DISTANCE LEARNING AND COMPUTER-BASED TRAINING IN EASA-REGULATED PILOT EDUCATION DURING THE COVID-19 PANDEMIC

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Abstract: The COVID-19 pandemic forced approved training organisations (ATOs) to move theoretical pilot instruction online, replace classroom examinations with computer-based testing, and ration the irreducibly hands-on flight phase. This review synthesises peer-reviewed evidence published between 2019 and 2025 on how pilot training adapted within the European Union Aviation Safety Agency regulatory framework, organising it into a four-domain framework: regulatory accommodation, online theoretical instruction, constrained practical training, and organisational-economic effect. A semi-systematic review of thirty-eight sources drawn from Scopus, Web of Science, and Crossref was conducted, with the case of a Bosnian-Herzegovinian ATO serving as an illustrative anchor. The synthesis shows that regulators permitted distance learning through competency-based provisions, that online theory proved feasible despite genuine assessment-integrity risks, that simulation and emerging virtual-reality tools only partially offset lost flight hours and the documented danger of skill decay, and that organisations which adapted early reported resilience. The review's contribution is an integrative framework connecting regulatory, pedagogical, technological, and economic strands treated separately in the literature. Distance learning emerges as a durable gain, assessment integrity and skill-decay monitoring as unresolved problems, and a hybrid model as the likely steady state.

Keywords: *pilot training, approved training organisation, distance learning, computer-based training, COVID-19, EASA, competency-based training.*

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INTRODUCTION

Few professional curricula are as tightly coupled to physical presence as pilot training. A student must sit prescribed hours of ground school, pass standardised written examinations, and then accumulate supervised hours in an actual aircraft, all under a licensing regime that treats each step as a regulated, auditable event. When the World Health Organization characterised COVID-19 as a pandemic in March 2020 (World Health Organization, 2020) and education systems worldwide closed their classrooms (UNESCO, 2020), this tightly coupled system was placed under a stress it had never been designed to absorb. Aviation as a whole suffered one of the deepest contractions of any industry, with civil-aviation revenue losses running into the hundreds of billions of dollars (International Civil Aviation Organization, 2022), and the training pipeline that feeds it was disrupted at every stage, from cancelled ground school to grounded aircraft to a workforce whose morale and mental health deteriorated (Xu et al., 2022).

The response of approved training organisations (ATOs) was improvised, rapid, and uneven, and it is now possible to study it with the benefit of several years of published evidence. Some schools suspended operations; others moved theoretical instruction to learning-management systems, replaced invigilated paper examinations with computer-based testing, substituted video conferences for a portion of classroom contact, and reorganised the flight line to keep crews apart. The students who lived through this reported measurable disruption to their education and anxiety about their careers (Miani et al., 2021), and the organisations that managed it discovered that their safety culture and institutional resilience were themselves being tested (Byrnes et al., 2022). What was an emergency in 2020 has, by the mid-2020s, hardened into a set of practices whose durability and effectiveness deserve systematic appraisal.

That appraisal is complicated by the fact that the relevant evidence is scattered across literatures that rarely speak to one another. Aviation-training research treats simulation, competency-based assessment, and flight-skill retention; education-technology research treats emergency remote teaching, learning-management systems, and online-assessment integrity; regulatory documents define what is permissible; and aviation-economics work treats the industry shock. A reader trying to understand how a pilot school actually adapted must assemble the picture from all four, and no existing review does that assembly. The present article sets out to provide it.

The review is guided by four questions. The first asks how the EASA and ICAO regulatory frameworks accommodated distance learning and computer-based training in ATO pilot education during the pandemic. The second asks what the literature establishes about the effectiveness and the integrity of online theoretical instruction and computer-based assessment in this setting. The third asks how the constraints on practical flight training were managed, what risks such as skill decay are documented, and what mitigations such as simulation and virtual or augmented reality are evidenced. The fourth asks what organisational and economic effects, including resilience and competitiveness, are reported, and how a concrete case illustrates them.

The contribution of this review is integrative rather than empirical. It proposes a four-domain framework, comprising regulatory accommodation, online theoretical instruction, constrained practical training, and organisational-economic effect, that connects the otherwise separate strands of evidence into a single account of how ATO pilot training adapted to the pandemic, and it maps an illustrative single case, a Bosnian-Herzegovinian flight academy, onto that framework to show how the domains interact in practice. The framework is offered as an organising instrument for a fragmented field,

not as a claim of new empirical discovery; that is the proper ambition of a review. The case is used illustratively, as a worked example of the synthesised mechanisms, and not as evidence in its own right.

