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Mapping Technical, Behavioural and Digital Competencies among Aircraft Maintenance Professionals

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Abstract

Aircraft maintenance technicians are the final human link in the airworthiness chain, yet the competencies expected of them are described in three largely separate literatures: technical proficiency, human-factors (behavioural) competence, and the emerging digital skills demanded by connected aircraft and data-driven maintenance. This paper reviews online scholarly, regulatory and industry sources to map these three domains into a single Technical–Behavioural–Digital (T-B-D) competency framework. Drawing on a systematic review of skills-assessment criteria, a competency-assessment study of technicians, a 2025 focus-group study of transversal competencies, Federal Aviation Administration human-factors guidance, digitization studies, and Boeing's 2026 workforce outlook, the paper identifies six technical, seven behavioural and five digital competency clusters and grades the strength of evidence for each. The review finds that technical competence is the best documented and most regulated domain, behavioural competence is the best linked to error causation but the hardest to assess, and digital competence is the fastest-moving and least evidenced. The paper proposes four testable propositions, outlines an assessment approach based on competency-based training and assessment (CBTA), and discusses implications for licensing, training and employer practice, with particular reference to India's CAR-66 and CAR-147 system.

Keywords: *Aircraft Maintenance Technician; Competency Mapping; Human Factors; Digital Skills; Competency-Based Training and Assessment; Industry 4.0*

1. Introduction

Air transport is one of the safest ways to travel, but this record is built on work passengers will never see: the inspection, repair, modification and certification of aircraft in hangars and on aprons. This function is performed by aviation maintenance technicians, who are the last link in the airworthiness chain, as the technician is the last signature on an aircraft before flying (Güneş et al., 2020). Their performance therefore bears directly on flight safety, operating cost and organizational reputation.

The safety stakes are well documented. Güneş et al. (2020) report that maintenance was a factor in 28.6% of fatal aviation accidents between 1999 and 2008, that maintenance errors account for approximately 12-20% of accidents across studies, that 20-30% of in-flight engine shutdowns are due to maintenance errors and that approximately half of engine-related cancelations and delays are the result of maintenance error. Failure to follow procedures alone is estimated to represent between 40.5% and 87% of maintenance-related occurrences, and this has been basically the same for two decades (Federal Aviation Administration [FAA], n.d.-b). Technological progress has improved aviation safety overall without producing a comparable fall in maintenance-related accidents and incidents (Güneş et al., 2020), which points toward the human element as a continuing source of improvement.

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Meanwhile, the workforce is under stress. Boeing's 2026 Pilot and Technician Outlook shows demand for 728,000 new maintenance technicians over 20 years among more than 2.4 million new aviation personnel, with two-thirds of the demand from replacing retiring staff and one-third from fleet growth (Boeing, 2026b). That figure is a modest increase over the 710,000 technicians projected a year earlier (AVweb, 2026). Boeing considers the employment of technicians as one of the most competitive parts of the aviation labor market, and next-generation aircraft require advanced diagnostic abilities and knowledge with digital maintenance systems (Boeing, 2026a). Boeing estimated that South Asia would need about 45,000 technicians through 2044 (Boeing Global Services, n.d.).

These pressures present a practical question: what should a competent maintenance person be able to do? The literature does not give fragments an answer. A systematic analysis showed that most technician assessment studies focused on a subset of criteria, usually technical knowledge and ability, and few addressed twenty-first century and Industry 4.0 competencies (Thulasy et al., 2022). Regulatory systems, for their part, continue to rely mainly on theoretical multiple-choice examinations and time-based experience, even as the International Civil Aviation Organization (ICAO) promotes competency-based approaches (Kes et al., 2025). Human-factors competence, meanwhile, has grown up as a separate tradition with its own vocabulary, the best known being the "Dirty Dozen" (FAA, 2023), and digital competence is discussed largely in industry commentary and technology studies.

This paper brings the three strands together. It asks four questions. First, what technical, behavioral and digital competencies does the available literature attribute to aircraft maintenance professionals? Second, how do these domains interrelate, and how strong is the evidence for each? Third, how can the competencies be assessed and developed? Fourth, what are the implications for licensing, training and employer practice, with reference to India?

