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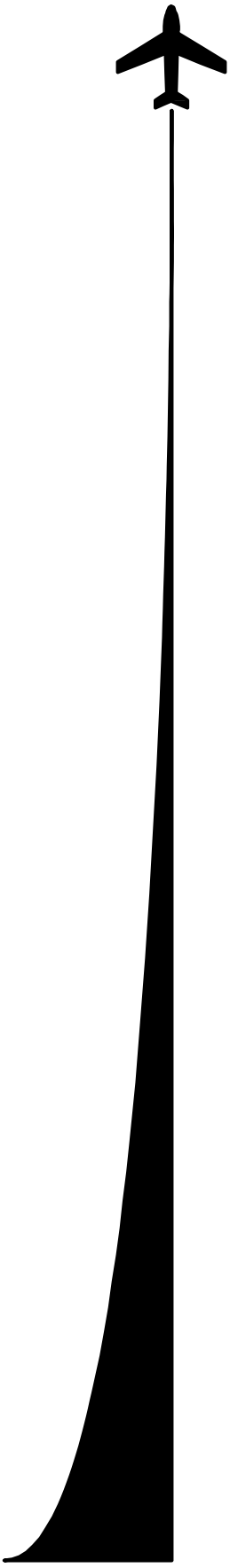

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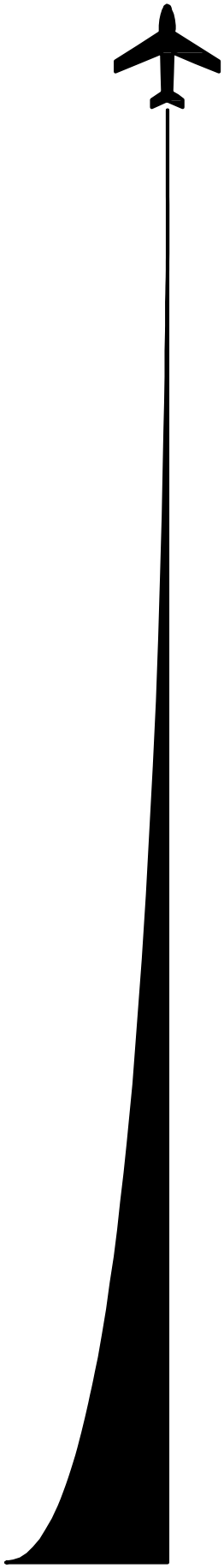

PLENARY SESSION

RESEARCH and TECHNOLOGY – STEP into the FUTURE, 2025, Vol. 20, No. 1, 10-12
Transport and Telecommunication Institute, Lauvas 2, Riga, LV-1019, Latvia

PROMPT ENGINEERING FOR SOFTWARE ENGINEERS: NEW DIGITAL COMPETENCE

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Keywords: Prompt engineering, software engineering education, technical universities, AI competence, curriculum design, educational challenges, problem-solving approaches

The rapid development of artificial intelligence technologies requires software engineers to acquire new competencies to use these tools effectively (Kabashkin, 2023). Prompt engineering, the art of crafting inputs to guide AI models toward desired outputs, has become integral to this skill set. Integrating prompt engineering into technical university curricula ensures that future software engineers are equipped to leverage AI capabilities proficiently.

Incorporating prompt engineering into software engineering programs requires a structured approach:

- **Curriculum Development**: Introduce dedicated courses on prompt engineering principles, techniques, and applications. For instance, courses like "ChatGPT Prompt Engineering for Developers" offer foundational knowledge in this domain (Fulford, 2025).
- **Practical Training:** Implement hands-on projects where students design and test prompts with AI models, fostering experiential learning.
- **Interdisciplinary Collaboration**: Encourage collaboration between computer science, linguistics, and psychology departments to provide a holistic understanding of language nuances in prompt design.
- **Ethical Considerations**: Incorporate discussions on the ethical implications of AI and prompt engineering to ensure responsible use of technology.

Several publications offer valuable insights into prompt engineering. The paper "Automatic Engineering of Long Prompts" explores methods for automating the creation of extended prompts to enhance LLM performance (Hsieh, 2023). The paper "Prompt Engineering a Prompt Engineer" investigates meta- prompting techniques to improve prompt engineering processes (Ye, 2023). The paper "ChatGPT Prompt Engineering for Developers" provides practical guidance on utilizing LLMs for application development (Fulford, 2025).

Educators may encounter several challenges when integrating prompt engineering into the curriculum:

- **Rapid Technological Evolution:** AI technologies evolve swiftly, making it challenging to keep course content up-to-date.
- **Resource Constraints:** Access to advanced AI models and computational resources may be limited in academic settings.
- **Interdisciplinary Complexity:** Prompt engineering intersects with many disciplines, requiring educators to cover different topics.
- **Assessment Difficulties:** Evaluating students' proficiency in prompt engineering can be subjective due to the creative nature of the task.

To address these challenges, the following strategies can be implemented:

- **Continuous Professional Development:** Educators should engage students in ongoing learning to stay abreast of AI advancements, attend workshops, and collaborate with industry experts.

- **Leveraging Open-Source Tools:** Utilize open-source AI models and platforms to provide students with practical experience without incurring high costs.
- **Fostering Interdisciplinary Teams:** Create collaborative teaching teams that combine expertise from various fields to enrich the learning experience.
- **Developing Clear Rubrics:** Establish objective assessment criteria that focus on the effectiveness, creativity, and ethical considerations of prompts designed by students.

Integrating prompt engineering into software engineering (SE) necessitates proficiency computational thinking and in design thinking. These competencies are pivotal for crafting effective prompts that guide AI models to produce desired outcomes.

Computational thinking involves problem-solving methods that draw upon concepts fundamental to computer science. It encompasses skills such as abstraction, decomposition, pattern recognition, and algorithm design, which are essential for developing precise and efficient prompts. The importance of computational thinking in the context of artificial intelligence and operational engineering is highlighted by Shuchi Grover, who notes that it remains relevant even in an environment where large language models (LLMs) generate code, prompting educators to reconsider the amount of programming training required for students (Grover, 2024).

Design thinking is a human-centered approach to problem-solving that emphasizes empathy, ideation, and iterative testing. In prompt engineering, design thinking guides the creation of prompts that are not only technically sound but also aligned with user needs and contexts. The inclusion of design thinking into software requirements engineering has been explored to create human-centered software- intensive systems, highlighting its relevance in developing prompts that resonate with users (Hehn, 2021). The author proposed and developed a bachelor's course, "Cognitive Fundamentals of LLMs Prompt Engineering," based on combining teaching prompting with mastering useful types of cognitive activity.

The course was well-designed using the principles of social constructivism. The course covers the following learning outcomes:

- LO1 Understand the cognitive principles underlying LLMs and prompt engineering.
- LO2 Apply critical thinking to assess and improve prompt engineering techniques.
- LO3 Design, evaluation, and optimization of LLM assignments for various academic and practical scenarios in computer and social sciences.
- LO4 Collaborate in teams to solve complex problems using LLMs, and effectively assess the quality of LLM-generated outputs.

The designed course attempted to combine the study of engineering competencies and the development of the necessary thinking for future engineers. The article considers the problems of presenting the subject and ways of assessing new digital competencies.

Integrating prompt engineering into software engineering education equips students with essential skills to navigate the evolving AI landscape. By addressing educational challenges through strategic approaches, technical universities can prepare a generation of software engineers who can use AI tools responsibly and effectively.

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Transport and Telecommunication Institute, Lauvas 2, Riga, LV-1019, Latvia

LEARNING THE SHAPE OF DEMAND: A GEOMETRIC FRAMEWORK FOR REAL-TIME SHARED MOBILITY

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Keywords: Demand-responsive transport systems, virtual stops, combinatorial complexes, Hodge decomposition

The proliferation of shared and automated transport services has challenged long-standing paradigms in urban mobility. As cities evolve to support flexible, sustainable, and demand-responsive transit, new computational and infrastructural concepts are needed to coordinate users, vehicles, and physical space in real time. At the center of this transformation is the concept of "virtual stops", dynamic data-driven access point where passengers engage with on-demand mobility services. Virtual stops offer the potential to bridge the rigidity of fixed infrastructure with the fluidity of user demand, enabling more adaptive and efficient transport systems.

Recent studies have made important progress toward operationalizing virtual stops in practice. Rule-based methods proposed by Harmann *et al*. (2022, 2023) and infrastructure-aware platforms like KoKoVi (Touko & Rummel, 2023) define and evaluate virtual stop locations based on static spatial features such as intersections, parking bays, or road furniture and regulatory or safety constraints. Parallel efforts by Hub *et al.* (2023) emphasize user experience, introducing augmented reality-based interfaces to help riders locate stops and vehicles, particularly in unfamiliar or unmarked environments.

While these contributions are essential for ensuring feasibility and usability, they also share a common assumption: that virtual stops must be externally defined, selected from a set of static spatial candidates and then filtered based on constraints. Demand is considered retrospectively, used to justify stop deployment, but not to generate or shape it. As a result, these systems risk decoupling virtual stop design from the dynamic, spatiotemporal patterns of urban mobility itself. To address this gap, this research proposes a change of paradigm. Drawing on current advances in geometric deep learning**,** manifold learning and topological data analysis, we propose a framework in which virtual stops and user assignments are inferred as emergent structures within a dynamic spatiotemporal system (Pham *et al.,* 2025; Hofer *et al.,* 2017, Berry & Sauer, 2019; Chakraborty *et al.,* 2020).

More specifically, we model urban mobility demand as a continuous field over space and time, learned from historical and real-time origin-destination (OD) data. This field induces a Riemannian geometry over the urban space, where regions of high curvature correspond to zones of converging user intent. These high-intensity regions act as natural attractors for shared transport and are interpreted as emergent virtual stop locations, adapting dynamically to shifts in demand across time and space.

To represent not only pairwise, but also group-level interactions among users, stops, and vehicles, we use combinatorial complexes (CC), a generalization of graphs that supports higher-order relationships and temporal evolution (Battiston *et al.,* 2021). These structures enable a more expressive encoding of ride-sharing assignments and multi-user coordination, moving beyond traditional graph-based methods.

On this evolving structure, we define assignment signals – probabilistic or flow-based relationships between users, vehicles, and virtual stops – using Hodge decomposition, a technique from algebraic topology that separates these flows into three meaningful components: a gradient

term capturing global coordination, a curl term representing localized inefficiencies or routing loops, and a harmonic term indicating structural or topological bottlenecks (Aoki *et al.*, 2022; Kan & López, 2022). These components are both interpretable, but also learnable, serving as objectives and constraints in our predictive model.

Another key advantage of this approach is its ability to cluster demand naturally, increasing vehicle occupancy and reducing the number of vehicles required to satisfy user needs (Hermann *et al*., 2024). This is particularly important for improving pooling efficiency and achieving scalable, sustainable operations.

The framework is evaluated using both real-world and synthetic datasets and benchmark against rule-based and graph-based baselines. Results might show that emergent virtual stops closely align with demand hotspots and adjust fluidly as conditions change and lead to measurable improvements in waiting times, vehicle utilization, and route efficiency. In addition, at the topological level, we analyze the decomposition of assignment flows, quantifying reductions in cyclic routing and clearer detection of structurally constrained areas via harmonic energy.

To conclude, this work proposes a new perspective for shared mobility systems, one that does not merely optimize within existing constraints, but learns structure from collective behavior, and coordinates dynamically as user requests change and evolve.

The research is supervised by Dr. Rita Cyganski.

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RESEARCH and TECHNOLOGY – STEP into the FUTURE, 2025, Vol. 20, No. 1, 16-17
Transport and Telecommunication Institute, Lauvas 2, Riga, LV-1019, Latvia

A MULTI-CRITERIA ANALYSIS OF OPEN-SOURCE RESEARCH AGENT SOLUTIONS

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Keywords: Deep research, research agents, large language models, information retrieval, scientific discovery, comparative analysis

The emerging field of Large Language Models (LLMs) is fueling the creation of Deep Research agents, or specialized AI tools for complex online investigations. This paper presents a comparison of the top open-source Deep Research agent repositories and vendor solutions. A systematic multi-criteria framework is used for evaluating their technological foundations and capabilities for automating online research and knowledge discovery.

The Deep Research domain is characterized by both commercial and open-source developments. Some examples of vendor in this domain are OpenAI, Google and Perplexity AI, which are meant for general use and ease of access. These platforms leverage sophisticated LLMs to search the Internet, gather information, and create reports complete with works cited. At the same time, open-source projects such as gpt-researcher (assafelovic, 2023), Virtual Lab (Swanson *et al.*, 2024), SciAgents (Buehler, 2024), Holosophos (Gusev, 2024), AI-Scientist (Lu *et al*., 2024) and Oval Storm (Shao *et al*., 2024) develop a variety of information retrieval capabilities and agentic structures. This paper examines a sample of open-source repositories and vendor solutions to discuss their technological approaches and to offer recommendations for future work.

A systematic multi-criteria analysis framework was developed and used to evaluate Deep Research solutions. The framework includes key technical categories:

- Information Gathering Approach
- Level of Source Analysis
- Data Storage Solutions
- LLM Capabilities Utilized
- Prompt Engineering Techniques Utilized
- Agentic Workflow Approaches
- Frameworks and Libraries Used
- Memory Organization
- Qualitative Assessment.

Generative AI technology was not only an object of this research, but also a useful tool. For open-source repositories analysis LLM based approach was used with the Gemini 2.0 Flash Thinking Experimental 01–21 model. The prompts were designed specifically to help the LLM identify and extract information that was in a structured format. This approach was used to help increase the efficiency and depth of the evaluation compared to that of a traditional manual review. The accuracy of the LLM's analysis was checked and contextualized by human researcher at every stage of the process.

The comparison shows that different Deep Research solutions are characterized by focuses on certain aspects such as:

- Strategies for retrieving information: keyword based, semantic, vector search,
- Types of data storage: vector databases, relational databases, file storage,
- Agentic workflow architectures: single agent, multi agent, orchestration mechanisms.

Some of the key differences of analyzed open-source projects include the use of vector databases for long term memory, the integration of complex multi agent communication protocols for large scale tasks, and the integration of specialized NLP models for data source analysis. Different architecture concepts are being implemented: while Virtual Lab and SciAgentsDiscovery demonstrate the effectiveness of multi agent systems for conducting complex research tasks, gpt-researcher and Holosophos present potential individual and group agent designs and information retrieval strategies.

The comparison offers practical findings for the improvement of the LLM-based research tools. A modular architecture is suggested for flexible and maintainable implementations, leveraging agentic frameworks like Smolagents or Langchain. The information retrieval approach combines keyword search with vector semantic search to achieve a good balance between efficiency and relevance.

Deep Research agents are a significant step forward in the evolution of LLM- powered tools for scientific exploration and hold the promise of reducing human burden by enabling the automation of many analytical workflows and thus speeding up the process of knowledge extraction. Proposed multi-criteria framework has proven its applicability for combative analysis of the open-source solutions, for identifying key architectural patterns, and for helping the development of improved LLM-based research tools. As a result of the research this paper presents actionable insights on how best to deploy LLMs to support the scientific community and fuel the evolution of new forms of automated knowledge extraction, classification and further analysis, therefore laying the solid foundation for responsible use of Generative AI based solutions in various areas of Scientific Research.

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The research is supervised by Dr.sc.ing., Professor Dmitry Pavlyuk.

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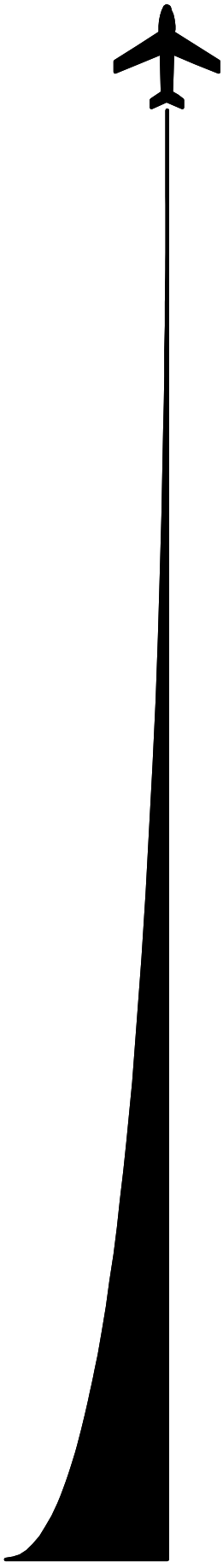

Session 1

Computer Problems of the Information Society and the Modern Electronics

Informācijas sabiedrības datorizācijas problēmas un mūsdienu elektronikas pasaule

RESEARCH and TECHNOLOGY – STEP into the FUTURE, 2025, Vol. 20, No. 1, 20-21
Transport and Telecommunication Institute, Lauvas 2, Riga, LV-1019, Latvia

INTERPRETABLE AND INTEGRATED CHURN EXPLANATION FRAMEWORK (IICEF) FOR MOBILE BANKING: AGGREGATING MULTIMODEL EXPLANATIONS IN A TRANSPARENT ARCHITECTURE

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Keywords: Churn prediction, explainable AI, machine learning, behavioral analytics, mobile banking, SHAP, predictive analytics

Mobile banking adopts churn prediction as an essential task because maintaining customer retention directly affects how well the platform performs in the long run. Traditional machine learning models achieve strong predictive outcomes yet remain untransparent to end users and they offer limited actionable results throughout various organizational stakeholders. The varied approaches to explainability techniques produce fragmented explanations which reduces their practical value to business organizations.

This research describes IICEF — Interpretable Integrated Churn Explanation Framework as a new architecture that merges several machine learning models and four explanation techniques to produce a unified aggregated interpretation for mobile banking customer churn. The complete system runs on Python through the integration of several libraries including scikit-learn, xgboost, catboost, tensorflow, and shap which enables both complete reproducibility along with maintainability.

The research evaluation includes five machine-learning models represented by Logistic Regression, Random Forest, XGBoost, CatBoost and Multi-Layer Perceptron (MLP). The models receive interpretation through SHAP (SHapley Additive Explanations), LIME, permutation importance and partial dependence plots analysis. A single unified space for interpretation combines different explanation outcomes to reveal factors which provoke customers to churn regardless of the modeling approach.

The main innovation of this work involves the aggregation method where multiple predictive models provide unified explanations in a single analytical structure but prior literature had not established such a system. Simulation of the Telco Customer Churn data (Kaggle, 2020) served as input for all training and evaluation operations with features including login frequency, transaction volume, session duration and inactivity periods. The selection of synthetic data allows for both privacy protection and results reproduction.

Power BI dashboards display the outputs which enables technical staff together with decision-makers to examine churn situations while testing assumptions to enhance retention methods. IICEF represents a flexible solution for explainable AI (XAI) which serves as a connection between complex modeling work and actual business deployment within digital banking domains.

The research is supervised by Dr.sc.ing. Professor Dmitry Pavlyuk.

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RESEARCH and TECHNOLOGY – STEP into the FUTURE, 2025, Vol. 20, No. 1, 22-23
Transport and Telecommunication Institute, Lauvas 2, Riga, LV-1019, Latvia

EMPLOYEE WELL-BEING THROUGH AI: A MACHINE LEARNING APPROACH TO ANALYZING FEEDBACK AND PREDICTING OUTCOMES

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Keywords: Human resource management, analytics, sentiment analysis, ethics

The integration of artificial intelligence (AI) and machine learning (ML) in human resource (HR) management has revolutionised employee well-being analysis, enabling organisations to assess workforce satisfaction and predict potential risks, such as burnout and attrition (Chaudhary *et al.*, 2023; Awada *et al*., 2024). This study examines how AI-driven sentiment analysis and predictive modelling can extract valuable insights from employee feedback, enabling organisations to proactively improve workplace conditions (Sin *et al.*, 2022). While AI enhances the accuracy and efficiency of HR decision-making, its application raises significant ethical and legal concerns, including data privacy, transparency, and bias (Huang *et al.*, 2023; Gričnik *et al.*, 2024).

This study employs a structured approach to data extraction, feature selection, and visualisation to identify key factors influencing employee well-being. Data collected from multiple sources, including HR databases, employee surveys, sentiment analysis of textual feedback, and, where applicable, anonymised digital well-being metrics. The dataset is analysed by categorising data types (numerical, categorical, and textual) and evaluating key features such as employee department, well-being scores, and feedback sentiment. Feature selection is conducted using statistical methods such as correlation analysis and ANOVA, alongside machine learning techniques like decision trees to determine feature importance. Visual exploration includes heatmaps for numerical correlations and bar charts for categorical distributions, such as identifying top stress factors in the workplace. The results focus on features that exhibit significant patterns, high correlations, or strong predictive value, ensuring robust insights into employee satisfaction and engagement trends and overall well-being.

This research investigates the effectiveness of machine learning models in predicting employee satisfaction and well-being by analysing structured and unstructured HR data. Unlike existing models that primarily rely on static survey data, the proposed approach integrates real-time feedback and contextual workplace factors to enhance prediction accuracy. By applying advanced AI techniques, including deep learning models, natural language processing and Explainable AI (XAI) methods, this study examines patterns in employee engagement and performance to develop actionable HR strategies (Sin *et al*., 2022). Additionally, the research addresses bias, data security, and GDPR compliance, aligning with the EU AI Act by using anonymised and voluntary feedback to ensure ethical and valuable application of AI in HR analytics. (Fenwick, Molnar, and Frangos, 2024).