The article proceeds as follows. The next section positions the review in the literature and states its method. A results section presents the thematic synthesis and the framework. Four analytical sections then develop the domains in turn, treating regulatory adaptation, online theoretical instruction, constrained practical training, and organisational-economic effect, with the illustrative case woven through the last of these. A conclusion answers the four questions, states the review's limitations, and identifies what the field still needs to learn.

LITERATURE REVIEW AND METHODOLOGY

Literature Review

The literature relevant to pandemic-era pilot training falls into four clusters that this review draws together. The first concerns the pandemic's impact on aviation and its training pipeline: the macro shock to the industry (International Civil Aviation Organization, 2022), the disruption to tertiary aviation education reported by students (Miani et al., 2021), the resilience of flight-training organisations as safety systems (Byrnes et al., 2022), the safety occurrences observed as operations resumed (Li et al., 2023), and the mental-health burden on aircrew (Xu et al., 2022). The second cluster is the education-technology evidence on emergency remote teaching and its tools, which matured rapidly during the pandemic and now offers systematic appraisals of what worked and what did not (Ferri et al., 2020; Bond et al., 2021; Koh & Daniel, 2022). The third concerns the irreducibly practical side of pilot training, where simulation, virtual reality, and augmented reality are studied as partial substitutes for aircraft time and where competency retention is the central anxiety (Marques et al., 2023; Mizzi et al., 2024). The fourth is the regulatory and competency-framework literature that defines the permissible (Ziakkas et al., 2022; Hwang & Kim, 2025).

Within the education-technology cluster the evidence is unusually rich because the whole world ran the same experiment at once. Systematic mappings of the first global online semester document both the scale of the shift and its pedagogical unevenness (Bond et al., 2021), and a systematic review of shifting-online strategies links specific teaching approaches to outcomes (Koh & Daniel, 2022). Learning-management systems, and Moodle in particular, have been reviewed for their teaching effectiveness (Gamage et al., 2022), and adoption has been explained through technology-acceptance and unified-acceptance models that predict students' behavioural intention to use e-learning (Mailizar et al., 2021; Abbad, 2021). On effectiveness, systematic reviews of online and blended learning and a meta-analysis of attitudes and performance during the pandemic provide the quantitative backbone (Müller & Mildenberger, 2021; Topping et al., 2022; Liu et al., 2022). The integrity of online assessment, the single most contested issue, is treated by a dedicated literature on e-proctoring and academic honesty (Kharbat & Abu Daabes, 2021; Patael et al., 2022; Janke et al., 2021; Reedy et al., 2021).

The practical-training cluster is thinner but pointed. A systematic review of ab initio flight training maps the field and its methods (Marques et al., 2023), while the danger that grounded pilots lose competency, and the role of self-study in arresting it, has been examined directly for the pandemic period (Mizzi et al., 2024). Simulation is treated both as a training device whose procedures must be standardised (Sabadas et al., 2024) and as an economic and ecological substitute for aircraft hours (Maciejewska et al., 2024). The emerging immersive technologies, virtual reality for ab initio and procedural training (Hight et al., 2022; McCullins et al., 2025) and augmented or mixed reality for advanced

training (Moesl et al., 2021; Moesl et al., 2022; Schaffernak et al., 2022), are studied as the next step beyond conventional simulators. Competency-based and evidence-based training, the pedagogical philosophies that make such substitution defensible, frame the whole (Ziakkas et al., 2022; Hwang & Kim, 2025).

The gap this review addresses is therefore not a shortage of evidence but its fragmentation. No existing synthesis joins the regulatory, the pedagogical-technological, the practical, and the economic strands into a single account of how an ATO adapted, and none maps that account onto a concrete case. The four-domain framework introduced here is the device by which the strands are joined.

Research Methodology

This article is a semi-systematic, thematic literature review rather than a meta-analysis or a fully protocolised systematic review, and I should state plainly why that design was chosen: the relevant evidence spans heterogeneous fields and study types, from regulatory documents to engineering evaluations of simulators to educational meta-analyses, which precludes the homogeneous effect-size pooling a meta-analysis requires while making thematic synthesis the appropriate tool. The search drew on three databases, Scopus, Web of Science, and Crossref, supplemented by targeted retrieval of regulatory and institutional documents from EASA, ICAO, the World Health Organization, and UNESCO. Search terms combined an aviation set, including pilot training, flight training, approved training organisation, ATO, and flight simulation, with a pandemic-and-technology set, including COVID-19, distance learning, e-learning, computer-based training, online assessment, and competency-based training, joined by Boolean operators.

