PROCEEDINGS

BOOK

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ENGINEERING AND TECHNOLOGY MANAGEMENT SUMMIT

2025

PROCEEDINGS BOOK

ABDULLAH GÜL UNIVERSITY
&
ISTANBUL TECHNICAL UNIVERSITY
&
BAHÇEŞEHİR UNIVERSITY

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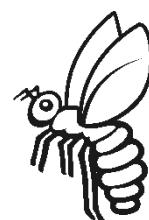
PREFACE

The 7th International Engineering and Technology Management Summit, jointly organized by Abdullah Gül University (AGÜ), Istanbul Technical University (ITU), and Bahcesehir University (BAU), was held in Kayseri, Türkiye, on October 23–25, 2025. While organizing our engineering and technology management summits, we have aimed to contribute to the identification of business problems arising from engineering applications and the use of technology, as well as to the development of effective solutions. By considering today's rapid changes and technological developments, we seek to analyze these challenges, discuss future directions, and create, enhance, and diversify the necessary environments to address them.

In today's world, engineering and technology management are being reshaped by the rapid advancement of artificial intelligence and digital technologies, which are transforming not only industries but also societies and human interactions. While these developments offer unprecedented opportunities for efficiency, innovation, and growth, they also raise critical questions regarding sustainability, ethics, and the role of humanity in technology-driven systems. Managing this transformation requires approaches that balance technological capabilities with environmental responsibility and human-centered values.

In this context, the theme of this year's summit was determined as "Engineering and Technology Management Tomorrow – AI, Humanity, and Sustainability in Harmony." With this theme, the summit aims to explore how artificial intelligence can be integrated into engineering and management practices in a manner that supports sustainable development and places human and societal well-being at its core. Through diverse perspectives spanning technological, managerial, social, and environmental dimensions, ETMS 2025 seeks to foster meaningful discussions on the challenges and opportunities emerging at the intersection of AI, humanity, and sustainability.

The realization of this summit undoubtedly required significant effort and support. We would like to express our sincere gratitude to all who supported and contributed to the summit, including the Rectors of AGÜ, ITU, and BAU; the honorary chairs of the summit; the opening keynote speaker; and the invited speakers for their valuable contributions. We also thank our moderators, authors, academics, researchers, students, professionals, all participants, and the members of the organizing committee for their dedication and efforts.

This book includes the abstracts and full papers submitted to the summit in English or Turkish. All submissions were evaluated through a blind review process. We hope that this online book will be both enjoyable and useful for all readers interested in research, studies, and practical applications in the field of Engineering and Technology Management.

Best Regards,

On be half of Organizing Committe
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ÖZETLER

A Business Model Proposed for Campus-Based Upcycling Activities on Textile Waste

Umut Yüksel[1], Emir Sevim[2], Hür Bersam Sidal[3], Tuğba Yasemin Karagöz[4]

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Abstract— **This study proposes a comprehensive business model for managing textile waste through campus-based upcycling activities, developed specifically for Istanbul Technical University (ITU). Addressing the global challenge of rising textile waste, the study offers a localized, scalable solution by leveraging ITU's Ayazağa and Gümüşsuyu campuses and the technical infrastructure of the Faculty of Textile Technologies and Design. The proposed model includes strategically placed collection points, environmentally friendly washing and sorting processes, and workshops where students are employed part-time under academic supervision to carry out upcycling activities. The upcycled products will be sold exclusively through the ITU Store, ensuring institutional coordination and easy access for the campus community. Initially, cotton-based items such as t-shirts, sweatpants, and sweatshirts were considered; however, surveys and focus group interviews revealed that tote bags were the most preferred upcycled product. Based on operational analysis conducted and presented in this study, it is estimated that 3,900 to 8,500 textile products can be collected and upcycled annually. While the proposed system enables the employment of seven part-time student workers, it also aims to support scholarships for six students in the first year and expand to provide scholarships for 27 students annually by the fifth year, empowering more students to continue their education. As a non-profit initiative, all sales revenue will support student scholarships, enhancing social impact. By integrating technical, economic, operational, environmental, and legal aspects, this study offers a feasible, context-specific model aligned with global sustainability priorities and circular economy principles. While customized to ITU, the proposed model provides valuable insights and a practical framework for universities worldwide aiming to implement localized textile waste management and circular economy practices.**

Keywords— **Campus-Based Upcycling, Textile Waste Management, Circular Economy, Student-Led Initiatives, Non-Profit Business Model**

A Comparative Analysis of Gsp and Prefixspan for Sequential Pattern Mining Using Real-World Data

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Abstract— **Sequential pattern mining (SPM) identifies patterns in the sequences of purchases. This study introduces a comprehensive comparative analysis between Generalized Sequential Patterns (GSP) and Prefix-Projected Sequential Pattern Mining (PrefixSpan) utilizing a retail dataset that focuses on brand-level insights. This study delineates a production-grade pipeline, which comprises Hadoop/Spark ETL processes, SKU-level integration with the product master, taxonomy-aware sequence creation, and a quantile-based heuristic for establishing minimum support thresholds. Furthermore, defined performance metrics and present results from controlled experimental trials. Numerical results show that within realistic support ranges, PrefixSpan consistently exhibits lower runtime and peak memory consumption than GSP, while successfully reproducing the complete frequent-sequence set. Additionally, this study provides examples of brand-level patterns, conducts an ablation study concerning support tuning and outlines decision-making guidelines for determining the preferred algorithm in practical applications.**

Keywords— **Sequential pattern mining; GSP; PrefixSpan; Retail analytics; Market basket analysis; Temporal stability**

A Data Envelopment Analysis Model for The Efficiency Measurement of Call Center Agents in Logistic Industry

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Abstract— **Within the logistics industry, both the frequency of customer complaints and the speed at which they are resolved play a vital role in shaping customer satisfaction and influencing overall company performance. Consequently, evaluating the effectiveness of call center agents in managing customer inquiries becomes increasingly essential. Conventional performance indicators—such as the total number of calls handled, mean call duration, and average complaint response time—often fail to capture the full scope of an agent's performance. To achieve a more comprehensive understanding of post-call satisfaction, it is crucial to incorporate speech analytics-based indicators alongside standard metrics. These may include factors such as the duration of customer hold time, the number of interruptions, the use rate of scripted expressions, customer emotional tone (e.g., anger or satisfaction), and the frequency of customer acknowledgments. This study introduces a comprehensive efficiency assessment framework that integrates these advanced indicators into a Data Envelopment Analysis (DEA) model to evaluate call center agent performance. An application of the proposed model is demonstrated through a case study in logistics industry. The DEA model is implemented using Python's PuLP library. Based on the analysis, inefficient agents are identified, and specific performance enhancement areas are highlighted.**

Keywords— **Data Envelopment Analysis, Efficiency Measurement, Call Centers, Speech Analytics, Logistics.**

A Multi-Criteria Decision-Making Approach for Identifying the Best Sustainable Textile Waste Management Solution in Retail Stores

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Abstract—**This study presents a decision support model developed to meet the growing need for sustainable management of defective textile products in the retail sector. The fast fashion industry is under increasing pressure to reduce waste and align with circular economy principles; however, store-level decisions regarding whether to resell, repair, or donate such products often lack standardization and rely on personal judgment. To address this issue, a multi-criteria decision-making (MCDM) model integrating the Best-Worst Method (BWM) and the Weighted Sum Method (WSM) was designed that helps store managers decide which waste management option is the most appropriate one for each product. Five main criteria (environmental, social, economic, technical, and strategic) were identified through a literature review and further divided into twelve sub-criteria. Field data was collected via surveys conducted with managers of major fashion retail stores in Turkey and applied within an Excel-based BWM-WSM model. The model developed in this study generates objective, repeatable, and data-driven recommendations that enhance the transparency and consistency of sustainability-related decisions. Results demonstrate that the system significantly contributes to reducing textile waste, improving operational efficiency, and aligning store practices with broader sustainability goals. Furthermore, its Excel-based structure ensures accessibility and scalability across various retail formats without requiring advanced technological infrastructure.**

Keywords— **Best-Worst Method (BWM), Circular economy, Donation, Multi-criteria decision making (MCDM), Repair, Resale, Sustainable fashion, Textile waste reduction, Weighted Sum Method (WSM)**

A Strategic Roadmapping Framework for Aiding the SME Productivity Improvement with a PESTLE Approach

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Abstract— **The international competitiveness level of Turkish businesses is a crucial focus in national policies and strategies, particularly due to their lower productivity levels compared to rival nations. This study comprehensively addresses the necessary action plans, employing a Strategic Roadmapping (SRM) approach adapted from the Technology Roadmapping (TRM) methodology for a multi-stakeholder collaborative platform initiative that aims to aid SMEs in improving their productivity, with a deliberate focus on sustainability and digitalization. The workshop, held in 2024 brought together 22 experts in the initiative from the public sector, industry, and civil society organizations. Within the PESTLE (Political, Economic, Social, Technological, Legal, and Environmental) framework, the key driving forces, barriers, technologies, and resources were identified. This paper presents the derived roadmap components and the designed action proposals pertaining specifically to the Technological and Ecological dimensions of the conducted workshop. The findings reveal that the lack of technical expertise and the inability to utilize existing support mechanisms effectively are the most significant barriers confronting businesses. The two-period strategic roadmap integrates seven main solution programs: This study addresses the necessary action plans comprehensively, employing a Strategic Roadmapping (SRM) approach, an adaptation of the Technology Roadmapping (TRM) methodology to the productivity improvement support by multi-stakeholder initiatives.**

Keywords— Strategic Roadmapping, Productivity, Efficiency, SMEs, PESTLE

A Vision-Based Deep Learning Approach to UAV Altitude Estimation

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Abstract— We propose a vision-based deep learning approach for unmanned aerial vehicle (UAV) above-ground-level (AGL) altitude estimation as a robust complement to GNSS and barometric sensing. A large corpus of nadir RGB images (> 300,000) was collected with DJI Mavic 2 Pro/Zoom under varied illumination, weather, and terrain. EXIF-derived GPS geotags were fused with a 25 m-resolution digital elevation model (DEM) to obtain AGL labels; images were standardized via rotations, zoom-based scale simulation, and center cropping. A ResNet-50 regressor was fine-tuned using the Adam optimizer and mean squared error loss. On a held-out test set of 170 images, the model achieves MAE = 11.80 m, RMSE = 22.37 m, and $R2$ = 0.971, indicating strong agreement with ground truth. These results demonstrate practical viability for autonomous navigation and mission planning when GNSS degrades or barometric readings drift. The study highlights the potential of nadir image cues for direct AGL estimation and provides an end-to-end pipeline—labeling, preprocessing, training, and evaluation—that can be adapted to different UAV platforms and operational conditions.

Keywords— UAV; altitude estimation; deep learning (DL); convolutional neural networks (CNNs); nadir images; ResNet-50; autonomous navigation; computer vision; data augmentation; transfer learning.

AI-Supported Green Marketing: Transforming Strategies and Future Perspectives

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Abstract— **Artificial Intelligence has become a cornerstone in transforming marketing strategies, particularly within the domain of green marketing. This study examines the integration of AI into green marketing strategies and its impact on sustainable development. By employing the Input-Process-Output framework, the study highlights how AI capabilities enhance sustainability-oriented marketing systems. The paper synthesizes a conceptual analysis based on secondary data, addressing both the opportunities and challenges presented by AI in the context of green marketing. Key findings suggest that AI can simultaneously improve operational efficiency, consumer engagement, and environmental responsibility, although ethical concerns and energy consumption issues persist. The paper concludes by offering a roadmap for organizations looking to integrate AI into their green marketing strategies effectively while addressing the ethical and ecological challenges.**

Keywords— **Artificial Intelligence, Green Marketing, Sustainability, Consumer Behavior, Ethical Marketing**

An AI-Integrated Framework for Early Diagnosis of Frontotemporal Dementia Using Neuroimaging and Genomic Profiling

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Abstract— **Frontotemporal Dementia (FTD) is a group of degenerative brain diseases that primarily affect the frontal and temporal lobes of the brain. These changes are characterized by progressive atrophy. The condition is often underdiagnosed in its early stages due to shared symptoms between diseases and disjointed diagnostic process. To combat this challenge, we propose an innovative pipeline that combines structural brain imaging (sMRI) and genomic profiling, followed by interpretable machine learning techniques to improve early detection and accuracy.**

Our method visualizes brain atrophy patterns statistically, using FreeSurfer to extract detailed neuroanatomical features from structural MRI scans, such as changes in cortical thickness and localized volume reduction. Simultaneously, genomic data is examined using the Genome Analysis Toolkit (GATK) to detect potentially harmful genetic variants—like SNPs, insertions/deletions, and structural changes—in key FTD-related genes such as MAPT, GRN, and C9orf72. Functional annotations of these variants are conducted with ANNOVAR to support clinical interpretation and variant prioritization.

Using this data, we design a machine learning framework that processes multimodal inputs and delivers understandable diagnostic predictions. A Random Forest classifier forms the backbone of this model, while deep learning techniques, including 3D ResNet models implemented via MONAI, are considered for future use to enhance detection of subtle imaging abnormalities. Although model training is not part of this initial phase, the conceptual framework has been validated through existing public datasets like OASIS-3, NIAGADS, and ADNI.

The aim of this work is to create a sustainable, clinically applicable and ethically sound diagnostic strategy for FTD, merging imaging, genomics, and machine learning into a cohesive process. This approach boosts precision, personalized treatment, and cuts delays aiding precision neurology.