Through a comparative analysis of different machine learning algorithms, this study evaluates the predictive accuracy of AI models in identifying at-risk employees and suggests frameworks for ethical and legal compliance in AI-driven HR systems. The findings aim to provide a roadmap for integrating AI into HR practises while maintaining fairness, privacy, and trust in employee data management.

The research is supervised by Dr.sc.ing., Professor Irina Yatskiv.

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RESEARCH and TECHNOLOGY – STEP into the FUTURE, 2025, Vol. 20, No. 1, 24-25
Transport and Telecommunication Institute, Lauvas 2, Riga, LV-1019, Latvia

DEVELOPMENT OF A DATA SYNCHRONIZATION ALGORITHM AND VISUALIZATION FOR MULTI-STREAM DATA IN WAAM PROCESSES

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Keywords: Wire arc additive manufacturing (waam), data synchronization, spatial-temporal data processing, multisource data integration, data visualization, data-driven decision making

Modern manufacturing processes, including Wire Arc Additive Manufacturing (WAAM), generate large volumes of heterogeneous data, the analysis of which is critical for quality assessment and process optimization (Orlyanchik *et al.*, 2025). This study addresses the challenge of synchronizing data streams originating from multiple sources during the WAAM process, with the goal of preparing them for subsequent analytical use.

The aim of this work is to propose a methodology for synchronizing spatial, temporal, and functional parameters of data that was collected both before and during the printing process. The types of data used include:

- Initial Data — parameters defined prior to the start of printing (such as the path coordinates and process-specific settings), structured in tabular format and saved as a CSV file;
- Processing Data — real-time data collected during printing. This data is acquired from multiple subsystems using custom software in C++, resulting in three separate CSV files, each representing a different aspect of the process.

These include:

(1) process-specific data (Dataset 1), which consists of momentary robot position coordinates (X, Y, Z), energy parameters, and timestamp;
(2) the laser scanner data (Dataset 2), which contains measured 2D points of the observed in a given moment surface (X, Z), signal intensity, and timestamp;
(3) momentary robot position coordinates (X, Y, Z) and timestamp during the scanning process (Dataset 3), which is used for 2d to 3d scanned points translation and future synchronization.

The complexity of synchronization between these sources prevents a comprehensive analysis of the process on a layer-by-layer basis.

The developed synchronization algorithm performs spatial and temporal alignment of the datasets, merging them into a unified analytical space based on functional “layer” concept. The result is an interactive visualization that enables layer-wise analysis of printing parameters. This opens up new opportunities for detailed monitoring, anomaly detection, and the implementation of data-driven approaches in WAAM processes (Liu *et al.*, 2018).

The research is supervised by Dr.sc.ing., Professor Mihails Savrasovs and consulted by Head of TSI Additive Lab dipl. Engineer Arseniy Kisarev.

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APPLYING LARGE LANGUAGE MODELS FOR AUTOMATED TEST GENERATION

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Keywords: Machine learning, large language model, automated testing, test generation, selenium, web application testing

Automated testing in software development plays a critical role in enhancing software quality while reducing both the time and cost associated with the testing process. As highlighted by Nettur *et al.* (2025), automation in software testing not only improves efficiency, but also helps organizations achieve higher accuracy and reliability in their software products.

With the rapid evolution of artificial intelligence (AI) and Machine Learning (ML) techniques, there has been a growing interest in leveraging these technologies to further optimize, prioritize and generate automated tests. According to Mehmood *et al.* (2024), ML, deep neural networks, generative AI and Large Language Models (LLMs) contribute to test automation by optimizing test selection and prioritization, improving the overall accuracy and reliability of the testing process. Their review highlights several methodologies, with most studies focusing on test case optimization and prioritization. In addition to these core areas, authors mention the possibility of applications of generative AI and LLMs for generations of automated tests. For this purpose, they highlight the role of computer vision techniques in identifying UI elements for automated testing.

This study focuses on applying LLM for generating automated tests based on screenshots and HTML structure of web pages and the zero-shot prompting method. This combination of input data allows for a more comprehensive representation of the web application structure and appearance, which may improve the quality of generated tests. The evaluation of this approach is based on key performance metrics related to test execution and outcome analysis. An open-source web application serves as the testing environment and each generated test is evaluated using a set of predefined metrics, including test executability, test execution time, test accuracy (measured through positive and false positive rates), mutation testing effectiveness (Mutation Score) and UI element visibility coverage.

The primary objective of this study is to assess whether the proposed approach enables the successful generation of automated tests for the Selenium tool for automating web application testing. To ensure a thorough evaluation of the proposed approach, this study takes into account the work of Khaliq *et al.* (2023), which applied computer vision techniques to generate tests based only on web application screenshots. Using the same web application and covering similar functionalities helps to understand the advantages and limitations LLM-based method.

The research is supervised by Dr.sc.ing., Professor Irina Pticina.

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RESEARCH and TECHNOLOGY – STEP into the FUTURE, 2025, Vol. 20, No. 1, 28-29
Transport and Telecommunication Institute, Lauvas 2, Riga, LV-1019, Latvia

A CUSTOMER SEGMENTATION MODEL USING ENSEMBLE CLUSTERING AND AUTOENCODERS

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Keywords: User segmentation, consensus clustering, feature extraction, deep learning, customer behaviour

Customer segmentation has traditionally relied on clustering techniques such as K-means, DBSCAN, and hierarchical clustering. These methods have been effective in grouping customers based on shared behaviors and attributes. However, they struggle with high-dimensional, dynamic, and sparse datasets, limiting their adaptability to modern data environments. A systematic review of algorithmic customer segmentation in (Salminen *et al.,* 2023) has highlighted that traditional clustering remains dominant in the field of customer segmentation despite its inherent limitations. With businesses generating vast and complex datasets, there is a growing need for more robust segmentation approaches that integrate advanced machine learning techniques.

The introduction of deep learning, particularly autoencoders, has provided a transformative approach to customer segmentation. Autoencoders compress high-dimensional data into compact latent representations, improving clustering accuracy by reducing noise and enhancing feature extraction. Studies have demonstrated the effectiveness of autoencoder- enhanced clustering in financial time series, where dimensionality reduction enables better segmentation of non-stationary and complex market behaviors (Cortés *et al.,* 2024). Similarly, stacked autoencoders have been successfully applied in the power grid sector, achieving superior classification of electricity consumption patterns and electric vehicle charging behaviors by extracting latent features before clustering (Deng *et al.,* 2022). These findings highlight the ability of autoencoders to enhance clustering performance in various industries.

Ensemble clustering has emerged as another major advancement in customer segmentation. Instead of relying on a single algorithm, ensemble clustering integrates multiple clustering methods to generate a more stable and accurate segmentation model (Hicham and Karim, 2022). By combining multiple clustering outputs into a consensus solution, this approach mitigates algorithmic bias and enhances segmentation.

This study proposes a novel model that integrates stacked autoencoders with ensemble clustering to enhance customer segmentation. The stacked autoencoders will be used for feature extraction, capturing non-linear patterns in customer behavior and reducing dimensionality. The latent representations generated by the autoencoders will then serve as input for an ensemble clustering framework that combines the strengths of multiple clustering algorithms. This approach aims to improve the performance and accuracy of segmentation of customers.

The main research question that this study aims to answer is - How does integrating stacked autoencoders with ensemble clustering improve performance (segmentation quality) and accuracy compared to traditional methods?

To answer this question, the dataset used for the KDD Cup 2009 (KDD Cup, 2009) from the French Telecom company Orange is used and the algorithms K-means, DBSCAN, and Mini Batch K-means are used to realize the proposed approach in python. As criteria for evaluating the performance of the proposed approach, metrics - Silhouette Score, and Davies-Bouldin Index are used whereas the Adjusted Rand Index is used to evaluate the accuracy. The author assumes that the use of this approach will increase the accuracy of the result for a dataset of high dimensionality and high degree of heterogeneity.

This research is supervised by Dr.sc.ing. Professor Irina Jackiva.

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RESEARCH and TECHNOLOGY – STEP into the FUTURE, 2025, Vol. 20, No. 1, 30-31
Transport and Telecommunication Institute, Lauvas 2, Riga, LV-1019, Latvia

ANALYSIS OF BLACK-BOX MODELS WITH EXPLAINABLE AI ON A TARGETED GROUP HATE SPEECH DATASET IN SOCIAL MEDIA

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Keywords: Hate speech detection, XAI, black-box models, social media, machine learning

Advances in natural language processing (NLP) and explainable artificial intelligence (XAI) have increased the use of "black-box" models for detecting and understanding hate speech in social media. Opaque black-box models often hinder interpretability, but XAI techniques enable researchers to explain the decisions made by these models. In this research, we analyze the decisions made by pre-existing black-box models to detect hate speech for targeted groups from a text dataset created from multiple pre-existing sources.

According to the United Nations (2024), hate speech is defined as "any kind of communication in speech, writing or behaviour, that attacks or uses pejorative or discriminatory language with reference to a person or a group on the basis of who they are, in other words, based on their religion, ethnicity, nationality, race, colour, descent, gender or other identity factor." Previous research from Antypas and Camacho-Collados (2023) shows the wide variety of labeling and creating data to detect hate speech. The labeling process varies from binary classification of hate speech to multiclass labeling with the targeted groups and/or if the text is offensive. The dataset created includes hate speech classification and labels of the targeted groups, based on identity factors from the United Nations definition.

A review of XAI techniques by Linardatos, Papastefanopoulos and Kotsiantis (2020) states that black-box models, such as deep learning and ensemble methods, often achieve superior accuracy due to their ability to learn complex representations of data. However, this increased accuracy often comes at the expense of interpretability, making it challenging to understand the reasoning behind a model's decisions.

To explain the decisions of black-box models, two XAI techniques utilized are local interpretable model-agnostic explanations (LIME) and Shapley Additive explanations (SHAP). These interpretability methods explain any black-box model after an individual prediction, providing information on the model's decision for post-hoc interpretability. Other XAI techniques exist that explain the whole black-box model or are specific to model architecture though are not considered in this study.

Recent studies have applied XAI to multilingual hate speech detection. Hashmi et al. (2024) used LIME to interpret model predictions for both hateful and non-hateful instances across 13 languages, while Siddiqui *et al.* (2024) applied LIME to a multilingual hate speech detection model with target group labels. However, the criteria for selecting individual samples for XAI analysis were not detailed beyond whether the predictions were correct.

In this research, we aggregate XAI explanations for samples sharing the same identity factor, comparing cases predicted as hate speech with those not predicted as hate speech to better understand model behavior. This research aims to detect bias of black-box models that detect hate speech grouped by identity factors.

The research is supervised by Dr.sc.ing., Professor Dmitry Pavlyuk.

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RESEARCH and TECHNOLOGY – STEP into the FUTURE, 2025, Vol. 20, No. 1, 32-33
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AUTOMATED RISK SCORING SYSTEM FOR FINANCIAL INSTITUTIONS

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Keywords: Synthetic data, risk scoring, fraud detection, XAI, AML, financial institutions

The financial sector encounters difficulties in overseeing and identifying fraudulent operations. The Basel AML/CFT Index 2024 identifies fraud as a principal offence within banks and financial institutions (Basel Institute on Governance, 2024). The scale of money laundering remains significant, amounting to 2-5% of global GDP annually, which is between €715 billion and €1.87 trillion per year (United Nations., 2024.). To encourage financial stability and enhance risk management, new rules and more stringent requirements for the ML risk assessment process are frequently implemented (FATF, 2025). This study aims to create an automated risk-scoring system for client transactions that will enhance financial institutions' ability to identify money laundering situations and comply with regulatory standards.

The decision to initiate the development of an automated risk assessment system involved the generation of synthetic data for the following reasons: insufficient access to extensive real-world data, coupled with the absence of data encompassing all potential suspicious circumstances, necessitates the use of synthetic data to enhance the diversity and resilience of deep learning model training (Altman *et al.*, 2023). In this context, the creation of synthetic data was used. An initial dataset of 60 distinct fraud types with a ratio of 1-5% suspicious transactions was created to simulate actual fraud trends.

Due to the limitations of real and synthetic data, several deep learning models have been applied, including Logistic regression, Random forests, and Gradient boost models, to identify the algorithm that is more accurate and efficient in detecting suspicious activity. To meet regulatory requirements and to increase model interpretability, explainable artificial intelligence (XAI) techniques, such as SHapley Additive Explanations, were employed to explain the fraud detection results (Kute *et al.*, 2021).

The implementation of such a system is also subject to various limitations; we cannot claim that this system will be unique and suitable for any type of financial institution; additionally, the following factors must be considered when implementing this system: geographic location, main business sectors, specific types of transactions, and the current percentage of true matches for suspicious transactions. As a result, financial institutions should prioritize the scenario groups and configure the model based on the above parameters, thereby the system will meet the risk profiles and regulatory requirements.

The proposed system of automated risk analysis is expected to increase the ability of financial institutions in risk identification and management, improving compliance and fraud prevention decision-making.

The research is supervised by Dr.sc.ing., Associate Professor Nadezda Spiridovska.

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RESEARCH and TECHNOLOGY – STEP into the FUTURE, 2025, Vol. 20, No. 1, 34-35
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ADAPTIVE BID MANAGEMENT IN PAY-PER-CLICK ADVERTISING USING REINFORCEMENT LEARNING

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Keywords: Pay-per-click advertising, reinforcement learning, autonomous bidding, Amazon marketplace, real-time bidding, Markov decision process

Pay-per-click (PPC) advertising has become a critical component of e-commerce marketplaces, with Amazon's advertising services generating over $56 billion in 2024 (Marketplace Pulse, 2025). Effective optimisation of PPC campaigns is crucial for sellers, yet manual bid management is inefficient and struggles to react to dynamic market conditions and evolving consumer behaviour. This paper addresses the problem of suboptimal and labour-intensive PPC bidding by developing autonomous bidding strategies using reinforcement learning (RL).

The bidding process on Amazon's marketplace is formalised as a Markov Decision Process (MDP), where each state captures the campaign context (e.g., keyword, budget, and recent performance), an action corresponds to adjusting a bid, and the reward reflects advertising success (such as profit or conversions). This formulation enables the agent to account for the long-term effects of bid decisions rather than just immediate outcomes, aligning with the sequential nature of advertising auctions (Jeunen *et al*., 2022). Building on advancements in RL for ad auctions (Zhou *et al.*, 2024; Zhao *et al.*, 2018; Cai *et al.*, 2017), two approaches were implemented: a value-based method (Q-learning) that learns optimal bid values through trial-and- error, and a policy-gradient method (Proximal Policy Optimisation, PPO) that directly optimises a bidding policy. These algorithms allow an agent to continuously adapt bids in response to real- time feedback, in contrast to static rule-based strategies.

RL agents were trained and evaluated using AuctionGym, a simulation environment for online advertising auctions introduced by Amazon researchers (Jeunen *et al*., 2022), enabling safe and reproducible testing of bidding strategies. Experimental results show that the RL-driven strategies outperform traditional rule-based bid management. Campaigns that utilised RL agents achieved higher conversion rates and significantly better return on ad spend (ROAS - more sales per advertising dollar) than baseline rules while greatly reducing the manual effort required for bid adjustments. These RL policies effectively adapt to changing competitor bids and market trends, providing a clear performance advantage over static bidding rules.

This study underscores the potential of RL to transform PPC campaign management on Amazon. Practical implications and addressing key challenges were discussed. Defining an effective reward function proved difficult – reward schemes focusing on immediate conversions versus long-term profit led to divergent bidding behaviours. Combining revenue and cost in the reward (effectively optimising for ROAS) produced the best balance of growth and efficiency. Finally, training solely in simulation has limitations: discrepancies between the simulated and real marketplace conditions necessitate fine-tuning and cautious deployment to ensure the learned policy performs well live. Overall, this work demonstrates that deep RL techniques can autonomously optimise PPC bids with superior outcomes, pointing to a promising direction for next-generation digital advertising.

The research is supervised by Dr.sc.ing. Professor Dmitry Pavlyuk.

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RESEARCH and TECHNOLOGY – STEP into the FUTURE, 2025, Vol. 20, No. 1, 36-37
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DEVELOPING A STATION-BASED MONTHLY DEMAND FORECASTING SYSTEM FOR CAR RENTALS USING DATA- DRIVEN ALGORITHMS

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Keywords: Car rental, demand, station based, machine learning, hybrid

The importance of the car rental as a service has been grown rapidly in the recent years, driven by the shift towards shared economy approach that moves away from the private car owning (Jędrzejczyk, 2024). The car rental as a service has transformed from the traditional short term car rental that was mainly driven by the tourism sector to the car rental services that are used for private individuals or corporate demand. Forecasting car demand becomes increasingly challenging for the rental industry with the introduction of various short-term mobility solutions, such as car-sharing and subscription services, in addition to traditional short-term rental mainly dependent on the travel demand.

The focus of researches have evolved from the standalone pricing predictions to demand predictions and, subsequently, to the more complex model building with supply-demand matching optimization problems and models for solution (Oliveira, 2017).

Recent studies explore extensively the car sharing hourly demand forecasting using geospatial data, driven by the rapid growth of particular segment, however, there has been very limited recent studies of the fleet demand forecasting for long term planning that is crucial to the industry, given that car rental sector is capital intensive as well as fact that vehicle acquisition has limitation in short term dictated by the procurement cycle of the fleet (Lazov, 2017).

Moreover, demand forecasting models may produce different outcomes for the station-based services, where cars pick up and drop off occur at designated branches or free-floating services, which allow flexible car pick up and drop off locations. Also, different factors should be taken into account for the short term versus mid and long term forecasting (Zhang *et al.*, 2022).

According to the recent studies the sufficient data size availability is crucial to produce solid prediction result, therefore approach of mixing of the synthetic data with original data to be able to train models improves their performance (Albrecht *et al.*, 2024; Chatterjee *et al.*, 2025). The initial data of this study is obtained from internal company source. Due to the sensitive nature of the dataset, it is not publicly available. Access to real world operational data provides a unique opportunity to evaluate model performance under authentic conditions, that is typically constrained to synthetic datasets in similar studies.

The current study addresses mid-term forecasting of fleet demand for multi service car rental fleet planning, which is constrained by the complexity of relationships among numerous factors influencing car demand.

This study proposes hybrid model for time series forecasting to achieve high accuracy in car demand prediction. To ensure data homogeneity, the initial preprocessing step involves segmenting the fleet based on fleet class, followed by clustering within each segment. A stacking ensemble learning technique is then employed, integrating multiple machine learning models with an emphasis on advanced multivariate time series projection such as VAR, LSTM, TFT, N-BEATS, and Mamba, which are capable to predict multiple interrelated variables alongside

demand, rather than using these variables solely as regressors. The final prediction is produced by a meta-learner, selected based on the model with the lowest error rate.

The research is supervised by Dr.sc.ing., Associate Professor Nadežda Spiridovska.

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RESEARCH and TECHNOLOGY – STEP into the FUTURE, 2025, Vol. 20, No. 1, 38-39
Transport and Telecommunication Institute, Lauvas 2, Riga, LV-1019, Latvia

DESIGN THINKING AS A CATALYST FOR WEB INNOVATION IN ENTERPRISES

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Keywords: Design thinking, web innovation, user-centric

Enterprises often struggle with web innovation due to rigid, traditional development methods. The classic waterfall approach, for example, often results in underperforming systems delivered over budget and behind schedule (Chart, 2021) In such environments, user needs are frequently overlooked until late in the process. This lack of early, continuous user involvement is critical – customer involvement has been identified as the number one factor for project success, and its absence is a leading cause of project failure in IT initiatives (Chart, 2021) Consequently, enterprise web projects can miss the mark on user expectations, hampering innovation and business value.

Design thinking is a promising approach to address these challenges by introducing a human-centered, iterative process. It has gained significant traction in the business world to drive innovation through a focus on end-user needs (Kwon *et al.*, 2021). Unlike traditional methods that emphasize upfront specifications and linear execution, design thinking encourages empathy with users, creative ideation, rapid prototyping, and continuous user feedback. This user-centric mindset has been shown to spur more innovative solutions and can lead to differentiation and competitive advantage for enterprises (Gibbons, 2016). In large organizations, design thinking also helps break down silos and align cross-functional teams around the user, creating an enterprise culture that values experimentation and customer insight.

My working hypothesis is that applying design thinking in enterprise web projects will lead to measurably better innovation outcomes than traditional development methods. I hypothesize that a web project using design thinking will achieve higher user experience ratings, faster development cycle times, and lower defect rates post-launch, resulting in greater overall project success.

To test the hypothesis, I conducted an in-depth case study at an enterprise. I selected a forthcoming internal web application as the pilot project and implemented a full design thinking framework with the team. The team progressed through the five key stages of design thinking – Empathize, Define, Ideate, Prototype, and Test (Shrey, 2021). During these stages, data were collected via multiple methods: user research (surveys and interviews), iterative development of low-fidelity and high-fidelity prototypes, usability testing in Test to gather feedback on the solutions. Throughout the project, it was tracked development metrics (such as time to first prototype, total development duration, and number of change requests) and gathered qualitative insights from team retrospectives. Then a comparative analysis was performed against a similar web project completed previously under a waterfall model within the same company to isolate the effects of the design thinking approach.