Inclusion criteria were peer-reviewed journal articles published between 2019 and 2025, written in English, and addressing at least one of the four domains; regulatory and institutional documents were admitted separately as primary sources of the legal and statistical context. Exclusion criteria removed pre-2019 work, non-peer-reviewed commentary, and predatory or non-indexed outlets. The screening prioritised Scopus-indexed venues, and of the thirty-eight sources retained, twenty-eight are peer-reviewed articles in Scopus-indexed journals, the remainder being regulatory instruments, intergovernmental reports, and one unpublished case manuscript. Table 1 records the criteria and counts. I want to be candid that the search was not exhaustive in the PRISMA sense, with no dual independent screening or formal risk-of-bias appraisal, and the review should be read as a structured narrative synthesis rather than a systematic review in the strict methodological meaning.

Parameter	Specification
Databases	Scopus, Web of Science, Crossref (+ EASA, ICAO, WHO, UNESCO documents)
Period	2019–2025 (legal instruments cited at source year)
Language	English (institutional documents also in original language)
Source types	Peer-reviewed articles; regulatory/intergovernmental documents; one case manuscript
Synthesis	Thematic synthesis into four adaptation domains
Sources retained	38 total; 28 in Scopus-indexed journals

Table 1. Search and selection summary for the semi-systematic review.

Synthesis proceeded by coding each source to one or more of four domains, which emerged inductively from the literature and were then used deductively to

organise it: regulatory accommodation, online theoretical instruction, constrained practical training, and organisational-economic effect. The single case of a Bosnian-Herzegovinian ATO, Glide Flight Academy, is used throughout as an illustrative anchor that grounds the abstract mechanisms in one organisation's experience; the case material derives from a manuscript describing that school's adaptation (Marković & Novaković, 2021) and is treated as illustration, not as independent evidence, a distinction I keep deliberately sharp because a single case cannot test the synthesised claims.

RESEARCH RESULTS

The thematic synthesis produced four domains, each populated by a distinct evidence base and each interacting with the others. The results are presented here as the structure of the evidence and the framework that organises it, with interpretation reserved for the analytical sections that follow. Table 2 sets out the framework, the principal mechanisms within each domain, the representative evidence, and the way the illustrative case expresses each mechanism.

Domain	Principal mechanism	Representative evidence	Illustrative-case expression
Regulatory accommodation	DL/CBT and video-conference provisions; competency- and evidence-based training	EASA Easy Access Rules; Ziakkas et al. (2022); Hwang & Kim (2025)	First BiH ATO certified under Part rules; AMC1 ORA.ATO.305(b) video-conference adoption
Online theoretical instruction	LMS delivery; computer-based testing; assessment integrity	Bond et al. (2021); Gamage et al. (2022); Kharbat & Abu Daabes (2021)	TalentLMS platform; randomised item banks (900/2000 items); webcam identity capture
Constrained practical training	Simulation/VR/AR substitution; skill-decay risk	Marques et al. (2023); Mizzi et al. (2024); Hight et al. (2022)	Flight phase largely continued (solo crew); glider phase paused Mar–Aug 2020
Organisational-economic effect	Resilience; cost structure; market reach	Byrnes et al. (2022); Maciejewska et al. (2024); Miani et al. (2021)	Lower overheads; single-candidate enrolment; multi-city student catchment

Table 2. Four-domain framework of pandemic adaptation in EASA-regulated ATO pilot training, with representative evidence and illustrative-case expression.

The distribution of evidence across the four domains is markedly uneven, and that unevenness is itself a finding. The online-theory domain is the best supported, because the global education-technology experiment generated systematic reviews and meta-analyses with large samples (Bond et al., 2021; Liu et al., 2022; Müller & Mildenberger, 2021). The organisational-economic domain is supported by a smaller but pointed set on resilience, cost, and student experience (Byrnes et al., 2022; Maciejewska et al., 2024; Miani et al., 2021). The regulatory domain rests on primary documents interpreted through the competency-training literature (Ziakkas et al., 2022; Hwang & Kim, 2025). The constrained-practical domain is the thinnest, with a single dedicated treatment of pandemic competency decline (Mizzi et al., 2024) supported by simulation and immersive-

technology studies that mostly predate or run parallel to the pandemic rather than measuring it directly (Marques et al., 2023; McCullins et al., 2025). Any honest synthesis must weight its confidence accordingly, and the analytical sections do.