The paper makes three contributions. It proposes an integrated Technical–Behavioral–Digital (T-B-D) competency map; it grades the strength of evidence behind each competency cluster; and it sets out testable propositions and an instrument design that can guide empirical work, for example a competency-gap survey of licensed engineers. The remainder of the paper is organized as follows: Section 2 sets out conceptual and regulatory background; Section 3 explains the review method; Sections 4 to 6 examine the technical, behavioral and digital domains; Section 7 integrates them; Sections 8 and 9 discuss assessment and implications; and Sections 10 and 11 present limitations, future research and conclusions.

2. Conceptual and Regulatory Background

2.1. Defining Competency

In the aircraft maintenance literature, competence is commonly defined as the full set of knowledge, skills, behaviors and attitudes a technician uses to carry out maintenance and repair tasks (Güneş et al., 2020; Thulasy et al., 2022). Two aspects of this concept are important for what follows. First, it is not only limited to what the technician knows, but also how the technician conducts and what attitudes they bring to the task. Second, competence is performed and not owned and so can only be assessed by looking at performance. This is the reason why ICAO's competency concept is based on observable behaviors (Kes et al., 2025).

A useful distinction is drawn by Kes et al. (2025) between technical and cross-cutting skills. Effective communication is a prime example of transversal abilities, higher-order and not subject-specific, multidimensional and focused on the correct application of knowledge and skills. In this paper the technical domain refers to the domain-specific competences of the trade; the behavioral domain refers to transversal

competences closely tied to human factors; and the digital domain covers competences required to work with digital records, data, connected systems and immersive tools. The digital domain overlaps with the other two but is studied separately because of differences in its evidence basis, rate of change and consequences for training.

2.2. Licensing and Authorization Architecture

Under the Chicago Convention, licensing of maintenance technicians is the responsibility of each state, with ICAO setting internationally recognized standards (Güneş et al., 2020). Technicians in the European Union are licensed by EASA Part 66 which defines categories A, B and C, each with different knowledge, experience and language requirements; a certifying technician must also have the relevant license and type training (Güneş et al., 2020). In India, all persons and organizations involved in maintenance or certification of Indian-registered aircraft are covered under Directorate General of Civil Aviation's CAR-66, which recognizes Categories A, B1, B2, B3 and C (Directorate General of Civil Aviation [DGCA], n.d.). Basic training courses approved under CAR-147 follow the CAR-66 syllabus (Indira Gandhi Rashtriya Uran Akademi [IGRUA], n.d.).

These systems are essentially knowledge-and-experience gateways. Kes et al. (2025) note that the standards of EASA, the FAA and ICAO still center on theoretical multiple-choice examinations and time-based practical experience. Multiple-choice tests rarely go beyond recognition and comprehension, and they are poorly suited to eliciting higher-level competence.

2.3. The Move to Competency-Based Training and Assessment

ICAO's competency framework for aircraft maintenance articulates both technical and transversal competencies and is intended to make training more holistic than the traditional hours-based model (Kes et al., 2025). The International Air Transport Association (IATA) frames competency-based maintenance training as a chain that runs from hiring, through the establishment of required competencies and ab-initio and recurrent training, to assessment of the competencies needed for specified maintenance tasks (IATA, n.d.). Regulators have begun to issue supporting guidance; Thailand's civil aviation authority, for example, published guidance material on competency-based training and assessment for aircraft maintenance personnel in 2026 (Civil Aviation Authority of Thailand [CAAT], 2026). Kes et al. (2025) describe the shift as a paradigm change, because it replaces the proxy of hours and test scores with direct evidence of performance.

3. Review Method

This study is an integrative narrative review of online sources, not a systematic review. Sources were located in November 2026 through web searches combining terms such as aircraft maintenance technician competencies, skills assessment, human factors and the Dirty Dozen, digital documentation, predictive maintenance, augmented reality in maintenance, Boeing Pilot and Technician Outlook, and DGCA CAR-66. Sources were retained if they were in English, accessible online, and addressed the competencies, training, assessment or workforce demand of aircraft maintenance personnel.

Three journal articles formed the analytical core and were read in full: the systematic review by Thulasy et al. (2022), the competency-assessment study by Güneş et al. (2020), and the focus-group study by Kes et al. (2025). Other sources, including regulatory pages, outlook reports and industry material, were used for specific claims, and statements drawn from them are limited to what the retrieved text supports. Table 1 summarizes the source base.

