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COMPETENCY-BASED TRAINING REFORM FOR AIR TRAFFIC CONTROLLERS: A COMPARATIVE STUDY OF INTERNATIONAL FRAMEWORKS AND IMPLICATIONS FOR CHINA

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Abstract: Air traffic keeps growing, and air traffic controller (ATCO) training has to change with it. Earlier work examined, in general terms, whether ICAO's TRAINAIR PLUS framework could be applied to the Chinese training system. What it left open is how Western reforms actually work at the level of institutions: who gets selected, how trainees are filtered out, and how courses are put together. We compare the training arrangements of the United States (FAA), Europe (EUROCONTROL) and China (CAAC) on four points—regulation, selection and attrition, curriculum structure, and assessment—and look at what each system does well and where it is held back. From this comparison we draw reform steps that China could take in moving from task-based to competency-based training. The main proposals are a competency framework adapted to Chinese conditions, a new selection process, and standard CBTA course packages built to ICAO Doc 10056.
Keywords: Competency-based training; Air traffic controller; Institutional reform; Training system comparison

1 INTRODUCTION

1.1 Background and Rationale

Controllers keep airspace orderly and flights moving safely and efficiently. Traffic volumes are rising and airspace is becoming more crowded and more complicated, so the bar for what a controller must be able to do keeps going up. Most new controllers come through the trainee pipeline. The quality of that pipeline therefore sets the competence of the workforce as a whole and, in the end, has a bearing on civil aviation safety [1].
ICAO published Doc 10056, the Manual on Competency-Based Training and Assessment for Air Traffic Controllers, in 2016 [1]. Since then, more and more training providers have moved away from counting hours and towards measuring competence. In earlier work, Wang et al. gave a first assessment of how well the TRAINAIR PLUS Programme fits Chinese controller training [2]; they compared training models at home and abroad and asked whether competency-based methods could be transferred. That study stayed at a general level. Here we go one step further and look closely at how training systems are designed—the specific rules, organisations and course structures that support CBTA in representative Western systems.

1.2 Research Aim and Scope

Earlier studies mostly asked whether ICAO frameworks suit China as a whole. This paper asks a narrower question: which concrete mechanisms make competency-based training work in practice? We look at four of them—selection, staged attrition, modular course design, and the way assessment is built into training. By setting the FAA, EUROCONTROL member states and the CAAC side by side, we try to pin down reform steps that China can actually act on. The intended result is an institutional roadmap for moving Chinese civil aviation from knowledge-centred to competency-centred training.

2 MATERIALS AND METHODS

2.1 Conceptual Foundations of CBTA

The basic idea of competency-based training and assessment (CBTA) is simple: training should be built around what a person can be shown to do on the job, not around how many hours they have logged. ICAO describes competence as a stable feature of work performance that predicts whether a task will be done well. It shows up as observable behaviour when someone draws on the right knowledge, skills and attitudes under given conditions [1]. Put differently, CBTA stops measuring inputs, such as time spent in the classroom or simulator, and starts measuring outputs, namely performance against a standard.

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Assessment in CBTA rests on observable behaviour (OB). Competence cannot be seen directly; it has to be inferred from performance. When an instructor watches a trainee complete a task successfully again and again, they can be fairly confident that the underlying skills are in place, including mental skills that are hidden from view. Take approach sequencing. A smooth sequence may come from good planning and situational awareness, or the trainee may simply have been reacting to whatever the traffic happened to do. Only observation over a longer period tells the two apart [1].
ICAO Doc 9868 sets out ten competency areas for controllers: situational awareness and anticipation; traffic and capacity management; separation and conflict resolution; communication; coordination; management of abnormal and emergency situations; problem solving and decision making; self-management; workload management; and teamwork [3]. Each area comes with observable performance criteria. These criteria feed into course design as well as assessment, and they give training providers in different countries a common point of reference.

2.2 Task-Based versus Competency-Based Training Paradigms

Task-based training breaks the controller's job into smaller subtasks and writes the syllabus around them. Trainees drill procedures and control techniques until they can carry out each task on their own. They are then tested by repeating the tasks in the simulator or on live traffic, and the process ends with solo certification. For routine traffic this works well enough. The weakness is that a controller trained this way may struggle when something happens that the syllabus never covered.
CBTA takes a different route. Training is organised by the competency areas in the framework, and instructors watch how trainees behave while doing tasks to judge whether the standard has been met. The assumption is that competencies carry over from one situation to another, so a controller trained in this way should cope in any scenario, not just the rehearsed ones. Western aviation authorities have been moving in this direction for some years; China still relies mainly on task-based training [2].