A second result concerns the assessment-integrity problem, which recurs across the online-theory evidence with unusual consistency. The e-proctoring and academic-integrity literature converges on the finding that moving examinations online raised genuine and measurable integrity concerns, that remote-proctoring responses were partially effective but provoked privacy and equity objections, and that institutions adopted them under emergency conditions with limited evaluation (Kharbat & Abu Daabes, 2021; Patael et al., 2022; Janke et al., 2021; Reedy et al., 2021). For a licensing-bound domain such as pilot training, where the examination is not merely academic but a regulated gate to operating an aircraft, this convergence is consequential, and it is taken up in the analytical treatment of online instruction.

REGULATORY ACCOMMODATION: EASA AND ICAO FRAMEWORKS

The first domain is regulatory, because in aviation nothing is permissible until a rule says so. The licensing of European pilots rests on Commission Regulation (EU) No 1178/2011 and its amendments (European Commission, 2011; European Commission, 2016), consolidated by EASA into the Easy Access Rules for Aircrew, which contain the Flight Crew Licensing requirements of Part-FCL and the Organisation Requirements of Part-ORA that govern how an ATO must operate (European Aviation Safety Agency, 2021). Distance learning is not a pandemic improvisation within this framework; Part-ORA already provided for it through the ORA.ATO.300 series, so the regulatory question during COVID-19 was less whether distance learning was allowed than how far classroom contact could be replaced and under what acceptable means of compliance.

The pandemic-era adjustment that mattered most was the provision permitting a defined share of classroom instruction to be delivered by video conference, introduced through the acceptable-means-of-compliance material attached to the organisation rules (European Aviation Safety Agency, 2021). This is a small change with large consequences, because it converted synchronous classroom presence from a hard requirement into a partly virtual one, and it did so without diluting the underlying competency standard. The deeper enabling logic is the shift toward competency-based training and assessment and evidence-based training, which define training outcomes in terms of demonstrated competencies rather than hours in a particular room (Ziakkas et al., 2022; Hwang & Kim, 2025). Once outcomes rather than settings are the standard, the medium of theoretical delivery becomes a matter of acceptable compliance rather than of principle, and distance learning follows naturally.

The international layer reinforces this. ICAO's training procedures, set out in the Procedures for Air Navigation Services — Training, provide the competency-based scaffolding for licences and for evidence-based recurrent training (International Civil Aviation Organization, 2020), and the macro context that made adaptation urgent is documented in ICAO's economic-impact analysis of the pandemic on civil aviation (International Civil Aviation Organization, 2022). The competency-based philosophy is what allows a regulator to accept a simulator hour, a video-conference lecture, or a self-study module as equivalent to a traditional one, provided the assessed competency is the same, and it is therefore the hinge on which the whole pandemic adaptation turns (Ziakkas et al., 2022).

Beneath the headline permissions sits a more demanding requirement that the regulatory literature is right to stress: a distance-learning course is not merely a set of files on

a server but a regulated training programme whose quality system must demonstrate that remote delivery achieves the same objectives as classroom delivery. Part-ORA obliges an organisation to define, in its approved training manuals, how distance learning is structured, how student progress is monitored, and how the responsible instructors maintain oversight, and the burden of proof rests on the school rather than on the regulator. The competency-based literature makes the same point from the pedagogical side, arguing that the legitimacy of any delivery medium depends on a defensible mapping from learning activity to assessed competency (Ziakkas et al., 2022; Hwang & Kim, 2025). This is why the regulatory domain is not a precondition that can be ticked off and forgotten; it conditions the design of every other domain, because the platform chosen, the testing regime adopted, and the records kept must all survive an inspection that asks whether the remote programme is genuinely equivalent to the classroom one it replaced.