Table 1. Source base of the Review

Source Group	Representative Sources	Used for
Peer-reviewed studies and reviews	Thulasy et al. (2022); Güneş et al. (2020); Kes et al. (2025); Aherne et al. (2025); Alomar & Yatskiv (2023)	Competency constructs; assessment evidence; digitization
Regulatory and safety-authority documents	FAA (2017, 2023, n.d.-a, n.d.-b); IATA (n.d.); DGCA (n.d.); CAAT (2026); IGRUA (n.d.)	Licensing; human factors; CBTA
Competency model	Minnesota Department of Labor and Industry (2024)	Task-level technical competencies
Labor-market outlooks	Boeing (2026a, 2026b, n.d.); AVweb (2026); Boeing Global Services (n.d.)	Workforce demand; skill shifts
Industry and trade commentary	KPMG Ireland (n.d.); Tata Consultancy Services (n.d.); Francis (2025); Automation.com (n.d.); Aviation Week (2026)	Digital practice and emerging skills (indicative only)

Note. Industry commentary was treated as indicative rather than conclusive because much of it is produced by technology vendors.

Content was coded thematically into the three domains. Each competency cluster was then given an evidence grade: strong where several peer-reviewed or regulatory sources agree, moderate where a single peer-reviewed source or consistent authority statements support it, and emerging where support comes mainly from industry commentary. These grades are the author's judgment and are offered to guide future research rather than as formal quality ratings.

Table 2 profiles the six sources that carry most of the analytical weight, so that readers can judge the kind of evidence behind each domain.

Table 2. Characteristics of the Core Evidence Sources

Source	Design and sample	Focus	Main contribution to this review
Thulasy et al. (2022)	Systematic review following PRISMA; 15 of 164 records retained	Skills assessment criteria in the Industry 4.0 context	Seven criteria, including technical knowledge, technical skills, communication and problem solving
Güneş et al. (2020)	Conceptual analysis of competency assessment processes	Technician competence, human factors, safety	Five workplace assessment methods; assessment across career stages
Kes et al. (2025)	Four focus groups with 27 stakeholders, summer 2025	Assessing communication and teamwork	Portfolio, rubric and mixed-method assessment design
Aherne et al. (2025)	Exploratory expert survey of 25 B1-certified engineers	Digital documentation and human factors	Divided views; added technology-knowledge demands
FAA (n.d.-b)	Literature-based report and operator manual	Failure to follow procedures	Contribution of procedural failure to 40.5–87% of maintenance events
Boeing (2026a, 2026b)	Twenty-year workforce forecast	Demand for technicians	728,000 new technicians; two-thirds replacement demand

Note. Descriptions are drawn from the cited sources' own accounts of their methods.

4. Technical Competencies

4.1. Knowledge and skill as distinct components

The systematic review by Thulasy et al. (2022) screened 161 records from database searches plus three supplementary articles, reviewed 25 in full text and retained 15. From them it derived seven assessment criteria, two of which are technical: technical knowledge and technical skills. Technical knowledge reflects the information and expertise a technician holds, and certifications are one way to evidence it (Thulasy et al., 2022). Technical skills are the ability to apply specialized knowledge to perform a task, and the review stresses that technical and soft skills are both needed for success.

The same review adapts a list of ideal technician skills in which the hands-on component is described as troubleshooting and repairing equipment, determining the amount of routine maintenance required,

determining and correcting technical difficulties, checking gages and dials for proper operation, judging the quality of output, and selecting tools and equipment as required (Thulasy et al., 2022). This captures the diagnostic character of the job: much of technical competence lies in recognizing that something is wrong and finding why.

4.2. Task-level competencies

Occupational competency models describe technical ability at the level of job task. In the Minnesota Department of Labor and Industry's (2024) model for the aircraft maintenance technician, industry-sector technical competencies include reviewing rigging and balance procedures for flight controls and working with avionics systems, performing all work in compliance with regulations and procedures, maintaining records and repair logs, and safely operating lifting machinery and equipment (Güneş et al. 2020) similarly describe duties spanning inspection, repair, revision, maintenance and ground handling, and they distinguish mechanical technicians, who work on structure and power units, from avionics technicians. They also note that the work is often done in noisy and hazardous hangar or apron settings and can be physically demanding.

4.3. Evolving technical content and the training gap

Technical content does not stand still. Thulasy et al. (2022), citing earlier work, point to new aircraft designs and materials and to technologies such as fly-by-wire and mission computers as drivers of change. A speaker quoted by Aviation Week (2026) identified composites, avionics and software as areas important to technicians but not typically covered in the general curriculum of airframe and powerplant programs in the United States. Boeing (2026a) likewise reports that employers find it difficult to fill roles requiring line-maintenance experience, airframe-specific expertise and strong troubleshooting skills.