3 RESULTS: INSTITUTIONAL ANALYSIS OF INTERNATIONAL TRAINING SYSTEMS

3.1 ICAO Regulatory Framework and TRAINAIR PLUS Programme

ICAO sets binding competency requirements for controllers through Annex 1 (Personnel Licensing) and the related Standards and Recommended Practices [4-6]. Training is divided into three phases: Initial Training (basic and rating training), Unit Training (pre-OJT and OJT) and Continuing Training (refresher and conversion) [1]. The TRAINAIR PLUS Programme (TPP), started in 2010, promotes common competency-based standards across aviation training. It relies on the Instructional System Design (ISD) method described in Doc 9941 [7]. By June 2025, 119 training institutions around the world had become TPP members.

3.2 United States: FAA Training System Design

The FAA's controller training system is one of the most mature in the world. Its legal basis is Title 14 of the Code of Federal Regulations (14 CFR) [8], while FAA Orders JO 3120.4S and JO 7110.65BB lay down training standards and procedures [9-10]. Selection runs on two tracks. Under the Air Traffic Collegiate Training Initiative (AT-CTI), 36 approved colleges across the country provide foundation training and skills assessment. Initial training itself, however, takes place in one location only: the FAA Academy at the Mike Monroney Aeronautical Center (MMAC) in Oklahoma City [9].
What sets the FAA apart is how hard it filters candidates, stage by stage. Applicants go through a biographical assessment, an aptitude test (the Air Traffic Skills Assessment, ATSA) and a medical examination. Around 40% are lost during selection and academy training. The cut is severe, but it means that the people who reach operational training have already shown the cognitive ability and stress tolerance the job needs. This is one reason why the system trains efficiently and has a good safety record.

3.3 Europe: EUROCONTROL and National Systems

In Europe, training sits within several layers of regulation. The European Union Aviation Safety Agency (EASA) sets the rules and EUROCONTROL coordinates [11-13], but it is the national civil aviation authorities that certify training organisations. The result is a common regulatory frame with quite different arrangements underneath it. Table 1 gives some examples.

Table 1 Representative European ATCO Training Systems

Country	Institution	Training Duration	Key Features
Germany	DFS Academy, Langen	1.5–2 years	Intensive vocational model; position-oriented training; ~50% attrition
France	ENAC, Toulouse	3–4 years	Academic model; Concours ICNA national exam; civil servant status
United Kingdom	NATS ATC College	2–3 years	Competency-focused; English proficiency emphasis; ~60% attrition

Country	Institution	Training Duration	Key Features
Sweden	Entry Point North	2–3 years	Pan-European intake; EUROCONTROL FEAST selection; modular design
Switzerland	Skyguide Academy	1.5–2 years	Trilingual operations; FEAST + structured interview selection

What the European systems have in common is a strong emphasis on selection. Many member states use EUROCONTROL's First European ATCO Selection Test (FEAST), which tests cognitive ability, spatial reasoning, multitasking and resilience under stress. Depending on the country, between 50% and 70% of candidates fall away during selection and initial training. Behind these figures lies a deliberate choice: screen hard at the start, and training later costs less and operations are safer.

3.4 China: CAAC Training System Architecture

China's ATCO training follows a stratified system structured around CCAR-93-R6 as the core competency standard and the Rules for Civil Aviation Air Traffic Control Training Management as the organisational framework [14-15]. CAAC classifies training institutions into three categories: basic professional training institutions (primarily civil aviation universities), basic simulator training institutions, and unit training institutions [16]. This architecture supports unified CAAC supervision with implementation delegated to training institutions.

One thing that sets China apart is that controller training is part of higher education. Students are admitted through the national college entrance examination and spend four years on an undergraduate degree that mixes general subjects with specialist ATC courses. After graduation they spend a further one to two years in unit training before they can obtain a licence. There is no staged aptitude screening of the Western kind, and no systematic attrition along the way. Fewer trainees wash out as a result, but some of those admitted may not be well suited to the mental demands of ATC work.

4 DISCUSSION

4.1 Institutional Design Comparison

Table 2 sets the three systems side by side on the main design features. Here we concentrate on structures and procedures, rather than on the broader questions of training philosophy discussed in our earlier work [2].