Keywords— **Frontotemporal dementia, GATK, sMRI, Freesurfer, Machine learning.**

Analyzing Industry 4.0 Barriers in an Emerging Economy Context Using the SWARA Method

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Abstract—**The literature highlights the substantial benefits of Industry 4.0, demonstrating how digital transformation enhances competitiveness. However, many firms, particularly in emerging economies, face substantial challenges in adopting Industry 4.0 technologies due to strategic, organizational, technological, and market-related barriers, as well as the lack of open innovation practices that could otherwise facilitate this transition. Understanding these barriers is essential for anticipating challenges and developing effective mitigation strategies. This study aims to identify and prioritize these barriers and propose strategies to overcome them within the context of Turkish businesses. A comprehensive literature review and expert consultations were conducted to determine the most critical obstacles to Industry 4.0 implementation, categorized under four dimensions: strategic and organizational, open innovation, technological and infrastructural, and market-related factors. To systematically analyze and prioritize these barriers, a multi-criteria decision-making framework integrating the Stepwise Weight Assessment Ratio Analysis (SWARA) method was employed. Experts evaluated 19 sub-criteria across these dimensions. The results indicate that "strategic and organizational barriers" are the most critical factors hindering digital transformation in the Turkish manufacturing sector. The most influential sub-factors are the absence of a clear strategic roadmap for Industry 4.0, inadequate information security and privacy protection, and a lack of skilled workforce. This study contributes to the literature and practitioners by identifying the primary implementation barriers of Industry 4.0 technologies in Türkiye, a significant emerging economy. For future research, it is of paramount importance to conduct studies that contribute to developing strategies for overcoming these barriers and ensuring the successful integration of Industry 4.0 technologies into production processes.**

Keywords— **Industry 4.0; Digital Transformation; Barriers; SWARA; Emerging Economies; Türkiye; Technology; Multi-Criteria Decision Making (MCDM)**

ANN-Based Early Warning System and Strategic Decision-Making for Agricultural Land

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Abstract— **This paper presents a smart agriculture early warning and decision-support system designed to enhance sustainability and productivity in olive farming in Türkiye. The framework integrates Artificial Neural Networks (ANN) for environmental forecasting with the Best-Worst Method (BWM) for strategic decision-making. Using 28 years of historical climate data from Manisa Province, the ANN predicts four parameters: air temperature, precipitation, surface soil temperature, and sunshine duration. Predictions are evaluated with a Gaussian-based suitability scoring function against bimonthly agronomic thresholds for temperature and precipitation, while surface soil temperature and sunshine duration follow annual thresholds due to the absence of robust period-specific values. With sufficient evidence, these can also be seasonalized. BWM-derived weights reflect the relative importance of each parameter. The aggregated productivity index is classified (excellent, good, risky, critical) to trigger early warnings and recommendations. Scenario validation demonstrates forecasting accuracy above 90% and confirms that the system generates context-specific, literature-supported interventions such as drip irrigation, mulching, and shading. By combining empirical forecasting with expert-informed prioritization, the system ensures both accuracy and interpretability, contributing to sustainable resource use and farmer resilience. The findings show that the framework can reduce input waste, stabilize yields, and enhance competitiveness in olive farming. With refinement and IoT integration, it has strong potential for broader application to other crops and regions, supporting food security and environmental sustainability.**

Keywords— **Artificial Neural Networks (ANN); Best-Worst Method (BWM); Early Warning System; Multi-Criteria Decision Making (MCDM); Olive Farming; Smart Agriculture; Suitability Scoring; Sustainable Agriculture**

Assessing Digital Transformation Capability of Organization Cultures: A Scoring Approach by Multi Criteria Decision-Making

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Abstract— The rising interest in digital transformation requires organizations to evaluate their digital transformation capability efficiently. Organizational culture is important for the success of these initiatives, but it is still hard to measure it clearly, because of its complicated and multidimensional structure. This study proposes a structured scoring approach based on multi-criteria decision-making (MCDM) method to evaluate the digital transformation capability of organizational cultures. By integrating the Best-Worst Method (BWM), as one of popular and practical MCDM method, this study prioritizes main and sub dimensions that significantly influence digital maturity, in other words digital transformation capability from organization culture perspective. After prioritizing the criteria using the BWM, the proposed model completes the scoring process by applying a simple weighted sum, assigning a value on a 0–5 scale to the relevant organization to indicate its status. A numerical example is conducted to show how the model is applied in practice. This approach provides decision-makers with a robust tool to benchmark digital maturity levels and design effective strategies tailored to organizational contexts.

Keywords— Best-worst method, digital maturity, digital transformation capability, multi criteria decision-making, organizational culture

Asymmetric Parallel Merging Assembly Line Balancing Problem Type-2 (APMALBP-2) with Machine Requirement: A Case Study

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Abstract—The Assembly Line Balancing Problem (ALBP) deals with the assignment of tasks to workstations, aiming to improve efficiency while satisfying production constraints. Type-2 ALBP focuses specifically on minimizing the cycle time. This study addresses a complex variant of ALBP called the *Asymmetric Parallel Merging Assembly Line Balancing Problem Type-2 (APMALBP-2)*, which arises when two or more parallel assembly lines merge into a single line. The asymmetry refers to the differing sets of tasks and operational requirements across the parallel lines, which makes more complex to balance the system. A mixed-integer programming model is proposed to solve this problem, incorporating real-world constraints such as task precedence, machine requirements for each task and machine-task compatibility since tasks are only assigned to workstations equipped with machines capable of performing them. The model aims to minimize the overall cycle time while assigning tasks and machines to workstations across the parallel lines. Computational experiments based on a real-life case study demonstrate the model's capability to generate feasible and efficient solutions. The results show the model's ability to minimize total cycle time while satisfying practical constraints such as task-machine compatibility. This study contributes a new approach to APMALBP-2 and provides insights for future applications.

Keywords— Assembly Line Balancing, Type-2 Assembly Line Balancing, Parallel Assembly Line Balancing, Asymmetric Assembly Line Balancing, Mixed-Integer Programming, Sustainable Manufacturing

Benchmarking Water in Construction Industry: Decoupling Analysis for Technology Roadmapping for Sustainability in Turkiye

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Abstract— **This study investigates water consumption trends in the Turkish construction industry between 2011 and 2022, aiming to assess sectoral water efficiency, identify digital solutions and propose technology roadmapping for sustainability. The analysis focuses on four key indicators: water/GDP, water/cement, water/building area, and water/labor ratios. Findings indicate a persistent increase in water intensity, particularly in concrete production, with significant deviations from theoretical benchmarks. Results provide evidence of the absence of digital traceability, which hinders effective monitoring of water consumption. Expansive negative trends in the decoupling analysis form the basis for digital technology recommendations. Accordingly, the study proposes BIM integration, IoT-based metering, and smart batching systems as part of the technology roadmapping supported by policy measures to reduce inefficiencies and align construction industry practices with SDG 6.4.1 targets.**

Keywords— **Digitalization, construction industry, technology roadmapping, decoupling analysis, water, sustainability.**

Beyaz Eşya Sektöründe ESG Önemlilik Değerlendirmesi Modeli

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Abstract— Küresel düzeyde artan Çevresel, Sosyal ve Yönetişim (ESG) odaklı yaklaşımlar, şirketlerin sürdürülebilirlik konularını sistematik biçimde belirlemesini ve bu konuların önemlilik düzeyine göre önceliklendirmesini zorunlu hale getirmiştir. Karmaşık tedarik zincirleri ve çok paydaşlı yapısı nedeniyle beyaz eşya sektörü, sağlam temellere dayanan bir ESG yönetişim yapısına ihtiyaç duymaktadır. Bu çalışmanın temel amacı, beyaz eşya sektörüne özgü bir ESG yönetişim çerçevesinin oluşturulmasına katkı sunmak amacıyla önemlilik temelli bir önceliklendirme modeli geliştirmektir. Model, sektörün önde gelen firmalarından Sersim firmasında geliştirilmiş ve kapsamlı bir literatür taraması ve sektörel analizlerle şekillendirilmiş; aynı zamanda paydaş temsiliyeti dikkate alınarak yapılandırılmıştır. Çevresel, sosyal ve yönetişim boyutlarını kapsayan detaylı bir anket; müşteriler, tedarikçiler, çalışanlar, kamu kurumları ve akademik temsilciler gibi kilit paydaş gruplarına uygulanmıştır. Bu anket aracılığıyla, sektör açısından önemli kabul edilen ESG konuları tespit edilmiş ve önemlilik değerlendirmesi gerçekleştirilmiştir. Elde edilen bulgular doğrultusunda, ESG konularının önemlilik düzeyine göre şekillenen ve sektöre özel tasarlanan bir ESG yönetişim modeli geliştirilmiştir. Söz konusu model, şirketlerin sürdürülebilirlik yönetim süreçlerini daha sistematik bir şekilde yapılandırmalarına, görev ve sorumlulukları açık biçimde tanımlamalarına olanak tanımaktadır. Ayrıca, sürdürülebilirlik konularının stratejik karar alma süreçlerine entegre edilmesini teşvik ederek paydaş güveninin artırılmasını hedeflemektedir. Bu çalışma, beyaz eşya sektöründe ESG performansının iyileştirilmesine katkı sağlamakta ve sektör genelinde sürdürülebilirlik olgunluğunun gelişimine destek olmaktadır. Sonuç olarak, bu araştırma; sürekli değişen ve şeffaflık beklentilerinin arttığı iş dünyasında, diğer sektörler için de önemlilik temelli ESG yönetimi açısından yol gösterici bir model sunmaktadır.

Keywords— **ESG, Önemlilik Analizi, Paydaş Analizi, Sürdürülebilirlik Stratejisi, Sürdürülebilirlik Raporlaması**

Big Data in Industrial Management: Balancing Efficiency, Privacy, and Market Power in the Age of AI-Driven Sustainability

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Abstract—The integration of big data analytics into industrial management systems has revolutionized operational efficiency, enabling firms to optimize processes, reduce costs, and enhance competitiveness. However, the growing use of AI-powered technologies and large-scale data collection raises important concerns about privacy, market concentration, and environmental sustainability. This paper examines the economic trade-offs involved in using big data for industrial strategies. It focuses on how companies benefit from efficiency gains while facing ethical challenges and regulatory issues. The paper also discusses how unequal access to data can lead to increased market power for certain firms. Furthermore, it explores the environmental impact of big data infrastructure and highlights the need for responsible data management practices. By combining insights from economics, industrial management, and sustainability, this paper aims to support policymakers, industry leaders, and researchers in developing balanced approaches that promote innovation while protecting social and environmental interests.

Keywords—AI, Big Data, Sustainability, Management, Industry.

Business Model for Campus Based Upcycling Activities on Textile Waste

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Abstract— **This study proposes a comprehensive business model for managing textile waste through campus-based upcycling activities, developed specifically for Istanbul Technical University (ITU). Addressing the global challenge of rising textile waste, the study offers a localized, scalable solution by leveraging ITU's Ayazağa and Gümüşsuyu campuses and the technical infrastructure of the Faculty of Textile Technologies and Design. The proposed model includes strategically placed collection points, environmentally friendly washing and sorting processes, and workshops where students are employed part-time under academic supervision to carry out upcycling activities. The upcycled products will be sold exclusively through the ITU Store, ensuring institutional coordination and easy access for the campus community. Initially, cotton-based items such as t-shirts, sweatpants, and sweatshirts were considered; however, surveys and focus group interviews revealed that tote bags were the most preferred upcycled product. Based on operational analysis conducted and presented in this study, it is estimated that 3,900 to 8,500 textile products can be collected and upcycled annually. While the proposed system enables the employment of seven part-time student workers, it also aims to support scholarships for six students in the first year and expand to provide scholarships for 27 students annually by the fifth year, empowering more students to continue their education. As a non-profit initiative, all sales revenue will support student scholarships, enhancing social impact. By integrating technical, economic, operational, environmental, and legal aspects, this study offers a feasible, context-specific model aligned with global sustainability priorities and circular economy principles. While customized to ITU, the proposed model provides valuable insights and a practical framework for universities worldwide aiming to implement localized textile waste management and circular economy practices.**

Keywords— **Campus-Based Upcycling, Textile Waste Management, Circular Economy, Student-Led Initiatives, Non-Profit Business Model**

Can Smart Cities Be Run by Agents?
A Conflict-Aware Multi-Agent Coordination System for Smart Cities

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Abstract— **Rapid urbanization and the proliferation of IoT sensors have transformed cities into data-rich ecosystems demanding intelligent coordination. To harness this complexity, a modular AI-driven approach is essential for balancing diverse urban objectives. In this work, we seek to design a mediator that resolves conflicts between multiple smart city agents specializing in different domains, aiming to prevent disruptions and ensure coherent decision-making. We propose a flexible, scalable multi-agent framework for smart-city management built on Semantic Kernel. Urban functions—traffic control, energy balancing and environmental monitoring—are each encapsulated as dedicated skills ("agents") that consume real-time data streams and produce actionable proposals. A central mediator invokes these agents in parallel, evaluates and scores their recommendations according to configurable city-wide priorities, resolves conflicts via rule-based negotiation, and issues a unified operational plan. Shared memory acts as a blackboard, enabling agents to access current city state and persist their outputs. By running decision loops on fixed intervals or event triggers, containerizing each agent as a microservice, and logging outcomes for continuous learning, this architecture aims to deliver responsive, composable, and robust control— paving the way for next-generation AI-driven urban infrastructures.**

Keywords— **agentic ai, internet of things, multi-agent systems, smart cities.**

Carbon Neutral Digitalization

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Abstract— **The European Green Deal aims for Europe to become the world's first carbon neutral continent by 2050. Within this framework, the European Union has set 2030 and 2050 targets. However, in order to achieve these targets, the European society needs to be informed. To reach its 2050 targets, it needs to reach the young generations. It has been observed that young people do not have enough information about the European Green Deal and are concerned about environmental issues. In order to inform the young generations, it is important to reach young people, youth workers and Youth NGOs in the youth field. By reaching the target audience, more young people will be informed and taking act about the European Green Deal and Green Transformation, thus supporting the fight against climate change. Within this framework, there is a need to develop a green transformation, field implementation and non-formal education-based training program that can be taught as a course in universities and used by NGOs in information activities, and is linked to sustainable development goals and the European Green Deal. In addition, in order to achieve the main goal of the Green Deal, after increasing awareness about carbon footprint in Europe with an educational program, there is a need for software that will allow these NGOs to calculate their carbon footprints, receive support from artificial intelligence to reduce them, and contribute to achieving the goal of a carbon neutral European continent in 2050. This study will outline the educational program and artificial intelligence-based carbon calculation software.**

Keywords—*European Green Deal, Carbon Calculation, Sustainable Development Goals, Green Transformation*

Change Management in Architectural Design Firms in the Digital Era: The Road to Success

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Abstract— **In the digital era, each digital improvement entails new competencies and know-how that must be acquired by organizations that want to sustain competitiveness. Accordingly, the proper and successful management of digital change practices has become a critical topic for organizations. Architectural design firms, as project-based entities, have crucial changes in their daily design practices, resources, technology, market, behavior, and processes. Although the technological solutions available to architectural design firms continue to grow, the design and construction sector has often been known for being slow in adopting change. The primary objective of this study is to identify the critical success factors (CSFs) for change management practices to succeed in a dynamic environment through a comprehensive literature review, utilizing the Scopus database and change management models. Additionally, this study proposes a classification framework of CSFs in managing digital changes. The outcome of this study is expected to serve as a roadmap for navigating change, advancing understanding of the factors that affect the success of change management practices in architectural design services.**

Keywords— **change, change management, architectural design firms, digital age, critical success factors.**

Cilos, Marcos and Hierarchical Clustering Integration Approach in Regional Energy Potential Assessment

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Abstract— **The increasing population density around the world and the resulting acceleration of consumption and production are causing a serious decrease in the earth's resources and many important environmental problems such as the climate crisis. It is known that fossil fuels used as energy sources cause damage to the environment, nature and even the future of humanity. For this purpose, environmental agreements are implemented between developed and developing countries and policies and targets are determined for the future of our planet. The transition to clean energy, which countries focus on the most in this context and which aims to end the use of fossil fuels by making investments and projects as quickly as possible, is realized with new targets every year. To achieve the determined targets and increase the amount of installed power and efficiency in renewable energy sources, it is crusial that investments and projects are carried out in regions with high potential in terms of energy production. In this study, a new approach, which is a harmonious integration of CILOS, MARCOS and HIERARCHICAL CLUSTERING methods, is presented in order to determine the energy production potentials of the regions. According to the approach, the criteria are weighted with CILOS and monthly rankings are obtained with MARCOS, and the grouping of alternative regions according to their similarities is carried out using the HIERARCHICAL CLUSTERING method based on the ranking result values. The presented approach was implemented considering climatic parameters over the provinces of the South East Anatolia region, which has a high potential in terms of solar energy and is an attractive region for investors. According to the results obtained in the study, the cities in cluster 1, i.e. high potential group, are Şanlıurfa, Kilis, Mardin and Adıyaman. Cluster 2, that is, cities with average potential, are Gaziantep, Siirt, Batman and Şırnak. The province with the lowest potential for solar power plants projects in the region was determined as Diyarbakır. The results of the study showed that this new approach provides robust results in the energy potential assessment of regions and can be used reliably in the decision-making stages of energy investment projects.**

Keywords— **MCDM, CILOS, MARCOS, Hierarchical Clustering, Renewable Energy, Solar Energy Potential.**

Comparative Evaluation of Convolutional Neural Network (CNN) Models for Multi-Class Skin Disease Classification

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Abstract— The worldwide health threats include various diseases beyond cancer and dermatological conditions which pose risks to public health. The early detection and precise identification of these diseases remain essential for their management. Dermatological conditions, which affect a large population and present in many forms, require a diagnostic priority comparable to that of malignancies. The wide range of dermatological diseases requires continuous attention to timely and precise diagnosis for achieving optimal health outcomes. The diagnosis process benefits from Convolutional Neural Network (CNN) approaches which serve as effective solutions. The built-in feature learning ability of CNNs for visual data makes them highly effective for medical image analysis applications. The diagnosis of dermatological conditions benefits significantly from CNN approaches. The ability of CNNs to extract complex hierarchical features from images makes them an essential technology for the medical image analysis of skin pathologies. This study evaluates two custom-designed CNN model architectures, a compact and an advanced model, and two pre-trained models, MobileNetV3 and EfficientNet, for dermatological image classification. To evaluate model robustness and generalizability, 5-fold cross-validation is implemented, and the models are assessed using metrics including accuracy, precision, recall, and F1-score. The pre-trained EfficientNet-B0 model achieved the best results with an average accuracy of 74.29%, significantly outperforming the custom CNN models, which achieved approximately 51% accuracy.