Güneş et al. (2020) argue that deficiencies in technician competency have direct financial consequences: poor training leads to wasteful removal of serviceable components and ordering of spares, longer troubleshooting, more man-hours and more difficulty using test equipment and technical documentation. They say that graduates of maintenance school don't always have enough job-training experience, and that training has not kept pace with technology.

Table 3. Technical Competency Clusters and Supporting Evidence

Cluster	Illustrative competencies	Main sources
Aircraft systems knowledge	Airframe, powerplant, avionics and systems knowledge evidenced by examinations and certification	Thulasy et al. (2022); Güneş et al. (2020)
Flight controls, avionics and electrical systems	Rigging and balance procedures; avionics systems; growing software and composites content	Minnesota DLI (2024); Aviation Week (2026)
Inspection, troubleshooting and diagnosis	Detecting abnormal conditions; reading gauges and outputs; isolating faults; advanced diagnostics	Thulasy et al. (2022); Boeing (2026a)
Compliance, documentation and records	Working to regulations and procedures; task cards; service and repair logs	Minnesota DLI (2024); Güneş et al. (2020)
Tools, equipment and workplace safety	Selecting tools; operating lifting equipment; using protective equipment	Minnesota DLI (2024); Güneş et al. (2020)
Certification and authorization	License categories; type training; certifying-staff privileges	Güneş et al. (2020); DGCA (n.d.)

Note. Evidence grade for the technical domain as a whole: strong.

The technical domain is the best documented and the most regulated. It is also the domain in which the literature most clearly says that technical ability alone is insufficient, a theme that leads into the behavioral domain.

5. Behavioral Competencies

5.1. Why behavior Matters in Maintenance

Human factors play a part in maintenance error. Güneş et al. (2020) They list deficits in education and planning, including attention, perception, tension, workload and situational awareness as sources of individual error. They also categorize the elements affecting technician performance into cognitive, physical, organizational and procedural categories. They also notice that increasing flight numbers, automation and competition expose technicians to the rare error even if businesses take preventive precautions.

The FAA defines the “Dirty Dozen” as the twelve most common maintenance-related causes of error: lack of communication, complacency, lack of knowledge, distraction, lack of teamwork, fatigue, lack of resources, pressure, lack of assertiveness, stress, lack of awareness and norms (FAA, 2023). The list is built into FAA guidance on maintenance human-factors training, which notes that the aviation maintenance technician general examination tests human-factors topics including human error, physiological factors and communication at work (FAA, 2017). Notably, one of the twelve, lack of knowledge, is a technical gap; the taxonomy thus already links the technical and behavioral domains.

5.2. Communication and Teamwork

Communication emerges as the most prominent behavioral competency. In the study by Kes et al. (2025), The authors state that prior research showed the aviation sector evaluated communication as much more important than other transversal competences in ICAO’s framework, with teamwork being the next most important. Their rubrics translate competencies into observable behaviors of maintaining situational awareness in selecting communication methods, communicating clearly and concisely, encouraging open communication, anticipating and responding to the needs of others. At the “competent” level, a technician examines that recipients have understood, not that information was clear.

The FAA’s Dirty Dozen briefing makes the same point in practical terms: it states that only about 30% of verbal communication is received and understood by either party, and it recommends putting key points first and repeating them, using checklists, and confirming that everyone understands and agrees (FAA, n.d.-a). Language proficiency is a related element; Güneş et al. (2020) recommend assessing reading, listening, writing and speaking skills during recruitment and later career stages.

5.3. Procedural Discipline and Professional Norms

Failure to follow procedures is a behavioral rather than a knowledge problem. The FAA’s operator manual on the topic identifies fatigue, stress, employee well-being, complacency, professional culture and normative behavior, and communication among the contributing factors (FAA, n.d.-b). An ethnographic study reviewed by Thulasy et al. (2022) discovered that deviations from permitted procedures were impacted by elements ranging from manuals to surroundings, including personal comfort and timetable pressure. Procedural discipline is therefore not merely a question of individual willingness, but rather it is influenced by organizational conditions and is a competency that involves recognizing and rejecting such influences.