Table 2 Institutional Design Comparison of ATCO Training Systems

Institutional Dimension	China (CAAC)	United States (FAA)	Europe (EUROCONTROL)
Regulatory foundation	CCAR-93-R6; CCAR-70TM	14 CFR; FAA Orders	EASA Regulation; EU Directives
Selection instrument	National college exam + vision	ATSA aptitude + bio assessment	FEAST battery + psychological screening
Training institution type	University-embedded	Centralised academy (MMAC)	National academies / pan-European centres
Curriculum architecture	4-year degree + unit OJT	AT-CTI + 3–6 month academy + OJT	12–36 month modular + OJT
Attrition mechanism	No staged attrition	~40% (selection + academy)	50–70% (selection + training)
Assessment paradigm	Knowledge exams + task checks	Progressive competency gates	Continuous competency assessment
Industry-academia linkage	University-led, limited industry input	AT-CTI partnership model	National ANSP-academy integration

4.2 Key Institutional Differences and Reform Implications

Three differences stand out from the comparison, and each matters for the direction of reform in China:

First, selection and attrition. The US and European systems use psychometrically validated aptitude tests (ATSA, FEAST) that measure abilities relevant to ATC work, such as spatial reasoning, multitasking under pressure and quick decision making. Candidates who are a good fit can be picked out early, and attrition of 40–70% acts as a quality check. In China, selection rests mainly on general academic results. These say little about ATC-specific aptitude, so the match between person and job may be weaker than it could be.

Second, how courses are structured and how competence is checked. In the US and Europe the curriculum is split into modules, and trainees have to pass a competency check at the end of each one before moving on. Trainees can progress at their own pace, and weak points can be dealt with as they appear. China's four-year degree, by contrast, runs on a fixed academic calendar. Competence is mostly assessed at the end of the programme rather than throughout it.

Third, industry-academia integration mechanisms. The FAA's AT-CTI programme and European ANSP-academy partnerships create tight feedback loops between training content and operational requirements. In China, the separation between university-based academic training and unit-based operational training creates potential misalignment between theoretical preparation and practical demands, particularly as operational environments evolve rapidly with new technologies and procedures.

4.3 Proposed Reform Pathways for China

On the basis of this analysis, we propose seven reform measures to help China move from task-based to competency-based controller training:

(1) Develop aptitude tests specific to ATC. China could build its own cognitive aptitude tests for controller candidates, taking ATSA and FEAST as models but adapting and validating them for Chinese candidates. The tests should cover spatial orientation, working memory, multitasking under time pressure, speed of decision making and stress tolerance. Validation studies in the West have shown that these traits predict ATC performance. The test could be taken after the national college entrance examination as an extra screening step, so that selection would rest on two filters: academic results and job-specific aptitude. A pilot could start at the Civil Aviation Flight University of China and the Civil Aviation University of China, and be extended to other institutions once the results have been validated.

(2) Introduce competency gates and staged attrition. We suggest adding competency checks at three points in the programme: after the foundation theory courses (Years 1–2), after initial simulator training (Years 2–3), and before unit training begins (Year 4). At each gate, trainees would have to meet set performance standards in structured assessments, for example simulated traffic scenarios and oral competency interviews. Those who fall short would receive targeted remedial training, but with a fixed limit on the number of attempts. In this way, trainees who are unlikely to succeed as controllers would be identified early and could move into related careers such as flight dispatch, aviation meteorology or ATC systems maintenance. People are put to better use, and training costs further down the line are reduced.

(3) Build a competency framework adapted to China. Doc 10056 offers a general ten-competency framework, but to work well it has to be fitted to Chinese operating conditions [17]. A Chinese ATCO Competency Framework would need to reflect the features of Chinese airspace: dense terminal traffic, the need to coordinate with military users, and RVSM and PBN procedures that are still changing. Communication in Chinese should be covered alongside ICAO English proficiency. The framework should also take in the new technologies now being introduced in Chinese airspace, for instance ADS-B surveillance, CPDLC data link and AI-based decision support. Operational controllers, instructors, regulators and researchers should all take part in developing it, so that it is sound in theory and usable in practice.

(4) Formalise cooperation between universities and industry. Civil aviation universities and the regional and national air traffic management bureaus need formal partnership arrangements. Several measures are possible. A joint curriculum committee could revise the syllabus every year in light of feedback from operations. Staff could be exchanged in both directions: university lecturers would spend periods at ATC units to keep their operational knowledge current, and working controllers would teach at universities as adjunct staff. Students could be given access to operational-grade simulators during advanced training. Joint research could look at training effectiveness, tools for competency assessment, and human factors in ATC. Setting up university–industry training bases at major ATC facilities, much like the FAA's AT-CTI partnerships, would give students a regular route from the classroom into operations.

