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Anayatova R.,¹  Tulekova G.,¹  Suranchiyeva N.,^{1*} 
Ryabchenko I.,¹  Kuanyshbayev B.² 

¹Civil Aviation Academy, Almaty, Kazakhstan

²Khoja Akhmet Yassawi International Kazakh-Turkish University, Turkestan, Kazakhstan

PREPARATION OF A TRILINGUAL MOBILE THESAURUS AIMED AT REDUCING THE COGNITIVE LOAD OF FUTURE AVIATION SPECIALISTS

Abstract

Communication errors remain a critical factor in aviation accidents, often rooted in language barriers and the cognitive load associated with complex terminology. While English is the global standard, the trilingual operational environment in Central Asia (Kazakh-English-Russian) presents unique challenges in conceptual equivalence and professional training. This research addresses the “descriptive-only” gap in current tools for training of future aviation specialists by developing an integrated linguistic and technological framework for a trilingual aviation thesaurus. Unlike traditional linear dictionaries, this project utilizes a “Concept Node” architecture based on ICAO, EASA, and IATA standards, mapping semantic relationships (hypernyms, hyponyms, and collocations) to facilitate intuitive understanding. The study analyzed a robust corpus of 5,800 specialized terms, with a projected expansion to 10,000 units. The framework was operationalized into a mobile application featuring 3D visual contextualization, fuzzy-match search algorithms, and standardized audio modules to mitigate psycholinguistic stress. The effectiveness and practical relevance of the developed tool were validated through official expert evaluations from SCAT Airlines and the 405 Aviation Repair Plant. The results demonstrate that a multidimensional thesaurus approach significantly reduces translation latency and cognitive errors, providing a scalable solution for enhancing global aviation safety and specialist training.

Keywords: future specialist, trilingual thesaurus, aviation, cognitive load, aviation communication, semantic modeling.

Р.Анаятова,¹  Г.Тулекова,¹  Н.Суранчиева,^{1*}  И.Рябченко,¹  Б.Куанышбаев² 

¹Азаматтық авиация академиясы, Алматы қ., Қазақстан

²Қожа Ахмет Ясауи атындағы Халықаралық қазақ-түрік университеті,
Түркістан қ., Қазақста

БОЛАШАҚ АВИАЦИЯ МАМАНДАРЫНЫҢ КОГНИТИВТІК ЖҮКТЕМЕСІН АЗАЙТУҒА БАҒЫТТАЛҒАН ҮШТІЛДІ МОБИЛЬДІ ТЕЗАУРУСТЫ ДАЙЫНДАУ

Аңдатпа

Авиациялық апаттарда байланыс қателері критикалық фактор болып қала береді, олар көбінесе тілдік кедергілерден және күрделі терминологиямен байланысты когнитивтік жүктемеден туындайды. Ағылшын тілі жаһандық стандарт болғанымен, Орталық Азиядағы үштілді (қазақ-ағылшын-орыс) операциялық орта тұжырымдамалық баламалылық пен кәсіби даярлықта бірегей қиындықтар туғызады. Бұл зерттеу үштілді авиациялық тезаурустың біріктірілген лингвистикалық және технологиялық негізін әзірлеу арқылы болашақ авиация мамандарын даярлауда қазіргі құралдардағы тек «сипаттамалық» тәсілдің олқылығын толтырады. Дәстүрлі сызықтық сөздіктерден айырмашылығы, бұл жобада интуитивті түсінуді жеңілдету үшін семантикалық байланыстарды (гиперонимдер, гипонимдер және коллокациялар) көрсететін ICAO, EASA және IATA стандарттарына негізделген «концептуалды түйіндер» (Concept Nodes) архитектурасы қолданылады. Зерттеу барысында 5 800 мамандандырылған терминнен тұратын үлкен корпус талданды, оның көлемін 10 000 бірлікке дейін кеңейту жоспарланған. Теориялық негіз психолингвистикалық стрессті азайтуға арналған 3D-визуализация, бұлыңғыр іздеу (fuzzy-match) алгоритмдері және стандартталған аудио модульдері бар мобильді қосымша түрінде жүзеге асырылды. Әзірленген құралдың тиімділігі мен тәжірибелік маңыздылығы «SCAT» әуе компаниясы мен «405-ші авиажөндеу зауытының» ресми сараптамалық қорытындылары арқылы расталды. Нәтижелер көпөлшемді тезаурус тәсілі аударма кідірістері мен когнитивті қателерді айтарлықтай азайтып, жаһандық авиациялық қауіпсіздік пен мамандарды даярлау сапасын арттыру үшін тиімді шешім ұсынатынын көрсетеді.