5.4. Cognitive and self-management competencies

The systematic review adds analytical and critical thinking, problem solving, active learning, communication, and experience and lessons learned to the technical criteria (Thulasy et al., 2022). Problem solving means knowing when something is wrong or likely to go wrong, knowing what the problem is, using reasoning to fix it, and focusing without interruption. The examination also identifies time and self-management and

cooperation, that is, adapting your behavior to the activities of others (Güneş et al. 2020) add working under time pressure, adapting to shift work, situational awareness, attention and perception, and recommend measuring attention, perception, stress tolerance and safety culture during selection.

Experience contributes a further dimension (Thulasy et al. 2022) report, citing a Jordanian study of aviation maintenance employees, a strong connection among behavioral, functional and managerial competencies and employee productivity, and they argue that working experience builds tacit knowledge that shapes behavioral competence.

Table 4. Mapping the FAA Dirty Dozen to Behavioral Competency Clusters

Behavioral Cluster	Dirty Dozen Elements Addressed	Illustrative Observable Behaviors
Communication	Lack of communication	Prioritizes safety-critical information; confirms understanding by repeating back; uses checklists
Teamwork and assertiveness	Lack of teamwork; lack of assertiveness	Asks questions; reports own errors; involves all affected team members; offers help calmly
Situational awareness and attention	Distraction; lack of awareness; complacency	Maintains focus on the task; notices changes in system state; does not assume prior work was correct
Stress, fatigue and pressure management	Stress; fatigue; pressure	Recognizes own fatigue; escalates unsafe schedule pressure; seeks a second check
Procedural discipline and professional norms	Norms (and failure to follow procedures)	Works to current documentation; challenges unsafe local habits
Knowledge currency and active learning	Lack of knowledge	Updates knowledge after type changes; consults manuals rather than memory
Resource management	Lack of resources	Identifies missing tools, parts or information early and reports them

Note. Dirty Dozen elements from FAA (2023). The clusters and observable behaviors are the author's synthesis, informed by Kes et al. (2025) and Güneş et al. (2020), and are illustrative rather than regulatory.

5.5. Culture as a Condition of Behavioral Competence

Behavioral competence cannot be separated from the culture in which it is exercised. Kes et al. (2025) imply that aviation students taught in a "just culture," where mistakes and near-misses are openly discussed without fear of penalty, were comfortable with open rather than anonymous peer input. In the same survey, industry participants mentioned a conflict of interest: if a company does not have enough certified people, the assessors within the company may feel pressure to pass the candidates, hence some participants preferred that the assessments be done by training companies. That is, behavioral competences are tested and practiced in organizational systems that may facilitate or impede them. The level of evidence for the behavioral domain is strong for communication and moderate for the other clusters.

6. Digital Competencies

6.1. The Industry 4.0 Context

Thulasy et al. (2022) claim that Industry 4.0 changes the role of technicians from manual work to process management and monitoring. Technicians will collaborate with smart machines, deal with information and data on a regular basis, use tablets and mobile devices and help with planning and process development. Assistant systems will help but ultimate judgments have to be made by qualified professionals. Importantly, the review stresses that these new skills are additional to, not substitutes for, existing competencies. On-board structural health monitoring illustrates the shift: sensors can check structural integrity, process data, and prompt technicians, reducing time-consuming manual inspections (Thulasy et al., 2022).

6.2. Digital Documentation and Electronic Records

A concrete digital change is the move from paper to electronic maintenance records. Alomar and Yatskiv (2023) describe the last two decades as a turning point in the transition from paper to electronic recording of technical operations and note that their study also reflects personnel readiness to improve their own skills. Aherne et al. (2025) state that digitized documentation will soon be the norm in aviation and surveyed 25 maintenance and technical services engineers about its human-factors implications. Participants were divided on the challenges: negative themes concentrated on the tactile nature of paper and on additional technology-knowledge requirements, and the participants also highlighted a lack of human-factors awareness in critical maintenance tasks. Güneş et al. (2020) similarly argue that interactive technologies in maintenance documents could make technician competency assessment more objective and effective.