Several criteria have been established to evaluate the results and quality of the design thinking intervention: quality of user experience - measured by usability test scores, development efficiency - measured by development time, business impact - measured by return on investment, team engagement - assessed qualitatively through team feedback.

The introduction of design thinking yielded notable improvements in the pilot project's outcomes compared to the traditional approach. Development time was reduced by approximately

20%, and post-launch defect rates dropped by about 30%, indicating higher build quality. User experience results were especially positive: the new web application prototype achieved a System Usability Scale score of 85 (graded "excellent"), compared to 68 for the earlier version that had been developed without a user-centered process. In user testing sessions, participants encountered fewer navigation issues and reported that the new design better met their needs. Moreover, project stakeholders reported higher satisfaction with both the process and outcome, citing improved team communication and a clearer vision of the end-user throughout development. These findings align with industry reports on design thinking in enterprises – for example, IBM's adoption of design thinking in product teams led to releases reaching the market twice as fast as before and an over 300% ROI in one study (Shrey, 2021) illustrating that the case results are part of a broader trend of efficiency and value gains.

In conclusion, the study demonstrates that design thinking can act as a powerful catalyst for web innovation in enterprise environments. By centering the development process on user needs and iterative experimentation, enterprises overcome many limitations of traditional methods, achieving faster delivery, improved usability, and greater project success. This observation echoes prior research suggesting that design thinking blends creative and analytical approaches to significantly improve innovation outcomes in organizations (Liedtka, 2017).

The research is supervised by Dr.sc.ing., Associate Professor Nadezda Spiridovska.

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Transport and Telecommunication Institute, Lauvas 2, Riga, LV-1019, Latvia

PERFORMANCE EVALUATION OF BLOCKCHAIN CONSENSUS MECHANISMS USING FUZZY LOGIC-BASED DECISION SUPPORT SYSTEMS

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Keywords: Blockchain, consensus mechanism, performance evaluation, fuzzy logic, decision support system

Blockchain technology has become an important facilitator of decentralized, secure, and transparent information management. Consensus algorithms are the backbone of blockchain networks, providing trust, reliability, and authenticity in a distributed environment. However, selection of the most suitable consensus protocol is a major challenge because of the inherent trade-offs between scalability, security, transaction fees, latency, and energy efficiency. Kaur and Gupta (2021) and other recent studies highlight that, although numerous consensus mechanisms have been suggested, no single protocol can fully optimize all performance metrics, thus a systematic evaluation that is tailored for diverse application requirements is necessary. Despite the widespread theoretical evaluations of consensus mechanisms presented in the literature, there is a significant lack of evaluations conducted in controlled experimental settings. (Touloupou *et al.*, 2022). This research aims to bridge this gap by creating an autonomous benchmarking testbed that would compare the efficiency of five most prevalent consensus algorithms: Proof of Work, Proof of Stake, Practical Byzantine Fault Tolerance, Delegated Proof of Stake, and Proof of Authority.

To create a reproducible and controlled testbed, a Docker- and Kubernetes-based blockchain benchmarking framework has been implemented. The crucial performance indicators such as Transactions Per Second (TPS), latency, transaction fees, security resilience, and energy consumption are gathered by using BlockBench, Hyperledger Caliper, and Gromit (Touloupou *et al.*, 2022). These metrics deliver insightful information about the performance-security-efficiency trade-offs, thus allowing a comprehensive comparison of various consensus mechanisms.

A significant contribution of this work is the creation of a Fuzzy Logic-Based Decision Support System (DSS) for an adaptive assessment of consensus mechanisms. Conventional rule-based selection mechanisms typically depend on fixed thresholds or deterministic conditions, restricting their potential to assist real-world blockchain applications in heterogeneous environments. In contrast, fuzzy logic provides a more flexible and context-sensitive decision-making process because it integrates empirical benchmarking data with a systematic option framework (Gardas *et al.*, 2022). The method provides the possibility of assessing several factors at the same time, thereby transcending uncertainties, variabilities, and trade-offs that cannot be handled by traditional ranking systems.

The benchmarking testbed systematically varies critical parameters, such as network sizes (4, 8, 16, and 32 nodes), block sizes (1KB, 2KB, and 4KB), and transaction load intensities (100, 500, and 1000 TPS), to evaluate scalability, efficiency, and robustness in realistic conditions. From real-time performance metrics, the fuzzy logic model offers flexible and dynamic guidance, allowing blockchain developers, businesses, and researchers to enhance consensus selection based on application-specific requirements.

This study contributes to both academic research and real-world industrial applications by developing a large-scale empirical benchmarking and decision-making framework that enhances

the understanding of blockchain performance dynamics. By combining theoretical understanding with implementation, this research proposes a data-driven methodology to determine the most appropriate consensus mechanism for blockchain networks. The proposed model offers a formalized and clear decision-making framework, thereby enabling developers, businesses, and researchers to apply a scalable, agile, and effective approach to blockchain optimization.

The research is supervised by Ph. D., Professor Emmanuel Merchán.

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UTILIZING MMWAVE RADAR FOR MOTION PLANNING OF A MOBILE ROBOT IN A DYNAMIC ENVIRONMENT

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Keywords: mmWave radar, autonomous navigation, dynamic environment, motion planning

Motion planning for a mobile robot in a dynamic environment is based on data from the robot's information sources and is characterized by constant changes due to the movement of objects, people, or vehicles. These factors create complex conditions for motion planning and localization, requiring sensor systems to be adaptive and resilient to interference.

Traditional sensors, such as video cameras, lidars, infrared, and acoustic sensors, are constantly being improved. Data processing methods, including photometric calibration (Zhang, 2000), image enhancement (He *et al*., 2010), and camera exposure control (Nayar and Branzoi, 2003), enhance their performance. However, the reliability of data from these devices remains low under insufficient lighting and visual disturbances (dust, smoke, fog, rain, snow), which complicates motion planning and robot localization in a dynamic environment (Thrun *et al.*, 2005).

At the same time, radar systems do not have these limitations (Skolnik, 2001). Millimeter-wave (mmWave) radars are used in modern advanced driver-assistance systems (ADAS) (Hasch *et al.*, 2012), improving safety through adaptive cruise control, blind-spot monitoring, and emergency braking (Zhang *et al.*, 2019). Additionally, mmWave radars enable contactless monitoring of heart rate and respiration with millimeter-level accuracy, which is valuable for patient observation, sleep studies, and elderly care (Li *et al.*, 2019).

The purpose of this work is to investigate the feasibility of using an mmWave radar as a sensor in the information system of a mobile robot in a dynamic environment. The main characteristics of existing microwave radars were analyzed: operating frequency range, detection range, resolution, and resistance to external interference. For this study, the Infineon BGT60TR13C radar was selected due to its suitability for use on a mobile robot. It is a compact 60 GHz FMCW radar with integrated antennas, a bandwidth of 5.5 GHz, and a digital SPI interface for configuration and data transmission.

During the study, a connection scheme for integrating the radar with the control device was developed, ensuring proper power supply and data exchange. An algorithm was created and tested for determining the distance, speed, and direction of moving objects using the BGT60TR13C. Software code was developed to assess noise levels and measurement errors for range and velocity. The radar visibility of building structures made of various materials was investigated, and the detection and identification of moving objects were conducted. The solutions were developed and integrated into ROS 2. Recommendations were formulated for the selection and application of millimeter-wave radars for mobile robot motion planning (Infineon Technologies, 2022).

The data generated by the radar was utilized by algorithms developed in ROS 2 (2023). Using the Occupancy Tree structure in ROS 2 and additional algorithms, a local spatial occupancy window around the robot was created, updated in real-time based on radar data about obstacles. If an obstacle was identified and classified (e.g., as a human), the vector of its movement direction was determined, and the possibility of a collision with the robot was assessed. This data was applied in a Decision Tree algorithm to evaluate collision risk, adjust the robot's trajectory, or initiate an emergency stop.

The main results of testing the mmWave radar BGT60TR13C when installed on a mobile robot are as follows: a detection range of up to 10 meters for objects with an area greater than 0.3 m², an angular resolution of 10°, enabling the differentiation of objects at a distance of 0.5 meters, and the ability to identify people moving at a speed of 1 m/s. The range measurement error for objects does not exceed 3%.

The research is supervised by Dr.sc.ing., Associate Professor Aleksandrs Krainukovs.

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Transport and Telecommunication Institute, Lauvas 2, Riga, LV-1019, Latvia

AI-ENHANCED CONTROL FOR UNDERWATER ROBOTICS IN FLUID ENVIRONMENTS: A SCOPING REVIEW OF BIO-INSPIRED APPROACHES AND BIOMEDICAL APPLICATIONS

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Keywords: Underwater robotics, artificial intelligence, scoping review, bio-inspired robotics, biomedical engineering, fluid dynamics

This Scoping Review maps the landscape of AI-enhanced control for underwater robotics, a domain of growing importance across sectors from environmental monitoring to biomedicine. The increasing sophistication of underwater tasks necessitates advanced control in complex fluid environments. Bio-inspired designs, mirroring nature's efficiency, offer optimised solutions, particularly fish-inspired robots exhibiting superior fluid propulsion and manoeuvrability, as reviewed by Raj and Thakur (2025). This review analyses the convergence of Artificial Intelligence (AI) and bio-inspiration in underwater robotics literature, focusing on control strategies, design approaches, biomedical applications, and inherent challenges within fluid media.

Reinforcement Learning (RL) and Neural Networks (NNs) are central to AI-enhanced control. Surveys, such as that by Yuh (2020), highlight the breadth of control strategies for autonomous underwater vehicles. Concurrently, bio-inspiration emerges as a pivotal paradigm, with Pfeifer *et al.* (2025) emphasising the potential of 'soft' robotics inspired by biological systems. Biomimetic designs, drawing from efficient natural locomotion, are key.

Targeted drug delivery is a key biomedical application for miniature underwater robots. Fluid dynamics presents significant control hurdles, especially at micro/nano scales relevant to biomedicine, as explored in research by Dong *et al.* (2025) on AI-enhanced biomedical microrobots in microfluidics. Overcoming these fluid challenges is paramount for effective biomedical applications.

Future trends point towards advanced AI algorithms and integrated smart materials for enhanced underwater robot autonomy and sensing. Despite technological strides, persistent challenges remain in autonomous underwater vehicle navigation, localisation, and communication, especially in collaborative missions, as reviewed by González-García *et al.* (2025). This Scoping Review underscores the transformative potential of AI-enhanced control and bio-inspired design, driving innovation in underwater robotics across marine and biomedical domains

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ANALYSIS OF INNOVATIVE WASTE HEAT RECOVERY SYSTEM IN INTERNAL COMBUSTION ENGINE VEHICLES

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Keywords: Thermoelectric generators, internal combustion engine, heat pipes, waste heat recovery

Although the use of electric vehicles has increased significantly in recent years, internal combustion engine vehicles are still actively used. The internal combustion engine (ICE) converts chemical energy into mechanical energy to provide transportation. However, in this conversion process, most of the energy is converted into temperature and is released as waste heat through friction, mechanical losses, and exhaust gases. This article analyzes the current status of waste heat recovery technology and the potential future development of its application in vehicles based on the latest innovations, research, and experiments. With the latest technological innovations, the efficiency of internal combustion engine vehicles is up to 40-45%, while the thermal efficiency of the innovative hydrogen-based H2-Starfire internal combustion engine introduced by Astron AeroSpace in 2024 is up to 60%.

These values are high compared to ICE technology, but reducing thermal losses is one of the main engineering problems. Compared to improving the internal structure of the engine to reduce thermal losses, a system for recovering waste heat that is not converted into mechanical energy by various ecological methods, especially Thermoelectric Generators (TEG) and Heat Pipe technology, is more appropriate.

TEGs are special modules based on N- and P-type semiconductors that can convert thermal energy into electrical energy based on the Seebeck effect when a temperature difference is created between their surfaces (Tohidi *et al*, 2022). The most common and economically viable models are those based on the semiconductor Bismuth-Telluride (Champier, 2017). The efficiency of TEGs is determined by the thermoelectric value (zT). In this context, the higher the zT value, the higher the amount of energy recovered. Commonly used Bismuth-Teluride-based TEGs have a zT value of 1, but experiments have been conducted on various other semiconductor combinations (Zr, Ni, Sb) and TEGs with higher zT values have been investigated (Zhu, 2019). At the same time, experiments are being conducted on the possibility of using more efficient TEGs in space stations in the future, based on a construction that includes special nano-coatings and insulation (Sadig and Isgandarov, 2024).

As a result of these experiments and analyses, it seems possible to use TEGs in a special construction with strong aerogel-based insulation and by applying heat pipe technology for faster temperature transfer. Heat pipe technology is a metal tube, closed at both ends, filled with liquid under low vacuum pressure. This allows it to have a much higher thermal conductivity than aluminum, copper and silver (Yang *et al*, 2012). According to the results of research and testing, this review examines the effective combination of TEGs based on special construction and insulation with heat pipe technology in vehicle internal combustion engines.

The research is supervised by PhD., Professor Islam Isgandarov.

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VISUAL RANGE HYPER SPECTRUM ESTIMATION ON THE BASE OF RGB SENSOR DATA

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Keywords: Hyperspectral imaging, RGB sensor simulation, spectral data reconstruction, color space conversion, artificial neural network

Computer vision systems make it possible to capture real-world data through electronic equipment for processing. These systems are increasingly used in fields such as navigation, the medical sector, and security. One particular aspect, the image processing, is at the core of certain processes. It enables the capture of specific wavelength bands. Specialized sensors, known as multispectral and hyperspectral, which are complex and very expensive, can capture Infrared + RGB bands or Infrared + RGB + Ultraviolet bands with wavelengths ranging between approximately 380-780nm (visible), 780-2500nm (infrared), and 100-400nm (ultraviolet). A less costly alternative would be to reconstruct a hyperspectral image from the output of an RGB sensor. To achieve this, a method is considered that would artificially and iteratively increase the number of channels in an image starting from an RGB-only input to progressively get the full hyperspectral image. This study aims to develop a tool capable of performing this task on a smaller scale by first simulating the RGB and hypothetical RGB-CMY sensor outputs from hyperspectral images and then establishing a relationship between RGB and CMY sensor data.

To clear these objectives, the study will be divided in four aspects. First, natural hyperspectral datasets are collected from publicly available sources, those datasets are used as raw input of the entire process. Then, RGB and CMY sensor output are simulated using spectral sensitivity curves following the method proposed by (Vora *et al.*, 2001), which presents how realistic is the sensor output using this spectral filtering process. The simulated output is cleaned and normalized to obtain a synthetic RGB- CMY dataset.

Next, an Artificial Neural Network (ANN) is designed to predict CMY channel output from the previously defined synthetic dataset. (Morata Dolz *et al*., 2022) highlights the efficiency of neural networks to estimate not directly available spectral bands. (Ahmed *et al.*, 2025) validate this approach as well by adding that Convolutional Neural Networks (CNNs) perform relevant results to establish non-linear relationships between spectral bands.

Finally, the neural network's performance will be analyzed using metrics (e.g. MSE, MAE and R^2). (Cheick Tidiani *et al*., 2022) presents, in the focus of spectral data reconstruction, that this process allows to prove the effectiveness of deep learning techniques.

The research is supervised by Dr.sc.ing., Professor Alexander Grakovski.

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APPLICATION OF THE LOCAL MEAN DECOMPOSITION (LMD) METHOD FOR DIAGNOSING FAN ROTOR IMBALANCE IN ASPIRATION SYSTEMS

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Keywords: Aspiration unit, method local mean decomposition, vibration transmitter, rotor, monitoring

The Local Mean Decomposition (LMD) method is an adaptive signal processing algorithm that decomposes complex oscillations into a series of monofrequency components with the isolation of their instantaneous amplitudes and frequencies (Wang *et al.*, 2010). Unlike classical Fourier analysis, LMD is particularly effective for analyzing transient and nonlinear signals and isolating instantaneous frequencies and amplitudes of various low- frequency signals (Li *et al.*, 2019; Li *et al.*, 2013), making it an ideal tool for diagnosing mechanical vibrations in rotary systems (Wang *et al*., 2010).

Safety standards (BSI, 2012) require the use of aspiration units for air purification at all industrial facilities whose activities involve the emission of harmful substances into the atmosphere. At STREK company, the aspiration system from HAZEMAG (2023) is used at the coal transshipment terminal in Riga (STREK, 2019) and should provide air filtration at a rate of 126000 m3 per hour. A fan of considerable dimensions, which collapsed after six months of operation due to an imbalance of the fan rotor, partially destroying the elements of the aspiration system. The installed new radial fan from the company "Ventspils Fan Factory" (2025), as well as the previously destroyed fan, is also not equipped with a fan rotor imbalance diagnostic system. The imbalance of the fan rotor manifests itself as mechanical vibrations of low frequencies, which determined the relevance of the research.

The purpose of this work is to determine the LMD parameters for diagnosing the imbalance of the fan rotor in the aspiration system described above. To process the vibration signals of the radial fan rotor, the LMD software implementation was implemented in the MATLAB application package.

In the course of research in the Simulink dynamic simulation environment, a radial fan model was created that made it possible to simulate the imbalance of the radial fan rotor. Using this model, model vibration signals of the radial fan rotor corresponding to four levels of imbalance were obtained: no imbalance, maximum allowable level of unbalance, 25% and 50% levels of the maximum allowable level Processing of model vibration signals using the software implementation of the LMD algorithm made it possible to determine the step size of moving average for each level of imbalance:

- the step size of moving average must be set in the interval from 3 to 9 counts;
- as the imbalance increases, the Step Size of Moving Average should be larger;
- the number of iterations of the LMD algorithm increases with the step size of moving average and can reach 20.

Real vibration signals obtained using IFM VTV122 (IFM, 2025) vibration sensors installed on the fan rotor were processed using the values of the step size of moving average in the range from 3 to 9. It was found that with the increase in the step size of moving average, the shape of the time dependencies of instantaneous amplitudes and instantaneous frequencies deteriorates.

On the basis of the studies performed and numerical estimates of the parameters of the LMD algorithm, an algorithm for diagnosing the imbalance of the fan rotor of the aspiration system was developed and the requirements for its development based on the Raspberry Pi microcomputer were determined.

The research is supervised by Dr.sc.ing., Associate Professor Aleksandrs Krainukovs.

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PROPOSAL FOR AN INTERACTIVE APPLICATION TO FACILITATE RESEARCH ON LLMS IN ROBOTIC PATH PLANNING

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Keywords: LLMs, robotic path planning, research tools, literature organization application, research initiation aid, automated paper management

For people who are not familiar with the search of scientific data bases or AI powered Research assistants like Gemini or OpenAI Deep Research, the discovery and synthesis of relevant scientific literature in an specialised area like Large Language Models (LLMs) used in robotic path planning, the discovery and synthesis of relevant scientific literature can be a time-consuming and fragmented process, often requiring researchers to navigate disparate academic databases and repositories (Mysore *et al.*, 2023; Passas, 2024).

To address this challenge, this work presents a proposal for an interactive application designed to streamline the exploration of scientific papers specifically focused on the intersection of LLMs and robotic path planning, offering a curated and organised platform for people who is interested in starting to get familiar with this field. The core objective of this application is to consolidate and present summaries of research articles into distinct, key research areas, including Perception & Vision, Planning & Decision, Human-Robot Interaction, Multi-Agent Systems, and Embodied Intelligence, thereby facilitating a more structured and efficient understanding of the field. The main focus of this application is to aid in the learning process of those who want to get familiar with the field of robotics and LLMs, by providing a centralized platform that eliminates the need for researchers to spend countless hours searching through different databases, reducing the time in the initial research stage in understanding its potential, like it has been done in other fields like material sciences (Lei *et al.*, 2024).

To automate the retrieval of relevant articles, a dedicated Python project, hosted on GitHub and integrated with GitHub Actions, is employed to perform regular queries on prominent academic databases such as ArXiv, IEEE Xplore, and Google Scholar, utilising keywords such as "LLM for robotic path planning". This automated workflow executes API requests to gather metadata from newly published articles, encompassing essential information such as title, abstract, authors, and access links,

Data is stored in Firebase and made available via a real-time listening system, enabling the application to update automatically when new publications are integrated. Finally, testing and feedback are conducted with target users to gather feedback and refine the platform for optimal user experience and educational value.

The actual version of the application displays a homepage with categorized research areas. When a category is selected, users can access multiple papers. That provides a centralized, categorized, and interactive platform to facilitate access to current research on LLMs in robotic path planning. It offers an educational tool and research assistant, particularly valuable for new researchers.

The research is supervised by PhD., Professor Emmanuel Merchan.

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DATA COMPARAISON DASHBOARD METHOD

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Keywords: Dashboard methodology, data visualization, storytelling dashboards, decision-making, data integration, analytical frameworks

Dashboards are essential tools for monitoring data and supporting decision-making. However, traditional dashboards often display disconnected charts with little context, making insights harder to interpret. This can lead to miscommunication and missed analytical opportunities (Ryan, 2024). Storytelling Dashboards offer a more effective alternative. By combining data with narrative flow, they guide users through a structured experience that aligns with how people naturally process information. This results in clearer insights and more confident decisions (Kosara *et al.*, 2013; Beheshti *et al.*, 2018). To overcome the limitations of conventional dashboards a structured methodology designed for storytelling is proposed. It brings together analytical frameworks, relevant data organization, and user- centered design to create dashboards that are both informative and intuitive.