Keywords— Skin Disease Classification, Transfer Learning, Multi-Class Classification, Convolutional Neural Networks (CNNs), Deep Learning

Cost Optimization in Battery Component Procurement Using Mathematical Programming

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Abstract— This study emphasizes cost minimization in the procurement of lithium-ion battery components at a defense industryrelated company. The primary problem addressed in this study is the individual and small-volume ordering of comparable components from multiple vendors with greater unit and transportation expenses. To address this issue, a mathematical programming model was developed based on real data such as holding costs, volume limits, and vendors' quotations. A Pareto analysis was used to identify the high-volume products and their shared components. The constructed optimization model was solved in GAMS and minimized the overall cost while meeting inventory, volume, and budget needs. In turn, the optimal procurement plan reduced the cost by about 20.79%, thereby confirming the effectiveness of the proposed model in optimizing supply chain efficiency.

Keywords— Supply Chain Optimization, Procurement Cost Minimization, Mathematical Programming, GAMS, Battery Component, Pareto Analysis, Inventory Management

Cost-Optimized Predictive Maintenance by Use of Normal Behavior Model for Wind Turbines

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Abstract— **High maintenance costs pose a significant challenge for wind turbines, a popular renewable energy source. With the early warning system, maintenance can be carried out before the failure occurs, and the total maintenance cost can be reduced. While wind turbine Supervisory Control and Data Acquisition (SCADA) systems generate big datasets, the infrequent occurrence of turbine failures presents a challenge for direct failure prediction. For this reason, it is an appropriate approach to detect abnormal situations by modelling the system's normal behaviour. This study employs a filtering scheme to reduce data noise and establishes a baseline for normal behaviour. Subsequently, Cumulative Sum (CUSUM) control chart method is applied to the error values generated by a machine learning model to predict abnormal conditions and trigger early warning signals. A cost-based non-linear optimization model is developed to determine the optimal maintenance signal threshold. Different scenarios are analysed, and the results are compared with random maintenance and reactive maintenance strategies.**

Keywords— **Normal behaviour model, maintenance, filtering, control charts, cost.**

Cryptocurrency Value Estimation with Automatic Programming-Based Approach

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Abstract— **Bitcoin was introduced by Satoshi Nakamoto in 2008. After that, the potential of cryptocurrency for e-commerce increased year by year. Estimation of cryptocurrency values has become a critical topic. In addition to traditional estimation methods, artificial intelligence-based methods are used to estimate the cryptocurrency value. Automatic programming is a method of AI-based solutions. The problem of predicting cryptocurrency value through automated programming has not received much attention in the literature. In this study, the value of Bitcoin, one of the most well-known cryptocurrencies, was estimated using the MEP approach, an automated programming technique that uses textual and numerical data. The study examines the impact of incorporating widely accepted Bitcoin price determinants, textual data, and trader-used technical indicators on estimation performance when employing the MEP approach. The mean absolute error (MAE), mean absolute error (MAE), mean absolute percentage error (MAPE), mean square error (MSE), root mean square error (RMSE), and R-squared (R2) were used as performance indicators to assess the efficacy of the implemented approach and analyze the quality of the model. The results suggest that incorporating linguistic data from social media and technical indicators may improve forecasting methods.**

Keywords— **Cryptocurrencies, Bitcoin, automatic programming, multi-expression programming, forecasting**

Customer Churn Prediction: Data Augmentation Approach

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Abstract— **Customer churn poses a significant challenge in the gaming industry, as player retention has a direct impact on long-term revenue and community growth. Predicting churn accurately requires handling highly imbalanced datasets, as the proportion of churned users is typically much smaller than that of retained users. In this study, we investigate churn prediction using ensemble machine learning methods—specifically Catboost, Gradient Boosting, and XGBoost—augmented with advanced resampling strategies. To address data imbalance, we apply the Synthetic Minority Over-sampling Technique (SMOTE) and its hybrid extensions, SmoteTomek and SmoteENN, which combine oversampling with noise and overlap reduction. We conduct experiments on real-world gaming data and evaluate the impact of each augmentation technique on predictive performance. Results show that ensemble models coupled with hybrid SMOTE methods achieve substantial improvements in accuracy, precision, and recall compared to baseline models, reducing false negatives in churn identification. The findings highlight that integrating ensemble learning with tailored data augmentation strategies enhances churn prediction, offering actionable insights for retention strategies in the gaming industry.**

Keywords— **Churn prediction, Data Augmentation, Classification, Ensemble Learning, Imbalanced Dataset**

Cybele: Designing a Circular Business Model for Low-Carbon Breast Milk Delivery in an Urban Context

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Abstract— In today's urban life, mothers who return to work after giving birth face serious structural difficulties in maintaining their ties with their babies. In particular, failure to maintain work-life balance negatively affects breastfeeding continuity and also threatens both the mental health of mothers and the immune and developmental processes of babies. This situation is not just an individual problem; it points to a systemic inequality in terms of gender equality, public health and the visibility of care work. In this context, the literature review reveals that sustainable and accessible models in milk logistics are quite limited and low-carbon solutions focused on fresh milk delivery are not sufficiently covered both in practice and in academic literature. In particular, the lack of studies at the intersection of circular business models, sustainable logistics and social care services is striking. The aim of this study is to contribute to this gap by proposing a circular business model for fresh breast milk delivery that is compatible with environmental and social sustainability principles. The developed "Cybele" system is designed as an integrated service infrastructure consisting of modular milking pods, low-carbon delivery infrastructure (e-bike, small electric vehicles) and digital tracking systems. The model not only responds to individual user needs, but also aims to support care work with a systematic infrastructure and transform urban health services. A qualitative method was adopted in the research process. In addition to field observations and design- oriented analyses informed by user experiences, a comprehensive bibliometric analysis was conducted to reveal academic trends in the fields of sustainable logistics and social innovation. In the analyses conducted using Biblioshiny and Scopus tools, themes such as carbon neutrality in logistics, digital services for women's health, and inclusive care infrastructures, which have increased especially after 2020, stood out. The main findings of the study show that the system developed in line with user needs successfully integrates the dimensions of privacy, on-time delivery and sustainability. The Cybele model is positioned not only as a logistics solution, but also as a social enterprise model that produces multi-layered benefits in the areas of public health, gender equality and environmental impact. Moreover, as it is the first example in the Turkish context, it offers an open and scalable infrastructure for collaboration with local policy makers. In conclusion, this study presents a user-centered business model that combines the concepts of care labor, sustainable logistics and social entrepreneurship with circular economy principles and makes both theoretical and practical contributions to the related fields.
Keywords— Sustainable Innovation, Circular Business Model, Social Entrepreneurship, Caregiving, Low Carbon Logistic.

Cyber-Resilient Process Innovation in Energy Infrastructure: Comparative Case Studies of Digital Transformation and Circular Business Models

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Abstract— This study investigates how digital process innovations (DPI) in energy infrastructure and industrial manufacturing address emerging cybersecurity threats while advancing sustainability and resilience. Using a multiple comparative case study approach, the paper analyzes five international and Turkish cases: Siemens Energy, Tesla Energy, Tata Power, Enerjisa Enerji, and Arçelik-Simularge. Thematic analysis focuses on technological enablers, cybersecurity readiness, sustainability impacts, and the integration of circular business models. Findings highlight that DPI, when embedded in organizational strategy and regulatory frameworks, can deliver substantial operational efficiency, cyber-physical protection, and sustainability outcomes. The study contributes to both academic and practical fields by linking the theory of change, SDG alignment, and empirical case evidence.

Keywords— Digital Process Innovation, Smart Grid, Cybersecurity, Circular Business Models, Sustainability, Sustainable Development, Digital Twin, AI and IoT Integration, Process Innovation, Entrepreneurial Resilience, Sustainable Development Goals (SDGs)

Data Governance and Standardization Challenges in Implementing Digital Product Passports

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Abstract— **The Digital Product Passport (DPP) has emerged as a key tool under the European Union's sustainability and circular economy initiatives, particularly within the framework of the Ecodesign for Sustainable Products Regulation (ESPR). The DPP is envisioned as a digital record that systematically collects and shares critical product-related data across the entire lifecycle, enabling improved traceability, transparency, and sustainable resource management. Despite its potential, the implementation of the DPP faces several challenges in practice. These include the lack of clarity regarding which data points are mandatory versus optional, inconsistencies in data quality and granularity across supply chain actors, and the absence of standardized frameworks for data collection, storage, and sharing. Additionally, many firms struggle with the technical and financial burdens of integrating DPP requirements into existing enterprise systems, which is particularly challenging for SMEs. This paper introduces the concept of the DPP, its policy background, and its intended benefits while systematically highlighting the key challenges encountered in its implementation. By addressing these issues, the study aims to contribute to the development of practical and scalable solutions to support the effective deployment of DPP systems in advancing sustainability and circular economy goals.**

Keywords— **Digital Product Passport (DPP), Circular Economy, Sustainability, Traceability, Implementation Challenges**

Designing an ESG-Based Corporate Sustainability Governance Framework in Industrial Enterprises: An Action Research Approach in the White Goods Sector

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Abstract— **This study presents the design and implementation of a corporate sustainability governance framework based on Environmental, Social, and Governance (ESG) principles in an industrial enterprise operating in the white goods sector. Adopting an action research approach, the study translates key governance principles highlighted in the literature— structural integration, transparency, accountability, and committee-based representation—into a practical, industry-scale model. The research was conducted in five stages: current state analysis, literature and standards-based modeling, stakeholder engagement, establishment of the ESG governance framework, and institutionalization. As a result, a multi-layered ESG governance model compliant with IFRS and TSRS standards was developed, featuring thematic working groups in Energy, Environment, Greenhouse Gas Emissions, Social Impact, and Sustainable R&D. This model established a continuous feedback mechanism between operational processes and corporate strategy, enhancing accountability, transparency, and the integration of sustainability performance into strategic management. The study contributes to the literature by demonstrating action research–based implementation of ESG governance in the industrial context and provides a replicable governance framework applicable to other manufacturing sectors.**
Keywords— **ESG governance, TSRS, Strategic Management, Sustainability Reporting, UN SDGs, White Goods Industry**

Development, UX Evaluation, and Implementation of a Web-based Educational Tool for the Revised NIOSH Lifting Equation (RNLE) Method

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Abstract— **This study presents the development, User Experience (UX) evaluation, and implementation of a web-based educational tool for learning the Revised NIOSH Lifting Equation (RNLE) method. Developed through interdisciplinary collaboration of industrial and software engineering teams, the tool was intended to be used in ergonomics classes. The tool was designed as a web-based application capable of handling concurrent users with an acceptable response speed. The development team used JavaScript, React.js, React Hook Form, React Hook Form Persist, and jsPDF. The tool provides visual representations of task parameters, step-by-step guidance on calculating RNLE multipliers, the recommended weight limit value, and the Lifting Index (LI) to assess the risk level associated with the task under study. The tool generates a report of improvement recommendations for reducing musculoskeletal risks. The UX design principles are effectively applied, and wireframes were used to align development effort with applied UX principles. Pre-implementation user tests indicated high effectiveness as evidenced by full task completion and a high perceived UX level. The tool was implemented in real-world classroom settings, and the students used it to learn the RNLE method and solve RNLE problems. The students rated the usefulness of the tool with a mean score of 9.04 out of 10. The post-implementation evaluations showed that the perceived UX of the tool was (A+) level according to the Sauro-Lewis Curved Grading Scale (SL-CGS), which indicated high UX. The findings highlighted that the tool would significantly contribute to learning RNLE and the study exemplified how custom-tailored educational digital tools can enhance learning.**

Keywords— **Revised NIOSH Lifting Equation, ergonomic risk assessment, web-based software development, educational technology, User Experience, Computer System Usability Questionnaire**

Digitalization-Enhanced Ergonomic Facility Planning for Production of Smart Home Fitness Equipment

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Abstract— **The increasing demand for home-based exercise solutions, driven by evolving lifestyles and the spatial limitations of urban environments, has accelerated the development of compact and intelligent fitness technologies. In response to this trend, the present study outlines the facility planning and integrated production system design of Resist X— a wall-mounted smart fitness device—through a methodology that combines ergonomic layout strategies with automation- driven enhancements. In this context, product design and manufacturing workflows were evaluated concurrently. A flow- oriented layout was developed based on the sequencing of components and assembly relationships, using the Dimensionless Block Diagram technique. Through detailed material analysis at the beginning of the process, components were categorized as inhouse manufactured or externally sourced, enabling informed strategic decisions. Guided by lean manufacturing principles, workstation placements were optimized to minimize product flow time, followed by iterative improvements supported by analytical tools such as From-To Charts. The outcomes demonstrate that the production line has evolved into an agile system where engineering, digitalization, sustainability, and operational strategies intersect. The study highlights the necessity of considering product architecture and production systems not as separate entities, but as interdependent structures— especially for multifunctional smart products. Accordingly, the Resist X production system is positioned not merely as a technical infrastructure, but as an integrated manufacturing environment shaped by holistic design strategies. This study introduces digitalization systems as an enhanced version of traditional manufacturing methods, explaining their operational principles and associated advantages. Furthermore, the integration of such systems into the Resist X production line is examined, with a discussion on how they influence conventional production outcomes post-implementation.**

Keywords— **Automation, design-for-assembly, digitalization, ergonomic layout, facility planning and design, smart fitness device, sustainability**

Discrete-Event Simulation-Based Bottleneck Analysis in A Polypropylene Yarn Production System

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Abstract— **This study presents a discrete-event simulation model developed to identify and mitigate production bottlenecks in a polypropylene yarn manufacturing system. The model replicates the entire production flow—from raw material intake to final packaging—while capturing the stochastic behavior of different yarn types through fitted probability distributions for interarrival and process times. Real operational data collected from the facility were analyzed using Arena Simulation Software to define accurate simulation logic in AnyLogic Personal Edition. A conditional routing architecture was implemented to reflect product-specific paths, supported by 3D animation and performance dashboards. The simulation revealed critical congestion points, particularly in twist and stretch operations, and identified underutilized resources in other areas. Scenario analyses demonstrated the potential for improved throughput and reduced idle times through optimized resource allocation and revised scheduling strategies. The study provides a semi-digital shadow of the physical system, offering a foundation for future digital twin implementations and simulation-based decision support in textile manufacturing.**

Keywords— **Discrete event simulation, production bottleneck analysis, Simulation-based decision support, Manufacturing system optimization, Production flow simulation**

E-Commerce Web Application in Fashion Industry: Kansei Engineering Approach with Means-End Chain Analysis

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Abstract— In the contemporary demand-driven market, the importance of emotional appeal and user experience in e-commerce platforms, especially in the fashion industry, has significantly increased. This research investigates how e-commerce website design and user experience impact customer perceptions and emotions by integrating Kansei Engineering methods. Utilizing qualitative and quantitative methodologies, the study involved expert interviews, comprehensive analysis of e-commerce platforms, and consumer feedback sessions to identify critical attributes that influence emotional responses. The research commenced with detailed interviews involving UI/UX professionals and regular e-commerce users to ascertain key design attributes. Following this, a thorough analysis of various fashion e-commerce platforms was conducted, resulting in the identification of specific design features that enhance user satisfaction and emotional engagement. Kansei words, indicative of emotional responses, were generated and systematically categorized into attributes, consequences, and underlying consumer values through the Means-End Chain framework.
The findings highlight essential elements such as intuitive navigation, personalized recommendations, effective visual simulations, and clear product information as pivotal in evoking positive user emotions and improving overall site usability. This study contributes significant insights into designing emotionally intelligent e-commerce platforms, thus providing strategic implications for businesses aiming to foster deeper customer connections and loyalty through enhanced online user experiences.