6.3. Data, Predictive Maintenance and AI-assisted Work

Industry sources point to predictive maintenance, AI-assisted inspection, document search and digital work-packs as ways to turn unscheduled events into scheduled ones and improve first-time-fix rates. They argue that the talent model must evolve through multi-skill pathways, competency-based training and AR or remote assistance, with time-to-productivity becoming a board-level measure (KPMG Ireland, n.d.). Commentary from the automation community notes that digital twins allow crews to simulate operating scenarios and assess the effect on maintenance needs, while AI moves maintenance from a reactive to a predictive footing (Automation.com, n.d.). Boeing (n.d.) predicts that connected systems and data-rich maintenance settings will transform the work of the technician, and the next generation of professionals will require better digital, analytical and systems-based skills. Technology-vendor commentary adds that the skills gap demands the same urgency and resources as technology investment (Francis, 2025). Because these claims are largely commercial, they are graded as emerging evidence.

6.4. Immersive and Remote Tools

Industry material describes augmented and virtual reality as tools for simulating maintenance activities such as opening panels and fastening components, enabling faster training of new hires and upskilling of the existing workforce (Tata Consultancy Services, n.d.). Augmented reality can overlay digital information on the technician's field of view and provide real-time guidance (Automation.com, n.d.). Stakeholders in the study by Kes et al. (2025) were less convinced: students who had tried virtual-reality inspection found it enjoyable but not realistic enough to add much, and among industry participants there was limited support for digital tools in assessment, with video-based assessment disliked chiefly because of privacy concerns. Evidence on immersive tools is therefore mixed, and the question of what competence is needed to use them is separate from the question of whether they improve training.

Table 5. Digital Competency Clusters and Evidence Maturity

Cluster	What Technicians are expected to do	Main Sources	Evidence
Digital documentation and e-records	Use electronic task cards and records accurately; recognize new error modes in digital systems	Aherne et al. (2025); Alomar & Yatskiv (2023)	Moderate
Data interpretation and condition-based maintenance	Read sensor and health-monitoring outputs; act on predictive alerts	Thulasy et al. (2022); KPMG Ireland (n.d.)	Moderate
Immersive and remote-assist tools	Work with AR guidance and remote experts; use simulation for practice	TCS (n.d.); Automation.com (n.d.)	Emerging
Human–machine decision-making	Work with assistant systems while retaining final judgment	Thulasy et al. (2022)	Moderate
Digital self-learning	Keep pace with new systems and shorten time-to-productivity	KPMG Ireland (n.d.); Francis (2025)	Emerging

Note. Evidence grades are the author's judgment (see Section 3). Data-integrity and cybersecurity awareness were not evidenced in the sources reviewed and are treated as a research gap rather than a cluster.

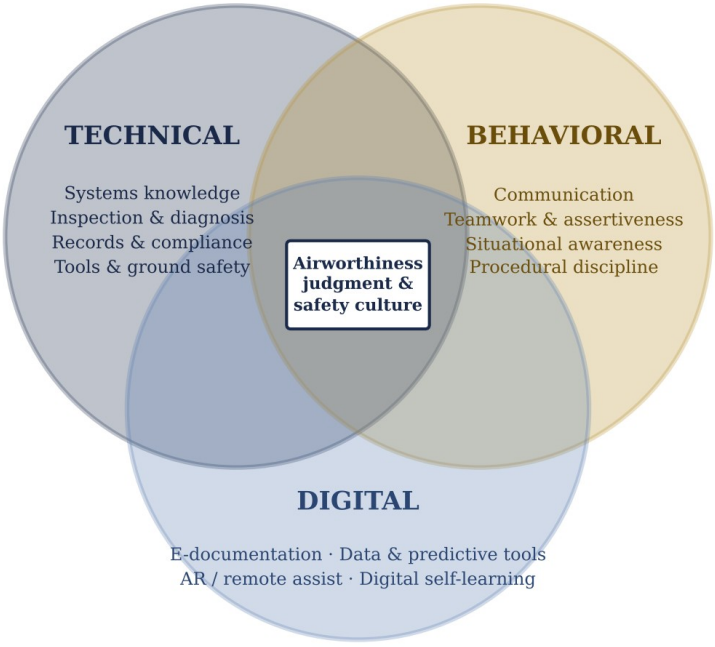
The digital domain shows a clear asymmetry between the confidence of industry commentary and the thinness of scholarly assessment evidence. A 2024 Springer chapter on digital competence assessment for Royal Malaysian Air Force technicians surfaced in searches, but its content was not accessible for this review and it is flagged for follow-up.