Түйін сөздер: болашақ маман, үштілді тезаурус, авиация, когнитивтік жүктеме, авиациялық коммуникация, семантикалық модельдеу.

Анаятова Р.,¹  Тулекова Г.,¹  Суранчиева Н.,^{1*}  Рябченко И.,¹  Куанышбаев Б.² 

¹Академия гражданской авиации, г.Алматы, Казахстан

²Международный казахско-турецкий университет имени Ходжи Ахмеда Ясави,
г.Туркестан, Казахстан

РАЗРАБОТКА ТРЕХЪЯЗЫЧНОГО МОБИЛЬНОГО ТЕЗАУРУСА, НАПРАВЛЕННОГО НА СНИЖЕНИЕ КОГНИТИВНОЙ НАГРУЗКИ БУДУЩИХ АВИАЦИОННЫХ СПЕЦИАЛИСТОВ

Аннотация

Коммуникативные ошибки остаются критическим фактором авиационных происшествий, зачастую обусловленным языковыми барьерами и когнитивной нагрузкой, связанной со сложной терминологией. Несмотря на то, что английский язык является мировым стандартом, трехязычная операционная среда в Центральной Азии (казахский-английский-русский) создает уникальные вызовы в области концептуальной эквивалентности и профессиональной подготовки. Данное исследование призвано восполнить пробел в существующих инструментах подготовки будущих авиационных специалистов, обусловленный преимущественно «описательным» подходом, путем разработки комплексной лингвистической и технологической основы трехязычного авиационного тезауруса. В отличие от традиционных линейных словарей, в проекте используется архитектура «концептуальных узлов» (Concept Nodes), основанная на стандартах ICAO, EASA и IATA, которая отображает семантические связи (гиперонимы, гипонимы и коллокации) для облегчения интуитивного понимания. В ходе исследования был проанализирован обширный корпус из 5 800 специализированных терминов с плановым расширением до 10 000 единиц. Теоретическая база была реализована в виде мобильного приложения с функциями 3D-визуализации, алгоритмами нечеткого поиска и модулями стандартизированного аудио для снижения психолингвистического стресса. Эффективность и практическая значимость разработанного инструмента подтверждены официальными экспертными заключениями авиакомпании «SCAT» и «405 авиаремонтного завода». Результаты показывают, что многомерный тезаурусный подход значительно снижает задержки при переводе и когнитивные ошибки, предлагая масштабируемое решение для повышения глобальной авиационной безопасности и качества подготовки специалистов.

Ключевые слова: будущий специалист, трехязычный тезаурус, авиация, когнитивная нагрузка, авиационная коммуникация, семантическое моделирование.

Introduction. Effective communication in global aviation is a vital component of the professional training of future aviation specialists and a crucial factor in ensuring flight safety. Despite the International Civil Aviation Organization (ICAO) designating English as the universal language for radiotelephony communication, language barriers remain a significant risk factor contributing to accidents caused by human error (International Civil Aviation Organization [ICAO], 2010). Therefore, preparing future aviation specialists to use aviation terminology accurately and effectively in a multilingual professional environment is a key aspect of their training. The complexity of this task lies at the intersection of three fields: linguistics (lexical and phraseological precision), psycholinguistics (cognitive load under stress), and technology (availability of reference tools).

Language support tools in the aviation sector are often based on traditional, linear (alphabetical) dictionary structures (International Civil Aviation Organization [ICAO], 2016). However, such tools may fail to adequately account for the conceptual connections within aviation terminology, as well as the psycholinguistic challenges faced by future aviation professionals, particularly those preparing to work in the trilingual (English, Russian, and Kazakh) environment of Central Asia. For future aviation specialists, the ability to quickly locate, comprehend, and correctly use aviation terminology is particularly important during professional training, when linguistic and cognitive demands arise simultaneously. The issue addressed in this study is the absence of a comprehensive linguistic and technological framework that ensures semantic precision and reduces cognitive load during terminology retrieval (European Union Aviation Safety Agency [EASA], 2025). The aim of the study is to develop and scientifically substantiate the structure and content of a trilingual (Kazakh, English, and Russian) mobile thesaurus designed to reduce the cognitive load on future aviation professionals when searching for and mastering aviation terminology. To achieve this, the study addresses the following Research Questions (RQs):

RQ1: What are the primary lexico-semantic discrepancies between English aviation terms and their Russian/Kazakh equivalents that lead to cognitive dissonance?