The illustrative case shows the regulatory domain in operation. The Bosnian-Herzegovinian academy operated under national rules transposing the EU framework (BiH Directorate of Civil Aviation, 2018; Parliamentary Assembly of Bosnia and Herzegovina, 2009), themselves aligned with Regulation (EU) No 1178/2011, and it positioned itself as the first organisation in its jurisdiction certified under the Part structure and an early adopter of the video-conference allowance (Marković & Novaković, 2021). The point the case makes is general: regulatory permission is a necessary precondition for every other adaptation, and organisations that understood the rule structure could move faster than those that treated the pandemic as a purely operational problem. The regulator did not have to invent distance learning; it had to clarify and, in one respect, extend the conditions under which an already-permitted method could carry more of the load.

ONLINE THEORETICAL INSTRUCTION: PLATFORMS, TESTING, AND INTEGRITY

The second domain is where the pandemic evidence is deepest, because the theoretical phase of pilot training is, pedagogically, a regulated instance of the higher-education teaching that the whole world moved online at once. The global education-technology literature establishes that emergency remote teaching was feasible at scale but pedagogically uneven, with outcomes depending on the strategies adopted rather than on the mere fact of going online (Ferri et al., 2020; Bond et al., 2021; Koh & Daniel, 2022). Meta-analytic and systematic evidence on effectiveness is reassuring without being triumphant: online and blended approaches can match or exceed face-to-face instruction under the right conditions, though the variance is wide and the conditions are demanding (Müller & Mildenberger, 2021; Topping et al., 2022; Liu et al., 2022). For a theoretical syllabus organised into discrete subjects with defined learning objectives, as the pilot groundschool curriculum is, these conditions are comparatively easy to meet.

The delivery vehicle is the learning-management system, and here the evidence is practical. Moodle and comparable platforms have been reviewed for their teaching effectiveness and found capable of structuring content, sequencing lessons, and administering assessment, with the caveat that effective use depends on instructor design rather than on the platform alone (Gamage et al., 2022). Whether instructors and students actually adopt such systems is explained well by technology-acceptance and unified-acceptance models, in which perceived usefulness, ease of use, and facilitating conditions predict behavioural intention to use e-learning (Mailizar et al., 2021; Abbad, 2021). The illustrative case is a textbook instance of these findings: the academy first trialled Moodle but abandoned it as too demanding in programming and server administration, then compared

two hosted platforms over a thirty-day trial and adopted the one judged simpler and better aligned to the regulatory syllabus, building randomised item banks of nine hundred questions for one language of instruction and two thousand for another (Marković & Novaković, 2021). The acceptance literature would predict exactly this outcome, in which ease of use and facilitating conditions, not raw capability, decided the choice (Abbad, 2021).

Synchronous video conferencing occupies a middle ground between fully self-paced online learning and the classroom, and the pandemic evidence treats it as the element that preserved the social and accountable dimension of instruction when the room disappeared. The systematic mappings of emergency remote teaching note that synchronous contact sustained engagement and a sense of presence that asynchronous materials alone did not (Bond et al., 2021; Koh & Daniel, 2022), which is the rationale behind the regulatory provision that a defined share of classroom instruction be delivered live rather than merely recorded. A practical by-product, visible in the illustrative case, is that recorded video lectures become a reusable asset and an auditable record of what was taught, turning a compliance obligation into a library (Marković & Novaković, 2021). The education-technology evidence cautions, however, that synchronous online contact is not a costless substitute for the classroom, since fatigue, attention, and equity of access vary across students, and that its benefits depend on deliberate facilitation rather than on the mere opening of a video channel (Müller & Mildenberger, 2021).

Computer-based testing is the pedagogically and legally fraught part. The pilot theoretical examination is not a formative classroom quiz; it is a regulated gate, and its integrity is a safety matter. The academic-integrity literature that the pandemic produced is unambiguous that online examination raised real risks of misconduct and that institutions reached for remote proctoring as a response whose effectiveness was partial and whose privacy and equity costs were significant (Kharbat & Abu Daabes, 2021; Patael et al., 2022; Reedy et al., 2021). The empirical work on ad-hoc online testing found that hastily deployed online examinations were vulnerable, and that integrity depended more on assessment design, such as large randomised item pools and tight time limits, than on surveillance alone (Janke et al., 2021). The illustrative case again tracks the evidence: the academy drew items randomly from large banks so that no two examinations matched, imposed a per-question time limit, and captured a webcam image of each candidate before the test as an identity record (Marković & Novaković, 2021). These are precisely the design-based mitigations the integrity literature recommends, and they are more defensible than proctoring alone, though the literature cautions that no online arrangement fully closes the integrity gap (Reedy et al., 2021).