This method begins by collecting analytical requirements from decision-makers using the i* framework. This approach defines goals, tasks, and relationships to ensure that dashboard components align with user needs (Lavalle *et al.*, 2024). These requirements are then organized into a hierarchical tree structure, reflecting the natural flow of analysis and how users think about the data (Lavalle *et al*., 2024). Once the structure is defined, the relevant datasets are selected to support the analysis tasks identified in the tree. Identifying those tasks allows a quicker and more efficient collection of data that could be otherwise laborious. Knowledge Graphs are used to represent relationships between key data points, helping users understand context and dependencies (Schäfer *et al.*, 2022). Then, an ETL (Extract, Transform, Load) process is applied to clean, transform, and centralize the data for integration into the dashboard (Gitzel *et al.*, 2015).

The dashboard design prioritizes clarity and interactivity. Visualizations such as bar charts and line graphs are chosen based on the type of data and intended insights. Interactive filters can be added to allow users to explore the data dynamically (Sedrakyan *et al*., 2019). The dashboard is built using appropriate software or web tools that support a responsive and intuitive user experience (Toasa *et al*., 2018).

Storytelling dashboards offer clear advantages over traditional dashboards. According to Kosara *et al*. (2013), they improve decision-making by minimizing misinterpretations and guiding users through structured insights. Beheshti et al. (2018) emphasize that aligning visuals with decision-makers' cognitive models makes data easier to understand. Ryan (2024) underlines the importance of clarity and precision in reducing errors during interpretation.

To evaluate the effectiveness of the approach, an experiment was conducted where participants were shown either a traditional dashboard or one created using this methodology. They were asked to answer analytical questions based on real business scenarios. The results showed that users of the storytelling dashboard made fewer interpretation errors, answered more questions correctly, and rated the experience as more intuitive and complete.

The research is supervised by Dr.sc.ing., Associate Professor Nadezda Spiridovska.

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RESEARCH and TECHNOLOGY – STEP into the FUTURE, 2025, Vol. 20, No. 1, 56-57
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BATTERY SAFETY IN INCREASING RELIANCE ON PORTABLE TECHNOLOGY AND ELECTRIC TRANSPORTATION

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Keywords: Battery technology, safety risks, electric transportation, lithium-ion batteries, incident analysis, reliability assessment

The reliance on battery technology has significantly increased over the past two decades, evolving from powering simple devices to being integral in electric transportation. This evolution presents both opportunities and challenges, particularly concerning safety risks (Ash, 2020). Incidents of battery failure can result in fires or hazardous smoke emissions, often due to external damage or internal overheating. A comparative analysis of battery failure incidents from 2010 to 2023 reveals a 15% increase in reported cases, highlighting the need for enhanced safety measures (BBC, 2025).

This study aims to investigate the safety risks associated with battery technology in portable devices and electric transportation, focusing on understanding the core reasons behind safety incidents and exploring potential future developments in battery technology.

A systematic review of existing literature and case studies related to battery incidents was conducted. The research employs a quantitative analysis methodology, including:

- Comparative Analysis: Examining incident rates over time, as highlighted by Hyatt (2024).
- Reliability Assessment: Evaluating safety risks associated with different battery types, which Sharma (2025) discusses in detail.
- Forecasting: Predicting future trends in battery technology based on current data, as noted by Strong (2025).

The analysis indicates that while battery technology, particularly lithium-ion batteries, has evolved, it still presents inherent safety risks. There is a pressing need for new technologies that can meet energy demands without the associated risks of current battery systems.

It can be concluded that solid-state batteries represent a promising solution to the challenges faced by current battery technologies. By utilizing solid electrolytes instead of liquid ones, these batteries enhance safety by reducing the risk of leaks and fires. They also offer higher energy density, which can lead to longer ranges for electric vehicles/devices, faster charging times, and a longer lifespan compared to traditional batteries. As such, solid-state batteries could pave the way for safer, more efficient, and environmentally friendly energy storage solutions, addressing the critical safety concerns associated with lithium-ion batteries (Nugraha, 2025; Voelcker, 2025).

This research is supervised by Dr.sc.ing., Associate Professor Sergejs Bratarčuks.

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AUTOMATED ANALYSIS AND STATISTICAL CHARACTERIZATION OF AIRPORT TOWER RADIO COMMUNICATIONS AND OPERATIONAL ACTIVITY USING MATLAB: A COMPARATIVE STUDY OF KJFK AND EVRA

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Keywords: Airport communications, automated analysis, MATLAB, Python, air traffic control, statistical modelling, gamma distribution

Airports all over the world are facing unprecedented challenges as air traffic grows and complexity increases. One of the key areas is analysis of radio communications between air traffic controllers and pilots, which reflects the operational load and efficiency of airport's management system. Automated statistical methods to describe the time course of these communications and their relationship to overall airport activity are lacking, even though progress in communication technologies. This study provides automated framework for tower radio communications analysis, with focus on two airports—KJFK and EVRA. The timeframe chosen was 01.03.2025 – 17.03.2025, each 30 minute segments were analysed.

Data for this study were collected using a custom Python script that leveraged web scraping techniques (via the requests library) to download archived audio recordings from LiveATC.net, a well-known source of real-time and historical ATC communications (LiveATC, 2023). The Python script automatically constructs download URLs based on user-specified parameters (station, location, month, day, and year) and retrieves half-hour audio files covering an entire operational day.

Once the audio recordings were collected, they were processed using MATLAB (MathWorks, 2022) to extract relevant communication sessions. The MATLAB (MathWorks, 2022) code applies a bandpass filter (300–3400 Hz) to the audio signals. Voice activity detection was then used to differentiate between periods of active communication and silence. Key parameters were computed: total speech duration, total silence duration, the number of sessions, and average session duration. These parameters are then aggregated by day and by airport tower.

To display the distribution of communication session lengths, statistical methods are used. To get the best match, the data was fitted to both the Gamma and Gaussian models. The Gamma distribution, which is frequently used to predict waiting times (Nikora, 2006), for instance, was not found to match any of the plots well. In addition to daily data, the MATLAB (MathWorks, 2022) code generates 2D heatmaps and 2D plots that analyze the temporal distribution of communications throughout the day, as well as overall session length histograms with Gamma fits and aggregated talking and silent profiles with Gaussian fits.

The comparison of both airports shows that KJFK, has more communications with shorter silence time between sessions than EVRA's small regional tower. These differences could be used to analyse, for example, some workloads on the specific tower, because there is a lack of information about such a specific workload analysis. The ability to have a tool that analyses the radio communication automatically would be also very efficient. Future versions of this work could also include such external factors as weather and local events, this would help to predict some airport future traffic and help for scheduling it.

This research not only shows the growing field of speech analysis in ATC, but also how modern methods of data analysis and collection using Python and MATLAB (MathWorks, 2022) is more time efficient than analysing and collecting data manually.

In summary, the research provides automated statistical analysis for radio communications between an airport tower and a pilot. By comparing these two tower environments, this study offers valuable insights that could lead for improvements in airport management strategies and workload optimization (Gibson, 1977), (Vroom, 1960).

The research is supervised by Dr.sc.ing., Associate Professor Sergejs Bratarčuks.

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E-BIKES REBALANCING OPTIMISATION WITH ARTIFICIAL INTELLIGENCE

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Keywords: Bike prediction, bike sharing system, optimization, location analytics, genetics algorithm

Bicycle share systems (BSS) are now widespread in major cities around the world and represent a sustainable mode of transportation. The main issue they face is rebalancing e-bikes between stations. Riders most often travel farther to find a station with available bikes, while others cannot park their e-bikes at full stations and must leave them elsewhere. This discourages people from using such sustainable transportation. To address this issue, one common solution is known as truck-based rebalancing, where the bikes are transported by vehicles between stations to maintain balance. However, this method still requires optimization to improve efficiency, reduce operational costs and greenhouse gas emissions, ensuring a more effective and sustainable rebalancing process.

This paper aims to find an optimized truck-based rebalancing solution for station-based BSS. Where the study compares two different strategies and evaluates which is most efficient based on the met-demand criteria. Divvy BSS of the city of Chicago serves as the case study to conduct this research. The first strategy used is short-term prediction for daily or multi-hour forecast using Random Forest algorithm, historical and weather data as seen in Ashqar *et al.* (2020) which was found to be the most efficient way to predict demand, followed by, identify likely deficits and surpluses at specified times to plan repositioning hours according to what Cho *et al*. (2021) suggested. Finally, a small Vehicle Routing Problem (VRP) solver is used for an optimal route within each timeslot. The second strategy is also predicting the demand with random forest however the rebalancing optimization depends on multi-stage Genetic Algorithm (GA) as seen in Xanthopoulos *et al.* (2024).

The Genetic Algorithm demonstrates to be more efficiency regarding overall optimization. However, it necessitates considerably greater resources and processing time in comparison to the initial strategy, which employs human-driven decision-making with a Vehicle Routing Problem (VRP) solver.

The research is supervised by Dr.sc.ing., Professor Dmitry Pavlyuk.

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Transport and Telecommunication Institute, Lauvas 2, Riga, LV-1019, Latvia

DECISION-MAKING IN INFORMATION SYSTEMS WITH AI TOOLS FOR COCA-COLA AND SIEMENS CASES

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Keywords: Decision-making, information systems, AI tools, case study analysis, organizational performance, predictive analytics, supply chain optimization, customer personalization

Decision-making in information systems (IS) is a critical factor in the success of modern organizations. With the increasing complexity of data and the need for faster, more accurate decisions, Artificial Intelligence (AI) tools have emerged as a transformative force in enhancing decision-making processes (Davenport and Ronanki, 2018). By leveraging AI technologies such as machine learning, predictive analytics, and natural language processing, organizations can extract actionable insights from vast datasets, enabling more informed and efficient decision-making across strategic, tactical, and operational levels (Brynjolfsson and McAfee, 2017).

This thesis explores the integration of AI tools into Management Information Systems (MIS) and their impact on decision-making processes through a multi-case study analysis. The study focuses on two prominent organizations, Coca-Cola (Coca-Cola Company, 2024) and Siemens (Siemens, 2024), to examine how AI-driven solutions enhance operational efficiency, customer experiences, and predictive maintenance. The research addresses the following key question: How can organizations effectively measure the impact of AI on decision-making outcomes?

The methodology relies on thematic content analysis of secondary data, including industry reports, academic publications, and official company documentation, to examine how AI solutions are deployed to improve decision-making outcomes in areas such as supply chain optimization, customer personalization, and predictive maintenance

The framework includes key performance indicators (KPIs) such as prediction accuracy, decision latency, user adoption rates, and return on investment (ROI). These KPIs were selected based on their relevance to both academic literature and real-world business metrics (Wamba-Taguimdje *et al.*, 2020). Although the framework provides actionable guidance, it remains conceptual and is not empirically validated due to the study's reliance on secondary data. Future research should focus on quantitative validation of the KPIs and include primary data collection for deeper insights.

This research contributes to the existing body of knowledge by offering practical recommendations for leveraging AI tools to enhance decision-making in IS. The findings highlight the transformative potential of AI in improving organizational performance, reducing costs, and fostering innovation. By analyzing real-world case studies, this thesis provides valuable insights for practitioners and decision- makers aiming to harness the power of AI in their organizations.

The research is supervised by Dr.sc.ing., Professor Boriss Misnevs.

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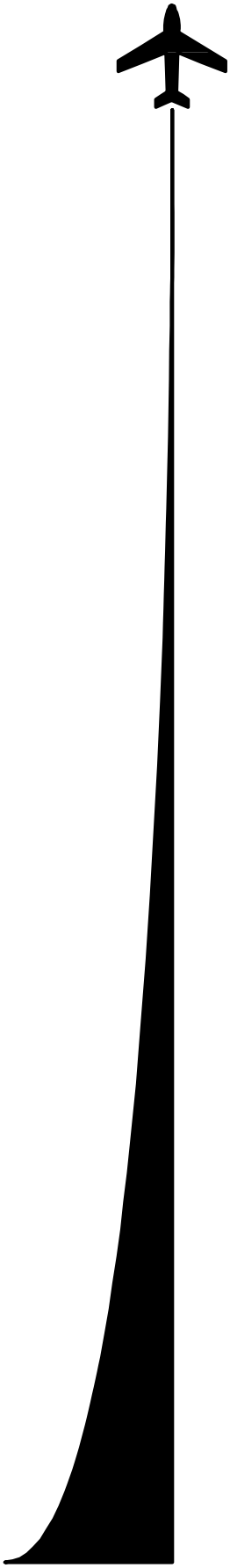

Session 2

Transport and Logistics

Transports un loģistika

RESEARCH and TECHNOLOGY – STEP into the FUTURE, 2025, Vol. 20, No. 1, 66-67
Transport and Telecommunication Institute, Lauvas 2, Riga, LV-1019, Latvia

PREDICTIVE ANALYTICS IN BUSINESS AVIATION USING A DATA-DRIVEN MODEL FOR AIRCRAFT AIRWORTHINESS MANAGEMENT

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Keywords: Business aviation, airworthiness, prediction, maintenance, AOG (Aircraft on Ground)

Business Aviation (or General Aviation (GA)) industry has been more dynamic for last decades not only in North American region, but also worldwide. Over the past decade, the global business jet fleet has experienced significant growth. As of 2019, the estimated quantity of business jets worldwide was about 21,979 aircrafts (Pangarkar, 2019). From this quantity, North America owns 71%, while Europe held approximately 13% of total jets which means about 2,860 aircraft (Pangarkar, 2019). The number of technical failures and system errors increasing apparently. Unfortunately, some technical tasks cannot be solved as quickly as planned due to some factors. Those factors can be related to spare parts logistics, weather conditions, lack of staff, wrong issued documents, maintenance ("MX") facility locations- capabilities. Most times these cases resulted by AOG status, which means aircraft is not operational or not Airworthy (technically healthy).

The research aim is to predict possible AOG ("Aircraft on Ground") cases in advance in Business Aviation industry and notifying Airlines or Carriers upcoming risks by providing the gap by demonstrating how predictive models can improve spare parts logistics and accordingly, aircraft airworthiness. Recent studies show that while predictive maintenance has been widely used in commercial aviation. However, prototype application in business aviation remains underdeveloped (Adi *et al*., 2022). Business aviation requires particularly high levels of reliability and fast turnaround times, making predictive maintenance a key factor in ensuring operational efficiency and reducing maintenance- related delays (Kang & Park, 2020).

In this research, quantitative, qualitative and comparative analysis used for obtaining accurate data flow. The major following questions are answered on this study. How can predictive analytics improve supply chain efficiency and reduce "Aircraft-on-Ground" (AOG) situations in business aviation? What factors are affecting to Aircraft Airworthiness? How the model that is going to be implemented, differs from the previous implemented data-driven models in the way of prediction? What impact does a data-driven model have on optimizing aircraft airworthiness management and spare parts forecasting for non-scheduled business aviation operations?

For data collection, one type of Embraer (aircraft model, manufacturer) aircraft is chosen. Accordingly, available "MEL" list for 2 or 3 revisions are collected. The file "MEL"- Minimum Equipment List, shows what errors are strict and according to standards, some error codes prohibit operation until the failure solved. More than that, manually data has been collected for qualitative analysis with different scenarios. These scenarios are different airlines cases. More scenarios-cases, more accurate model would be (Erb and Birsch, 2021).

A developed data-driven model is applicable on a software for airlines (business aviation operator) or can be implemented to the Aircraft Health Monitoring systems such as "CAMP" A successful data-driven model supports carriers by notifying expected risks on spare parts or upcoming MX check to reduce the AOG cases.

The research is supervised by Dr.sc.ing.habil, Professor Jurijs Tolujevs and Dr.sc.ing., Associate Professor Evelina Budilovica.

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AVIATION FUEL PRICING FORMATION AND INFLUENCING FACTORS STRATEGY IN THE CONTEXT OF SUSTAINABLE FUEL REGULATIONS: CASE STUDY RIGA INTERNATIONAL AIRPORT

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Keywords: Aviation fuel pricing, sustainable aviation fuel, Riga International Airport (RIX), fuel policy, EU ReFuelEU, decision-making

With the introduction of mandatory Sustainable Aviation Fuel (SAF) usage from 2025 under the European Union's ReFuelEU regulation (European Commission, 2023), the aviation fuel sector faces significant challenges and transformations. This study investigates the formation and structure of aviation fuel pricing at Riga International Airport (RIX), with a particular focus on the components that determine the final price, the key influencing factors in decision-making, and the barriers and pressures introduced by the SAF mandate. The author has identified that there is no similar research about such topic/ The research presents novelty with the topic coverage and presents a paper that could be used by policymakers and other stakeholders of the aviation market to help create an in-depth understanding of the aviation fuel market and it's influencing factors and challenges.

The research aims to develop a comprehensive understanding of how aviation fuel prices are currently determined and how they are likely to evolve in light of regulatory, economic, and market changes. The limitation of the research is set to the time frame starting withing the research period and geographically – to territory of Latvia. Specific attention is paid to the perspectives of different stakeholders involved in this process–including fuel suppliers, airlines, policymakers, and the travelling public. Through deep analysis of all the components and practices and factors that influence the fuel price in practice and theory, the author creates a generally applicable "formula" of fuel price that can also be used to analyze local aviation sector and compare it to other airports and deducts the problematic areas that reduces competitiveness.

Research tasks include: identifying and analysing all current and potential factors influencing fuel price formation at RIX; collecting and examining historical fuel pricing data to determine the potential market size of SAF product in the nearest future and to make prognosis based on the projections; conducting a survey and structured expert interviews with potential SAF factory building company management and other companies who are in the process of SAF implementation to gather insights into the practical implications of SAF implementation; and formulating a practical pricing "formula" with all of the key elements that can be applied and taken into consideration in decision-making and stakeholder negotiations (ICAO, 2021).

The theoretical significance of this research lies in its potential to deepen understanding of aviation fuel market dynamics in the face of sustainability-driven change. Practically, the study offers valuable tools and recommendations for policymakers and industry actors navigating SAF adoption and price-setting, particularly at regional airports competing within international markets (Eurocontrol, 2022). The researcher's long-standing professional experience within the aviation fuel industry further supports the relevance and applicability of the proposed solutions.

The study aspires to offer a balanced approach to pricing strategy, facilitating dialogue among stakeholders and encouraging compromise, thereby helping to ensure economic viability, regulatory compliance, and fairness across the aviation sector.

The research is supervised by Dr.sc.ing., Professor Evelīna Budiloviča.

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OPTIMIZATION OF STANDARD INSTRUMENT DEPARTURE ROUTES AT RIGA INTERNATIONAL AIRPORT FOR MORE FUEL-EFFICIENT AND LESS RESTRICTIVE FLIGHT PLANNING

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Keywords: Fuel efficiency, airspace routing analysis, data-driven optimization

Airports all over the world are constantly seeking ways to improve operational efficiency, reduce fuel consumption, and enhance environmental sustainability. As the aviation industry faces growing pressure to minimize its carbon footprint, optimizing flight routes has become a key strategy. Among the critical components of flight planning, Standard Instrument Departure (SID) routes play a significant role in determining the efficiency of airport departures. At Riga International Airport (EVRA), optimizing these SID routes presents an opportunity to not only improve fuel efficiency but also reduce airspace congestion and minimize restrictive flight planning.

As Standard Instrument Departures for Riga International Airport (EVRA) are designed with noise abatement procedures, for day Instrument Flight Rules (IFR) operations, aircraft operators are required to carry unnecessary additional fuel, because in most cases instrument flight rated departures are being directed over densely populated areas to next waypoints shortly after take-off.

Adjusting existing Standard Instrument Departure (SID) routes and introducing new optimized SID routes from Riga International Airport (EVRA) allow aircraft operators to reduce fuel burn and at the same time avoid some local temporary segregated areas, which would allow them to plan most direct and fuel wise more optimum routes for their flights.

After analysing the EVRA Terminal Manoeuvring Area (TMA) and incorporating temporary segregated areas along with population density into the optimization process, we applied A* algorithm to calculate shorter and more fuel-efficient aircraft departure routes. By applying A* algorithm, we generate optimized routes that not only reduce required trip fuel but also minimize required workload for pilots, by eliminating the need to adjust flight path en route. In our analysis, by comparing fuel burn and required trip fuel for specific flights, aircraft operators, by using optimized Standard Instrument Departure (SID) routes, would be able to reduce trip fuel by approximately 45 to 65 kg for category C aircrafts (e.g., Airbus A220-300), depending on used optimized departure route. Over time, this translates into substantial operational cost savings for airlines, as well as environmental benefits by lowering carbon emissions.

By analysing population density within the EVRA Terminal Manoeuvring Area (TMA) and combining this data with existing temporary segregated areas in and around TMA we are able to design new and more optimum SID routes for Riga International Airport. These routes could be implemented during periods when noise abatement procedures are not active (0500 to 2100 UTC (0400-2000)).

The research is supervised by Dr.sc.ing., Associate Professor Sergejs Bratarčuks.