7. An Integrated Competency Map

Figure 1 presents the T-B-D map. The three domains overlap, and at their center lies what the literature repeatedly names as the ultimate purpose of maintenance competence: sound airworthiness judgment exercised within a safety culture. Surrounding the domains are the regulatory and organizational conditions, including licensing, CBTA, just culture and schedule pressure, which determine whether competence is developed and exercised.

Three interdependencies stand out. First, technical and behavioral competencies are intertwined: knowledge gaps appear inside the Dirty Dozen, and the best technical diagnosis is of little use if it is not communicated clearly to a colleague or shift handover. Second, digital change reshapes behavioral demands. Aherne et al. (2025) link the transition to digital documentation to human-factors awareness and to the additional technology knowledge technicians must hold. Third, digital tools do not replace the need for technical judgment; Thulasy et al. (2022) insist that qualified professionals make the final decisions.

Figure 1. Technical–Behavioral–Digital (T-B-D) competency map



Source: Author's synthesis of the literature reviewed. Surrounding context: licensing (ICAO, EASA Part 66, FAA, DGCA CAR-66), CBTA, just culture and schedule pressure.

Table 6. Summary of the T-B-D Map

Domain	Core Clusters	Dominant Assessment Methods	Evidence
Technical	Systems knowledge; flight controls and avionics; diagnosis; compliance and records; tools and safety; certification	License examinations; practical tasks; type training; task-card review	Strong
Behavioral	Communication; teamwork and assertiveness; situational awareness; stress and fatigue; procedural discipline; knowledge currency; resource management	Direct observation; rubrics; peer and self-assessment; SMS and quality records	Strong (communication); moderate (others)
Digital	E-documentation; data interpretation; immersive and remote tools; human–machine decision-making; digital self-learning	Authentic digital tasks; simulation; workplace records (not yet standardized)	Moderate to emerging

Note. Evidence grades are the author's synthesis. Assessment methods draw on Güneş et al. (2020) and Kes et al. (2025).

7.1. Propositions for empirical testing

The review suggests four propositions. They are derived from the literature and have not been tested in this paper.

- P1. Behavioral competence explains variance in procedural compliance beyond that explained by technical competence alone.
- P2. Digital competence moderates the relationship between the adoption of digital tools (for example electronic task cards) and maintenance outcomes such as rework and first-time-fix rate.
- P3. Gaps between perceived importance and self-assessed proficiency are widest in the digital domain and narrowest in the technical domain.
- P4. Organizational culture, including just-culture climate and schedule pressure, moderates the effect of behavioral competence on safe performance.

8. Assessment and Development Implications

8.1. Assessing what can be observed

Because competence is shown in performance, assessment must observe it. Kes et al. (2025) tested a design built around a personal portfolio holding multiple assessment data points, qualitative rubrics describing performance at three levels (beginner, in development and competent), and a mix of self, peer and instructor assessment. Four focus groups with 27 stakeholders from several countries preferred this programmatic approach to a single final test. Students saw it as less stressful and more objective, and industry participants considered it feasible, while stressing standardization, oversight, instructor training and the avoidance of financial conflicts of interest. The groups preferred narrative rubrics to numerical scoring for transversal competencies, provided assessors received clear guidance.

8.2. Using Workplace Evidence

Güneş et al. (2020) propose five competency-assessment methods for maintenance organizations: direct observation by senior technicians; review of tracking records such as maintenance documents and training results; review of quality-control records; review of Safety Management System records; and comparison of technician performance across these sources. They add that feedback should be given to technicians, for example through case-study discussion. They further recommend that competency assessment run across the whole career path, from selection and placement through to certifying-technician status, with attention, perception, time-pressure tolerance and language proficiency evaluated at selection. These methods use

data that organizations already hold, which makes them attractive to employers and to management researchers.

Applied to the T-B-D map, the career path in Güneş et al. (2020) suggests that the weight of each domain may shift over time. At selection, attention, perception, language and aptitude carry more weight than deep system knowledge. As an assistant technician becomes a certifying technician, technical depth and procedural discipline become decisive, while authority to sign for work places greater demands on communication, assertiveness and judgment. This progression is an inference from the sources, not an empirical finding, but it indicates that a single competency checklist is unlikely to suit every career stage.

8.3. Assessing Digital Competence

No consensus method for assessing digital competence emerged from the sources. Kes et al. (2025) found limited enthusiasm for digital tools in assessment, though one participant suggested that video analyzed by AI could increase the amount of feedback. A reasonable inference, offered as a hypothesis rather than a finding, is that digital competence is best assessed through authentic tasks performed in the digital systems technicians actually use, such as completing and closing an electronic task card, with rubrics comparable to those used for behavioral competencies.