RQ2: How can a thesaurus-based (thematic and semantic) structure, as opposed to an alphabetical one, facilitate better conceptual understanding of ICAO/EASA standards?

RQ3: In what ways can 3D visualization and audio integration in a mobile interface mitigate psycholinguistic barriers like stress and phonetic interference?

The impact of communication failures on aviation safety has been extensively analyzed in classical studies by Cushing (1997) and Tajima (2004). Further linguistic research by Estival et al. (2016) has defined “Aviation English” as a specialized Lingua Franca, emphasizing the need for standardized phraseology. However, while much research focuses on native/non-native English interactions, there is a significant gap in studies concerning the integration of the Kazakh language into this global framework through modern digital lexicography. Recent works in the region (e.g., Ryabchenko et al.) discuss the general problems of language barriers but do not provide a technological model for a conceptual thesaurus. This study fills this gap by proposing a multidimensional approach that integrates semantic modeling with mobile application development. Research in the field of aviation communication has highlighted the importance of teaching professional language during the training of future aviation specialists. Students are required not only to understand standardized aviation phraseology but also to establish a consistent link between terminology, professional concepts, and real-world operational scenarios. This approach allows for viewing the mastery of terminology not as an isolated language-learning task, but as a crucial component of professional training.

From a pedagogical perspective, aviation terminology presents a unique challenge because students must simultaneously acquire professional knowledge and specialized foreign language vocabulary. The difficulty is compounded when the same professional concept is encountered across multiple linguistic codes. In a trilingual learning environment, students may need to establish correspondences between the English terminology used in international aviation standards and its Russian and Kazakh equivalents, while also grasping the underlying professional concept.

In the context of aviation communication, Cognitive Load Theory (CLT), originally developed by John Sweller (2011), assumes critical importance. Under severe time constraints and high-stress conditions, processing information in a non-native language demands substantial working memory resources. This can rapidly lead to cognitive overload and a subsequent loss of situational awareness. Recent studies suggest that employing multimodal tools - integrating textual, auditory, and visual inputs - helps distribute cognitive load across different processing channels, thereby facilitating faster and more accurate information retrieval from long-term memory. From an instructional perspective, this raises the question of how to design learning resources in a way that minimizes unnecessary cognitive processing while supporting the mastery of specialized terminology.

Despite the rapid advancement of Mobile-Assisted Language Learning (MALL) systems (Apostolou & Geitona, 2022), the majority of existing aviation dictionaries remain 'flat' and linear. They typically provide direct textual translation without considering the broader semantic context. Concurrently, 3D visualization and semantic mapping have been recognized as highly effective methods for bridging the 'lexical gap' (Elias & Ismail, 2020). These techniques appeal directly to the spatial reasoning skills of aviation professionals, which are often heavily relied upon during operational tasks (Erival et al., 2016). In this regard, mobile-assisted learning enables terminology acquisition to move beyond the use of traditional dictionaries. Mobile resources can support repeated exposure, contextual learning, search-based practice, and the multimodal presentation of specialized vocabulary. Such functionality can be particularly significant for future aviation professionals, as terminology remains accessible during both structured learning activities and independent study.

Furthermore, the trilingual operational environment of Central Asia (encompassing Kazakh, Russian, and English) introduces an additional layer of complexity: the frequent lack of direct conceptual equivalence between technical terms across these languages. Developing localized tools that harmonize specific Kazakh and Russian aviation terminology with established ICAO standards is not merely a linguistic exercise, but a critical imperative for enhancing flight safety in the region (Tulekova & Anayatova, 2023). From a pedagogical perspective, a thesaurus differs from a standard dictionary by presenting terminology through semantic and conceptual connections. Such a structure facilitates not only the retrieval of individual terms but also the establishment of relationships between interconnected concepts. For students preparing for professional careers in aviation, this method of organizing information can ease the transition from merely memorizing isolated lexical units to understanding terminology within the framework of a professional conceptual system. Thus, existing scientific literature highlights the relevance of issues such as aviation English, cognitive load management, mobile-assisted language learning, and multilingual terminological support. However, these areas of research have largely been addressed in isolation. There remains a need for a pedagogical digital tool—designed for future aviation professionals—that integrates multilingual aviation terminology, semantic relationships, multimodal presentation methods, and mobile accessibility within a unified learning environment.