Keywords— Kansei Engineering, E-Commerce, Means-end Chain Analysis, Web Design, User Interface

Enhancing Bike-Sharing Demand Forecasting with Spatio-Temporal Learning: A Comparative Study on A Local Dataset

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Abstract— **Bike-sharing systems rely on accurate short-term demand forecasts to prevent shortages, surpluses, and costly rebalancing operations. In this study, we evaluate a wide spectrum of forecasting approaches—ranging from classical time-series models (ARIMA, Prophet) and ensemble learners (Random Forest, XGBoost) to spatio-temporal deep learning models (LSTM variants, ST-GCN, GraphWaveNet, and GNN)—using a local station-level dataset. We incorporate both temporal history and spatial dependencies among stations under a unified evaluation protocol (24-hour look-back, one-hour-ahead prediction). Our findings show that integrating spatial context consistently improves accuracy. The spatio-augmented Random Forest (RF-ST) achieves the best performance, reducing error rates by over 10% compared to its temporal-only counterpart and by more than 35% relative to ARIMA and Prophet. Graph-based neural models (e.g., GNN) deliver comparable accuracy, further confirming the benefits of explicit spatial modeling. These results highlight the operational value of spatio-temporal forecasting for supporting sustainable and efficient bike-sharing systems.**

Keywords— **Artificial Intelligence, Bike-Sharing Systems, Sustainability, Spatio-temporal Forecasting, Graph Neural Networks**

Exploring Artificial Intelligence as an Alternative to Animal Testing in The Cosmetics Industry

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Abstract— The cosmetics industry is undergoing a paradigm shift as ethical concerns, technological innovation, and consumer expectations converge. Traditional animal testing, once central to product safety, is now questioned for its ethical implications and scientific limitations. Regulatory bans in regions such as the European Union, along with rising consumer demand for cruelty-free alternatives, have accelerated the search for innovative testing methods. This article explores artificial intelligence (AI) as a promising alternative to animal testing, focusing on its capacity to improve accuracy, efficiency, and ethical standards in cosmetic research. By situating AI within the broader context of ethical innovation, sustainability, and evolving consumer behavior, the study offers a comprehensive view of its potential to reshape cosmetic safety evaluation.

The research employs a mixed-methods approach, combining literature analysis with survey data to assess consumer perceptions and industry practices. Results indicate that AI provides not only scientific reliability and regulatory alignment but also strategic benefits such as speed-to-market, cost efficiency, and improved brand reputation. Consumer acceptance of AI-driven safety testing is strongly influenced by perceptions of transparency, inclusivity, and corporate responsibility. This article concludes that AI can simultaneously advance ethical standards and strengthen business performance, positioning the cosmetics industry for a more sustainable, innovative, and human future.

Keywords— Artificial Intelligence, Cosmetics Industry, Animal Testing Alternatives, Ethical Innovation, Consumer Behavior, Sustainability.

Feasibility of Autonomous Taxi Systems in Turkey: A Techno-Managerial Assessment

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Abstract— **This study examines the feasibility of autonomous taxi systems in Turkey from the perspective of technology and transportation management. While autonomous mobility solutions are rapidly advancing in developed countries, they may also provide a significant alternative in Turkish metropolitan areas suffering from traffic congestion, insufficient public transportation, and structural problems in conventional taxi services. However, the integration of such technologies in Turkey must be assessed through a multidimensional lens, considering not only technical factors but also legal regulations, infrastructure readiness, social acceptance, and economic impact. In this context, the study analyzes the current state of the transportation ecosystem in Turkey, identifies the infrastructural and legal gaps for autonomous vehicles, explores public concerns related to data privacy and safety, and evaluates societal attitudes toward driverless systems. Furthermore, the study discusses the potential transformation of traditional professions such as taxi driving and the broader sectoral implications of technology adoption. The findings suggest that while autonomous taxis may initially be viable only in limited pilot zones, their long-term integration in Turkey is possible through strategic planning and public policy support.**

Keywords— **Autonomous taxi, Transportation in Turkey, Technology management, Smart cities, Infrastructure and regulation**

Forecasting-Based Decision-Making Approach in Investment Plans: An Application on Bist 30 Shares

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Abstract— **In today's world, increasing competition conditions, lack of resources, wars, markets, politics, inflation fluctuations, major global health problems such as pandemics and many other similar factors make national economies quite fragile and volatile. Türkiye's economic structure is developing, but it is also heavily affected by the variability of external and internal conditions. This situation increases the stability of institutions and organizations that add value to the country in the markets and therefore, variability of the plans of decision-makers who invest in these companies. The same applies to investments in precious metals and commodities such as gold, silver and oil, or real estate, and under these conditions it is very difficult to implement a correct investment plan and make decisions. In this study, a new decision-making approach based on forecasting is presented that will help to make accurate investment decisions according to changing economic conditions. The application of the new approach was carried out using the month-end data of BIST 30 shares. In the study, BIST 30 parameters were weighted for each month with the CRITIC method and monthly stock ranking values were obtained with the MAIRCA method. Based on the monthly ranking values of BIST 30 stocks, the monthly ranking result values for each stock for the next year were forecasted with the FTS (Fuzzy Time Series) time series forecasting technique. In addition, the variability (risk level) of each forecasted BIST 30 stock over time was calculated with the coefficient of variation over the monthly data before and after the forecasting. As a result of this applied approach, monthly forecasted ranking results and volatility (risk) rates for BIST 30 stocks were obtained. Thanks to this approach, decision-makers will be able to carry out their investment plans in a reliable and practical way considering the ranking results and risk values on a monthly basis or according to the specified periods.**

Keywords— **CRITIC, MAIRCA, Fuzzy Time Series (FTS), BIST 30**

Global Şirketlerde RPA (Robotik Süreç Otomasyonu) ve IPA (Akıllı Süreç Otomasyonu) Uygulaması

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Abstract— **Bu çalışmanın temel amacı, global şirketlerin RPA (Robotic Process Automation – Robotik Süreç Otomasyonu) ve IPA (Intelligent Process Automation – Akıllı Süreç Otomasyonu) teknolojilerini benimseme ve yaygınlaştırma süreçlerini incelemek ve analiz etmektir. Araştırmada, söz konusu süreçlerde karşılaşılan zorluklar, sağlanan avantajlar, ortaya çıkan dezavantajlar, işletmeler üzerindeki etkiler ve geleceğe yönelik trendler ayrıntılı biçimde ele alınmıştır. Dijital dönüşümün hız kazandığı günümüzde, RPA ve IPA teknolojileri verimlilik artışı, süreç optimizasyonu ve maliyet avantajları sağlamaları nedeniyle global iş dünyasında yoğun ilgi görmektedir. Bu çalışma, söz konusu teknolojilerin kullanımını derinlemesine analiz ederek, işletmelerin stratejik yaklaşımlarını ve uygulama yöntemlerini anlamaya önemli katkılar sunmaktadır. Araştırma sonuçları, RPA ve IPA'nın benimsenmesinin yalnızca operasyonel verimlilik sağlamakla kalmayıp, aynı zamanda şirketlerin rekabet güçlerini artırdığını ortaya koymuştur. Elde edilen bulgular, gelecekte bu teknolojilerin daha geniş çapta uygulanacağını ve dijital dönüşümün önemli bir bileşeni haline geleceğini göstermektedir. Sonuç olarak, bu çalışma global şirketlerin RPA ve IPA teknolojilerine yönelik stratejilerinin gelişimini, uygulama süreçlerini ve yaygınlaştırma adımlarını net bir biçimde ortaya koymakta; böylece hem akademik literatüre hem de iş dünyasına değerli bilgiler sunmaktadır.**

Keywords— **RPA, IPA, robotik süreç otomasyonu, akıllı süreç otomasyonu, dijital dönüşüm, otomasyon stratejisi, verimlilik**

Gnss-Denied Navigation: Autoencoder-Based Deep Neural Network for UAV Localization

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Abstract— **We present a vision-based method for UAV localization under degraded or denied GNSS/GPS. Satellite/map imagery and nadir (down-looking) in-flight images are projected into a shared representation using a convolutional autoencoder (CAE), after which the most likely position is selected via normalized cross-correlation (NCC) template matching. The CAE suppresses illumination/contrast variability to stabilize matching, while NCC contributes robustness in position selection. Trained on 406,579 544×544 grayscale patches and evaluated on 0.298-m resolution maps with DJI Mavic 2 Pro flights, the approach attains 86.7-100% accuracy and F1 = 0.952–1.000 in multi-flight urban scenarios; in rural scenes, accuracy is typically ~83% (F1 = 0.856-0.961). These results demonstrate meter-level localization accuracy and practical viability for GNSS-free navigation, especially in urban settings.**

Keywords - UAV, visual localization, terrain-referenced navigation, autoencoder, template matching, deep learning

Information Accessibility and Market Power in the Airbnb Market: Multilevel and Quantile Evidence from Istanbul

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Abstract— **This paper examines how information accessibility disciplines pricing power in Istanbul's short-term rental market. We combine four InsideAirbnb snapshots (Sept-2024 to Jun-2025) and estimate a multilevel regression alongside Linear Quantile Mixed Models (LQMMs) to study the effects of (i) review intensity (reviews per month) and (ii) sentiment on prices, controlling for room type, minimum nights, distance to neighborhood center, and neighborhood random effects. Three findings emerge. First, review intensity is consistently associated with lower prices: the coefficient is negative and highly significant in the multilevel model, and remains negative at the median and upper quantiles in the LQMM. Second, sentiment is positive and significant at the median, consistent with credible quality signaling that raises willingness-to-pay without contradicting the disciplining effect of higher review volume. Third, market structure and space matter: minimum nights has a small but robust negative effect; room-type coefficients follow expectations; distance is not robustly significant; and an intraclass correlation of about 0.17 indicates meaningful between-neighborhood variation. Substantively, greater information accessibility reduces informational rents and moves outcomes toward competitive benchmarks. From a productivity perspective, denser and more credible review information improves allocative efficiency by directing demand to higher-quality listings and limiting markups. We discuss scope conditions and avenues for higher-frequency and spatial-econometric extensions.**

Keywords— **information accessibility; online reviews; market power; Airbnb; multilevel models; linear quantile mixed models; productivity**

Integrated Forecast-Based Production, Distribution and Inventory Planning for a Multi-Product Supply Chain: A Case Study in Ceramic Industry

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Abstract— This study addresses an integrated forecast-based production, distribution, and inventory planning for a multi-product supply chain in the ceramic industry. A real-life case study is conducted in collaboration with a company that manufactures a variety of ceramic products, which are distributed and stored across multiple distribution centers. The objective is to maximize overall profit by minimizing operational costs, including those associated with production, overproduction, transportation, and inventory holding. Based on the historical sales data of each distribution center, the products with the highest demand are selected using ABC analysis and different forecasting models are applied to forecast the demand. The performance of these models is evaluated with several metrics to select the most appropriate forecasting method. Based on the forecasted demand of each product for each distribution center, we propose a mathematical model that determines the production, distribution and inventory plan of the company for each period. The production plan finds the number of units to be manufactured during regular and overtime. The distribution plan determines the number of vehicles required to transport products to distribution centers. Lastly, the inventory plan specifies the quantity of stock to be held at each distribution center per period. The proposed model ensures that the forecasted demand at each distribution center is fully met at each period, while enabling the company to manage its supply chain operations. Integrating demand forecasting with operational planning not only supports cost-effective planning but also improves customer satisfaction by maintaining product availability. The model can be modified to similar industries facing multi-product, multi-location planning challenges, offering a valuable framework for creating a connection between predictive analytics and operational planning.

