To design, implement and evaluate an ontology alignment algorithm for ontologies of the educational courses and modules.

The main research question and the objectives of this work are the following:

1. Which information about educational courses and modules should be used for comparison with necessary competences of ATM personal and how will it be stored in ontology?
2. How to automate the population of the ontology with the data from the documents?
3. What is the alignment algorithm for ontologies of educational courses and modules? Which similarity measures should it utilize?

The main contribution of this work is ontology alignment-based methodology for the automated comparison of education courses and modules, belonging to the cognitive learning domain, for development necessary competences of ATM personal in new technological environment.

Early Results and conclusions

At the first stage of research the general approach for staff development was proposed (Fig.2). This approach is based on three models of competencies:

1. The competencies required for GANP implementation;
2. Competence actually available for individuals of ATM staff;
3. Competences that are formed by existing programmes,

courses and modules in the process of education and training (E&T).

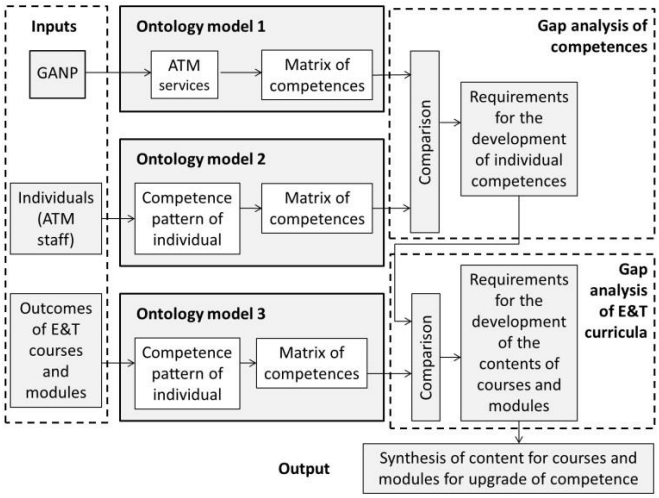

Figure 2. General model of ATM staff development

The input for the first model created on the base of analysis of ATM services taxonomy and necessary competencies (knowledge, skills, and attitudes) for staff for GANP implementation.

The input for the second model created on the base of analysis and testing of real competences of real individuals, who work in ATM enterprise, on the base of surveillance and set of questionnaires.

The input of the third model created on the base of analysis of the key components (outcomes) that are formed in the process of training the staff in the existing E&T courses and modules.

The core element of all three mentioned models is the matrix of competences (Fig.3).

Input	Knowledge				Skills				Attitudes			
	K_1	K_2	...	K_k	S_1	S_2	...	S_s	A_1	A_2	...	A_a
I_1	k_{11}	k_{12}	...	k_{1K}	s_{11}	s_{12}	...	s_{1S}	a_{11}	a_{12}	...	a_{1a}
I_2	k_{21}	k_{22}	...	k_{2K}	s_{21}	s_{22}	...	s_{2S}	a_{21}	a_{22}	...	a_{2a}
...	...	...	...	...	...	...	...	...	...	...	...	...
I_i	k_{i1}	k_{i2}	...	k_{iK}	s_{i1}	s_{i2}	...	s_{iS}	a_{i1}	a_{i2}	...	a_{ia}

Figure *3.* Matrix of competences

These matrices are formed for each of three models from the sets of necessary competences in the field of knowledge $K = \overline{k_{11}, k_{ik}}, \forall i, \forall k$, ∀i,∀k , skills $S = \overline{s_{11}, s_{is}}, \forall i, \forall s$, and attitude $A = \overline{a_{11}, a_{ia}}, \forall i, \forall a$ formed on the basis of the input requirements of each model.

The set of inputs and matrix for each of three models were converted to the three ontologies. Ontology was chosen as the data model due to its ability to formally specify semantics, to represent taxonomies and to make inferences regarding data.

ontology should characterize conceptualization and should restrict the possible values of predicates and functions in order to agree on knowledge representation in a certain logic-based language. In this view, ontology refers to a logical theory in which axioms restrict the interpretation of non-logical symbols of the language.