8.4. Designing Training

Training design should reflect the integrated nature of the map. Participants in Kes et al. (2025) proposed combining technical tasks with scenarios that force collaboration, such as a simulated aircraft-on-ground event with an anxious pilot, a shift handover, or tasks that cannot be done alone because one person is in the cockpit while another rigs controls. Such scenarios develop technical, communication and teamwork competencies together. FAA guidance supports a structured approach to human-factors training for maintenance organizations and schools (FAA, 2017). On the supply side, a Boeing speaker cited by Aviation Week (2026) noted that early-career partnerships, including cadet programs, maintenance apprenticeships and school partnerships, have grown fourfold over the past decade.

9. Implications for Policy, Training and Practice

The review was not designed to evaluate Indian curricula, so the following implications are inferences from the evidence rather than findings about India. India's licensing model, built around CAR-66 categories and CAR-147 basic training that follows the CAR-66 syllabus (DGCA, n.d.; IGRUA, n.d.), is knowledge-and-experience based, like its European counterpart. Given Boeing's projection of about 45,000 technicians needed in South Asia through 2044 and more than $195 billion in aviation services growth, including maintenance, digital services and training (Boeing Global Services, n.d.), explicit attention to behavioral and digital competence could strengthen the quality of the expanding workforce. Four groups have a role.

- Regulators could consider following the CBTA direction signalled by ICAO and operationalized by authorities such as CAAT (2026), specifying observable behaviors for transversal competencies alongside knowledge syllabuses.
- Training organizations could embed communication, teamwork and human-factors scenarios within technical practical training and introduce digital documentation practice, with portfolios and rubrics to record evidence.
- Employers, including airlines and MROs, could use the five workplace-evidence methods described by Güneş et al. (2020) to align selection, placement, appraisal and promotion with a competency

framework, and could protect assessment from short-term staffing pressure, as industry participants suggested.

- Researchers can use the T-B-D map to design competency-gap studies that test the propositions in Section 7.1.

From a management perspective, the map treats competencies as an integrated human-resource system, not as a set of isolated training topics. That framing resonates with the argument in Güneş et al. (2020) that technician competence should be considered in performance evaluation and assignment using widely used human-resource methods.

10. Limitations and Future Research

The paper has several limitations. It is a narrative review, not a systematic one, so the search was not exhaustive and selection may be biased toward sources that are freely available online. Several non-academic sources were available only as excerpts, and industry commentary, particularly on digital tools, may reflect commercial interests. The evidence grades are the author's judgment. Most core studies are from Europe, Southeast Asia and North America, and little of the evidence reviewed concerns Indian technicians or the Indian regulatory setting. Finally, the framework is conceptual and has not been validated empirically.

Future research should proceed in four steps. First, a systematic review following PRISMA could extend the corpus, including the digital-competence literature that could not be accessed here. Second, a Delphi study with licensed engineers, supervisors and trainers could validate the clusters and refine the observable behaviors, as Kes et al. (2025) did for ICAO's framework. Third, a survey of B1 and B2 license holders and their supervisors could measure the importance and proficiency of each cluster on five-point scales, using importance–proficiency gap analysis, confirmatory factor analysis and structural equation modeling to test P1 to P4. Fourth, field studies could evaluate portfolio-based assessment and scenario training in Part 145 and CAR-147 settings, and could examine data-integrity and cybersecurity awareness, which this review found unevidenced.

11. Conclusion

Aircraft maintenance competence is multidimensional. The technical domain is well documented and tightly regulated, yet the literature consistently shows that technical ability alone does not secure safe performance. The behavioral domain is closely tied to error causation, through communication, teamwork, awareness, stress management and procedural discipline, but it is harder to assess and depends on organizational culture. The digital domain is changing fastest, with electronic records, predictive tools and immersive technologies altering the technician's role, but its evidence base is thin and often commercial.

The Technical–Behavioral–Digital map offers a way to hold these domains together, to see where evidence is strong and where it is not, and to design assessment and training that mirror the integrated nature of maintenance work. With demand for 728,000 new technicians projected globally and large growth expected in South Asia, getting the competency mix right is a workforce, safety and economic concern. The propositions and research design set out here offer a starting point for empirical work that can turn this map into a validated tool.

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