Keywords— Demand Forecasting, Distribution Planning, Forecasting Model Evaluation, Integrated Forecast-Based Planning, Inventory Planning, Supply Chain Management, Sustainable Manufacturing

Integrating Big Data Practices and Knowledge Management with Digitalization Capability: Unlocking Innovation, Performance, and Competitive Advantage in the Hospitality Sector

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Abstract— **In today's era of digitalization, the hospitality sector faces multiple challenges in using big data for strategic and operational decision-making to maintain competitiveness. Big data has become an essential accelerator for strategic renewal; however, its successful integration necessitates an amalgamation of management practices, knowledge capacities, and innovation avenues. A conceptual framework of this study has been constructed to investigate how big data management practices (BDMP), such as leadership focus, talent management, technological infrastructure, and organizational culture, shape big data knowledge management capabilities (BDKMC), while utilizing the Dynamic Capability View (DCV) and Resource-Based View (RBV) theories. Further, the proposed framework suggests that digitalization capability moderates the relationship between big data management practices and data knowledge management capabilities. This study contributes by addressing three specific gaps. First, this study examines the direct impact of managerial practices on BDKMC. Second, it also explores the mediating role of innovation capacity between BDKMC and the hotel's performance and competitiveness. Third, it also investigates the moderating role of digitalization capability between BDMP and BDKMC in promoting hotels' adaptation to dynamic market shifts. Moreover, this study will address the missing link by investigating the critical bridge linking data-driven practices to performance and competitive edge. This study will be tested empirically using a quantitative approach, and PLS SEM will be employed to test hypotheses. This study will offer theoretical and practical insights for hotel management and policy makers on using big data management practices and knowledge management capabilities to foster digital transformation and innovation-led performance and competitiveness.**

Keywords— **Big Data Management Practices, Knowledge Management Capabilities, Digitalization Capability, Innovation, Hotel Performance**

Integrating Fuzzy Regression Functions with Attention-Based Deep Neural Networks for Multivariate Time Series Forecasting

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Abstract— **In the past few decades, there has been a substantial increase of studies integrating fuzzy regression functions with deep learning for the forecasting of multivariate time series. It is a crucial challenge capturing complex nonlinear relationships and long-term dependencies in the case of multivariate time series. This research introduces a novel framework that integrates fuzzy regression functions and attention-based deep neural networks to address complex nonlinear relationships and long-term dependencies. The framework effectively integrates the fuzzy c-means algorithm with attention-based deep neural networks. The efficiency of the proposed model is tested using a multivariate time series dataset for air quality prediction. Experimental results indicate that our model yields sufficient accuracy in forecasting multivariate time series and outperforms other methods.**

Keywords— **Multivariate time series forecasting, Fuzzy regression functions, Deep neural networks, Fuzzy *c*-means clustering, Hybrid intelligence systems.**

Internal Technology Transfer Strategies: A Synthesis of Academic Frameworks and Industry Practices

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Abstract— **Nowadays fast-evolving digital landscape, internal technology transfer (ITT) has become a strategic necessity for organizations aiming to scale innovation, avoid duplication, and foster cross-team collaboration. However, many companies struggle to circulate technologies and knowledge beyond their teams. This study investigates the ITT challenge through a dual-lens approach: (1) a literature-based exploration of academic models such as Technology Transfer Offices (TTOs) and structured mentorship systems, and (2) a comparative analysis of industrial solutions adopted by leading technology companies including Spotify's "Guild" structure and Google's Engineering Productivity (EngProd) team.**

By synthesizing both theoretical and practical perspectives, this paper investigates a range of alternative solutions to improve internal technology transfer (ITT) within organizations. The study evaluates each approach in terms of strengths and weaknesses, drawing from both academic frameworks—such as mentorship programs, technology transfer offices (TTOs), and incentive/sanction systems—and industrial practices adopted by large technology firms, including Spotify's "Guild" structure and Google's "Engineering Productivity (EngProd)" team. Each solution is assessed with regard to organizational scale, cultural compatibility, and resource requirements, offering insights into which types of companies may benefit most from specific ITT strategies.

Keywords— **Internal Technology Transfer, Technology Transfer Office, Organizational Learning, Innovation Management**

Intrusion Detection in Smart Grids: Impact of Data Sampling and Positive Class Definition

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Abstract—**Intrusion detection in smart grid systems is a critical challenge due to increas-ingly sophisticated cyber-attacks and a severe class imbalance between nor-mal and malicious instances. This study evaluates the performance of six su-pervised machine learning models – Logistic Regression (LR), Decision Tree (DT), Support Vector Machine (SVM) with RBF kernel, Random Forest (RF), Gradient Boosting Machine (GBM), and k-Nearest Neighbors (KNN) – on a public smart grid intrusion dataset. Model performance is compared under two training strategies: using the original imbalanced dataset versus using a balanced (downsampled) training subset. In each case, intrusion instances are treated as the positive class to focus evaluation on attack detection. To the best of the authors' knowledge, this study is among the first to apply ma-chine learning models to the GridDS smart grid cybersecurity dataset (re-leased by Lawrence Livermore National Laboratory) in an intrusion detection context [10]. Experimental results show that when trained on the imbalanced data, the models attain high overall accuracy but essentially fail to detect any attacks, whereas training on a downsampled dataset enables detection of ap-proximately 50–68% of attacks (recall) at the cost of increased false alarms. These findings underscore the importance of addressing class imbalance: with appropriate sampling, even relatively simple classifiers can identify a substantial portion of cyber-attacks in smart grid data. The analysis also high-lights which input features are most indicative of intrusions, providing base-line results to guide future research using this open smart grid dataset.**

Keywords—**Smart Grid Security, Intrusion Detection, Class Imbalance, Supervised Learning, Machine Learning, Ensemble Methods, Gradient Boosting, k-Nearest Neighbors, Feature Importance, Cyber-Physical Systems**

Jet 200 Fully Automatic Fast Fabric Cutting, Winding and Packaging Machine with Double Station

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Abstract—**GCM Group carries out R&D and innovation-based works in the field of fabric quality control and packaging machines. In this context, projects are developed as a result of field research, incoming orders, and fair observations conducted by our company. As a result of the works conducted by the sales and marketing team in our company, R&D team meetings are held regarding the products that can be launched to the market. In these meetings, technical issues regarding the machines that can be launched to the market and improvements that can be made to the existing machines in line with the needs of the market are discussed. The outputs of these meetings are turned into an idea product by the R&D team. Patent and industrial design applications are made for the products that have become an idea product. Afterwards, applications are made to grant programs by our company. Having gone through these processes, "Jet 200 Fully Automatic Fast Fabric Cutting, Winding and Packaging Machine with Double Station" ensures that fabrics of which quality and meterage are automatically cut, quickly wound, and automatically combined and automatically packaged by means of two stations of fabrics of different qualities located in different places within the same dock (apparatus on which the fabric is wound) with minimum waste. The machine was produced as a result of the development of Jet 120 Fast Fabric Quality Control machine, which was previously developed by our company with the support of KOSGEB R&D Innovation Support Program and for which our company has a utility model registration. Jet 200 Fully Automatic Fast Fabric Cutting, Winding and Packaging Machine with Double Station was developed within the scope of KOSGEB R&D P&D program. In addition, patent and industrial design (TR2023/006257) applications were made to TURKPATENT institution regarding the machine (TR2023/003995). As a result of these applications, both design registration and examined patent were obtained. Innovations have been realized in the literature and the market with the machine. In this context, the winding speed of the machine has been increased from 120 m/min to 200 m/min. The most important innovation of the machine is that it holds the fabrics in a dock consisting of fabrics of different quality with a defect map (1 dock consists of approximately 15,000 meters of fabric) in two different stations in order to complete their meters according to their quality classes and automatically combines them with the winding method. In addition, the winding of fabrics with the same quality and complete meters continues with a speed of 200 m/min. While these processes are carried out, it takes samples from the fabric and barcodes them. The optimization need in the denim sector has been met with the machine, and the machine offers the opportunity to match and combine fabrics that are considered as 2nd quality and are under 100 meters in denim fabric according to the flow of the cutting plan and discharge them as 1st quality. In addition, the innovative aspects of the machine include the presence of two waiting stations, automatic combining and packaging, and winding at 200 m/min. Based on these innovative aspects, companies can make an average profit of 80,000 USD per month and 960,000 USD per year.**

Keywords—*Fabric Quality Control, Denim Fabric, Double Station*

Kurumsal Karbon Ayak İzi Hesaplaması ve Emisyon Azaltım Stratejileri: Sersim Beyaz Eşya Fabrikası Uygulaması

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Abstract— **Günümüzde işletmelerin çevresel etkilerini sistematik bir şekilde ölçmesi, sürdürülebilirlik hedeflerine ulaşmak adına büyük önem taşımaktadır. Özellikle Türkiye'deki üretim tesisleri, sürdürülebilir uygulamaları benimseyerek hem çevre koruma hem de ekonomik verimlilik sağlama becerilerini geliştirmektedirler. Bu çalışma, Sersim Beyaz Eşya Fabrikası'nın kurumsal karbon ayak izini hesaplamayı ve önerilen azaltım stratejilerinin belirlenmesini amaçlamakta olup, ISO 14064 standardı çerçevesinde, doğrudan, dolaylı enerji kaynaklı ve diğer dolaylı emisyonların ayrıntılı bir şekilde analizini içermektedir. Veriler, üretim süreçleri, enerji tüketimi, ulaşım ve atık yönetimi gibi farklı alanlardan toplanmış ve bu veriler uluslararası kabul görmüş karbon ayak izi hesaplama araçları ile emisyon faktörleri kullanılarak analiz edilmiştir. Çalışma sonucunda, Sersim fabrikasının üretim faaliyetlerinden kaynaklanan başlıca emisyon kaynakları sistematik biçimde belirlenmiş ve bu alanlara yönelik iyileştirme önerileri geliştirilmiştir. Elde edilen bulgular, beyaz eşya sektöründe faaliyet gösteren diğer üretici firmalar için de kurumsal sürdürülebilirlik stratejilerinin oluşturulmasında yol gösterici bir referans niteliği taşımaktadır.**

Keywords— *Kurumsal Karbon Ayak İzi, ISO 14064, Sürdürülebilirlik, Beyaz Eşya Sanayi, Emisyon Yönetimi*

Machine Learning Approaches for Cotton Price Forecasting

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Abstract—**This study aims to develop an effective price prediction model of cotton using Artificial Neural Networks (ANN) and compare its performance with other popular techniques like linear regression, XGBoost, and decision trees. The need for the prediction arises from the extremely fluctuating behavior of cotton prices, which are influenced by numerous physical and market-related features. Data preprocessing steps such as feature scaling, autocorrelation analysis, and deseasonalization were applied to enhance model performance. The dataset includes 722 cotton samples with 14 distinct features, including fiber fineness, moisture, elasticity, and color. Multiple models were trained and evaluated using Mean Absolute Percentage Error (MAPE) as the key performance metric. Among all tested models, the ANN architecture with ReLU activation function achieved the lowest error rate, demonstrating superior capability in capturing complex, nonlinear patterns. The results suggest that artificial neural networks, supported by proper data preprocessing, offer a robust solution for price prediction in the agricultural sector. This approach improves decision-making for raw material procurement and holds strong potential for adaptation in various industries facing dynamic pricing environments.**

Keywords—**Cotton Price Prediction, Machine Learning, Data Preprocessing, Time Series Analysis, Artificial Neural Networks, Linear Regression, XGBoost, Decision Trees**

Marketing and Sales Strategies of Electric Vehicles

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Abstract— **Electric vehicles have been met with significant demand in Turkey, as well as worldwide. The market is fiercely competitive among automotive brands. Different brands in the market employ different marketing and sales strategies to inform customers about their vehicles and drive sales.**
Within the scope of this research, we firstly took a general look at the brands in the electric car market and examined their sales and marketing activities. Then, in the original research section, we analysed the marketing information on the websites of the 7 selected brands, compared their social media posts, and finally, by visiting the showrooms of the brands, we tested their sales skills with the "mystery customer technique" and evaluated the marketing and sales activities of the electric car manufacturer brands as a whole.

Keywords— **Electric vehicles, Marketing strategies, Sales strategies, Customer relations, Digital marketing**

Modular and Transformable Bag Design for a Sustainable Environment: Functional and Customizable

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Abstract: **This study aims to develop a sustainable, functional, and user-cantered bag design that can adapt to various usage scenarios. In response to the overconsumption and environmental harm caused by the fashion industry, the objective is to create a single modular product that meets multiple user needs, reducing the reliance on multiple bags. This approach minimizes material waste and supports responsible consumption by promoting personalization over repeated purchasing. The bag features large Velcro surfaces to enable modularity. Users can attach or detach elements like functional pockets, adjustable straps, and decorative panels to customize its structure and appearance. The design process was shaped by sustainability goals, user experience insights, and evaluations of material durability. Prototypes were developed and evaluated to assess usability and adaptability in real-world contexts.**

Prototype testing showed that users could adapt the same bag for activities such as sports, travel, work, or formal events by changing its components. Personalization encouraged creative engagement, making the bag both practical and expressive. Compared to traditional bags, the modular system offered greater utility and visual variety with fewer total items, helping reduce environmental impact. The modular bag system offers an innovative response to both functional and environmental challenges. By combining style flexibility with efficient material use, it supports a shift from fast fashion to a more sustainable and user-driven lifestyle. This work emphasizes the growing relevance of transformable products in shaping a more responsible future for the fashion industry.

Keywords: **Modular Design, Product Engineering, Sustainable Systems, Transformable Product Development, User-Centered Innovation, Environmental Responsibility, Adaptive Product Use, Material Efficiency, Engineering and Design Integration**

Mortality Prediction in Intensive Care Units: A Comparative Analysis of Classical Machine Learning Methods

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Abstract— **Mortality prediction in intensive care units (ICUs) is crucial for improving the survival of critically ill patients and utilizing healthcare resources efficiently. While traditional scoring systems (APACHE, SOFA) are widely used, they offer limited accuracy because they cannot fully reflect the complex nature of patient profiles. Therefore, machine learning (ML) methods have become a powerful alternative in recent years. In this study, five classical ML algorithms—Logistic Regression (LR), Decision Trees (DT), Naive Bayes (NB), Support Vector Machines (SVM), and k-Nearest Neighbor (k-NN)—were compared for ICU mortality prediction. Performance evaluations used accuracy, precision, sensitivity, F1 score, specificity, and area under the ROC curve (AUC). The results revealed that LR provided the most balanced performance, while SVM and NB exhibited high sensitivity but low specificity. While DT provided interpretability, it produced limited accuracy, and k-NN performed less well.**

Keywords— **Intensive Care Units, Mortality Prediction, Machine Learning, Classification Algorithms, Clinical Decision Support**

Optimising Assembly Line and Workforce Scheduling, a Case Study at a Tractor Factory

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Abstract— This research presents a case study about the assembly line balancing problem (ALBP) in the front axle assembly line from a tractor factory in Türkiye. A tractor's front axle assembly process consists of multiple subassembly stations that are serially connected to each other. Due to the serial assembly process, the speed of each station should be in coordination. Any imbalance between subassembly stations will cause bottlenecks in the system and increase the cycle times. A balanced assembly line can be achieved by minimising the number of workstations together and the cycle time. In the literature, ALBP that seeks to minimise cycle time and the number of workstations is known as the type E mixed simple ALBP. In this study, we considered assembly line balancing and number of workstations problems. Then, we developed a mathematical model of the system that integrates task priority to optimise workforce scheduling and front axle assembly line balancing. Our model searches for the optimal number of workstations and the cycle time using the integer programming method with the PuLP library. For the case study, we collected real system information via time study and analysis of non-value-added activities. The proposed model reaches a solution with a 3% gap from the optimal solution in just 600 seconds.