The balance of evidence for this domain is therefore favourable but conditional. Online theoretical instruction is effective when designed well, learning-management systems are adequate vehicles, adoption follows predictable acceptance dynamics, and assessment integrity can be substantially protected by design even if not perfectly guaranteed. For a licensing authority the residual integrity risk is the binding concern, and it is the reason the theoretical examination, more than any other element of ground school, remains the part of the online transition that regulators continue to scrutinise (Kharbat & Abu Daabes, 2021).

CONSTRAINED PRACTICAL TRAINING: SIMULATION, IMMERSIVE TOOLS, AND SKILL DECAY

The third domain is where aviation training departs decisively from ordinary education, because no learning-management system can teach a student to land an aircraft. Flight instruction requires the aircraft, or a

device of sufficient fidelity to stand in for it, and the pandemic constrained both the hours available and the people who could be in close proximity to deliver them. The systematic review of ab initio flight training makes clear that the practical phase is methodologically distinct and that its evidence base, while growing, is less mature than that for theoretical instruction (Marques et al., 2023). This asymmetry, deep evidence for the theoretical phase and thin evidence for the practical one, is the central tension of pandemic-era pilot training.

Skill decay is the documented danger. When pilots are grounded, perishable competencies degrade, and the pandemic created an unprecedented natural experiment in mass grounding whose training implications are only beginning to be measured. The most direct treatment finds that structured self-study can help arrest competency decline among airline pilots during the pandemic, but it frames self-study as mitigation rather than cure and stresses that hands-on currency cannot be fully replaced by reading (Mizzi et al., 2024). The safety literature observed the corollary as operations resumed, with flight-data monitoring capturing occurrences consistent with the friction of returning under-practised crews to the line (Li et al., 2023). For ab initio students the risk is different in kind but real, since interrupted training disturbs the carefully sequenced acquisition of skills that the ab initio literature shows is foundational (Marques et al., 2023).

Simulation and immersive technologies are the substitution levers, and the evidence for them is encouraging but bounded. Flight-simulation training devices are well established as partial substitutes for aircraft hours, with documented cost and ecological advantages that the pandemic made newly salient (Maciejewska et al., 2024), and the procedures for using them in specific exercises such as engine-failure-after-takeoff are being standardised (Sabadas et al., 2024). The newer immersive tools push the substitution further: virtual reality has shown promise for civilian ab initio training and for procedural training on modern airliners (Hight et al., 2022; McCullins et al., 2025), and augmented and mixed reality have been proposed and trialled for advanced and more socially sustainable pilot training (Moesl et al., 2021; Moesl et al., 2022; Schaffernak et al., 2022). The consistent message across this work is that immersive tools are effective for procedural and cognitive elements of flying while remaining weaker for the psychomotor and full-sensory elements that still demand the aircraft, so they extend the reach of distributed training without closing the gap entirely.

The reason immersive tools extend rather than close the gap lies in the long-standing idea of transfer of training, which holds that a device trains a skill to the extent that competence acquired on it carries over to the aircraft. Higher-fidelity flight-simulation training devices transfer well for instrument procedures, checklist discipline, and emergency drills, and standardising their use for specific manoeuvres such as engine failure after takeoff improves that transfer further (Sabadas et al., 2024), while their cost and ecological advantages make them attractive for the high-repetition elements of a syllabus (Maciejewska et al., 2024). Virtual and augmented reality push fidelity into new dimensions of spatial and procedural realism at a fraction of the cost (Hight et al., 2022; Schaffernak et al., 2022), and the systematic ab initio review suggests the field is moving toward blended sequences in which immersive practice precedes and economises aircraft time rather than replacing it (Marques et al., 2023). What none of this changes is that the final, full-sensory integration of flying still demands the aircraft, so the honest reading is that the pandemic accelerated a substitution already under way without ever promising to complete it.

The illustrative case is instructive precisely because it could not virtualise its flight phase. The academy kept aircraft training running largely unchanged on the reasoning that a student and instructor alone in a light

aircraft did not breach distancing requirements, while its glider phase, which needs a ground party of several people to launch, was suspended from March to August 2020 until restrictions eased (Marković & Novaković, 2021). The case thereby exposes the limit of the whole adaptation: the theoretical phase could be moved online almost completely, but the practical phase could only be reorganised, not relocated, and where the practical activity required people to gather, it stopped. This is the domain where the pandemic's lesson is least comfortable and where the synthesised evidence is weakest, which is also why it is the priority for future research.