Materials and Methods. This study employs a mixed-methods research design, integrating linguistic analysis with software architecture modeling.

Data Collection and Corpus Description

The primary material was sourced from ICAO Doc 9835, Annex 10, and EASA (SERA) glossaries, as well as authentic technical manuals used in aircraft maintenance. Currently, the lexicographic database comprises a corpus of 5,800 specialized terms and standard phrases compiled using continuous sampling, with an ongoing expansion plan to reach 10,000 lexical units. The corpus was developed to meet the needs of future aviation specialists in mastering professional terminology within a trilingual educational environment. The criteria for term selection included: (1) frequency of use in radiotelephony and technical maintenance; (2) degree of semantic complexity; and (3) direct impact on flight safety. It is shown in Figure 1.

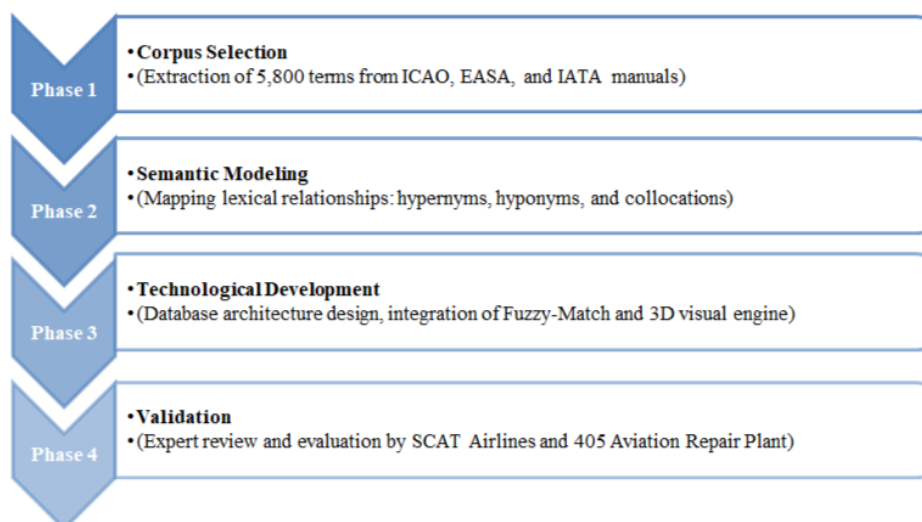


Figure 1 - Flowchart of the Research and Development Methodology

Analytical Procedures . The research followed a three-stage sequence:

1. *Linguistic Phase*: component analysis was used to identify semantic gaps between the three languages. We analyzed terms where direct translation was insufficient (e.g., “Runway Incursion”).
2. *Modeling Phase*: semantic graphs were constructed to represent hierarchical relationships (hypernyms, hyponyms) and collocations for the thesaurus database.
3. *Technological Phase*: UI/UX design was developed to minimize cognitive load, incorporating 3D models for visual context and audio samples for phonetic validation.

Validation and Expert Evaluation

To ensure the highest level of scientific validity and practical applicability, the linguistic accuracy and technological usability of the trilingual thesaurus were subjected to rigorous expert evaluation. Official expert conclusions were obtained from two major industry stakeholders: SCAT Airlines (validating operational and radiotelephony terminology) and the 405 Aviation Repair Plant (validating technical and maintenance vocabulary). This dual-expert review confirmed that the tool effectively reduces cognitive load and translation latency in both active flight operations and ground maintenance environments.

Results and Discussion. Lexico-Semantic Analysis and Conceptual Discrepancies (Addressing RQ1).

During the linguistic modeling phase, the selected corpus of ICAO/EASA terms was systematically processed to identify cross-linguistic asymmetries. Quantitative and qualitative analysis revealed that a significant portion of English aviation terms lack direct, one-to-one conceptual equivalents in the Kazakh language, necessitating descriptive conceptualization.