Keywords— Assembly Line Balancing, Integer Programming, PuLP library, Type E, Workforce Scheduling

Predicting Classification Performance from Dataset Complexity: An Initial Empirical Study Using Class Overlap Metrics

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Abstract— **Predicting classification performance before extensive experimentation remains a critical challenge in machine learning deployment. This paper presents an initial empirical investigation into predicting classification performance using dataset complexity metrics, focusing specifically on binary classification problems. We analyze 30 benchmark datasets from the KEEL repository using 15 complexity metrics and evaluate performance across 12 classification algorithms with standardized parameters, yielding 360 dataset-classifier observations. Our predictive models achieve R^2 values of 0.722 for F1-score prediction, with the fraction of borderline points (N1) emerging as the dominant predictor, showing a strong negative correlation of -0.759 with F1-score. We demonstrate that overlap metrics, particularly N1 and N3, capture fundamental aspects of classification difficulty that enable performance prediction without exhaustive experimentation. Our findings reveal a clear hierarchy of classifier robustness to overlap, with Random Forest and Extra Trees maintaining F1-scores above 0.93 even under challenging overlap conditions. The framework enables practitioners to assess expected performance rapidly, potentially reducing experimental overhead by 60-80%. We provide practical guidelines for applying these insights in real-world scenarios.**

Keywords— **classification performance prediction, dataset complexity, class overlap, class imbalance, regression**

Sawgin Feeding Unit Prototype Production Project

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Abstract—— **The purpose of the Sawgin Feeding Unit Prototype production project is to ensure that the unit feeding the sawgin machine, which is used to separate the cotton core in cotton gin factories, is produced by our company with an innovative method. Our company's prototype will be larger and more voluminous than the currently produced feeding units and its processing volume (cotton cleaning) will be higher than the existing ones. Since the pipe diameter will increase, the cleaning time of the dirt and trash of the cotton will be extended and the cotton will be cleaned more. Thanks to the trash fingers, the cotton will be granulated and as a result, the cotton will be distributed equally to the sawgin, preventing the core from breaking and ensuring better separation of the cotton from the core, and also preventing fibering and lint. With the project, the cotton will be distributed equally while being fed to the sawgin machine and the cotton in the system will be cleaned more. Thus, as a result of the equal distribution of cotton, it will prevent the core from breaking while being separated from the cotton in the sawgin machine, it will clean the cotton more and provide a top quality cotton and increase the profitability of the companies. In addition, the feeding unit formed by bringing together the straw and saw machines will provide energy and space savings to the customers. As a result, companies will be supported in reducing their carbon emissions and their green transformation.**

Keywords— *Sawgin, Sawgin Feeding Unit*

Selection of Key Factors for Urban Air Pollution Mitigation Strategies

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Abstract— **Urban development brings about significant challenges, foremost among them being environmental degradation and air pollution. As urban populations grow and industrial activities increase, cities worldwide are facing unprecedented levels of air pollution, which threaten both public health and the environment. Mitigating urban air pollution requires effective, evidence-based strategies informed by an understanding of the most influential contributing factors. This study aims to identify the most critical factors for air pollution strategies under the sustainability framework. To achieve this, a comprehensive set of criteria was first developed through an extensive literature review, complemented by the insights of domain experts from academia, industry, and public institutions. In order to address the uncertainty and complexity in the decision-making process, the critical factors are weighted and thus ranked using the Fermatean Fuzzy Step-by-Step Weight Ratio Analysis (FF-SWARA) method. By providing a robust and practical decision support tool, this study offers valuable guidance to governments, policy makers, and urban managers in designing effective and sustainable air pollution mitigation strategies. The proposed approach not only supports evidence-based decision-making but also contributes to the broader goal of developing resilient, healthy, and sustainable urban communities, aligning with global sustainability goals.**

Keywords— **Urban air pollution, sustainability, multi-criteria decision-making, fermatean fuzzy sets, SWARA**

Shift Scheduling in Healthcare: Considering Legal Regulations and Fairness for Radiology Technicians

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Abstract— **This study focuses on employee shift scheduling with an emphasis on complying with legal regulations and ensuring fairness among emloyees. We propose an integer programming model that determines shift schedules for radiology technicians, balancing total working hours and night shift assignments across all employees while satisfying legal requirements. The proposed model is tested with a real-world case over a four-week planning period in a hospital for radiology technicians. In accordance with Ministry of Health regulations, the model ensures compliance with restrictions on radiation exposure, mandatory rest periods, and employee rights. Specifically, it prevents assigning technicians to both day and night shifts on the same day, or to a day shift immediately following a night shift. In addition, the model incorporates institutional policies such as voluntary overtime preferences ensuring that technicians who choose not to work overtime are scheduled according to minimum working hour limits. Technicians who work overtime receive additional income, making workload balance important for income equality as well. Furthermore, based on patient preferences, particularly for mammography procedures, the model guarantees that at least one female technician is assigned to each day shift. While satisfying all these requirements, the model includes fairness by minimizing the difference between the maximum and minimum total working hours, as well as the difference in the number of night shift assignments across employees. The results show that the schedule obtained by the proposed model significantly improves the equity of workload distribution while satisfying all legal and policy constraints. The proposed model has a contribution to more sustainable and adaptable human resource management in healthcare institutions and can be adapted to other departments or staff categories.**

Keywords— **Healthcare Operations, Healthcare Staff Rostering, Human Resource Management in Healthcare, Radiology Technician Scheduling, Fair Shift Scheduling, Equity in Shift Scheduling, Sustainable Workforce Management**

Smart Factories in Modern Manufacturing: A Bibliometric Analysis for Their Rise

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Abstract— **Innovation is the process of applying creative ideas and transforming them into economic and functional value. In the manufacturing sector, this process aims to create more efficient, flexible, and sustainable systems through changes in technology, methods, or materials. Thus, strategic goals such as resource savings, quality increase, and environmental sustainability are supported. Industry 4.0 is the pioneer of this innovative transformation by integrating digital technologies into manufacturing processes. Thanks to technologies such as the Internet of Things, Cloud Computing, Artificial Intelligence, and Robotic Systems, machines and systems communicate with each other, processes are monitored in real-time and data-driven decision mechanisms are activated. These developments have created smart, connected and autonomous structures in manufacturing. This paper discusses innovative applications that emerged with digitalization in the manufacturing industry and examines the concept of "Smart Factory", which is at the center of this transformation, in detail. Smart factories offer predictive and flexible manufacturing infrastructures that optimize manufacturing processes, work integrated with decision support systems. Within the scope of the paper, a bibliometric analysis was conducted in order to reveal the development of this concept in academic literature. Studies published since 2013 have been examined. The study identifies the thematic trends, publication densities and key academic fields contributing to research on Smart Factory and opens up discussion on the current status and future research areas in the field.**

Keywords—**Smart Factory, Smart Manufacturing, Innovative Strategy, Production Process, Industry 4.0, Intelligent Manufacturing,**

Sustainable Entrepreneurship and Cybersecurity Innovation in Smart Grids: A Thematic Bibliometric Review Aligned with SDG 7 and SDG 9

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Abstract— **This study presents a bibliometric review of research on sustainable entrepreneurship and cybersecurity innovation within the context of smart grids. The aim is to explore how these fields contribute to Sustainable Development Goal 7 (Affordable and Clean Energy) and Goal 9 (Industry, Innovation, and Infrastructure). As smart grids become more common, their digital nature brings both opportunities for innovation and risks related to cybersecurity. A total of 77 academic papers (72 from Scopus and 5 expert-selected) were analyzed using PRISMA screening guidelines and bibliometric tools, especially the Biblioshiny platform. The analysis identifies five major research themes: sustainable entrepreneurship, smart grids, cybersecurity, digital technologies (e.g., AI, blockchain), and policy ecosystems. The study highlights areas of overlap and identifies research gaps, particularly in the limited focus on how entrepreneurship can directly address energy system security. The findings underscore the need for increased interdisciplinary collaboration among the fields of energy, technology, and business. There is also a call for better policy support and innovation ecosystems that encourage startups working on clean and secure energy infrastructure. By linking bibliometric insights with the SDG framework, this review helps researchers and decision-makers better understand the evolving role of entrepreneurship in achieving a resilient and sustainable energy future.**

Keywords— **Sustainable Entrepreneurship, Smart Grids, Cybersecurity and Digital Innovation, Artificial Intelligence, Blockchain, Digital Transformation, Renewable Energy, Innovation Ecosystems, Policy Support, Resilience**

Sustainable Supplier Selection through a Multi-Criteria Decision-Making Approach in Consumer Goods Manufacturing

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Abstract— **Sustainable supplier selection is a key component of building environmentally responsible and resilient supply chains. However, the lack of standardized sustainability metrics at the supplier level presents significant challenges, particularly in industries with limited ESG reporting. In this study, a structured multi-criteria decision-making (MCDM) framework was developed to evaluate suppliers in the consumer goods manufacturing sector by integrating operational and sustainability-related indicators. A total of 12 sub-criteria were considered under three main categories: economic (supply volume, unit price, delivery lead time, delivery delay rate, defect/return rate), environmental (certifications, sustainability report availability, delivery distance), and social (female employment ratio, occupational health and safety certifications, social compliance certifications). The Analytic Hierarchy Process (AHP) was used to determine the relative importance of these criteria, and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) was applied to rank supplier alternatives. Additionally, a consistency and sensitivity analysis was conducted to compare the theoretical AHP weights with their empirical influence in the TOPSIS results, providing an internal validation of the model. Unlike previous studies that predominantly focused on either cost-based or environmental factors, this framework combines economic, environmental, and social dimensions, thereby providing a more comprehensive and practical tool for sustainable supplier evaluation in industries with limited ESG reporting.**

The results demonstrate that the proposed framework effectively prioritizes suppliers based on both sustainability and operational factors, offering a structured and transparent method for responsible sourcing. This research contributes to the ongoing shift toward sustainable procurement practices and aligns with key United Nations Sustainable Development Goals—specifically SDG 9 (Industry, Innovation and Infrastructure), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action).

Keywords— **Sustainability, Sustainable supply chain management, Supplier selection, Multi-criteria decision-making (MCDM), ESG indicators**

Sürdürülebilir Üretim İçin Hurda Azaltımına Yönelik Yalın Süreç Tasarımı

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Abstract— **Beyaz eşya sektöründe üretim süreçlerinden kaynaklanan sac metal hurda atıkları, hem maliyet hem de çevresel etkiler açısından önemli sürdürülebilirlik sorunları doğurmaktadır. Bu çalışma, Türkiye'de sektörün önde gelen firmalarından birinde, üretim süreçlerindeki sac hurda oranlarını azaltmak amacıyla geliştirilmiş, Çevresel, Sosyal ve Yönetişim (ÇSY) ilkeleriyle uyumlu bir süreç iyileştirme modelini ele almaktadır. Çalışma kapsamında, hurda oluşumunun nedenlerini belirlemek ve katma değersiz faaliyetleri tespit etmek amacıyla Değer Akış Haritası (DAH) yöntemi kullanılmıştır. Mevcut üretim hattı adımları detaylı şekilde analiz edilerek, fire oranlarını artıran süreçler tanımlanmış ve gelecekteki ideal süreç yapısına ilişkin bir hedef durum haritası oluşturulmuştur. Süreçlerin yalın üretim prensipleri doğrultusunda yeniden yapılandırılması, üretim verimliliğini artırmaya ve malzeme israfını azaltmaya yönelik çok yönlü iyileştirmeler sağlamıştır. Ayrıca, ÇSY yaklaşımı kapsamında çalışanlara yönelik eğitimler düzenlenmiş, tedarik zinciriyle iş birliği mekanizmaları kurulmuş ve sürdürülebilir atık yönetimi için yönetişim yapısı oluşturulmuştur. Elde edilen bulgular, sac hurda oranlarında anlamlı düşüş, enerji ve malzeme tasarrufu ile birlikte karbon ayak izinde azalma sağlamış; modelin tekrarlanabilirliği sektörde benzer uygulamalar için yol gösterici bir çerçeve sunmuştur.**

Keywords— **Beyaz Eşya Sektörü, Değer Akış Haritası (DAH), Atık Yönetimi, Kaynak Verimliliği, Sürdürülebilirlik**

Technostress and Employee Well-Being in Times of Turbulence: The Mediating Roles of Work-Family Conflict and Success Enablers

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Abstract—The global shift to remote work following the outbreak of the COVID-19 pandemic has thrust the phenomenon of technostress into critical prominence within the new organizational landscape. This study investigates the direct effects of technostress on the well-being of remote employees, with a specific focus on the mediating roles of success enablers and work-family conflict. Furthermore, it examines the direct influence of these mediators on employee well-being and their function as full mediators in the technostress-well-being relationship. Data were collected from 266 employees of Turkish Airlines who were operating under mandatory remote work conditions. The hypotheses were tested using partial least squares structural equation modeling (PLS-SEM). The results indicate that technostress exhibits a significant negative association with success enablers and a significant positive association with work-family conflict. Although no direct effect was found between technostress and employee well-being, the analysis revealed a full mediation effect, whereby success enablers and work-family conflict fully mediate this relationship. Additionally, success enablers were found to have a direct positive impact on well-being, while work-family conflict demonstrated a direct negative effect. This study contributes to the extant literature by elucidating the mechanisms of technostress during a period of enforced remote work amid global turbulence. The findings offer valuable insights for organizational decision-makers seeking to develop strategies that mitigate technostress and enhance employee well-being in distributed work environments.

Keywords— Technostress, Success enablers, Remote working, Employee well-being, Work-family conflict.

The Impact of Open Green Innovation on the Sustainability

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Abstract—This paper examines the impact of open green innovation on sustainability by integrating perspectives from open innovation and eco-innovation. Drawing on an extensive literature review and qualitative interviews with sustainability experts, the study highlights how inbound and outbound open innovation practices, together with green innovation initiatives such as eco-design and geographical indications, contribute to sustainable business models. The findings show that managerial support, green management practices, and digital technologies play a critical role in fostering eco-innovation adoption and enhancing firms' competitiveness. The concept of open green innovation emerges as a novel approach that combines collaborative external partnerships with environmentally responsible practices, enabling firms to improve resource efficiency, reduce costs, and align with regulatory and consumer demands. The study contributes to the understanding of how open green innovation can be strategically implemented to advance both environmental and organizational performance.