(5) Develop standard CBTA course packages. Training materials should be modular, tied to specific competencies, and built according to the ISD method set out in ICAO Doc 9941. Every module needs clear competency objectives, learning activities that build on one another, formative assessment along the way and a criterion-referenced summative assessment at the end. The packages should be usable across all of China's training institutions: local operational differences can be accommodated, while the national standard stays the same. Digital platforms would make blended learning possible, combining classroom teaching with self-paced online modules, virtual reality simulation and computer-based scenario practice.

(6) Set up a national quality assurance system for ATCO training. A central quality management framework would keep standards consistent across institutions and help them improve over time. It would have four parts. The first is a set of standard outcome measures linked to the competency framework. The second is regular external audits of training programmes by assessment teams appointed by the CAAC. The third is a national training database that follows trainees over time, recording their progress, the competencies they attain and how they perform after certification. The fourth is a feedback loop in which lessons from operational incidents are used to improve training. With such a system in place, decisions on training policy and resources could be based on evidence.

(7) Make use of advanced training technology. China's strong technical infrastructure could help speed up the introduction of CBTA. We see four priorities. One is high-fidelity ATC simulation that can present the full range of scenarios needed to assess competence properly. Another is AI-based adaptive learning that adjusts content and pace to each trainee's competency profile. A third is performance dashboards that give trainees and instructors live feedback during simulator sessions. The last is trial use of extended reality (XR) for immersive tower and approach training. Together, these would allow competence to be tracked more closely and continuously, which is exactly what progression by competence rather than by time requires.

5 CONCLUSIONS

We compared controller training in the United States, Europe and China, looking at the rules, organisations and procedures that support competency-based training. A detailed look at the FAA, EUROCONTROL and CAAC systems shows that the strength of the Western systems does not come simply from having adopted a competency-based philosophy. It comes from a set of institutional arrangements that work together: psychometric selection, attrition in stages, modular courses that build step by step, assessment that continues throughout training, and close links between training providers and industry.

China's system has real strengths of its own, and reform should not lose sight of them. Because controller training sits inside higher education, trainees receive a broad theoretical grounding in aerodynamics, aviation meteorology, navigation and air traffic management theory. Vocational models do not always offer that breadth. The training network is also large: several institutions together produce thousands of new controllers each year, which shows considerable organisational capacity. A strong safety culture and centralised regulation, in turn, provide a stable base on which systematic reform can be carried out.

There are, however, several gaps that limit how well the system meets the changing needs of modern air traffic management. To begin with, selection includes no ATC-specific aptitude testing. Trainees are chosen mainly on general academic results, and their spatial reasoning, multitasking and speed of decision making are never checked, even though these abilities bear directly on how well they will control traffic. Nor is there staged attrition during training. There is therefore little filtering for quality, and some trainees continue whose profiles are not well matched to operational work. Competence is assessed mostly at the end of the programme, which makes it harder to spot gaps early and to provide individual remedial training. Finally, academic training at university and operational training at the units are kept apart, so what students learn in theory may not match what fast-changing operations require.

To close these gaps we have proposed seven reform measures: aptitude tests specific to ATC; staged competency gates with progressive attrition; a competency framework adapted to Chinese operations; formal university–industry cooperation; standard CBTA course packages built on the ICAO ISD method; a national quality assurance system for training; and advanced training technology, including AI-based adaptive learning and XR simulation. All of them can be introduced within China's existing institutions. The aim is to build on what the current system does well, not to replace it.

Reform should proceed in phases. In the first one to two years, the priority is to develop and pilot aptitude tests and to try out competency gates at a few institutions. Over the following three to five years, controllers, instructors and regulators should work together on the localised competency framework, while standard CBTA course packages are developed in parallel. In the longer term, over five to ten years, CBTA should be extended to all training institutions, backed by a national quality assurance framework and the necessary technology.

Moving from task-based to competency-based training is not just a technical change. It is a change of paradigm, and it requires institutional culture, ideas about assessment, instructor development and regulation to shift together. Experience in other countries suggests that such a change takes years of sustained effort, with adjustments made as evidence from pilot schemes comes in. For China, this argues for step-by-step reform grounded in evidence rather than replacing the whole system at once. Each measure should be properly evaluated before it is rolled out more widely.

Several questions call for further research. Longitudinal studies are needed to test whether scores on the proposed aptitude tests predict later training results and operational performance. Competency assessment rubrics suited to Chinese operations have to be developed and validated psychometrically. Controlled experiments could show whether technology-supported training leads to better learning and higher rates of competency attainment. Comparing pilot results across institutions would also help to identify the local factors that affect how well CBTA works. Findings of this kind would give policymakers the evidence they need and allow the reform strategy to be refined over time.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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