To illustrate the complexity of linguistic provision, Table 1 presents an extract from the developed trilingual thesaurus. The selection emphasizes terms that frequently cause cognitive overload or translation delays due to conceptual disparities as shown in Table 1.

Table 1 - Extract from the Trilingual Aviation Thesaurus (ICAO/EASA Standards)

English Term	Russian Translation	Kazakh Translation	ICAO / EASA Standardized Definition
Wind Shear	Сдвиг ветра	Желдің ығысуы	A change in wind speed and/or direction in space, including updrafts and downdrafts, affecting aircraft performance.
Clearance	Разрешение (диспетчерское)	Диспетчерлік рұқсат	Authorization for an aircraft to proceed under conditions specified by an air traffic control unit.
Empennage	Хвостовое оперение	Құйрық жаймасы	The tail assembly of an aircraft, including the horizontal and vertical stabilizers, elevators, and rudder.
Squawk	Установка кода ответчика	Жауап бергіш кодын орнату	The transmission of an assigned code by an aircraft's transponder to air traffic control radar.
Go-around	Уход на второй круг	Екінші айналымға кету	A procedure executed if a pilot decides that a safe landing cannot be completed, initiating a climb and new approach.
Taxiway	Рулежная дорожка (РД)	Жүру жолы (ЖЖ)	A defined path on a land aerodrome established for the taxiing of aircraft and intended to provide a link between one part of the aerodrome and another.
Deadhead	Перелет не при исполнении (пассажиром)	Қызметтен тыс ұшу	A crew member traveling as a passenger on a flight to re-position for a flying assignment.

Analysis of Complex Terminological Units highlighted several critical patterns of semantic dissonance:

1) *Spatial and Legal Implication*: Terms like “Runway Incursion” cannot be translated word-for-word. The developed thesaurus maps it to the Russian “Несанкционированный выезд на ВПП” and Kazakh “ҰҚЖ-ға рұқсатсыз шығу”. The analysis shows that the target languages explicitly require the element of “unauthorized”, which is only implied in the English source (Kaya & Ateş, 2023). Failure to understand this implicit legal weight under stress leads to critical safety errors.

2) *Metaphorical to Functional Shift*: The term “Squawk” originates from aviation jargon. The research demonstrates that effective translation into a trilingual context requires shifting from a metaphorical verb to a highly descriptive technical phrase (“Установка кода ответчика”/“Жауап бергіш кодын орнату”), prioritizing functional action over linguistic origin.

3) *Morphological Gaps*: Borrowed terms such as “Empennage” lack single-word equivalents. The semantic modeling required linking it directly to its hyponyms (rudder and elevators) to ensure comprehensive understanding by cadets and non-native speakers.

Thesaurus Architecture as a Cognitive Solution (Addressing RQ2).

To resolve the identified lexico-semantic discrepancies (Kaya & Ateş, 2023), the project transitioned from a traditional alphabetical dictionary structure to a relational “Concept Node” architecture which is shown in Figure.

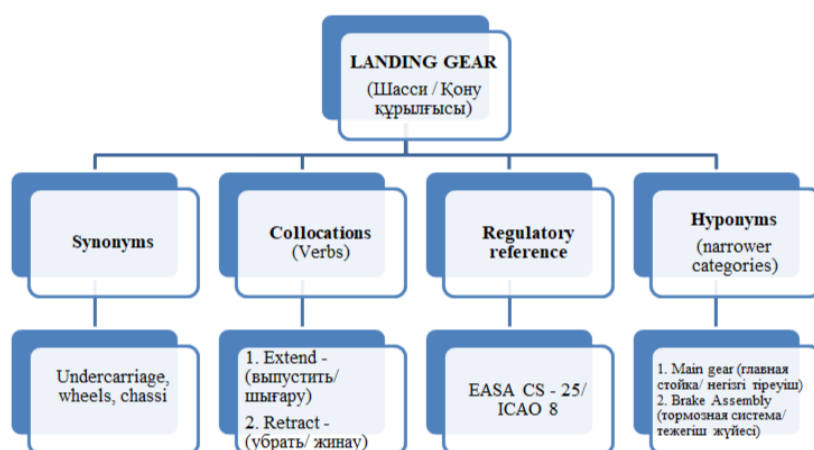


Figure 1- Concept Node

As illustrated in Figure 1, the semantic tree structure mitigates cognitive overload. By mapping synonyms, collocations (e.g., *extend / retract*), and ICAO regulatory references within a single node, the thesaurus provides immediate operational context. The SCAT Airlines and 405 Plant expert evaluations confirmed that this non-linear structure accelerates cognitive recognition compared to traditional glossaries, significantly reducing the psychological burden during translation.