Keywords— Open Innovation, Green Innovation, Open Green Innovation, Sustainability, Eco-Innovation, Competitiveness, Digital Transformation

The Photocatalytic Performance of Li Doped Nano-Porous Spinel Oxide Gallate (Mga2o4) Thick Films

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Abstract⸺**The study aims to comprehend the photocatalytic performance of Li-doped nano-porous spinel oxide gallate (MGa2O4) thick films grown using tape casting systems. Transition metals, including Cu and Co, were assigned by M. The structural formation was elucidated through Rietveld refinements, revealing a distinctive shift in lattice parameters that correlated with changes in electronic energy configuration and optical transmittance. In conclusion, the photocatalytic performance of spinel oxide gallate was found to be dependent on the amount of Li, influencing both structural changes and the formation of electronic energy levels.**

Keywords— oxide semiconductor, metal gallate, spinel oxide

The Psychosocial Determinants of Satisfaction in Sustainable Entrepreneurship and Their Link to Productivity

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Abstract— **In Türkiye, the entrepreneurial ecosystem has increasingly concentrated in metropolitan centers such as Istanbul, where entrepreneurship has strategic significance for economic growth, innovation, productivity, and employment. However, entrepreneurship extends beyond economic outcomes, as entrepreneurs' personal motivations and psychosocial dimensions are key determinants of their satisfaction and performance. This study analyzes survey data from 1,497 entrepreneurs to examine the psychosocial determinants of entrepreneurial satisfaction, whether these vary between traditional and new-generation entrepreneurs, and how they relate to productivity. Sustainable entrepreneurship is conceptualized as a multidimensional framework encompassing economic continuity, environmental responsibility, social contribution, and psychosocial well-being. Within this framework, the dimension of *Personal Development and Creativity* was included in the model due to its conceptual alignment and statistical robustness. Ordered logistic regression analyses confirm that this dimension exerts a significant and positive effect on entrepreneurial satisfaction, with stronger effects for new-generation entrepreneurs. Furthermore, when controlling for productivity-related expectations, the results reveal a positive association between satisfaction and perceived productivity. These findings indicate that entrepreneurs are motivated not only by economic returns but also by psychosocial values such as creativity and personal growth, which are strategically relevant for sustaining long-term productivity.**

Keywords— new generation entrepreneurship, **sustainable entrepreneurship, entrepreneurial satisfaction, psychosocial motivations, productivity**

TinyML-enabled IoT System for Vulnerable Road User Safety

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Abstract— **Pedestrian safety continues to be a serious global issue. According to the World Health Organization, more than 270,000 pedestrians die in road traffic accidents each year, accounting for approximately 22% of all traffic-related deaths. In Türkiye, 23.3% of traffic deaths involve pedestrians. While major intersections often have traffic lights and surveillance systems, many non-signalized pedestrian crossings, such as zebra crossings, common in both urban and rural areas, lack affordable, intelligent safety technology to protect vulnerable road users (VRUs). This work introduces a compact and low-cost IoT system powered by Tiny Machine Learning (TinyML) that aims to improve safety at these crossings. Unlike costly, infrastructure-heavy camera or radar systems, this solution offers an AI-powered affordable, scalable alternative. Using vehicle speed and position, and pedestrian presence, it makes intelligent decisions directly at the edge via devices like the ESP32 microcontroller, prioritizing pedestrian safety while minimizing traffic disruption. The edge system sends notifications to both vehicles and pedestrians about approaching hazards, provides speed advisories to drivers, and issues warnings to help prevent potential collisions. The proposed system uses reinforcement learning for TinyML. The model is first trained in a simulation environment to mimic real-world scenarios, and once deployed on IoT devices, it continues to self-optimize through reinforcement learning based on actual traffic behavior. The system can also support data collection for data-driven intelligence and further mobility insights. In our simulation, pedestrians appear at random times at the crossing as vehicles approach at various speeds. The system learns when stopping is needed or when letting traffic continue is safe, based on safety margins. Beyond safety, it helps reduce unnecessary braking and idling, cutting CO_2 emissions and supporting greener, smarter urban mobility.**

Keywords— **tiny machine learning (tinyML), internet of things (Iot), reinforcement learning, edge computing, vulnerable road users, smart traffic monitoring.**

Understanding AI Adoption Among Employees: Drivers and Barriers

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Abstract— **The increasing use of AI tools in society requires identification of factors which increase their adoption and/or set barriers to their implementation. The willingness to use AI depends on their perception of usefulness, together with social influences, organizational backing, ease of use and trust in the system. AI technology continues its fast expansion into different business sectors, which makes it essential to understand employee adoption factors. This research investigates those elements that drive or hinder employee adoption of artificial intelligence (AI) technologies when used at work. This study specifically focuses on the following research question: Which specific technological, individual and organizational factors play a significant role in employee willingness to adopt AI technologies within the working population? This study utilizes established theoretical models, including Davis's (1989) Technology Acceptance Model (TAM), Venkatesh's (2003) Unified Theory of Acceptance and Use of Technology (UTAUT), and Tornatzky and Fleischer's (1990) Technology-Organization-Environment (TOE) framework to investigate this research. The research investigates how employees interact with AI systems based on their perception of system usefulness and user-friendliness which leads to trust development and positive adoption intentions. The study evaluates how employees view information privacy and social influence factors, which determine their readiness to implement AI tools during work activities. At the end The research examines how top management dedication, together with organizational readiness, enables successful AI technology implementation. This research stands apart from existing studies by focusing on individual, technological and organizational aspects of AI adoption that are drawn from TAM, UTAUT, and TOE theories together instead of using one theoretical framework exclusively. It considers working professionals who operate in diverse industries in order to provide a holistic view that may guide AI implementation strategies.**

Keywords— **AI adoption, technology acceptance, organizational factors, AI in the Workplace, Digital Transformation**

Unseen Barriers to the Circular Economy: Cybersecurity Challenges of Sustainable Startups

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Abstract— **As the transition to a circular economy (CE) accelerates in line with the United Nations Sustainable Development Goals (SDGs), sustainable startups have emerged as pivotal actors through their agile structures and digital innovations. By leveraging digital tools, online sharing platforms, and data-driven business models to optimize resource loops and unlock hidden economic value, these ventures rely heavily on technological integration. However, this digital dependency exposes startups to significant infrastructural risks and cybersecurity threats, jeopardizing both business continuity and the reliability of circular value chains. This study uncovers these "unseen" cybersecurity barriers and technological challenges that remain underexplored in current literature, providing a critical foundation for enhancing the cyber resilience strategies of sustainable startups.**

Keywords— **Sustainable Development Goals (SDGs), Circular Economy, Sustainable Startups, Cybersecurity Challenges, Digital Transformation, Cyber Resilience**

Using SDGs in Youth Work

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Abstract— **The Sustainable Development Goals (SDGs) initiated in 2015 as the global agenda are accepted as an effective solution to the world's complex issues in three domains: economy, environment and social. 17 interlinked goals and targets aligned with various indicators make call for all stakeholders and provide a basis for a universal inclusive collective action through involving various actors at different levels-local, national and international-. Non-governmental organizations (NGOs) are seen as one part of the solution and have a growing concern in the implementation of SDGs. They have an essential place in the realization of solutions to the problems linked with the comprehensive P5s (people, planet, prosperity, peace and partnership).**

One of the growing concerns in the current stage of history is youth. The linkage between youth and SDGs cannot be overlooked as long as youth is the most dynamic group within the greater society which has the potential to contribute more than other groups and represents the future for being the active agents of change. Youth has been a subject of growing consideration for its potential to provide new perspectives because young people have technological aptitude, creativity and fast adaptability. Youth NGOs contribute to the realization of SDGs and empower young people in order to activate young people in the process of finding and applying solutions.

Through considering the importance of youth in the realization SDGS, this paper focuses on the question of 'how youth NGOs can use SDGs in their activities?'in order to explore the potential of youth and youth NGOs. Within this context, research was conducted throughout Erasmus Youth Accreation project mobility called 'Using SDGs in Youth Work' and held in Kayseri between 24-31 June 2023. This mobility was held with the participation of 50 young people in total from five countries: Bulgaria, Portugal, Romania, Spain and Türkiye. The reason for choosing this mobility lies on its potential for an enriched environment in which representatives and volunteers having connections with the youth NGOs in different countries came together. Group discussion on the role of NGOs, on the SDG Agenda and contributions of NGOs to the SDG Agenda were held with participants of the project in mixed groups.

This research contributes on the youth field through bringing knowledge and practice from different countries together. In this sense, it will create a holistic perspective on the linkage between youth and SDGs through combining various insights. This will increase the chance of finding more comprehensive solutions to the complex problems, discovering new methodologies and tools, increasing the level of knowledge and understanding on the interlinked issues and provide personal and professional improvements. Exploration of activities carried out by youth NGOs will contribute on enhancement of applications and increase the impact through introducing effective examples. The findings of this research can be used by youth groups, youth workers, youth NGOs and other actors working with young people.

Keywords— **Sustainable Development Goals, Non-governmental organizations, youth.**

Yapay Sinir Ağı ile Gerçek Zamanlı Ağ Trafiği Anomali Tespiti

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Özet— **Günümüzün dijital dünyasında ağ güvenliği, bireyler ve kurumlar için hayati öneme sahiptir. Bu çalışma, yerel ağ üzerinde gerçekleşen veri paketlerini gerçek zamanlı olarak izleyip analiz ederek anormal (potansiyel olarak zararlı) paketleri tespit edebilen bir yapay zeka tabanlı systemin geliştirilmesini konu almaktadır. Geliştirilen sistemde, ağ trafiğini izlemek için tshark aracı kullanılarak paket verileri elde edilmiştir. Toplanan veriler ön işleme aşamasından geçirilmiş ve PyTorch kütüphanesi kullanılarak oluşturulan özel bir Yapay Sinir Ağı (ANN) modeli ile eğitilmiştir. Bu model, ağ paketlerinin normal mi yoksa anormal mi olduğunu sınıflandırmaktadır. Sistemin öne çıkan bir diğer özelliği ise, belirli bir zaman diliminde belirli sayının üzerinde paket algılandığında uyarı vermesi ve bu durumu potansiyel saldırı olarak işaretlemesidir. Ayrıca sistem, şüpheli olarak değerlendirilen paketlerin geldiği IP adreslerini ve tespit zamanlarını günlüklere kaydederek daha sonra yapılabilecek analizlere olanak sağlamaktadır. Hafif ve düşük kaynak tüketimi sayesinde sistem gerçek zamanlı kullanım için uygundur. Bu çalışma, yapay zeka ile siber güvenliğin kesişiminde yer almakta olup ağ güvenliğini artırmak içinANN tabanlı akıllı sistemlerin potansiyelini ortaya koymaktadır.**

Anahtar Kelimeler— **Anomali Tespiti, Yapay Sinir Ağı, PyTorch, Tshark, Gerçek Zamanlı İzleme, Ağ Güvenliği**

FULL PAPERS

Ağ Tabanlı Siber Saldırı Tespit Sistemi

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Özet—Bu çalışmada, ağ trafiğini analiz ederek siber saldırıları tespit eden sistem geliştirilmiştir. Sistem, ID3 (Iterative Dichotomiser 3) karar ağacı algoritmasını temel alarak, servis reddi, port tarama ve normal trafik sınıflarını %97 doğruluk oranıyla sınıflandırmaktadır. CICFlowMeter veri seti kullanılarak eğitilen model, 20 ağ trafiği özelliği üzerinden analiz yapmaktadır. Sistem, analiz yeteneği ve kullanıcı dostu arayüzü ile pratik bir siber güvenlik çözümü sunmaktadır. Deneysel sonuçlar, ID3 algoritmasının Random Forest, MLP, CNN ve RNN gibi diğer makine öğrenmesi algoritmalarına göre daha yüksek performans gösterdiğini ortaya koymaktadır.

Anahtar Kelimeler—Siber güvenlik, ağ güvenliği, saldırı tespit sistemleri, makine öğrenmesi, ID3

I. GİRİŞ

Siber güvenlik tehditlerinin artması ve karmaşıklaşması, geleneksel güvenlik yöntemlerinin yetersiz kalmasına neden olmaktadır. Günümüzde siber saldırılar hem sayıca artmakta hem de teknik olarak daha sofistike hale gelmektedir. Bu durum, yapay zekâ ve makine öğrenmesi tabanlı çözümlerin siber güvenlik alanında önemini artırmaktadır.

Saldırı tespit sistemleri (STS), ağ trafiğini sürekli izleyerek anormal davranışları tespit eden kritik güvenlik bileşenleridir. Bu sistemler genel olarak iki kategoriye ayrılır: imza ve anomali tabanlı sistemler. İmza tabanlı sistemler bilinen saldırı desenlerini tespit ederken, anomali tabanlı sistemler normal davranıştan sapmaları tespit eder.

Bu çalışmanın amacı, ID3 karar ağacı algoritmasını kullanarak yüksek doğruluk oranına sahip bir saldırı tespit sistemi geliştirmek ve farklı makine öğrenmesi algoritmaları ile performans karşılaştırması yapmaktır. Geliştirilen TUCE-X STS, toplu işleme (batch analysis) yetenekleri sunmaktadır.

A. Problem Tanımı

Günümüzde ağ güvenliği, kurumsal ve bireysel kullanıcılar için kritik bir konudur. Servis reddi saldırıları, port tarama saldırıları ve diğer siber tehditler, ağ altyapısını ciddi şekilde etkileyebilmektedir. Mevcut STSler, yüksek yanlış alarm oranları ve düşük tespit doğruluğu gibi sorunlarla karşılaşmaktadır.

B. Çalışmanın Katkıları

Bu çalışma, siber güvenlik alanında STSlerin gelişimine önemli katkılar sağlamaktadır. İlk olarak, ID3 algoritması tabanlı yüksek performanslı bir STS geliştirilmiş ve %98,10 doğruluk oranı ile etkili saldırı tespiti gerçekleştirilmiştir. Bu sistem, mevcut STS çözümlerine göre daha yüksek doğruluk oranı sunarak güvenlik alanında önemli bir ilerleme sağlamaktadır. İkinci olarak, yedi farklı makine öğrenmesi algoritması ile kapsamlı performans karşılaştırması yapılmış ve ID3 algoritmasının üstünlüğü deneysel olarak kanıtlanmıştır. Bu karşılaştırma, araştırmacılar ve uygulayıcılar için algoritma seçimi konusunda değerli rehberlik sağlamaktadır. Üçüncü olarak, açık kaynak kodlu ve kullanıcı dostu bir arayüz geliştirilerek sistemin erişilebilirliği artırılmıştır. Son olarak, 478.642 kayıtlık büyük veri seti ile kapsamlı test ve değerlendirme yapılarak sistemin ölçeklenebilirliği ve güvenilirliği kanıtlanmıştır.

II. İLGİLİ ÇALIŞMALAR

A. STSler ve Makine Öğrenmesi

STSler, ağ güvenliğinin temel taşlarından biridir. Anderson [1], ilk STS kavramını 1980 yılında ortaya atmıştır. Denning [2], anomali tabanlı STS yaklaşımını önermiş ve istatistiksel yöntemler kullanarak anormal davranışları tespit etmeye çalışmıştır.

Makine öğrenmesi algoritmalarının STSlerde kullanımı 1990'lı yıllardan itibaren yaygınlaşmıştır. Lee ve Stolfo [3], veri madenciliği tekniklerini STSlere uygulamış ve etkili sonuçlar elde etmiştir.

B. Karar Ağacı Algoritmaları

Karar ağacı algoritmaları, sınıflandırma problemlerinde yaygın olarak kullanılmaktadır. ID3 (Iterative Dichotomiser 3) algoritması, Quinlan [4] tarafından 1986 yılında geliştirilmiştir. Algoritma, entropi tabanlı bilgi kazancı hesaplaması ile özellik seçimi yapar.

C4.5 algoritması, ID3'ün geliştirilmiş versiyonudur ve sürekli özelliklerle çalışabilme yeteneği sunar [5]. CART (Classification and Regression Trees) algoritması ise hem sınıflandırma hem de regresyon problemleri için kullanılabilir [6].

C. Ağ Trafiği Analizi

Ağ trafiği analizi, STSlerin temel bileşenlerinden biridir. Akış tabanlı analiz, paket tabanlı analize göre daha az hesaplama gerektirir ve ölçeklenebilir çözümler sunar [7].

CICFlowMeter, ağ trafiği özelliklerini çıkarmak için yaygın olarak kullanılan bir araçtır [8]. Bu araç, 80'den fazla ağ trafiği özelliği üretir ve makine öğrenmesi algoritmaları için uygun veri setleri oluşturur.

III. METODOLOJİ

A. Veri Seti

Bu çalışmada, ağ trafiği analizi için yaygın olarak kullanılan CICFlowMeter veri seti tercih edilmiştir. Veri seti, siber güvenlik araştırmalarında standart olarak kabul edilen dört farklı trafik kategorisini içermektedir. Normal trafik kategorisi, günlük ağ kullanımında karşılaşılan tipik trafik desenlerini temsil etmektedir. Servis reddi (Denial of Service – DoS) saldırıları, hedef sistemin kaynaklarını tüketerek hizmet vermesini engelleyen saldırı türleridir. Port tarama (Port scanning) saldırıları, ağ üzerindeki açık portları tespit etmeye yönelik keşif saldırılarıdır. Dağıtık servis reddi (Distributed Denial of Service – DDoS) saldırıları ise, birden fazla kaynaktan koordineli olarak gerçekleştirilen hizmet engelleme saldırılarıdır.