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METHODOLOGY FOR ANALYZING THE STABILITY OF A VESSEL'S MOTION CONTROL SYSTEM

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Keywords: Hybrid control strategy, segmented linear dynamics, combined quadratic stability functions, convex optimization constraints

This study introduces an analytical framework for evaluating the stability of a segmented linear control system designed for marine vessel navigation. The system mitigates actuator saturation risks while guaranteeing convergence to a predefined smooth reference trajectory. A formal stability verification is essential for validating the system's robustness. Simulation results demonstrate the efficacy of the proposed methodology and confirm the stability of a specific implementation of this navigation control system.

Contemporary maritime navigation systems employ automated guidance technologies to maintain vessel trajectories under dynamic environmental disturbances (Astrom & Wittenmark, 2008; Dovgobrod, 2021a; Lukomsky, 1996). However, actuator constraints such as maximum rudder deflection and angular velocity pose operational challenges. Exceeding these thresholds induces actuator saturation, potentially destabilizing vessel control (Dovgobrod, 2016).

In practical control systems, operational constraints inherently impose bounds on the magnitude of control inputs, such as maximum permissible rudder deflection and angular velocity. Violating these thresholds risks actuator saturation, which may destabilize vessel navigation (Dovgobrod, 2016). To mitigate such saturation effects (Dovgobrod, 2021a), a piecewise affine control strategy has been devised, guaranteeing the vessel's asymptotic convergence to a predefined smooth trajectory-attractor regardless of lateral displacement.

Each trajectory-attractor segment corresponds to a piecewise affine system **S** comprising three stable subsystems: $S1$, $S2$, and $S3$. These subsystems activate based on predefined lateral deviation thresholds: a right boundary $L\mathrm{p} > 0$ and a left boundary $L\mathrm{l} < 0$. Specifically, $\mathbf{S_1}$ engages when the lateral deviation $L \le L_\mathrm{l}$, $S1$ operates within $L_\mathrm{l} \le L \le L_\mathrm{p}$, and $\mathbf{S_3}$ activates for $L\mathrm{p} \le L$.

Piecewise affine systems fall under the broader category of hybrid control architectures. Analyzing their stability demands rigorous scrutiny due to phenomena such as system-wide instability arising from stable subsystems, paradoxical stability from unstable subsystems, and Zeno behavior (Lin & Antsaklis, 2014, DeCarlo *et al*., 2000). Prior research by Johansson (1999), Lin & Antsaklis (2014), and others employs composite quadratic Lyapunov functions to assess hybrid system stability.

This work proposes a stability analysis framework for piecewise affine ship control systems (Dovgobrod, 2021b) through solutions to a tailored linear matrix inequality (LMI) system. Solvability of these LMIs permits the derivation of a Lyapunov function, thereby verifying system stability (Johansson, 1999; Lin & Antsaklis, 2014). As outlined in (Johansson 1999), stability can be established when the state space Ω is partitioned into unbounded regions.

Let us consider the methods for constructing matrices necessary for applying Theorem 4.1 (Johansson, 1999). The system is based on the works of Johansson (1999), Molina Acosta, (2018). Also used algorithms of Dovgobrod *et al.,* (2021) and Dvornikov *et al.* (2017).

The construction of matrices for applying Theorem 4.1 draws from methodologies in Johansson (1999), Molina Acosta (2018), Dovgobrod *et al.* (2021), and Dvornikov *et al.* (2017).

Key transformations include appending a row vector $x(t) \in \cup_{i\in I}\Omega_i$ satisfying for $\forall t \geq 0$ converge to zero exponentially. Theorem 4.1 (Johansson, 1999): For symmetric matrices T, Ui, Wi with non-negative entries in Ui, Wi if the inequalities hold for all subsystems, trajectories converge exponentially to zero. A feasible solution to these inequalities suffices to prove stability, though failure does not preclude it Lyapunov-based criteria remain sufficient, not necessary.

The proposed methodology evaluates stability for piecewise affine systems partitioned by two parallel hyperplanes into three unbounded cells, with the origin lying between them. A notable advantage is its accommodation of unbounded partitions, unlike conventional composite Lyapunov approaches that often restrict cell boundaries.

Finally, this framework has successfully validated the stability of the piecewise affine control system for ship motion introduced in Dovgobrod (2021b), addressing prior theoretical gaps, because space Ω is divided into unbounded cells (Johansson, 1999), can be used to prove the stability of S.

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THEORETICAL FOUNDATIONS OF PIGGYBACK TRANSPORTATION AND THEIR SIGNIFICANCE FOR THE TRANSPORT SYSTEM

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Keywords: Piggyback, Uzbekistan, benefits, challenges

Piggyback transportation has continued to increase in recent years, particularly because of the growing calls for sustainable transportation and environmentally friendly transportation systems. This study investigated the state of piggyback transportation in the world and sought to offer lessons and recommendations for Uzbekistan's piggyback transportation system. The methodology used was a literature review. The findings of the study revealed several things. First, the majority of the literature on piggyback transportation is from Europe, meaning that's where it may be a more common form of transportation. Second, piggyback transportation is associated with various benefits such as environmental protection, cost-effectiveness, etc.

Recognized as early as the 1960s, piggyback transportation was deemed a solution for the rising transportation costs and the need for greater flexibility in product distribution and handling (Bowser, 1960). In the present day, the relevance of piggyback transportation has continued to increase, particularly because of the growing calls for sustainable transportation and environmentally friendly transportation systems. Transportation contributes to almost a quarter of many countries' greenhouse gas emissions and is the leading cause of air pollution in urban areas (Zhang *et al.*, 2022). As such, concepts such as "green logistics" have come up. Green logistics implies the need to reduce emissions of harmful substances from vehicles and improve environmental friendliness (Kukla *et al*., 2021).

Consequently, there has been an increase in literature focusing on intermodal transport systems like piggyback transportation, revealing several of its benefits. One significant benefit is its environmental impact, as revealed by Heinold and Meisel (2018). They conducted a simulation study for Europe, which revealed that 90% of the shipments have a lower environmental footprint if transported in an intermodal rail-road connection rather than a road-only connection. Another key benefit is increased accessibility. Chebotareva *et al*. (2022) revealed the effectiveness of piggyback transportation in overcoming logistical problems in areas that would be impassable by road. Furthermore, piggyback transportation can reduce fuel usage as well as promote road maintenance (Kurhan *et al.*, 2019). These studies underscore the importance of piggyback transportation and its numerous benefits to countries.

As a result, many countries across the globe have continually adopted piggyback transportation as an alternative method of transportation. In Europe, America, Canada, and Australia, piggyback transportation has become widespread in recent years (Chebotareva *et al*., 2022). In the United States of America, it has formed the "one-stop" transport, in Europe, it has formed a "piggyback transport contractor" (Xia *et al.*, 2021). In Russia, attempts to introduce piggyback transportation have been undertaken since the start of the 90s (Tsyganov, 2019). These attempts and interest in piggyback transportation have continually increased in recent years, particularly because of piggyback's accessibility in regions that would otherwise be impassable with roads (Chebotareva *et al.*, 2022).

Furthermore, countries with undeveloped piggyback systems plan to establish it. In China, for instance, the China State Council issued "The medium- and long-term plan for the

development of multimodal transport system, which includes systems such as piggyback transportation (Xia *et al*., 2021).

Uzbekistan has not been left behind when it comes to piggyback transportation. While the first piggyback establishments in the country were limited to transit piggyback transportation, over time, investments in this sector of the economy led to the establishment of several piggyback yards in container terminals (Mukhamedova, 2024). The development of these piggyback yards meant the construction and upgrading of specialized facilities and infrastructure at container terminals that are specially designed to handle piggyback transportation. According to Mukhamedova (2024), by 2021, such piggyback yards had already been built in 24% of terminals across the country. By doing so, Uzbekistan has enhanced its ability and capacity for rail and road transportation systems, which may lead to a more efficient piggyback transport system.

The research is supervised by DSc., Professor Ziyoda Mukhamedova.

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ENHANCING ACCESSIBILITY AND INCLUSIVITY IN MALTESE PUBLIC TRANSPORT: ADDRESSING THE NEEDS OF VULNERABLE GROUPS

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Keywords: Public transport, accessibility, vulnerable users, inclusivity, survey

Public transport (PT) plays a vital role in human life as it provides accessible mobility and enables individuals to reach different places, including education, work, healthcare, and other significant areas, for multiple reasons (Bajada *et al.,* 2016). The study focuses on evaluation of the current situation related to PT facilities in the Malta, while also addressing the importance of enhancing accessibility and inclusivity from the perspectives of needs of vulnerable groups (VGs) within Maltese PT.

Vulnerable Road Users (VRU) are defined in the ITS Directive as "non-motorised road users, such as pedestrians and cyclists as well as motor-cyclists and persons with disabilities or reduced mobility and orientation". The classification of VRUs can vary slightly depending on the source, but scientific literature generally recognizes several key groups based on their exposure to traffic risks and the degree of protection they have. VRUs groups include elderly pedestrians, children, disability people, cyclists, motorcyclists, scooter and e-scooter Riders, etc. In this regard, it becomes highly important for the government to identify and address the basic needs of the vulnerable groups (Holländer *et al.,* 2021).

Author reviews the comprehensive literature that devoted current trends in user-centric approach in PT development with focus on VRUs' needs and explore the current state of PT system and its quality in Malta. For this data collection in the frame of organised survey with VRUs representatives in Malta is conducted.

The inadequate infrastructure as well as economic constraints is identified as some of key factors or reason causing lower accessibility within the PT of Malta. Additionally, the main factor determining the low accessibility of PT for vulnerable people is the physical appearance of transport and bus infrastructure (Moura *et al*, 2022). Operational, social as well as financial barriers are some of major challenges that have been determined in this paper faced by vulnerable people while accessing Maltese PT. So, author explores the importance of addressing the needs of VRUs in Maltese PT and investigates the challenges faced by them while accessing Maltese PT.

The main importance related to addressing the needs of VGs within the Maltese PT is associated with promotional of social inclusion and equality within the country (Suryani *et al.,* 2024). Moreover, prioritising safety, convenience as well as comfort are some of other factor that justifies the importance of addressing the needs of VGs. Accessible transport for the public is necessary for all, irrespective of disability, age, socioeconomic status, or gender. In addition, increasing the accessibility of transport services is a necessity since it underlines the principles of human rights and equality which are essential in Malta as a member of the European Union.

At the end author recommends strategies to improve accessibility and inclusivity in Maltese PT for vulnerable groups.

The research is supervised by Dr.sc.ing., Professor Irina Jackiva.

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ELEKTRISKO KRAVAS TRANSPORTA LĪDZEKĻU IEVIEŠANA LATVIJAS RAŽOŠANAS KOMPĀNIJĀ: IESPĒJAS UN IZAICINĀJUMI

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Atslēgvārdi: Kravu pārvadājumi, elektriskie kravu transporta līdzekļi, ilgtspēja, loģistika, emisijas

Mūsdienu industriālā attīstība un klimata pārmaiņu radītās problēmas rada nepieciešamību un veicina pāreju uz ilgtspējīgiem risinājumiem loģistikā un transportā. Elektrisko kravas transporta līdzekļu (EKTL) integrācija ražošanas un loģistikas procesos piedāvā virkni priekšrocību, tostarp oglekļa dioksīda (CO_2) emisiju samazinājumu, degvielas izmaksu ietaupījumu un trokšņa piesārņojuma mazināšanu. Tomēr šo transportlīdzekļu ieviešanas plāns ir apgrūtināts un saskarās ar dažādiem izaicinājumiem, piemēram, ierobežotu uzlādes infrastruktūru, augstām sākotnējām investīcijām, ierobežotu nobraukuma diapazonu un nepieciešamību pielāgot esošās loģistikas operācijas.

Šajā pētījumā tiek analizēti EKTL ieviešanas priekšnosacījumi, galvenās priekšrocības un potenciālie trūkumi, kā arī sniegti priekšlikumi to efektīvai integrācijai ražošanas uzņēmumos. Pētījumā tiek izvērtēta transporta elektrifikācijas ietekme uz uzņēmumu darbības efektivitāti un konkurētspēju, ņemot vērā Latvijas valsts un Eiropas Savienības regulējumu attiecībā uz ilgtspējīgu transportu. Tāpat tiek apskatīti citi alternatīvie degvielas veidi, dažādi tehnoloģiskie risinājumi, piemēram, uzlabotas akumulatoru tehnoloģijas un jaudīgākas uzlādes sistēmas.

Pētījuma rezultāti sniedz praktiskus ieteikumus uzņēmumiem, kas apsver elektrisko kravas transporta līdzekļu ieviešanu, kā arī identificē stratēģijas, kas palīdz pārvarēt galvenos izaicinājumus un maksimizēt iespējamos ieguvumus.

Pētijuma zinātniskais vadītājs Ph.D. Aleksandrs Kotļars.

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RESEARCH and TECHNOLOGY – STEP into the FUTURE, 2025, Vol. 20, No. 1, 78-79
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IMPROVEMENT OF SUSTAINABILITY: NET-ZERO SUPPLY CHAIN IN INDIA

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Keywords: Sustainability, net-zero supply chain, Indian e-commerce, green logistics, supply chain management, factor analysis

Currently, the growth in the India e- commerce segment is swift, resulting in the transformative change in the retail landscape, consumer behaviour (Ranjan, 2024). However, the industry has some legal tussles especially in relation to; competition and abuse of dominance or the provisions of the Competition Act, 2000. Thus, the role of technology and customer behaviour in interaction with the legal context forms the basis for the further development of e-commerce in India (Kaur, 2024). Drawing upon Stakeholder Theory and Institutional Theory (Li, 2024; Reynolds, 2024), the study identifies critical dimensions—financial constraints, infrastructural and technological barriers, regulatory factors, and organizational culture and awareness—that impede or enable sustainability adoption. The present paper focuses on how sustainability can be incorporated into e-business models for sustainable profitability and customer satisfaction (Vanshika and Renu, 2024).

Using a quantitative research approach, data were collected via an online structured questionnaire distributed to logistics professionals, e-commerce managers, sustainability officers, procurement specialists, and academic researchers. A factor analysis was conducted on 206 responses to determine latent variables influencing sustainable practices in supply chains. Results reveal that initial investment costs (Wangsa *et al.*, 2023; Patel, 2023), lack of electric vehicle charging infrastructure (Dohale *et al.*, 2024), fragmented environmental regulations across Indian states (Sarin and Srivastava, 2024), insufficient sustainability training (Yadav *et al*., 2023), and limited access to green financing (Huang *et al.*, 2024) significantly hinder the adoption of eco-friendly practices in logistics operations.

This research contributes to the development of a conceptual model tailored to India's e-commerce environment, providing actionable insights for policymakers, logistics firms, and e-commerce platforms. The research aims to assess the factors affecting the implementation of sustainable practices within the logistics of the e-commerce sector of India to improve sustainability and establish a net-zero supply chain. The object of the research is the supply chain systems in India, particularly focusing on sectors with significant carbon footprints. The subject of the research focuses on improving sustainability practices and achieving net-zero emissions within supply chains in India.

The main tasks of the research are: (1) to conduct a thorough review of relevant literature to identify the factors affecting implementation of sustainability practices within logistics of the e-commerce sector in India; (2) to conduct an online survey via social media platforms with logistics experts and students; (3) to perform a factor analysis test; and (4) to develop and propose a model for effective implementation of sustainability practices within logistics and supply chain management and establish a zero-supply chain.

While the research offers valuable insights, several limitations may affect its applicability and reliability, including geographic scope, survey bias, self-reported data, and the evolving nature of the sector. Technological constraints, regulatory inconsistencies, financial feasibility, and access to expertise further complicate analysis. Recognising short- vs long-term effects is also critical. Addressing these will improve research credibility.

This study adopts a thorough quantitative methodology to examine the determinants affecting sustainability practices in India's e-commerce logistics. Data are collected through an online survey and analysed using statistical methods, including factor analysis. The findings will support the creation of a conceptual model to guide sustainable supply chain transformation toward net-zero emissions. Ethical considerations and a defined timeframe ensure the study's rigour and practical relevance.

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The research is supervised by Dr.sc.ing., Professor Genadijs Gromovs.

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THE IMPACT OF COVID-1G ON HEALTHCARE DISTRIBUTION AND WAREHOUSING CHALLENGES, ADAPTATIONS, AND FUTURE RESILIENCE

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Keywords: Supply Chain Resilience, Crisis Management, COVID-19 pandemic

The COVID-19 pandemic exposed critical vulnerabilities in global healthcare logistics, particularly in distribution and warehousing functions. Timely delivery and storage of essential items—such as personal protective equipment, ventilators, and medication—were hampered by transport bottlenecks, volatile demand, supplier shutdowns, and workforce shortages (Choi *et al*., 2020). This research aims to identify the key operational challenges faced during the pandemic and evaluate the effectiveness of strategic adaptations in enhancing supply chain resilience.

The study addresses two primary research questions:

1. What were the most impactful disruptions to healthcare distribution and warehousing during COVID-19?
2. Which strategies contributed most effectively to operational continuity and resilience?

To answer these, a quantitative research design was employed, using a structured survey instrument developed from validated supply chain resilience frameworks (Ivanov & Dolgui, 2020; Khezr *et al*., 2019). The survey was distributed to logistics managers, warehouse supervisors, and supply chain coordinators in healthcare institutions across Europe.

Results were analysed using regression modelling and correlation analysis. The findings show that companies which adopted blockchain, AI-based tracking, automation, and supplier diversification were significantly more resilient (Ivanov & Dolgui, 2020; Khezr *et al*., 2019). In contrast, organizations relying solely on just-in-time models struggled with response times.

Despite these innovations, challenges such as high operational costs, limited data interoperability, and regulatory complexity continue to hinder long-term resilience. By integrating practitioner insights and prior research, this study contributes a framework for crisis-ready medical logistics systems. The results offer actionable guidance for policymakers, healthcare administrators, and scholars aiming to build sustainable, shock-resistant healthcare supply chains.

The research is supervised by Dr.sc.ing., Associate Professor Evelīna Budiloviča.

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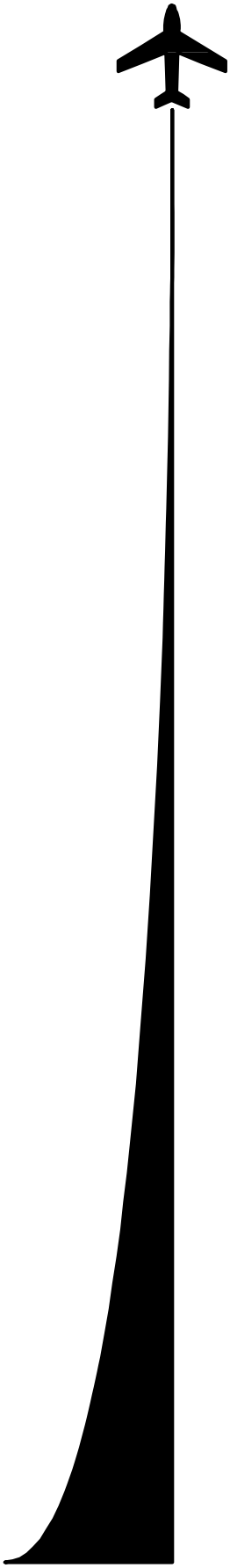

Session 3

Market: Research, Projects, Technologies and Problems of the Modern Economy and Business

Tirgus: pētījumi, projekti, tehnoloģijas un mūsdienu ekonomikas un biznesa problēmas

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BARRIERS AND CHALLENGES TO DIGITAL TRANSFORMATION IN E-GOVERNMENT: A SYSTEMATIC REVIEW IN POST-CONFLICT AND DEVELOPING COUNTRIES

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Keywords: Digital transformation, e-government, post-conflict countries, developing countries

Digital transformation is a massive challenge for post-conflict and developing nations, where infrastructural deficits, policy constraints, and socio-economic limitations hinder progress. This study critically examines the literature to identify significant impediments and strategic loopholes in the implementation of e-government in these nations. Using the PRISMA guideline, 20 relevant studies out of 291 records were chosen. Bibliometric mapping through VOSviewer was applied to reflect trends in research and thematic development.

Findings suggest that the most relevant impediments include insufficient technological infrastructure, regulatory disjointedness, budget constraints, resistance, and low technical capacity. These factors highlight institutional and governance deficits subtracting from digital progress under fragile settings. Further, stability in governance and external regulatory climates considerably impact digital transformation efforts, emphasizing the importance of consistent policy environments.

Despite these difficulties, emerging technologies such as blockchain, artificial intelligence, and decentralized digital platforms offer feasible solutions, mainly if supported by strategic investment, capacity-building interventions, and strong institutional support. The study requires tailored digital policies, capacity development programs, and more substantial institutional arrangements to support sustainable e- government adoption, particularly in fragile and post-conflict environments.

The research is supervised by Dr.sc.ing., Professor Dmitry Pavlyuk.

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INTERCONNECTED AND EXPOSED: MODERN PERSPECTIVES ON SYSTEMIC RISK IN EUROPEAN FINANCIAL INSTITUTIONS

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Keywords: Systemic risk, financial stability, European financial institutions, interconnectedness

The increasing interconnectedness among European financial institutions has heightened the complexity of systemic risk assessment, particularly in an era dominated by digital and technological advancements. This literature review examines and highlights key developments in systemic risk analysis methodologies on financial stability within the European Union.