Technological Integration and UI/UX Evaluation (Addressing RQ3) The theoretical linguistic models were successfully operationalized into a cross-platform mobile application. The architectural results of the application directly address the psycholinguistic aspects of the language barrier:

1. *Fuzzy-Match Search Algorithm*: To combat phonetic spelling errors (a primary linguistic barrier for non-native speakers), the app's predictive search corrects inputs like “*Sckwok*” to the standardized “*Squawk*”.

2. *3D Visual Contextualization*: The most significant technological result is the integration of an interactive 3D visual dictionary. For mechanical terms (e.g., *Aileron*), the system renders a manipulable 3D aircraft model. This bypasses the need for textual translation entirely, relying on spatial memory, which research indicates is far more resilient in high-stress aviation environments.

3. *Phonetic Standardization*: The integration of standard ICAO synthesized audio directly addresses the issue of accent and pronunciation discrepancies identified in the literature review.

The structural logic and user interaction flow of these integrated technological modules are visualized in Figure 2 below, demonstrating the transition from user input to multi-modal cognitive output:

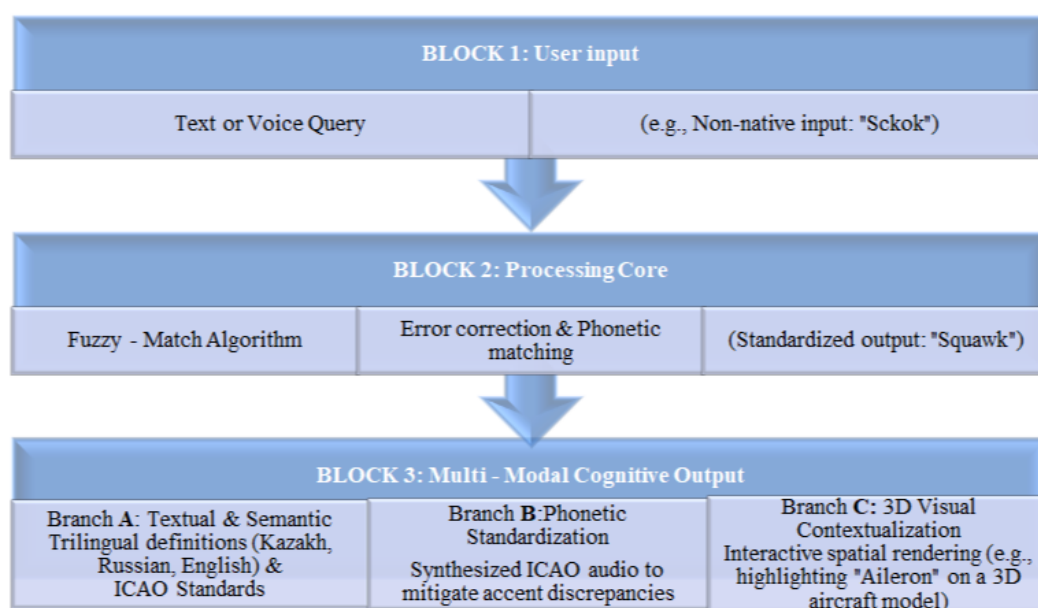


Figure 2 - Technological Integration and UI/UX Architecture of the Mobile Thesaurus

From a pedagogical perspective, the proposed technological architecture can be considered not only as a mechanism for terminology retrieval but also as a digital learning environment for the professional training of future aviation specialists. The combination of textual, phonetic, and visual information provides learners with several complementary ways of approaching a professional concept. Trilingual definitions support the comparison of aviation terminology across Kazakh, Russian, and English, while standardized pronunciation and audio materials provide additional support for the development of professional listening and speaking skills. The 3D visual component, in turn, connects a lexical unit with its corresponding aircraft element or operational context, which can facilitate a more concrete understanding of specialized concepts.