Thus, informally, ontology is a description of the system of views concerning a data domain as applied to a certain task. An ontological description includes the terminology and the imposed rules that restrict the definitions and the relationships between the terms. Formally, ontology is a system of concepts and a set of assertions, based on which a system of classes, objects, relations and inferences can be built.

ontology defined as the following tuple, which is added in the study by set A of axioms:

$$O =< C, I, R, T, V, A, \leq, \perp, \in, => $$

where

- C is the set of classes used to store the sets of individuals in a domain of interest,
- I is the set of individuals, which are particular objects in the data domain of interest,
- R is the set of binary relations, either between two individuals (known as Object property), or between an individual and a data type (known as Data type property),
- T is the set of data types (for example, integers, strings),
- V is the set of particular values (C, I, R, T, V being pairwise disjoint),
- $\leq$ is a relation on $(C \times C) \cup (R \times R) \cup (T \times T)$, called specialisation,
- $\perp$ is a relation on $(C \times C) \cup (R \times R) \cup (T \times T)$, called exclusion,
- $\in$ is a relation over $(I \times C) \cup (V \times T)$, called instantiation,
- $=$ is a relation over $I \times R \times (I \cup V)$, called assignment.
- A Is a set of axioms, which consist of logical statements that are always true, and the knowledge that can be.

This definition includes the concepts of classes, objects and data type relations. It enables the representation of the classes' taxonomies and hierarchies of properties, the instantiation of classes and the assignment of relations. At the same time, it is easily readable and clear in terms of human understanding.

As a result of the research, to form formal procedures for synthesis of content for courses and modules for upgrade of ATM staff competence be possible.

During the research erected models between personnel competencies and new technological environment to make them harmonized and as a result have an increased safety, capacity and efficient level of ATM operation for the future growth requirements of air transportation in Poland and Georgia.

Acknowledgment

This work was supported by Shota Rustaveli National Science Foundation of Georgia (SRNSFG) [YS-21-483].

References:

[1] Doc 9750-AN/963 (2016) 2016–2030 Global Air Navigation Plan. ICAO, 137p.

[2] ASBU Implementation Monitoring Report ICAO EUR States (2017) ICAO, 140 p.

[3] European Air Navigation Plan (2021), ICAO EUR States,Volume III.

[4] Human Performance in Air Traffic Management Safety. A White Paper (2010). EUROCONTROL/FAA Action Plan 15 Safety, September 2010, 36 p.

[5] EUROCONTROL (2022) Local Single European Sky Implementation (LLSIP) Poland, Georgia.

[6] SESAR. The Roadmap for Delivering High Performing Aviation for Europe. Executive View European ATM Master Plan, pp. 56-59.

[7] Human Factors, Federal Aviation Administration, Chapter 14, pp 14-28.

[8] EUROCONTROL Seven-Year Forecast February 2018; Edition V1.0, pp 14-84 [online] https://www.eurocontrol.int/sites/default/files/content/documents/officialdocuments/forecasts/seven-year-flights-service-units-forecast-2018-2024-Feb2018.pdf

[9] „Ontology based approach for human competency gap analysis in Air Traffic Management“ Autors: Igor Kabaskin, Nika Tikanashvili. Publication of paper in Transport and Telecommunication Journal, 2019, volume 20, no. 3 (ISSN 1407-6179, indexed in Scopus, Web of Science and others scientific data bases)

[10] Human Factors Digest No.6 ERGONOMICS, ICAO Circular 238-AN/143.

[11] Official Web-Page of Causes of Fatal Accidents by Decade. http://www.planecrashinfo.com/cause.htm

[12] Jörg Kundler Doctoral Thesis “The methodology of maintenance and technical service model development for air traffic control service providers”, Scientific supervisor Dr.habil.sc.ing., Professor Igor Kabashkin, Riga 2014.

[13] Protégé -a free, open-source ontology editor and framework for building intelligent systems. https://protege.stanford.edu/

[14] Manual on Air Traffic Controller Competency-based Training and Assessment, ICAO Doc 10056, First Edition, 2017

[15] International Standards and Recommended Practices, ICAO Annex 19 to the Convention on International Civil Aviation.