This study's goal is to ascertain the extent of the research gap pertaining to systemic risk and interconnectedness

The object of this study is the publications indexed in Scopus and Web of Science that focus on systemic risk and financial stability, while the subject of the study is the set of articles identified through the application of the specified keyword queries.

This review delves into existing studies employing advanced analytical frameworks, including the Spillover Index (Diebold and Yilmaz, 2009, 2012) and Dynamic Conditional Correlation models (Engle, 2002). Attention is given to the mathematical evolution of these tools, with a critique of earlier approaches such as Cholesky orthogonalization and Generalized Forecast Error Variance Decomposition, advocating instead for Square Root Matrix Orthogonalization (SQRTM) due to its superior order-invariance and intact formulation.

Recent literature has further enriched the understanding of systemic risk. For instance, Fiori and Porro (2023) introduced a compositional data approach to analyze systemic risk contributions across European countries, shedding light on cross-country variability patterns. Tafakori *et al*. (2021) proposed a novel latent space model to visualize financial network dependencies, presenting empirical evidence on default contagion and systemic threats. Additionally, Nistor and Ongena (2023) examined the impact of policy interventions on systemic risk, highlighting the nuanced effects of liquidity injections and recapitalizations on financial stability.

The ongoing development and refinement of systemic risk measurement methodologies underscore the persistent challenge of capturing the evolving complexities of financial systems. This literature review highlights the importance of a multi-faceted approach that integrates diverse methodologies and adapts to the changing nature of systemic risk, ultimately contributing to the goal of mitigating risk and promoting a more resilient financial environment.

By reviewing theoretical foundations, empirical applications, and regulatory implications, this study provides evidence-based recommendations for policymakers and regulators. These recommendations aim to enhance the resilience of Europe's financial systems, ensuring stability against challenges posed by digital transformation and interconnected markets. The literature review concludes with recommendations for incorporating advanced systemic risk assessment tools into regulatory strategies to combat emerging vulnerabilities in the evolving financial landscape.

The research is supervised by Dr. oec., Professor Jelena Popova.

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THE EVALUATION OF CUSTOMER LOYALTY IN THE SCOPE OF DIGITAL TOOLS FOR THE 50+ MARKET SEGMENT

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Keywords: Customer loyalty, digital tools, mobile application, market segment 50+

Nowadays we have the most paradoxical situation in the scope of using mobile applications from a management point of view (Díaz-Bossini and Moreno, 2014; Abdullah and Hamid, 2019). According to economic research, the most solvent group of the population (Chen *et al*., 2022), with the highest income is in the age segment of 45–60 years (50+ segment) (De Barros *et al.*, 2014). Moreover, after reviewing several popular mobile applications in Latvia it appears that each of them ignores a specific requirement for people 50+ such as simplified and adaptive interface (Gomez-Hernandez *et al.*, 2023). The situation creates many issues to strengthen the loyalty of customers in this segment for using digital tools (Goumopoulos *et al.*, 2017). The situation leads to direct economic and reputational losses for large trading and service companies (Awan *et al.*, 2021).

The *object of the research* is the scope of digital tools for the 50+ segment. The *subject of the research* is the ways to strengthen the customer loyalty of this age group via using the digital tools.

The *aim of the research* is to identify and evaluate the ways to strengthen the loyalty of customers in the 50+ segment in the scope of digital tools.

To achieve the aim of the study, the following research tasks are posed:

1) To study and analyse the 50+ market segment for the use of digital tools.
2) To provide a preliminary assessment of the impact of the analyzed result on customer relationships and management performance.
3) To identify the specific ways to increase customer loyalty and provide solutions to strengthen the motivation of the 50+ market segment in the application of digital tools.

To solve the tasks, various research methods were used, such as:

1) Literature review;
2) Observation of mobile apps;
3) Questionary;
4) Statistic analysis;
5) Graphical interpretation of data analysis;
6) Comparative data analysis;
7) Generalization of information.

The result of the research is the development of recommendations for company management policy to strengthen the customer loyalty of the 50+ segment in using digital applications.

The research is supervised by Dr.oec., Professor Jelena Popova

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DIGITAL SOCIALIZATION: THE IMPACT OF SOCIAL MEDIA AND DIGITAL PLATFORMS ON CONSUMER BEHAVIOR AND BUSINESS MODELS

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Keywords: Digital socialization, social media, digital platforms, consumer behavior and business models

Digital socialization has become an integral part of the modern economic and social environment, influencing both individual behaviour patterns and business strategies of companies. According to the analytical group Kepios, at the beginning of January 2025, there were approximately 5.24 billion social media users in the world, which is 63.9% of the total population of the planet (Kemp, 2025). The growth of 206 million new users within a year, as well as the fact that 94.2% of all Internet users use social media at least once a month, highlight not only the scale of the phenomenon, but also its sustainability. Thus, it is becoming clear that digital communication platforms are playing an increasingly important role in shaping consumer behaviour and transforming corporate communications. Moreover, digital socialization has become an integral part of the modern economic and social environment, influencing both individual consumer behaviour patterns and companies' strategic approaches to interacting with audiences.

Against this background, this aim of the research is to analyse the mechanisms by which digital socialization influences consumer behaviour patterns to study how businesses adapt their models under the influence of these changes. Particular attention is paid to studying engagement, the formation of digital loyalty, and personalized experiences formed in an algorithmically controlled environment (McKinsey & Company, 2023).

To achieve the objectives of the analysis, specific practices of digital commerce and influencer marketing are considered, including examples of successful integration of social-behavioral tools into brand strategy. For example, the educational platform Duolingo is a clear case: the use of gamification, push notifications and rating systems not only helps to retain users, but also forms stable models of digital behaviour (UNICEF, 2022). In addition, a McKinsey & Company report (2023) describes examples of the use of artificial intelligence in digital interactions with customers, which allows for greater personalization accuracy and brand trust.

Along with the positive effects of digital socialization, key challenges facing both consumers and the business environment have been identified. These include increasing digital dependence, decreasing ability to critically evaluate information, manipulative behavior of algorithms, and ethical issues of data use (WHO, 2023a; WHO, 2023b).

Young users are particularly vulnerable, as highlighted in the UNICEF report (2022), which raises the need for a systemic approach to developing digital literacy and digital ethics.

Consequently, the results of the analysis demonstrate that companies that implement conscious and ethical digital engagement strategies achieve higher levels of customer engagement, sustainability and trust.

In conclusion, practical recommendations are offered for businesses aimed at strengthening digital culture, developing transparent communication channels and creating sustainable mechanisms for digital interaction, considering the risks and expectations of the modern consumer.

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FACTORS AFFECTING CUSTOMER ADOPTION OF VIRTUAL BANKING SERVICES IN SRI LANKA

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Keywords: Virtual banking, customer adoption, Sri Lanka, technology acceptance model (TAM), theory of reasoned action (TRA), innovation diffusion theory (IDT)

This research aims to identify specific factors impacting the readiness and willingness to embrace digital banking services by customers in Sri Lanka in the light of changing technological and economic environments. Virtual banking has emerged as a key service dimension in the banking sector that enables online execution of financial transactions with ease. Despite the rising usage of online banking globally, the uptake of online banking in Sri Lanka is uneven due to local socio-economic, technological and behavioural factors. The result of the study will be offering insights for financial institutions to enhance customer engagement strategies and improve service delivery.

To analyse the factors affecting adoption of virtual banking services, this research applies three theoretical models: The Theory of Reasoned Action (TRA), the Technology Acceptance Model (TAM), and the Innovation Diffusion Theory (IDT). Fishbein and Ajzen (1975) introduced TRA, which explains the relationship between attitude, subjective norms, and behavioural intention. Davis (1989) proposed TAM, which focuses on two primary determinants: perceived ease of use and perceived usefulness, influencing technology adoption. Rogers (1962) developed IDT, which describes how innovations diffuse within a social system, emphasizing relative advantage, compatibility, and complexity as key adoption factors.

This research investigates the impact of factors such as security perception, perceived ease of use and perceived usefulness, trustworthiness and the presence of infrastructure on the adoption of virtual banking services in Sri Lanka, drawing on prior literature. (Jayasiri & Weerathunga, 2008; Suraweera *et al.*, 2008)

Data will be collected via structured surveys distributed among Sri Lankan online banking customers, with subsequent analysis using statistical methods to interpret adoption behaviours and the influence of socio-demographic factors.

The findings are expected to offer valuable insights for financial institutions to enhance customer engagement strategies and improve the delivery of online banking services, fostering greater adoption rates in Sri Lanka's banking industry.

The research is supervised by D.S.Sc. Professor Alexander Plyats.

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RESEARCH and TECHNOLOGY – STEP into the FUTURE, 2025, Vol. 20, No. 1, 92-93
Transport and Telecommunication Institute, Lauvas 2, Riga, LV-1019, Latvia

ANALYSIS OF THE ENTRY OF CHINESE ELECTRIC VEHICLES IN LATVIA: IMPACT ON THE AUTOMOTIVE INDUSTRY AND FUTURE SALES PROSPECTIVE

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Keywords: Chinese electric vehicles, entry of Chinese electric vehicles in Latvia, electric vehicles market in Latvia, electric vehicles sales prospective in Latvia

Nowadays sales of new electric vehicles (EVs) are not growing as quickly in Europe. The prices of electric vehicles are still too high compared to petrol and diesel engine vehicles and many European countries face challenges related to electric vehicle charging infrastructure. This presents a significant challenge for Chinese auto manufactures to entry Europe automotive industry with the competitive prices and offer. However, the Europe Union have to protect the local market and for this reason Chinese automotive industry is now facing increasing challenges in Europe, especially with the new EU restrictions and additional taxes.

In recent years, the automotive industry has faced many challenges, including Covid-19 pandemic, the war in Ukraine, economic decrease in Europe, growth in the Chinese market and other factors that have impacted automotive manufacturers and consumers. More of these challenges are discussed in the latest research "Automotive Industry in The European Union" by Bobowski *et al.* (2022).

One of the latest research projects, published in 2024, analysing the Latvian automotive industry is "Latvia Automotive Market Report - Analysing EV Trends and Car Sales Volume Data." (Global Monitor, 2023). The authors describe an overview of Latvian automotive sector and highlight the key points that are particularly important for manufacturers and suppliers that are operating in this region. Additionally, the authors thinking that the automotive industry is a major contributor to the country' s economy.

Latvia is a small market compared to larger European countries. In last few years, several Chinese automotive brands have entered the Latvian market, with the success story of Ora electric vehicle sales in 2024 drawing significant attention. How will the entry of new Chinese EVs impact the Latvian automotive market and what is the forecast for future sales of new Chinese electric vehicles in Latvia? To what extent can third-party factors – such as government, Europe Union regulations, economic indicators, taxes, support and fleet programs – influence the sales process and demand for Chinese EV sales in Latvia?

The research is supervised by Ph.D.sc.pol., Assistant Professor Juris Kanels.

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E-COMMERCE AND ITS ROLE IN ACHIEVING SUSTAINABLE DEVELOPMENT AT THE COUNTRY LEVEL

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Keywords: E-commerce, sustainable development, digital economy, environmental impact

The relevance of the study of the role of e-commerce in achieving sustainable development at the country level is due to the global trends of digitalization of the economy and the growing importance of sustainable development in modern conditions. In recent years, e-commerce has become a powerful driver of economic growth, contributing to the creation of new jobs, the development of small and medium-sized enterprises and the expansion of export potential of countries. At the same time, issues of sustainable development are becoming a priority on the international stage, which requires finding effective ways to integrate digital technologies into the economy with minimal impact on the environment and social structures.

However, despite the significant potential of e-commerce, the relationship between e-commerce development and sustainable development indicators at the national level remains under-researched.

Aim of the study: to identify the relationship between e-commerce and sustainable development indicators of the countries included in the European E-Commerce Report 2024.

To achieve the objective, the author formulated the following research questions:

1. What are the main trends in online shopping across different European countries, and how do they correlate with sustainability indicators?
2. Which sectors experience the highest growth in e-commerce, and how does this align with sustainable development trends?
3. How does the share of medical and pharmaceutical products in online purchases impact the development of digital healthcare services?

The object of the study is e-commerce and its impact on the achievement of sustainable development goals at the country level. The subject of the study is the relationship between e-commerce development and sustainable development indicators in the countries included in the European E-Commerce Report 2024, taking into account environmental, economic and social aspects.

The European continent is home to a range of diverse markets, especially in the digital sector. Internet usage has grown steadily, rising from 87% in 2019 to 92% in 2023, with further growth anticipated in 2024. The economy faced a setback in 2020 with a decline in GDP due to the Covid-19 pandemic, but it has since rebounded strongly. (EuroCommerce, 2024)

Inflation has hurt shoppers' spending power around the world and helped fuel rapid growth in online platforms selling cheap products. (Reid, 2024) The emergence and growth of low-cost platforms is increasing competition in the e-commerce market, raising concerns among local players regarding regulatory compliance and fair competition. These findings emphasize the importance of European online retailers adapting to the changing market conditions, considering both economic factors and increasing competition from international platforms.

Among the most important aspects affecting sustainability are reducing carbon footprints by optimizing logistics processes, shifting to greener delivery methods and implementing

innovative packaging solutions. In addition, e-commerce helps strengthen international trade and export opportunities, which contributes to the growth of the national economy and strengthens the country's position in the global market.

The research is supervised by Mg.oec. Oksana Skorobogatova

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ASSESSING THE RELATIONSHIP BETWEEN JET FUEL PRICES AND CONSUMPTION IN U.S. AVIATION FROM 2000 to 2025

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Keywords: Jet fuel consumption, fuel price trends, oil market fluctuations, geopolitical influence on fuel costs, seasonal travel patterns, fuel price distribution

Jet fuel consumption and fuel prices are key economic factors that drive the aviation industry, affecting both passenger and cargo flights. This study aims to analyze the relationship between jet fuel consumption and fuel prices in the U.S. aviation sector from 2000 to 2025, investigating whether chnages in fuel consumption directly impact fuel prices and vice versa. The research specifically examines seasonal trends, economic disruptions, and geopolitical influences on these variables. The key research questions include: (1) How does jet fuel consumption vary seasonally and in response to major global events? (2) To what extent do changes in fuel consumption influence jet fuel prices? (3) What external factors, beyond consumption, play a significant role in determining fuel prices?

The research subject is the U.S. aviation sector, with a focus on both international and domestic flights, while the research subject involves statistical patterns in jet fuel consumption and pricing trends. This study utilizes data from the Bureau of Transportation Statistics (Bureau of Transportation Statistics, 2025) and economic reports. Statistical and distribution analysis and time-series modeling is used to identify trends and correlations.

Charts display that fuel consumption follows a seasonal pattern, peaking in summer and declining in winter, with significant drops observed after events like 9/11, the 2008 financial crisis (Investopedia, 2022), and the COVID-19 pandemic. In contrast, fuel prices are primarily driven by global oil production, economic downturns (Petro Online, n.d.), and geopolitical instability (Baffes *et al.*, 2018) rather than direct changes in jet fuel demand. Removing COVID-19-related outliers, fuel consumption demonstrates a near-normal distribution, whereas fuel prices exhibit no such distribution.

This research provides insights that can aid airlines in fuel procurement strategies, budget forecasting, and operational planning. Additionally, it offers economic analysts a clearer understanding of fuel price determinants beyond demand-driven factors (Brooks, 2024). Ultimately, while fuel consumption trends are relatively stable, geopolitical events remain the predominant driver of jet fuel price fluctuations.

The research is supervised by Dr.sc.ing., Associate Professor Sergejs Bratarčuks.

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ASSESSING THE FINANCIAL PERFORMANCE OF A MULTINATIONAL AUTOMOBILE COMPANY

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Keywords: Financial performance, financial analysis, multinational automobile company

To assess the long-term sustainability and profitability of a company, it is very essential to evaluate the financial position of a company. Financial position assessments help a company's stakeholders to make managerial and financial decisions. After evaluating the financial position of a company, investor make the decision regarding the investment in a company as investors invest only in those companies which have long-term sustainability and profit earning company (Mahdawi *et al.*, 2021).

The aim of the research is to assess the financial position of a multinational automobile company and develop recommendations for its improving. To assess the company financial position, various techniques are used by researchers in economic and scientific literature. Literature review helps the author to select appropriate methods of financial analysis that can be applied for a multinational company in automobile industry. The main source of information for financial analysis is a company's annual report, which includes income statement, balance sheet, cash flows statement, and other types of reporting. To assess the company financial position, one of the fundamental tools is financial ratios included profitability ratios, liquidity ratios, business activity, and solvency ratios (Hasanaj & Kuqi, 2019). The object of the research is the multinational automobile company Ford Motor Ltd. From the last two years, Ford Motor Ltd faced the financial loss as Ford Motor invested significant amount on electric vehicle segment but unable to generate good revenue from it.

The aim of financial analysis is to provide useful information for a wide type of stakeholders in the process of decision making. For example, a company investor evaluates its solvency and probability of bankruptcy using Altman Z-score model. Some researchers have a view that a liquidity ratio is also very important most to determine financial distress position of company (Kim-Soon *et al*., 2013). To bring efficiency in the financial assessment advanced technologies like machine learning and artificial intelligence used (Kunwar, 2019). Creditors also assess the financial position of the company before providing loan to the company. When the company financial position is weak then company unable to pay the loan amount back which become loss for creditors. Management evaluates the financial position of a company to develop strategies regarding the cost structure and resource allocation (Barauskaite & Streimikiene, 2021).

Expected results of the study are identification of main trends of the industry development, determination of the main issues in the case company's financial position based on financial calculations, assessment of the case company financial health, and development recommendations for the improvement of the case company financial performance, which can be useful for any other such type of companies in automobile industry.

The research is supervised by Dr.oec., Professor Irina Kuzmina-Merlino.

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RESEARCH and TECHNOLOGY – STEP into the FUTURE, 2025, Vol. 20, No. 1, 100-101
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THE IMPACT OF ARTIFICIAL INTELLIGENCE ON LABOR MARKETS

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Keywords: Artificial intelligence, labor market, employment, automation, skills gap

Artificial intelligence is one of the emerging technologies that has been adopted in many organizations and economies around the world that alters the nature of employment. The research design of this task was to find the overall impact of AI on employment from the positive and negative impacts.

The aim of the present study is to identify the impact of AI on jobs features, skills required, and the job market.

Research Objectives:

- To assess the extent of AI's impact on existing job roles and the emergence of new occupations.
- To investigate the skills gap created by AI integration and the necessity for reskilling and upskilling.
- To evaluate ethical and social issues arising from AI-driven automation, including income disparity and job loss.

The scope of this research is in the area of dynamics of employment, skills needed for employment in future, and the impact of AI on socio-economy and selected industries such as manufacturing, health, banking and customer relations (Agrawal *et al*., 2019).

Thus, the whole concept of AI at the workplace is not only an attempt at the innovation of technology at the workplace; it's a new orientation to work (Dahlin, 2024; Frank, 2019). Given that AI is gradually pushed forward for handling mundane repetitive activities, human beings are called upon to apply their skills in solving problems and innovativeness (Gips, 1979). This has made the existing job description to change and could be a continuous process that requires new concepts such as flexibility, problem-solving skills, and training (Holsapple and Whinston, 1985).

That is why in this new environment flexibility and the ability to adapt is the key. Workers need to embrace the change and the use of new tools as well as predict future trends or inconveniences (Uçar *et al.*, 2024). Such a setting requires a proactive approach in the workforce as opposed to a reactive approach necessary when employees are helpless against the AI tools now being used by their organizations (Lindsay, 1985).

Furthermore, the increase of the AI affects the need for the multifunctional competencies that combine tech and interpersonal skills. For example, teachers ought to be conversant with various AI tools he or she could use in analyzing students' performance but should also possess interpersonal skills, cultural sensitivity and emotional intelligence when handling the learners (Nilsson, 1985). This combination is important to help work with AI in order to avoid it taking over the type of work that is more appropriate accomplished with a human approach. However, it should also be noted that a human analyst can interpret AI-generated data and utilize them or apply the result, which calls for analytical thinking as well as emotional intelligence (Walker and Winders, 2023).

In this process, organizations need to develop a culture of learning for a lifetime and the approach to innovation. This requires fostering of culture in which learning is a continuous

process, and the employees are encouraged pursue more professional training (Webb, 2019). Through training, development and policies companies can only be in good stead to address existing issues arising from AI implementation. Employee education also promotes retention within the organization as well as strengthening of the human resource department (Zarifhonarvar, 2023).

In addition, there are additional recommendations such as humans and AI working in synergies that should come out clearly in organizations in order to help teams to flourish. The combination of AI as a part of organizational decision-making supports and the decentralization of the decision-making process help to enable employees. This not only aids in making the general business functioning agile but also encourages the employees to become part of the larger responsibility of contributing towards organization success amid the advanced AI environment.

The research is supervised by Dr.oec., Professor Inna Stecenko.

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RESEARCH and TECHNOLOGY – STEP into the FUTURE, 2025, Vol. 20, No. 1, 102
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FACTORS AFFECTING CUSTOMER SATISFACTION IN ONLINE BANKING

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Keywords: Customer satisfaction, online banking, user experience, competitive advantage

This research examines the incremental role of determinants in their impact on customer satisfaction in online banking, especially focusing on Pan Asia Bank, Sri Lanka. In a revolutionary era of e-commerce, understanding customer satisfaction has now become of ultimate significance for the financial institutions seeking to enhance their degree of competitive advantage (Hapuarachchi and Samarakoon, 2020).