ORGANISATIONAL AND ECONOMIC EFFECTS: RESILIENCE AND COMPETITIVENESS

The fourth domain treats the organisation as a whole, and it is where the strands converge into outcomes that a school's management can recognise. The pandemic was, for training organisations, a test of resilience as much as of pedagogy, and the evidence shows that flight-training organisations which preserved their safety culture under acute stress emerged more robust, whereas the crisis exposed those whose resilience was shallow (Byrnes et al., 2022). Resilience here is not a metaphor; it is the documented capacity of a safety-critical organisation to keep training to standard while its operating environment collapses, and it correlates with early, rule-aware adaptation rather than with size or wealth.

The human dimension qualifies the otherwise favourable economic story, and it would be dishonest to omit it. The same pandemic that let schools cut classroom costs also imposed real psychological strain on the people inside the system, with aircrew reporting deteriorating mental health under job insecurity, isolation, and the stress of an uncertain industry (Xu et al., 2022), and with aviation students reporting anxiety about careers that seemed to be evaporating even as their training continued online (Miani et al., 2021). An organisation that reads its pandemic adaptation purely as a cost-and-reach optimisation misreads it, because the resilience that the safety-culture literature identifies as decisive (Byrnes et al., 2022) is in part a human resilience that depends on supporting instructors and students through the disruption rather than merely digitising their interaction. The economic advantage of distance learning is real, but it is sustained only by organisations that treat the wellbeing of their people as part of the same adaptation.

The economics reinforce the case for adaptation. Moving theoretical instruction online removes a layer of fixed cost, because a video-conference or learning-management delivery does not incur classroom rental, heating across a winter season, or instructor travel, and because the marginal cost of an additional online student is far below that of an additional classroom seat. The simulation literature points the same way, documenting that flight-simulation training devices reduce both the cost and the environmental footprint of the practical phase relative to aircraft hours (Maciejewska et al., 2024). On the demand side, the students whose pandemic experience was surveyed valued continuity and flexibility, even as they reported stress and career anxiety (Miani et al., 2021), so an organisation that could offer uninterrupted, flexible training held a real advantage in a contracting market.

The illustrative case quantifies the mechanism at the scale of one school. Classroom theory carried a fixed cost on the order of 1,320 convertible marks per course, dominated by instructor fees and classroom provision, which forced the school to assemble a minimum group before a course could run; moving theory online removed most of that fixed cost, allowed enrolment of even a single candidate, and opened a catchment spanning several cities simultaneously rather than the one city a physical classroom could serve (Marković & Novaković, 2021). The school reported lower overheads from eliminated

heating and travel and a competitive position it framed as regional leadership. The numbers are a single organisation's and cannot be generalised, but the structure they reveal, fixed-to-marginal cost conversion plus geographic reach, is exactly what the economic and student-experience literature would predict (Maciejewska et al., 2024; Miani et al., 2021), which is why the case earns its place as illustration of the synthesised mechanism.

Read across the four domains, the organisational-economic evidence completes the account. Regulatory permission enabled the shift, online instruction delivered the theoretical phase effectively if imperfectly, simulation and immersive tools cushioned but did not eliminate the practical constraint, and the organisations that combined these early converted a survival problem into a competitive advantage while building resilience for the next disruption. The framework's value is that it shows these as connected moves rather than as separate responses, which is how a training organisation actually experiences them.

CONCLUSION

The pandemic compressed a decade of cautious experimentation in pilot training into a single emergency, and the evidence accumulated since allows that emergency to be read as a structured adaptation rather than as improvisation alone. This review set out to assemble the scattered evidence into one account and to answer four questions about how EASA-regulated ATO pilot training adapted.

On the first question, the regulatory frameworks accommodated distance learning and computer-based training not by inventing new permissions but by clarifying and modestly extending existing ones, with the competency-based and evidence-based training philosophy providing the logic that lets an outcome standard be met through varied media, and with the video-conference allowance carrying more of the classroom load (European Aviation Safety Agency, 2021; Ziakkas et al., 2022). On the second, the literature establishes that online theoretical instruction is effective when well designed and that learning-management systems are adequate vehicles, while identifying assessment integrity as the genuine and only partly solved problem, best mitigated by assessment design rather than surveillance alone (Bond et al., 2021; Janke et al., 2021; Reedy et al., 2021).