თანამედროვე ტექნოლოგიებისა და ადამიანის ფაქტორის ტაქსონომია საჰაერო მოძრაობის მართვის სისტემის განვითარებაში. პოლონეთის და საქართველოს მაგალითი

ნიკა თიკანაშვილი
საქართველოს საავიაციო უნივერსიტეტის საინჟინრო ფაკულტეტი,
თბილისი,საქართველო

ანტონ კოპიტი
ენერგეტიკისა და საავიაციო ინჟინერიის ფაკულტეტი, ვარშავის ტექნოლოგიური უნივერსიტეტი, ვარშავა, პოლონეთი

ანოტაცია - საჰაერო ნავიგაციის გლობალური გეგმის (GANP) მიერ შემოთავაზებული მოქნილი საინჟინრო მიდგომა სამოქალაქო ავიაციის საერთაშორისო ორგანიზაციის (ICAO) წევრ სახელმწიფოებს საშუალებას აძლევს გააუმჯობესონ საჰაერო ნავიგაციის შესაძლებლობები მათი სპეციალური საექსპლუატაციო მოთხოვნების დაკმაყოფილებით. საავიაციო სპეციალისტები მნიშვნელოვან როლს ასრულებენ GANP-ის წარმატებით დანერგვაზე გადასვლის პროცესში. GANP-ის წარმატებული განხორციელების ერთ-ერთი ყველაზე მნიშვნელოვანი პრობლემური საკითხია საჰაერო მოძრაობის მართვის ინოვაციური სისტემის და საჰაერო ხომალდების თანამედროვე საბორტო ტექნოლოგიების ეფექტური ურთიერთკავშირი ადამიანური ფაქტორის გათვალისწინებით.

კვლევის მიზანია საჰაერო მოძრაობის მართვის სისტემას, საჰაერო ხომალდების თანამედროვე საბორტო სისტემებსა და საავიაციო პერსონალის კომპეტენციებს შორის ტაქსონომიური მოდელის შექმნა, ვინაიდან გლობალური სანავიგაციო გეგმის რეალიზაციის ერთ-ერთი პრობლემა იმაში მდგომარეობს, რომ, ერთის მხრივ, ამჟამად არ არსებობს ერთიანი მოთხოვნები საჰაერო მოძრაობის მართვის პერსონალის ყველა კატეგორიისათვის, ხოლო, მეორეს მხრივ, საჰაერო მოძრაობის მართვის ტექნოლოგიური განვითარება ბევრად წინ უსწრებს შესაბამისი კვალიფიკაციის პერსონალის მომზადების ტემპს. ეს პრობლემა უფრო მეტად შესამჩნევია იმ ქვეყნებში, რომლებმაც ბოლო წლების განმავლობაში დაიწყეს საჰაერო მოძრაობის მართვის სისტემათა აქტიური მოდერნიზაცია. კვლევითი სამუშაოები ფოკუსირებულია საქართველოს და პოლონეთის მაგალითებზე დაყრდნობით ნაწილობრივ ავტომატიზებული მეთოდოლოგიის შექმნაზე საჰაერო მოძრაობის მართვის პერსონალის კომპეტენციათა შეფასებისათვის, ასევე კურუკულუმის, სასწავლო კურსებისა და მოდულების სინთეზზე ონტოლოგიური მიდგომის გამოყენებით როგორც ამ პრობლემების გადაწყვეტის ერთ-ერთი ძირითადი ინსტრუმენტი.

ნაშრომში შემოთავაზებულია ონტოლოგიურ მოდელზე დაფუძნებული მეთოდოლოგიური მიდგომა საჰაერო მოძრაობის მართვის თანამედროვე მოთხოვნებსა და უნივერსიტეტის სასწავლო პროგრამების სწავლის შედეგებს შორის საქართველოს და პოლონეთის მაგალითზე. ვინაიდან ორივე ქვეყანაში სწრაფად ვითარდება ტექნოლოგიები ადამიანური კომპეტენციების განვითარება უფრო მნიშვნელოვანი

ხდება, სწორედ ადამიანის კომპეტენციათა ანალიზის საფუძველზე შემოთავაზებულია პერსონალის კომპეტენციათა გაუმჯობესებისათვის გასათვალისწინებელი საკვანძო საკითხების ტაქსონომია საჰაერო მოძრაობის მართვის ფართომასშტაბიანი პროგრამების შემუშავებისა და ინტეგრაციის მიზნით.

საკვანძო სიტყვები — საჰაერო მოძრაობის მართვა, ავიონიკა, ადამიანური ფაქტორი, ახალი ტექნოლოგიები.