The aim of this study is to identify significant independent variables influencing customer satisfaction, i.e., perceived usefulness, perceived ease of use, perceived relative advantage, and compatibility (Kumari, 2016). A quantitative research approach was followed with the administration of a structured questionnaire among 120 online banking customers selected through a simple random sampling technique. This research approach facilitated the successful collection of data that is representative of real user experiences and perceptions (Madumanthi and Nawaz, 2016). Data were analysed utilizing IBM SPSS software with descriptive statistics and Pearson correlation analysis to establish strong relationships between the variables identified. Results show a strong positive correlation between customer satisfaction and all four independent variables, and among them perceived usefulness demonstrated the most substantial relationship. Findings indicate the importance of financial institutions assigning high priorities to enhance online banking services to achieve maximum levels of customer satisfaction. By focusing on these key determinants, financial institutions can develop strategic, data-driven improvements on online banking platforms, paving the way for solutions that meet customer desires. Furthermore, the results contribute to the existing body of knowledge in online banking by validating the relevance of these determinants in the specific Sri Lankan context.

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Transport and Telecommunication Institute, Lauvas 2, Riga, LV-1019, Latvia

ANALYSIS OF THE CONDITIONAL CONSTRUCTION INTEGRATION IN UNIVERSITIES' MARKETING COMMUNICATION MODELS

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Keywords: Marketing communication, metrics indicators, conditional constructions, higher institutions

The rapid development of artificial intelligence and information and communication technology (ICT) has changed the landscape of marketing communications models in higher education, requiring a comprehensive approach to engaging and communicating effectively with students. (Saadjad, 2025).

Previous research shows universities have begun integrating various digital value metrics into their marketing communications models. (Petersen, 2025). Digital value metrics are numerical components that represent the success of an organisation's digital presence to assess user activity and engagement (Angelou *et al.*, 2024). Despite the multitude of analytical tools, there are notable gaps in forecasting methods that affect the effectiveness of marketing communications models (Tarchiani and Grey, 2025). To address the above issue, the article's author proposes combining digital value metrics with integrating the approach based on conditional construction statements into the model of university marketing communications. A conditional construction statement defines a cause-and-effect relationship between two events, actions, or conditions. It typically follows an "if-then" format, where the "if" clause presents the condition, and the main clause describes the result or consequence if the condition is met. (Liu *et al.*, 2025.)

This article aims to analyse how conditionals are integrated into a university marketing communications model and how they are combined with various digital value metrics. The study examined the possibilities of integrating various online tools into university communication models and analysed the mathematical and marketing communication models that provided the foundation for construction conditionals. By incorporating digital value metrics into a university marketing communications model, institutions can evaluate the effectiveness of their communication activities while considering seasonal fluctuations. This approach also facilitates the assessment of the impact of the content used during specific periods. (Timmy *et al.*, 2024)

The study used various research methods, such as comparative analysis of multiple marketing communication models to estimate differences, similarities, and efficiency, qualitative research for content analysis, and digital social media analytics to measure the efficiency of communication models in online marketing. The study resulted in a marketing communications model structured as a conditional statement design for higher education institutions. This model can predict a decline or rise in specific indicators, such as engagement and interaction rates, and evaluate the effectiveness of the proposed model.

Further research should focus on categorising digital value metrics to facilitate the use of such tools.

The research is supervised by Dr.oec. Jekaterina Vozņuka.

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WORKSHOP

Future Aviation Technologies: Research Perspectives from Aero Group

Nākotnes aviācijas tehnoloģijas: aero grupas pētniecības perspektīvas

RESEARCH and TECHNOLOGY – STEP into the FUTURE, 2025, Vol. 20, No. 1, 106-107
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MANAGEMENT OF AIRCRAFT MAINTENANCE PROCESSES, PROSPECTS, AND OPPORTUNITIES

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Keywords: Aircraft maintenance processes, predictive maintenance, safety management, health management

Modern technology, such as digitalization and the use of artificial intelligence (AI) within aircraft maintenance operations, is rapidly gaining prominence today. Such technology holds the key to substantially improving the efficiency, reliability, and cost- effectiveness of aircraft maintenance processes. This is a key point against the increased demands for safety and strong observance of the standards of the Safety Management System (SMS) (Kabashkin *et al.,* 2023) (Agustian & Pratama, 2024). A key aspect of implementing AI and digital technologies is compliance with aviation safety regulations and standards, such as ICAO, EASA, and FAA. This requires comprehensive research and development of methodologies to ensure seamless integration of new technologies without violating safety regulations and procedures (Federal Aviation Administration, 2024).

Scientific activity in this area is of specific significance, as it enables the development and implementation of new diagnostic, failure prognosis, health monitoring, and automated maintenance management techniques. One of the key achievements of digitalization is the implementation of Predictive Maintenance (PdM) based on big data and machine learning. This concept facilitates prompt identification of potential breakdowns, reducing the chances of occurrences and ensuring flight safety (Meissner, & Wicke, 2022).

Managing the organization of maintenance processes also requires a comprehensive approach that includes not only digital technologies but also an effective SMS. The introduction of digital tools for monitoring compliance with safety requirements, analyzing operational data, and automating reporting improves risk control and reduces human errors in routine maintenance (Psico-smart Editorial Team, 2024).

Airplane Health Management (AHM) significantly lowers Aircraft On-Ground (AOG) events and helps air operators to reduce flight delays and cancellations events, consequently reducing expenses and establishing a more effective maintenance operation (Boeing, 2025). Moreover, the maintenance organizations can swiftly determine the underlying cause of a problem and dispatch the personnel, parts, and equipment required to service the aircraft and safely return it to by receiving real-time maintenance alerts from aircraft that are in flight. Modern data monitoring and analysis systems allow the identification of potential threats and prevention critical situations, ensuring a high level of aircraft reliability.

The introduction of intelligent algorithms makes it possible to predict the technical condition of aircraft structure, engines, and components more accurately, and that reduces the likelihood of unexpected failures and improves overall flight safety. Thus, aviation researchers shall consider this fact and initiate and initiate appropriate research to overcome this issue.

Using digital technology is considered a helpful planning tool in aircraft maintenance operations, thus, special attention shall be divided on inventory management, resource allocation, and logistic optimization as a core part of maintenance planning. Lack of resources will lead to AOG events and thus bring enormous economic losses. Another significant area of interest in scientific activities is the design of adaptive and learning systems possessing the capability for

automatic adjustment of maintenance strategy from data on real operating conditions. Such systems ensure the possibility to react flexibly to changes in the technical aircraft status, regulate maintenance intervals with the purpose of optimization, and reduce operating expenses.

In conclusion, research in digitalization and the incorporation of artificial intelligence into aircraft maintenance operations, safety management, stock and resource allocation, health management and even PdM are a requirement if one aim is to improve the reliability, efficiency, and safety of the aviation industry. They contribute to the development of innovative technology that improves failure forecasts, resources optimization, and compliance control. Application of digital technologies in combination with an effective safety management system allows us to achieve a high degree of automation and risk reduction, assuring stable aircraft operation and safety of flights. Hence, development of scientific research and technology in this area is becoming an important strategic trend for the aviation sector, stimulating its further growth and development.

Another area of interest for scientific research is the reduction of carbon dioxide emissions in the atmosphere using alternative energy sources, such as electric aircraft, and aircraft operating on Sustainable Aviation Fuel (SAF).

The author's interest in the research areas stated above, aligns with the objectives of the newly created research group, Aviation Education and Research Operation (AERO), at the Transport and Telecommunication Institute that aims to foster interdisciplinary research and academic excellence in aviation.

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RESEARCH and TECHNOLOGY – STEP into the FUTURE, 2025, Vol. 20, No. 1, 108-109
Transport and Telecommunication Institute, Lauvas 2, Riga, LV-1019, Latvia

ENHANCING AUTOMATED VALUE IDENTIFICATION USING MULTIMODAL DATA SOURCES IN THE AIR TRANSPORTATION INDUSTRY

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Keywords: Automation, values, NLP, aviation transportation

The air transport industry is undergoing rapid changes driven by technological advancements, evolving consumer expectations, and increased competition. My previous research methodology (Zervina, 2022) employs Natural Language Processing (NLP) techniques for extracting values from e-texts such as landing pages of startups in aviation domain. While effective, this approach is limited to textual sources and does not account for the multimodal nature of modern digital content, including images, videos, and speech. To enhance value identification, my next study proposes an expanded methodology integrating multiple data modalities.

This research aims to:

- Improve automated value identification in air transport by incorporating multimodal data (text, images, video, and audio).
- Develop and test a deep learning-based framework for extracting values from heterogeneous data sources.
- Compare the effectiveness of multimodal value extraction with existing text-based methodologies.

Previous research has extensively explored text-based value identification in business contexts. However, studies on multimodal sentiment analysis and information extraction suggest that non-textual data can provide significant contextual insights. The integration of image recognition, speech processing, and video analysis has been successfully applied in areas such as marketing and security but remains underexplored in air transportation.

The proposed study will utilize a combination of Natural Language Processing (NLP), Computer Vision (CV), and Speech-to-Text (STT) to extract values from multimodal datasets. The methodology includes:

- Data Collection: aggregation of landing pages, social media content, airline advertisements, and customer reviews.
- Data Preprocessing: cleaning and normalizing text, extracting features from images and videos, and transcribing speech. Large Language Model approach is tested.
- Model Development: training a deep learning model combining NLP, CV, and STT techniques for value identification.
- Evaluation: comparing performance metrics (accuracy, precision, recall) against existing text-only models.

This research is expected to make the following contributions:

- Development of a novel multimodal framework for automated value identification;
- Improved accuracy in detecting value propositions within the air transport industry, evolving LLMs in value identification;
- Insights into how different data modalities contribute to value perception in aviation.

By integrating multimodal data sources, this study aims to advance automated value identification methods in the air transport industry. This approach will provide a more comprehensive and nuanced understanding of consumer values and market trends, contributing to more effective decision-making in aviation business strategies.

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LONG-RANGE SURVEILLANCE UAV WITH AI APPLICATIONS: CAPABILITIES, CHALLENGES, AND FUTURE OPPORTUNITIES

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Keywords: Artificial intelligence, unmanned aerial vehicles, image processing, autonomous navigation, computational fluid dynamics, aerodynamic optimization

Unmanned aerial vehicles (UAVs), have become a common and essential part of society in recent years. UAVs can be found in a wide range of applications for commercial, academic, recreational, military, and economic reasons. Over the past ten years, the drone industry has rapidly gained traction as a model for manufacturing and delivering convergence, providing synergy by combining many different technologies. UAVs are becoming increasingly safe, lightweight, robust, accessible, and economical as a result of technological trends and quick developments in control, miniaturization, and computerization. The use of artificial intelligence (AI) into UAVs has significantly improved their capabilities, Specific in long-range applications. AI-driven UAVs provide autonomous flights, Moderated image processing, and real-time data transfer, making them advanced and valuable which can asset for secure monitoring, environmental evaluation, and emergency response. This research investigates the conception, creation, and implementation of long-range UAVs with AI-based features, such as autonomous navigation predictive analytics and object identification. (Wang *et al.*, 2023; Zhang and Liu, 2024).

A key challenge in AI-integrated UAV surveillance is ensuring reliable performance under different environmental conditions, while maintaining regulatory compliance. Addressing safety, cybersecurity, and ethical considerations is crucial for responsible deployment. The development of energy-efficient power management solutions, including hybrid or solar-assisted propulsion, enhances endurance and operational efficiency (Smith and Brown, 2023). Additionally, advancements in AI models for real- time threat detection and adaptive learning contribute to improved mission success rates (Ahmed *et al.*, 2024).

Computational fluid dynamics (CFD) simulations play an important role in optimizing UAVs aerodynamic performance, enhancing flight stability, and minimizing energy consumption. Nowadays, CFD techniques are widely used in a diversity of sectors, including vehicle design, turbomachinery, UAVs design, ship design, and aircraft production. Furthermore, it has applications in astronomy, biology, oceanography, oil recovery, architecture, and meteorology. Numerous numerical algorithms and software have been developed for CFD analysis, and simulations (Mader and Kenway, 2020). Because of recent advances in computer technology, numerical simulation for physically and geometrically complicated systems may now be assessed on PC clusters. The use of fluid dynamics analysis aids in refining airframe designs, reducing drag, and improving lift-to-drag ratios for better fuel efficiency and extended flight endurance (Li *et al.*, 2023). CFD-based simulations also enable the evaluation of UAV performance in different atmospheric conditions, ensuring robust operation in diverse environments (Gonzalez and Patel, 2024). Integrating CFD methodologies with AI-driven flight control systems allows for adaptive aerodynamics, further improving UAVs maneuverability and efficiency.

Scientific research in this field is substantial to overcoming technical limitations, refining AI-driven for decision-making processes, and optimizing data processing for enhanced situational

awareness. The incorporation of advanced data analytics, deep learning models, and sensor fusion technologies enables UAVs to operate with increased autonomy and precision. Future research should focus on enhancing UAV swarm intelligence, improving AI-driven flight stability, and integrating UAV networks for coordinated surveillance missions. Additionally, the combination of CFD simulations with AI-based aerodynamic optimization is a promising direction for designing next- generation UAVs with high efficiency and performance (Gonzalez and Patel, 2024).

In conclusion, AI-powered UAVs represent an advancement in surveillance technology, Provide significant improvements in efficiency, accuracy, and operational flexibility. Continued Multifaceted research in AI, UAV engineering, fluid dynamics, and CFD simulations is necessary to unlock their full potential while addressing emerging challenges. The evolution of intelligent UAV surveillance systems is expected to play a crucial role in security, disaster management, and scientific exploration, shaping the future of autonomous aerial monitoring.

The author's interest in the research areas stated above, aligns with the objectives of the newly created research group, Aviation Education and Research Operation (AERO), at the Transport and Telecommunication Institute that aims to foster interdisciplinary research and academic excellence in aviation.

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SOME APPLICATIONS ON VIBROACOUSTICS FOR NOISE REDUCTION IN HELICOPTER CABIN

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Keywords: Vibroacoustics, helicopter, sound pressure level, acoustic power level

This study explores the application of vibroacoustic soundproofing techniques to helicopter interiors using Computational Fluid Dynamics (CFD) simulations. Helicopter noise, generated by rotors, gearbox vibrations, and aerodynamic turbulence, significantly impacts passenger comfort and communication (Lu *et al.*, 2018). Excessive noise levels in the cabin can lead to pilot fatigue, reduced situational awareness, and diminished passenger experience, making effective soundproofing solutions essential for both military and civilian helicopters. Addressing these challenges requires the integration of advanced noise control techniques that are efficient, lightweight, and cost-effective.

Building on previous research conducted on the Aerospatiale Gazelle, which achieved a 7.2% noise reduction through optimized materials (Pavithra *et al.*, 2023), this study extends the methodology to a different helicopter model. The focus is on passive noise reduction techniques that use advanced materials and computational simulations. Active noise control methods, although effective, involve complex implementations and additional power consumption, making passive solutions more viable for many applications. By leveraging computational analysis, this research evaluates how material selection and cabin modifications can significantly improve noise insulation and reduce sound pressure levels (SPL) and acoustic power levels (APL).

Utilizing ANSYS and SOLIDWORKS Flow Simulation, this study examines the impact of different material configurations on the interior noise environment. The research evaluates the effectiveness of titanium and aluminum alloys in absorbing noise and reducing vibrational transmission through the helicopter structure (Wang *et al.*, 2020). Additionally, the study investigates how varying the sound absorption coefficient material (SACM) can further optimize the noise reduction process. Prior research has shown that a SACM of 0.92 provides better uniform soundproofing than a SACM of 0.7, resulting in more effective noise attenuation (Li and Xuan, 2017). These findings serve as a reference for enhancing the acoustic performance of the newly selected helicopter model.

The methodology consists of computational simulations to model sound propagation, identify primary noise sources, and optimize interior modifications. The study defines boundary conditions that closely replicate real-world operating conditions, including airflow interactions, structural vibrations, and acoustic transmission. Through Harmonic Acoustic Analysis in ANSYS, the effects of different materials on vibrational damping and acoustic absorption are examined. Meanwhile, SOLIDWORKS Flow Simulation enables the study of airflow patterns and noise propagation within the helicopter cabin. These tools provide precise, high-resolution data on noise distribution and allow researchers to analyze how material properties influence overall soundproofing effectiveness.

By focusing on CFD-based simulations, this research provides a predictive framework for assessing noise reduction techniques before practical implementation. This computational approach allows for detailed analysis without the need for extensive experimental testing, making the process more efficient and cost-effective. Furthermore, it enables iterative design modifications, allowing engineers to optimize material placement and thickness to achieve the highest noise reduction performance while maintaining weight and structural integrity constraints.

The expected outcome is a validated CFD-based framework that supports aerospace engineers in developing quieter and more efficient helicopter interiors. The study aims to demonstrate that strategic material selection and design modifications can achieve significant noise reduction, improving overall flight experience and operational efficiency. By comparing different material combinations and configurations, the research provides practical recommendations for manufacturers and engineers seeking to implement effective vibroacoustic solutions in helicopter design.

In addition to benefiting helicopter manufacturers, the findings of this study have implications for broader aviation applications, including urban air mobility (UAM) vehicles and tiltrotor aircraft. As the demand for quieter and more energy-efficient aircraft continues to grow, understanding the impact of vibroacoustic soundproofing will be essential in shaping future aircraft design and noise mitigation strategies. The research also contributes to the advancement of sustainable aviation by exploring lightweight and environmentally friendly materials that enhance acoustic insulation while minimizing added weight.

Furthermore, this study contributes to the existing body of knowledge on helicopter noise control by providing a computational approach that can be adapted to various rotorcraft models. Future research could explore additional passive noise control methods, such as composite material layering, advanced insulation techniques, and novel structural modifications to further enhance acoustic performance. Integrating experimental validation with computational findings would be a logical next step in refining these techniques and ensuring their applicability across diverse operating environments.

By applying CFD simulations to study vibroacoustic behavior, this research advances both theoretical understanding and practical solutions for mitigating helicopter interior noise. The findings are expected to support the development of next-generation rotorcraft with superior acoustic comfort, making helicopter travel more viable for various commercial, military, and emergency applications. Through the combination of material optimization, computational modeling, and industry-relevant case studies, this study lays the foundation for future innovations in helicopter soundproofing technology.

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A NOVEL ANALYSIS OF THE ANISOTROPIC NATURE OF ENERGY CASCADE IN LARGE EDDY SIMULATIONS

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Keywords: Energy cascade, large eddy simulation, hypercomplex fractals, anisotropy, turbulence eigendecomposition

Turbulence is a fundamental phenomenon within fluid dynamics and consistently brings large consequences within, but not limited to, aviation. With the aim to perform the analyses and predictions of the airflow around the aircraft effectively, multiple mathematical models such as Large Eddy Simulation (LES) and Reynolds-averaged Navier-Stokes (RANS) have been developed with the basis of filtered Navier-Stokes equations (Hamba, 2011). While turbulence modeling ultimately focuses on ensuring a stable flight, their approaches vary and therefore yield their own respective strengths and weaknesses in the results they deliver. Depending on the issue, not only must the appropriate model be used but selecting the suitable variables such as the meshing type and boundary conditions is important (van Hooff *et al*., 2017).

The primary goal of this research is to introduce a novel approach in the analysis of the anisotropic attribute of the turbulent eddies in the energy cascade, specifically for LES. It introduces an approach of incorporating hypercomplex fractal geometry and eigendecomposition. The status of self-similarity during the energy cascade will be observed with hypercomplex fractal geometry. This will then translate to formulating expressions by manipulating Reynold's and the sub-grid stress tensors with quaternionic algebra. The scale invariance and rotational symmetries present in the fractal facets of turbulence will be illustrated (Montani and Carlevaro, 2024). Subsequently, eigendecomposition will be performed to procure the individual direction and intensity of the strain and shear of each turbulent eddy (Bachman, 2024). Additionally, this will reveal more about the nature of multi-dimensional interactions and orientational behavior of the turbulence. Despite the additional accuracy it may deliver in practice, the increase in complexity may add onto the preexisting computational costs and resources of LES, which will provoke attention for improvement in terms of efficiency.

Another perspective this research offers is to formulate a turbulence model with chaos theory, namely strange attractors, and the catastrophe theory. One research has focused on an approach towards the time dependence of turbulent flows (Lanford III, 1982). A significant limitation lies in the fact that the final state of a turbulent system may greatly vary to that of its initial state. This can be addressed by recalling the Hessian matrix to inspect the global stability of the solutions derived from the Navier-Stokes equations with the nonlinear system of turbulence (Saeedinia *et al.,* 2024). To elaborate on this, in terms of chaos theory, the probability of the trajectory taken by the eddy from the initial to the final state can be taken by the numerous unpredictable outcomes. The flow will be described with certain parameters, such as the boundary conditions, and the Reynold's number, further known as the control parameters. The turbulent system can be analyzed to find the probabilities of resulting into large-scale fluctuations when subjected to minimal changes to the control parameters in certain areas, as per the catastrophe theory. Ultimately, investigating these areas for variation in the flow regimes for local minima or maxima with the Hessian matrix will help determine its global stability.