On the third question, the constraints on practical training were managed by reorganisation rather than relocation, with simulation and emerging virtual and augmented reality offsetting some lost aircraft time and structured self-study arresting some skill decay, but with the psychomotor core of flying still requiring the aircraft and with the evidence base thinnest exactly here (Mizzi et al., 2024; Marques et al., 2023; McCullins et al., 2025). On the fourth, organisations that adapted early reported resilience and competitive advantage, driven by the conversion of fixed classroom costs into low marginal online costs and by widened geographic reach, a structure the illustrative case displays clearly even though a single case cannot establish it (Byrnes et al., 2022; Maciejewska et al., 2024).

The principal contribution of this review is the four-domain framework that connects the regulatory, the pedagogical-technological, the practical, and the economic strands of evidence that the literature has treated apart, together with the mapping of an illustrative ATO case onto that framework. The framework does not claim new empirical findings; its value is integrative, giving a fragmented field an organising structure and giving a training organisation a way to see its pandemic adaptations as connected moves. That is the legitimate ambition of a review, and it is the one pursued here.

The review's limitations are real and shape its claims. The practical-training evidence base is thin, and, most tellingly, no controlled comparison of pandemic-era and conventional pilot competency outcomes yet exists, so the most important question,

whether pilots trained under pandemic constraints are as competent as those trained conventionally, cannot be answered from the present literature. The method was a structured narrative synthesis rather than a protocolised systematic review, without dual screening or formal bias appraisal, and the single illustrative case is drawn from one organisation in one jurisdiction and carries no evidential weight beyond illustration. These boundaries point directly to what the field needs next: longitudinal studies tracking the competency and safety records of pandemic-trained cohorts, controlled evaluations of virtual- and augmented-reality transfer to actual flight, and multi-organisation comparisons of the economic and resilience outcomes that the present evidence can only sketch. Until that work is done, the safest reading is that distance learning is a durable gain for the theoretical phase, that assessment integrity and skill-decay monitoring are the unresolved problems, and that a hybrid model combining online theory with irreducible in-aircraft practice is the likely and sensible steady state.

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UČENJE NA DALJINU I UČENJE PUTEM KOMPJUTERA U OBUCI PILOTA PREMA EASA PROPISIMA TOKOM PANDEMIJE COVID-19

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Sažetak: Pandemija COVID-19 primorala je odobrene organizacije za obuku (ATO) da teorijsku obuku pilota premjeste u onlajn okruženje, da ispite u učionici zamijene testiranjem na računaru i da racionalizuju fazu letačke obuke, koja se nesvodivo zasniva na praktičnom radu. Ovaj pregledni rad sintetizuje recenzirane dokaze objavljene između 2019. i 2025. godine o tome kako se obuka pilota prilagođavala unutar regulatornog okvira Agencije Evropske unije za bezbjednost vazduhoplovstva (EASA), organizujući ih u okvir od četiri domena: regulatorno prilagođavanje, onlajn teorijska nastava, ograničena praktična obuka i organizaciono-ekonomski efekti. Sproveden je polusistematski pregled trideset osam izvora preuzetih iz baza Scopus, Web of Science i Crossref, pri čemu slučaj jedne bosanskohercegovačke ATO služi kao ilustrativno uporište. Sinteza pokazuje da su regulatori dozvolili učenje na daljinu kroz odredbe zasnovane na kompetencijama, da se onlajn teorijska nastava pokazala izvodljivom uprkos stvarnim rizicima po integritet provjere znanja, da su simulacije i novi alati virtuelne realnosti samo djelimično nadoknadili izgubljene sate naleta i dokumentovanu opasnost od opadanja vještina, te da su organizacije koje su se rano prilagodile iskazale otpornost. Doprinos ovog pregleda jeste integrativni okvir koji povezuje regulatorne, pedagoške, tehnološke i ekonomske tokove koji se u literaturi obrađuju odvojeno. Učenje na daljinu izdvaja se kao trajna dobit, integritet provjere znanja i praćenje opadanja vještina kao neriješeni problemi, a hibridni model kao vjerovatno stabilno stanje.

Ključne riječi: *obuka pilota, sertifikovana organizacija za obuku, učenje na daljinu, učenje putem kompjutera, COVID-19, EASA, obuka zasnovana na kompetencijama.*