Such organization is particularly relevant for aviation education, where terminology cannot be considered separately from professional actions and operational situations. The thesaurus therefore

creates a connection between term, concept, pronunciation, visual representation, and professional context, allowing learners to move from simple word recognition toward a more integrated understanding of aviation terminology. In this sense, the mobile thesaurus can be used as a supplementary digital pedagogical tool in classroom activities, independent learning, and professional language training. Its structure also provides opportunities for learners to repeatedly access and compare terminology according to their individual learning needs, without being limited to a conventional alphabetical dictionary format.

Conclusion. In the highly standardized and linguistically complex aviation sector, minimizing language barriers requires far more than traditional linear translation. This task demands a comprehensive, multifaceted approach that integrates linguistic modeling, psycholinguistic strategies (Kaya & Ateş, 2023), and modern software development technologies. The present study addresses this need by developing a trilingual mobile thesaurus for future aviation professionals and by treating aviation terminology not merely as a collection of isolated lexical units, but as a system of interconnected professional concepts.

An analysis of a corpus comprising 5,800 lexical units (with plans to expand this to 10,000) demonstrates that developing such a resource goes beyond merely identifying direct equivalents across English, Russian, and Kazakh. The meanings and definitions of terms within aviation terminology are closely linked to specific aircraft systems, technical operation processes, professional duties, or communicative contexts. Therefore, these interconnections must be taken into account when systematizing the terminology. The semantic asymmetries identified among the three languages are of particular importance, especially in situations where a learner knows the lexical equivalent but does not fully grasp its professional meaning or its connections to other concepts.

The proposed technological solution—a cross-platform mobile application utilizing "concept node" architecture, 3D visual contextualization, and "fuzzy-match" search algorithms—aims to address these identified obstacles. This architecture allows a term to be presented not merely as an isolated dictionary entry, but as part of a broader conceptual framework. Such an approach fully aligns with the need to consider professional terminology in conjunction with its context of use. This tool goes beyond mere translation; by clarifying functional relationships, it can reduce the cognitive load associated with searching for specialized terms and interpreting their meanings.

The practical significance and viability of this architecture have been confirmed through official expert assessments by specialists from leading industry enterprises, such as SCAT Airlines and the "405th Aviation Repair Plant." The involvement of aviation industry specialists is of particular importance, as the terminology used in the training materials must align with the linguistic and conceptual structures encountered in actual professional practice. Consequently, this expert assessment serves as a practical basis for validating the proposed thesaurus for further use and development within aviation education and training processes.

Furthermore, the results of this study should be considered within the context of its design characteristics and limitations. The research focused on developing the lexical corpus, semantic structure, and technological architecture of a mobile thesaurus. Although these elements were evaluated by aviation industry specialists, the application's direct impact on user cognitive load was not determined through controlled experimental comparison. Therefore, the conclusion regarding the reduction of cognitive load should be viewed not as a quantitatively proven result of this study, but rather as the intended functional effect of the proposed architecture.

Future research could focus on testing the thesaurus with the participation of both aspiring and experienced aviation professionals. Such studies would make it possible to compare metrics—such as the time required to search for and interpret aviation terms, the accuracy of terminology comprehension, the retention of new vocabulary, and user cognitive load—when using traditional dictionaries versus the proposed mobile environment. These indicators would pave the way for more precisely determining which architectural elements contribute most effectively to terminology processing.

Therefore, the developed thesaurus can serve as a foundation for further integrating multilingual terminological resources into aviation education and professional training. Its use in academic curricula could facilitate a gradual shift from the rote memorization of isolated terms to an understanding of their professional relationships and application. Furthermore, clearer access to terminology within professional maintenance and flight-related contexts could support consistent communication among specialists operating in diverse linguistic environments.

Ultimately, integrating this trilingual thesaurus into academic curricula and professional activities—such as technical maintenance and flight operations—could help reduce human-factor errors stemming from misunderstandings (Chute & Wiener, 1995; Moder, 2013; Tajima, 2004) and thereby strengthen overall aviation safety standards. Thus, the study's primary contribution extends beyond the mere creation of a mobile terminological resource; it also encompasses the development of an approach that integrates multilingual aviation terminology, semantic relationships, and digital technologies into a unified system.

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