The anticipated results of this research would offer additional solutions for handling the anisotropic nature of turbulence within computational fluid dynamics to help bridge a knowledge

gap within a preexisting model. While accounting for its computational intensity is necessary, it would further encourage engineers to embrace taking more holistic and interdisciplinary approaches when formulating solutions in aviation, and in this case, in the engineering domain. As a member of the Aviation Education and Research Operation (AERO) of the Transport and Telecommunication Institute, the objective of interdisciplinary research in aviation fostered by this organization aligns with the author's interest in the research areas mentioned.

The research is supervised by Dr.sc.ing., Professor Iyad Alomar.

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DIGITAL TOOLS FOR AVIATION EDUCATION AND TRAINING

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Keywords: Artificial intelligence, learning platform, AI assistance in learning, emotional programing, maximizing learning outcome

Learning is an essential part of every human life. Unfortunately, the learning ability of an individual is often limited by emotional and physical factors. Laziness, inability to focus, and lack of motivation often stop an individual from completing a degree or even approaching a learning process (Ahmad *et al.*, 2023).

There are ways to motivate a person via the use of trainers, teachers and figures of authority. Some studies are made to implement better techniques using emotions, state of mind, human needs, ego and motivation (Johnson, 2017). Duolingo is a world-renowned digital language learning platform, built on a video game concept, using human need for satisfaction and outside approval, providing easy access to both, in exchange for completing simple vocal and grammar tasks (Duolingo, 2025). Similar to banana and monkey experiment.

This research is focuses on a similar concept model, creating a similar but more advanced AI , focusing on APAC modules 1-17 as a learning materials, wrapped in an attractive visual game with a father figure vocal interaction, replacing a classroom teacher, or a personal coach, allowing a deeper dive in learning process, seeking an everyday emotional bond (one hour a day interaction) in order to complete large volume materials up to 2000 pages in a matter of 2-3 weeks with immediate examination , seeking 90% success rate.

The bond with a learning platform is formed by constantly asking the subject a set of provocative questions, aimed at student's ego, self-esteem and approval from society. By convincing a student through his own approval, that a desired goal is achievable through learning tasks.

The Lucid chart below (see Figure 1), illustrates the students' interaction with the platform.

The option to abandon is always there. The question in this case is: the purpose of attending university.

If successful, this AI can be updated to every single subject at any institution's walls. Using this platform as a voluntary addition to a classroom discipline, but in fact securing a 90% pass rate with the highest mark.

Future development aims at every other kind of material existing, through fully autonomous AI. That way, by uploading any desirable material to the platform, AI will process it, split it into chunks and feed it to a user using a banana approach, creating a bond with a long-term relationship, for processing large amounts of materials.

The main challenge of this research is developing AI that is able to process, randomly (any), material and present output in form of tasks, of acceptable humanlike quality. In the beginning faze (developing AI-APACS modules), AERO group members' expertise can be used, as many of them are aviation professionals. Products can be tested by TSI volunteers.

If add such common wide subjects as: math, physics, biology, the platform can be marketed online, in the form of app and website.

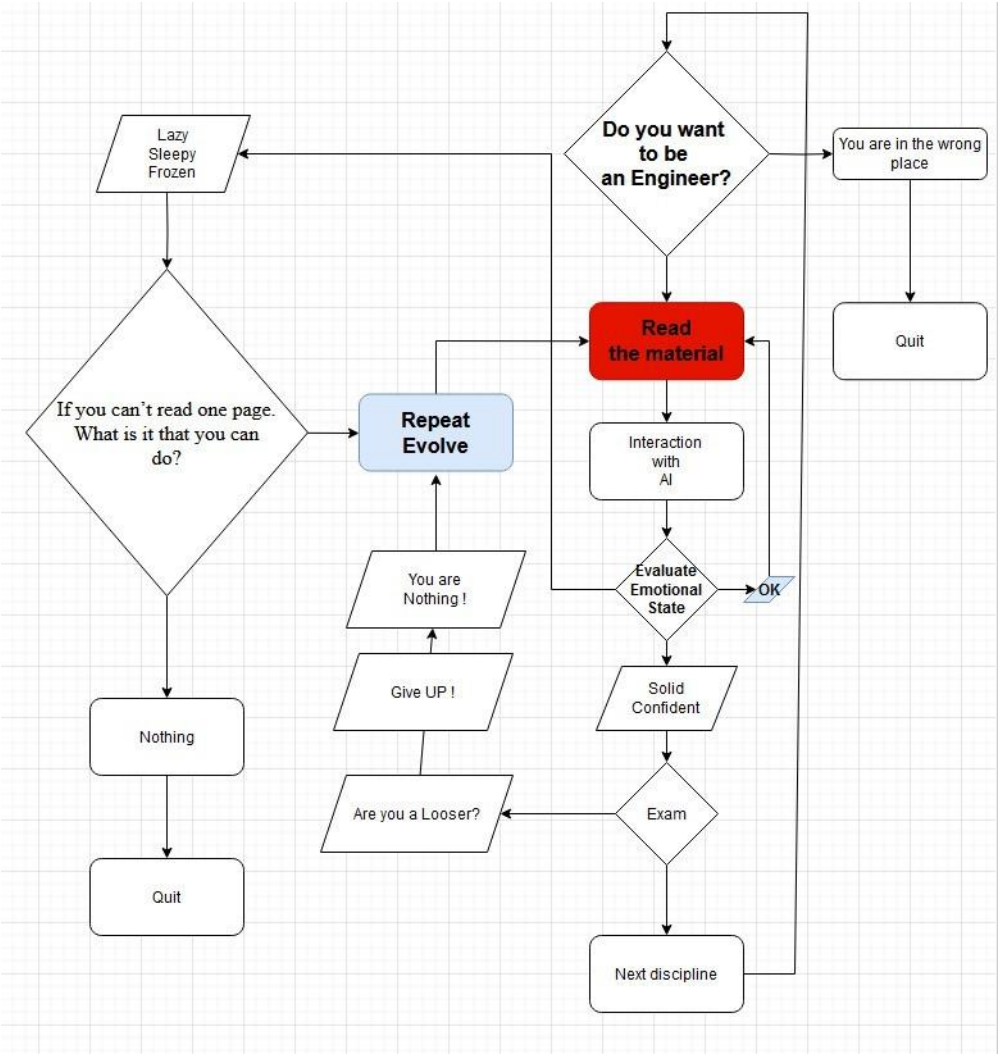

Figure 1. The students' interaction with the platform

The author's interest in the research areas stated above, aligns with the objectives of the newly created research group, Aviation Education and Research Operation (AERO), at the Transport and Telecommunication Institute that aims to foster interdisciplinary research and academic excellence in aviation.

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SYNCHRONIZING SCIENTIFIC RESEARCH WITH AVIATION INDUSTRY OBJECTIVES AND EVOLVING ENGINEERING & MAINTENANCE CHALLENGES

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Keywords: Aviation industry, strategic objectives, MRO, innovative solutions, sustainable development

The modern aviation industry is undergoing a significant transformation, driven by a need to achieve strategic sustainable development goals and address challenges associated with geopolitical, economic, and environmental changes. This report examines key aspects of aligning scientific research with current aviation industry challenges, including the strategic objectives of the International Civil Aviation Organization (ICAO) and current challenges in maintenance, repair, and overhaul (MRO) services, as well as prospects for the adoption of digital technologies. According to ICAO's strategic goals, the priorities for aviation development include improving flight safety, reducing environmental impact, ensuring the sustainability of the industry, and fostering global cooperation. To achieve these goals, scientific research in areas such as aerodynamics, material science, energy, and artificial intelligence to develop innovative solutions, such as the use of composite materials, hybrid power plants, and control systems based on big data.

One of the key challenges facing the industry is the dynamics of the supply chain and the need to optimize MRO processes. As noted in a number of industry reports, demand for MRO services is expected to increase in the coming years, which requires the introduction of digital technologies to increase efficiency and reduce costs. Modern technologies such as the Internet of Things, machine learning, and digital twins enable the transition to predictive maintenance, minimizing downtime and extending the life of aviation equipment. Companies implementing these solutions are already demonstrating significant improvements in operational efficiency.

In addition, many aviation industry experts point out that the digital revolution in MRO opens up new opportunities for process automation, data analysis, and the integration of artificial intelligence. This allows not only to optimize current operations, but also to predict the future needs of the industry, such as adaptation to new environmental standards and safety requirements. For example, the use of blockchain to track the maintenance history of components or the introduction of robotic systems for inspection and repair.

An important aspect of synchronizing scientific research with the needs of the industry is to take into account socio-economic and environmental factors. The sustainable development of aviation requires the development of alternative energy sources such as hydrogen fuel cells and electric motors, as well as reducing the carbon footprint by optimizing routes and using biofuels.

In conclusion, in order to successfully overcome the challenges and achieve the strategic goals of the aviation industry, close cooperation between the scientific community, representatives of the aviation industry and regulatory authorities is necessary. Integrating cutting-edge technologies, adapting to changing conditions, and focusing on sustainability will be key determinants of the future of aviation. Simultaneously, it is crucial to consider that technological advancements and industry standards can evolve rapidly, and in some instances,

recent innovations may swiftly become obsolete. It is extremely important for the scientific community to maintain constant communication with the aviation industry in order to receive feedback, promptly adjust research directions and ensure their practical applicability. This approach will ensure the long-term sustainability of the industry in the face of global changes.

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FRAMEWORK OF INTERACTIONS AND DATA EXCHANGE MECHANISMS BETWEEN AIRLINES, AIRCRAFT MANUFACTURERS, AND MAINTENANCE ENTITIES: ANALYSIS OF PRINCIPLES, OBSTACLES, AND INNOVATIVE APPROACHES IN ENHANCING AVIATION COMPONENT RELIABILITY

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Keywords: Component reliability, engineering support, airworthiness, extracting data

Within the standardized process of transferring documentation from airlines to aircraft manufacturers, there are several key considerations. Manufacturers are interested in receiving data from various airlines, as this information allows them to address existing issues with the design of aircraft, components, engines, and auxiliary power plants. Additionally, it involves adjusting and improving various parameters of aircraft and their parts and engines. Airlines, on the other hand, have a strong interest in receiving high-quality engineering support and services from aviation technology suppliers to ensure the maintenance of aircraft components prior to installation. Therefore, they have no obligation to share flight, parametric, voice recording, technical record, or other airworthiness-related information with manufacturers due to the lack of relevant legal requirements or agreements on joint procedures.

However, there are requirements on airlines, requiring them to provide reliable reports. In some cases, these reports may also be submitted by aircraft manufacturers as specified in the contractual agreement between the parties. These reports on reliability typically include a comprehensive inventory of components that have been replaced, a detailed analysis of malfunctions in aviation equipment, careful documentation of the operational duration of components during the replacement process, and various other metrics that significantly affect component dependability. Manufacturers place a high value on these reports, carefully handling them with the utmost diligence and attention to detail. Furthermore, these reports allow manufacturers to improve their services for other airlines, thus enhancing their competitiveness in the market.

However, given that this data represents a proprietary asset of significant value to other airline companies, it is kept confidential. Airline operators use this information to improve operational efficiency, particularly with regard to increasing the reliability of aircraft components. Maintenance organizations play a crucial role in the maintenance process, receiving components for repair and conducting various stages such as disassembly, inspection, cleaning, repair and reassembly to ensure the components are in good working order. If any abnormalities or damage is identified during these stages, appropriate measures are taken.

These organizations maintain direct communication with airlines, and in cases where damage or abnormalities exceed certain thresholds outlined in their operating documentation, they immediately contact the component manufacturer. This is the only way for component manufacturers to obtain insights into the current state of aviation technology, which allows them to analyze and improve the technical specifications and reliability of their products.

Maintenance organizations often have to replace components because of the defect. This practice hinders component developers' ability to gain insights into defects, hindering their efforts

to improve component reliability and performance. Additionally, by aggregating data on components, aircraft manufacturers gain insight into airlines, and maintenance organizations, which can be shared with relevant component manufacturers. While this practice is not mandatory, it is commonly used by aircraft designers and manufacturers, but it may not always be the most efficient approach.

Component manufacturers can also collect information on the reliability of components from suppliers. This approach provides greater flexibility, but it also allows suppliers to access data from maintenance organizations, airlines, aircraft manufacturers, and other suppliers. As a result, suppliers may have vast amounts of information about component reliability. However, this information is often stored unstructured and not systematically collected. This makes it difficult to share this information with component manufacturers. Given all these factors, component manufacturers usually have limited information available for conducting research aimed at improving component reliability and performance. This ongoing research may not have as significant an impact as it could due to lack of information.

The second approach, which allows both component and aircraft manufacturers to collect more data in order to improve critical reliability metrics, parameters and other characteristics of components, involves providing various incentives. Typically, this information is included in agreements between airlines, component or aircraft manufacturers, or maintenance organizations with component manufacturers or suppliers. This arrangement places additional responsibilities on participating entities, especially maintenance companies and suppliers.

These obligations involve sharing information in the form of reliability reports, statistical data and technical records. Information provision is mandatory, taking into account all policies on commercial confidentiality and other relevant matters. Aircraft manufacturers and component manufacturers often offer various incentives to maintenance companies and their suppliers. These incentives may take the form of discounts on services, parts or improved technical support. Alternatively, they may involve access to the manufacturer's database allowing airlines to conduct independent analyses aiming at improving the reliability of their aircraft and components.

In addition, aircraft manufacturers and component suppliers regularly organize events such as conferences, symposia, and workshops. These events provide an opportunity for attendees to exchange insights into the most significant challenges facing airlines and maintenance facilities. The issues identified during these discussions are then addressed by relevant developers who implement measures to improve component reliability and performance. These conferences, meetings, and other events usually take place regularly, contributing to the improvement of factors such as customer focus and the perceived value of the products offered by the developers.

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HUMAN ERRORS AND VIOLATIONS PROTECTION SYSTEM BASED ON THE CONDITION OF AN AIRLINE SAFETY CULTURE

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Keywords: Flight safety, safety culture, risk management, artificial intelligence

In addition to technical and environment factors, human and cultural factors are also included in the composition of the factors creating the situation of the occurrence of the main undesirable events, that is, the safety culture (SC) has formed in the aviation company (AC), the impact of which is shown schematically in Figure 1. It is very important for the leadership of AC to be aware of the level of internal SC, as it has a direct impact on flight safety (FS). Aviation employees of various levels make mistakes in countless quantities, but in aviation this is unacceptable. Eliminating the causes of these errors requires deep knowledge and work experience of managers. In this case, the manager must be able to process a very large amount of information and quickly make the right decisions regarding improving the SC. Nowadays, based on various control methods (voluntary reporting, audit, surveys etc.) that must be carried out in an AC, a large amount of data is accumulated. By properly processing this data, it is possible to obtain very important information that could serve to improve flight safety quickly and efficiently thanks to timely measures and appropriate decision making. The processing of this data and the development of recommendations can be carried out by artificial intelligence (AI), since not every manager has the time, the necessary knowledge and personal experience to do it. So, the AI system is a kind of advisor to managers of different levels, thanks to which they are able to better understand the shortcomings of the company's SC and, by eliminating them, achieve FS improvement.

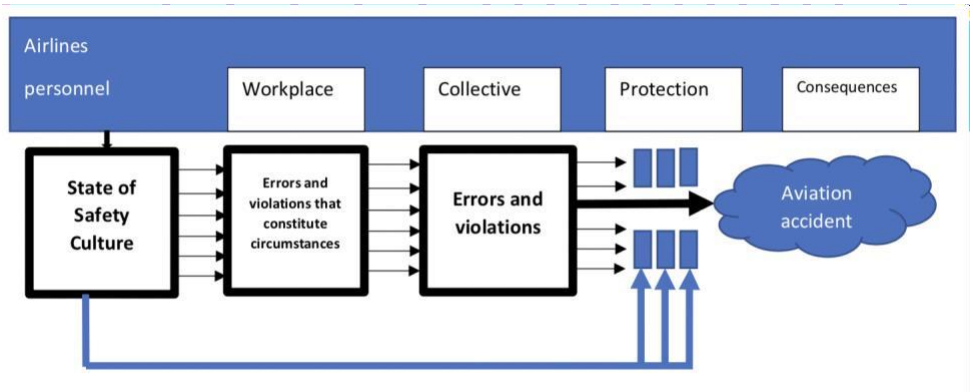

Figure 1. Aviation accident causation model (adopted from Professor J. Reason's scheme)

The importance of this work can be met in ICAO documents. (ICAO, 2007, 2018, 2019) The ICAO Global Aviation Security Plan is a strategic document containing a planning

methodology designed to achieve global harmonization in the field of aviation security and safety. SC evaluation process in the AC includes several stages, which are also accurately described in the recommending documents, which are mentioned in the regulations of different levels of international aviation organizations (ICAO, IATA, CANSO, EASA). The essence of the process does not differ strongly in different models (Balk, 2016), and it includes the following basic elements:

1. SC understanding, namely model development.
2. Measurement and evaluation of SC.
3. Improvement of safety culture in the AC.

First step is very important due to the fact, that social system constantly changing. However, any social system (including the AC) exists stably if four conditions are met:

1. The system must be adapted to the environment.
2. The system must be self-regulating.
3. The system must be internally integrated.
4. The system must be structurally stable.

This model is what will form the AC database, which will serve to compare the ideal SC level with the current state. Based on this comparison, a decision will also be made on possible solutions for improving SC in the company.

The proposed research presents the development of mathematical model for assessing the level of a positive SC in an AC and indicating the actions for the improvement based on the decision of AI.

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PROBLEMS OF ACADEMIC AVIATION EDUCATION IN LATVIA

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Keywords: Aviation maintenance, aviation education problem

In accordance with the requirements of the Republic of Latvia, education in state universities is only possible in the official state language (Saeima of Latvia, 1998). Education in other languages can be conducted either in private universities or in non-state-funded groups. Several educational institutions in Latvia, including Riga Technical University, National Defense Academy, Transport and Telecommunication Institute, and Riga Aeronautical Institute, offer aviation programs.

Additionally, as a negative factor, it is necessary to consider the "imbalance" in the certification conditions for academic staff, where primary attention is given to scientific rather than teaching activities of university lecturers (Republic of Latvia Cabinet, 2021).

Currently, several issues hinder the improvement of the quality of aviation education in Latvia:

1. The practical absence of a unified official aviation terminology (except for an aviation dictionary defining basic terms in air traffic management). At present, there are dictionaries in the field of general mechanical engineering that were published more than 30 years ago, such as Russian Latvian Polytechnic Dictionary (Ziņģītis, 1977) or Russian Latvian, Latvian Russian Dictionary of Aviation Terms, published in 1997 by Riga Aviation University.
2. The lack of necessary aviation textbooks in the Latvian language.
3. Some inconsistency in Bachelor's programs in the field of Aircraft Maintenance, implemented by different universities in Latvia. The main "reference point" for program development is the Part-66 program (EASA, 2014).
4. Challenges in organizing internships in aircraft maintenance organizations.
5. The difficulty of adapting graduates of aviation programs, who study in the state language, to aviation organizations (the primary working language in aviation is English).

To explore these challenges, an in-depth analysis was conducted on the structural and regulatory factors affecting aviation education in Latvia. The study examined inconsistencies across academic programs, the lack of standardized Latvian-language resources, and the limited integration of practical training opportunities. Particular attention was given to the effects of national language policy and academic staff certification criteria on the overall quality and accessibility of aviation education.

Based on this analysis, a concept for a unified national aviation education centre was developed. The proposed centre would serve as a coordinating body to harmonize curricula, facilitate cooperation among educational institutions, support the creation of Latvian-language materials, and strengthen ties with industry stakeholders. This initiative is intended to ensure alignment with both national educational requirements and international aviation standards, ultimately enhancing the preparedness of graduates for careers in the global aviation sector.

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INTEGRATION OF EMERGING TECHNOLOGIES IN AVIATION DIGITAL ECOSYSTEMS: TRENDS, CHALLENGES, AND STRATEGIC IMPLICATIONS

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Keywords: Education aviation digital ecosystem, emerging technologies, systems integration, digital transformation, IoT, AI, blockchain, maintenance, digital twins

The rapid evolution of digital technologies is fundamentally transforming the structure and operation of aviation ecosystems. This paper explores how emerging technologies, such as artificial intelligence, digital twins, blockchain, the Internet of Things, and cloud computing, are being integrated into various components of the aviation sector, including aircraft maintenance, air traffic management and airport digitalization. This paper builds upon the systems-based research of Prof. I. Kabashkin and colleagues, conducted over the last three years, to examine the integration of advanced digital technologies within modern aviation ecosystems.

The research identifies key trends, technological enablers, and implementation models shaping the digital transformation of aviation. Special attention is given to the role of data interoperability, cybersecurity, and new generation of communication in the development of robust digital ecosystems.

The study highlights both the opportunities and challenges associated with this transformation, including the need for standardized architectures, cross-sector collaboration, and workforce reskilling. It concludes with strategic recommendations for stakeholders—airlines, airports, technology providers, and regulators—seeking to harness the full potential of digital innovation while ensuring system resilience and sustainability in the aviation industry.

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