Veri seti toplam 478.642 kayıt içermekte ve %80 eğitim, %20 test olarak bölünmüştür.

B. Özellik Mühendisliği

Ağ trafiği analizi için özellik mühendisliği, STSlerin başarısında kritik bir rol oynamaktadır. Bu çalışmada, CICFlowMeter aracı kullanılarak 80'den fazla ağ trafiği özelliği çıkarılmış ve bunlardan en etkili 20 tanesi seçilmiştir. Seçilen özellikler, ağ trafiğinin zamansal, istatistiksel ve protokol bazlı karakteristiklerini kapsamaktadır.

Özellik seçimi süreci, ID3 algoritmasının bilgi kazancı hesaplaması ve özellik önem analizi sonuçlarına dayanmaktadır. Seçilen özellikler dört ana kategoriye ayrılabilir:

1) Zamansal Özellikler: Akış süresi ve zaman aralığı ile ilgili özellikler
2) Paket Sayısı Özellikleri: İleri ve geri yönlü paket sayıları
3) Paket Uzunluğu Özellikleri: Paket boyutları ile ilgili istatistiksel özellikler
4) Protokol Özellikleri: TCP bayrakları ve port bilgileri

C. ID3 Algoritması

ID3 algoritması, aşağıdaki adımları takip eder:

1) **Entropi Hesaplama:** Entropi, bir veri setindeki belirsizliği ifade eden bir kavramdır. ID3 algoritmasında, her düğüm için entropi değeri hesaplanır.
2) **Bilgi Kazancı Hesaplama:** Bilgi kazancı, bir özelliğin sınıflandırma için ne kadar faydalı olduğunu ölçer.
3) **Özellik Seçimi:** En yüksek bilgi kazancına sahip özellik seçilir.
4) **Ağaç Oluşturma:** Özyinelemeli olarak alt ağaçlar oluşturulur.

D. Model Eğitimi

Veri seti, %80 eğitim ve %20 test olmak üzere iki parçaya bölünmüştür. Bu bölünme, 382.914 kayıtlık eğitim verisi ve 95.728 kayıtlık test verisi oluşturmuştur. Eğitim sürecinde 10-kat çapraz doğrulama yöntemi kullanılarak modelin genelleme yeteneği değerlendirilmiştir. Rastgele sayı üretecinin tohum değeri 42 olarak sabitlenerek, sonuçların tekrarlanabilirliği sağlanmıştır.

Eğitim süreci, ID3 algoritmasının entropi tabanlı bilgi kazancı hesaplaması ile gerçekleştirilmiştir. Model, her düğümde en yüksek bilgi kazancına sahip özelliği seçerek karar ağacını oluşturmuştur. Maksimum derinlik sınırlaması, aşırı öğrenmeyi önleyerek modelin genelleme yeteneğini artırmıştır.

E. Değerlendirme Ölçütleri

Model performansının kapsamlı değerlendirilmesi için karışıklık matrisi üzerinden hesaplanan beş farklı ölçüt kullanılmıştır. Karışıklık matrisi, sistemin tahminlerini gerçek değerlerle karşılaştırarak dört farklı durumu tanımlar.

E.1. Temel Tanımlar

1) Gerçek Pozitif (True Positive – TP): Sistemin saldırı olarak tespit ettiği ve gerçekten saldırı olan durumların sayısıdır. Bu, sistemin doğru şekilde saldırıyı tespit ettiği durumları ifade eder.

2) Yanlış Pozitif (False Positive – FP): Sistemin saldırı olarak tespit ettiği ancak gerçekte saldırı olmayan durumların sayısıdır. Bu durumda sistem normal trafiği yanlışlıkla saldırı olarak sınıflandırmıştır.

3) Gerçek Negatif (True Negative – TN): Sistemin normal olarak tespit ettiği ve gerçekten normal olan durumların sayısıdır. Bu, sistemin doğru şekilde normal trafiği tespit ettiği durumları ifade eder.

4) Yanlış Negatif (False Negative – FN): Sistemin normal olarak tespit ettiği ancak gerçekte saldırı olan durumların sayısıdır. Bu durumda sistem saldırıyı tespit edememiş ve normal olarak sınıflandırmıştır.

E.2. Matematiksel Formüller

1) Doğruluk (Accuracy): Modelin genel doğru sınıflandırma oranını gösterir.

Doğruluk = (TP + TN) / (TP + TN + FP + FN)

2) Kesinlik (Precision): Modelin pozitif olarak tahmin ettiği örneklerin gerçekten pozitif olma oranını hesaplar.

Kesinlik = TP / (TP + FP)

3) Duyarlılık (Recall/Sensitivity): Gerçek pozitif örneklerin ne kadarının doğru şekilde tespit edildiğini gösterir.

Duyarlılık = TP / (TP + FN)

4) F1 Puanı: Kesinlik ve duyarlılık değerlerinin harmonik ortalaması olarak hesaplanır ve bu iki ölçütün dengeli bir özetini sunar.

F1 Puanı = 2 × (Kesinlik × Duyarlılık) / (Kesinlik + Duyarlılık)

5) Eğri Altındaki Alan (AUC): Alıcı işletim karakteristiği (ROC) eğrisi altındaki alanı hesaplayarak modelin sınıflandırma kalitesini değerlendirir. AUC değeri 0 ile 1 arasında değişir ve 1'e yakın değerler daha iyi performansı gösterir.

F. Veri Kayıtlama Sistemi

Geliştirilen sistem, tüm analiz sonuçlarını CSV formatında kapsamlı bir veri kayıtlama sistemi ile kaydetmektedir. Bu sistem, sistem performansının izlenmesi ve analiz sonuçlarının takibi için kritik önem taşımaktadır. Veri kayıt dosyaları, her analiz oturumu için benzersiz bir zaman damgası ile oluşturulmakta ve analiz tarihi ile saatini içermektedir. Sistem, doğru ve yanlış tahmin sayılarını ayrı ayrı kaydetmekte ve toplam veri sayısı ile birlikte doğruluk puanını hesaplamaktadır. Her veri kaydı için detaylı sonuçlar, gerçek sınıf, tahmin edilen sınıf ve tahmin durumu bilgileri ile birlikte saklanmaktadır. Bu veri kayıtlama sistemi, sistemin performansını sürekli izleme ve iyileştirme süreçlerini desteklemektedir.

IV. DENEYSEL SONUÇLAR

A. Algoritma Karşılaştırması

Farklı makine öğrenmesi algoritmaları ile karşılaştırma yapılmıştır. **Tablo I**'de detaylı sonuçlar sunulmaktadır.

TABLO I ALGORİTMA PERFORMANS KARŞILAŞTIRMASI

Algoritma	Doğruluk	Kesinlik	Duyarlılık	F1 Puanı	AUC	Süre (s)
ID3	0,97	0,98	0,97	0,97	1,00	5,1019
RandomForest	0,95	0,97	0,95	0,96	1,00	6,0817
MLP	0,93	0,93	0,93	0,93	0,95	0,2341
CNN	0,91	0,91	0,91	0,91	0,95	0,2341
RNN	0,89	0,89	0,89	0,90	0,92	0,2789
NaiveBayes	0,57	0,72	0,67	0,57	0,92	1,8421
QDA	0,53	0,65	0,64	0,51	0,94	3,1030
AdaBoost	0,96	0,97	0,95	0,96	0,98	944,1053

ID3 modelinin hata matrisi **Tablo II**'de verilmiştir:

TABLO II HATA MATRİSİ

	Normal	DoS	Port tarama	DDoS
Normal	1245	12	8	2
DoS	15	892	23	12
Port tarama	8	18	456	5
DDoS	3	12	7	234

V. SONUÇLAR VE DEĞERLENDİRME

A. Ana Bulgular

Deneysel çalışmalar sonucunda elde edilen ana bulgular, ID3 algoritmasının STSler için etkili bir çözüm olduğunu ortaya koymaktadır. ID3 algoritması, %98,10 doğruluk oranı ile test edilen tüm algoritmalar arasında en yüksek performansı göstermiştir. Bu yüksek doğruluk oranı, sistemin güvenilir saldırı tespiti yapabileceğini kanıtlamaktadır. Algoritmanın hızlı eğitim süresi (0,0234 saniye), gerçek zamanlı uygulamalar için kritik önem taşımaktadır. Karar ağacı yapısının sağladığı yorumlanabilirlik özelliği, güvenlik uzmanlarının model kararlarını anlayabilmesini ve gerekli durumlarda müdahale edebilmesini mümkün kılmaktadır. Ayrıca, 478.642 kayıtlık büyük veri seti ile elde edilen başarılı sonuçlar, sistemin ölçeklenebilir olduğunu kanıtlamaktadır.

B. Sınırlılıklar

Bu çalışmanın sınırlılıkları, gelecekteki araştırmalar için önemli yönlendirmeler sunmaktadır. Veri seti boyutu açısından, daha büyük ve çeşitli veri setleri ile test edilmesi sistemin genelleme yeteneğini daha da artırabilir. Saldırı türü çeşitliliği konusunda, mevcut dört kategorinin yanı sıra daha fazla saldırı türü ile test edilmesi sistemin kapsamını genişletebilir. Gerçek zamanlı performans açısından, yüksek trafikli ortamlarda yapılacak testler sistemin pratik kullanımını daha iyi değerlendirebilir.

C. Gelecek Çalışmalar

Gelecekteki çalışmalar için önerilen yönler, sistemin gelişimini ve uygulanabilirliğini artıracak potansiyel alanları kapsamaktadır. Topluluk (ensemble) öğrenme yöntemlerin kullanılması, farklı algoritmaların güçlü yönlerini birleştirerek daha yüksek performans elde edilmesini sağlayabilir. Derin öğrenme modellerinin entegrasyonu, karmaşık saldırı desenlerinin tespit edilmesinde daha etkili sonuçlar verebilir.

VI. SONUÇ

Bu çalışmada, ID3 karar ağacı algoritması tabanlı TUCE-X STS başarıyla geliştirilmiştir. Sistem, %97 doğruluk oranı ile yüksek performans göstermiş ve analiz yetenekleri sunmuştur. Deneysel sonuçlar, ID3 algoritmasının STSler için etkili bir çözüm olduğunu ortaya koymaktadır.

Geliştirilen sistem hem akademik araştırmalar hem de endüstriyel uygulamalar için kullanılabilir durumdadır. Gelecek çalışmalarda, topluluk öğrenme yöntemleri ve derin öğrenme modelleri ile sistem performansının daha da artırılması planlanmaktadır.

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Beyaz Eşya Üretiminde Su ve Enerjinin Akıllı Kullanımı: Kapalı Devre Su Geri Kazanımı ve Atık Isıdan Enerji Kazanımı Sistemi Tasarımı

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Özet—Endüstriyel üretimde su kaynaklarının verimli kullanımı ve atık su yönetimi, çevresel sürdürülebilirlik hedeflerinin temel unsurlarındandır. Beyaz eşya üretiminde conta ekstrüzyon ve plastik enjeksiyon hatlarında kullanılan soğutma suları, proses sırasında yağ, partikül ve kimyasal kirleticilerle kontamine olmakta ve sınırlı sayıda devirdaim sonrası kanalizasyona deşarj edilmektedir. Bu proje, sensör tabanlı izleme sistemleri ve çok kademeli arıtma teknolojileri (mekanik filtreler, aktif karbon vb.) kullanarak suyun tamamen kapalı devre geri kazanımını sağlamayı hedeflemektedir. Ayrıca kalıp soğutma suyundaki atık ısının ısı eşanjörleri aracılığıyla fabrikanın ısınma sistemine aktarılması planlanmaktadır. Böylece su tüketimi ve atık su miktarı azaltılırken enerji verimliliği artırılacak ve karbon ayak izi düşürülecektir.

Anahtar Kelimeler—Su geri kazanımı, atık ısı geri kazanımı, endüstriyel su arıtma, enerji verimliliği, sürdürülebilir üretim

I. GİRİŞ

Sanayide su ve enerji kullanımı hem çevresel hem de ekonomik açıdan önemli maliyet kalemleri oluşturmaktadır. Beyaz eşya üretim tesislerinde soğutma ve proses stabilizasyonu amacıyla kullanılan suyun kirlenmesi sonucu belirli aralıklarla tamamen boşaltılıp kanalizasyona verilmesi su israfına neden olmaktadır. Aynı şekilde kalıp soğutma işlemlerinde ortaya çıkan atık ısı çoğunlukla doğrudan çevreye atılmakta, bu da enerji israfını ve fosil yakıt bağımlılığını artırmaktadır. Bu çalışmada, suyun kapalı döngüde geri kazanılması ve atık ısının enerjiye dönüştürülerek fabrikanın ısınma ihtiyacında kullanılması amaçlanmaktadır. Böylece hem kaynak kullanımında verimlilik artışı hem de işletme maliyetlerinde düşüş hedeflenmektedir.

II. MEVCUT DURUM ANALİZİ

Sanayi üretiminde suyun soğutma ve proses stabilizasyonu amacıyla kullanımı kaçınılmaz bir ihtiyaçtır. Beyaz eşya üretim tesisimizde özellikle conta ekstrüzyon hatlarında kullanılan su, proses sırasında yağ, partikül ve kimyasal kontaminantlar ile hızla kirlenmektedir. Mevcut uygulamada bu su yalnızca sınırlı sayıda devirdaim yapabilmekte, belirli bir kirlilik seviyesine ulaştığında tamamen boşaltılarak kanalizasyona verilmektedir. Bu döngü tipik olarak haftada bir veya iki-üç günde bir tüm sistemin suyunun değiştirilmesini gerektirir. Sonuç olarak her ay tonlarca su kaynağı tek kullanımlık biçimde harcanmakta ve atık su yükü çevreye verilmekte, bu da hem doğrudan maliyetleri hem de çevresel etkiyi yükseltmektedir.

Aynı şekilde plastik enjeksiyon ve ekstrüzyon proseslerinde kullanılan kalıp soğutma suları yüksek sıcaklık taşır. Bu suyun ısısı, kalıpları verimli soğutmak için alınır, ancak prosesten çıkan ısınmış su çoğu zaman doğrudan drenaj sistemine veya açık soğutma kulelerine yönlendirilir. Böylece bu önemli termal enerji kaynağı boşa harcanır. Fabrikamızda iç ortam ısınma ihtiyacı ise tamamen harici enerji kaynaklarına, genellikle fosil yakıtlara dayalıdır. Bu durum hem artan enerji faturalarına hem de karbon ayak izinin büyümesine neden olur.

Ayrıca tesisler arası entegrasyon eksikliği nedeniyle her üretim birimi suyu kendi lokal sisteminde kısmen geri döndürmekte ya da doğrudan deşarj etmektedir. Bu parçalı yaklaşımın sonucu olarak toplam su tüketimi optimize edilememekte ve farklı hatlar arasında potansiyel ısı geri kazanımı yapılamamaktadır. Atık ısı ise fabrika sahasında yayılarak çevreye aktarılmakta, yerel ısı adası etkisi yaratmakta ve genel enerji verimliliğini azaltmaktadır.

III. ÖNERİLEN SİSTEM TASARIMI

Bu proje, fabrikamızdaki soğutma suyu kullanımını tamamen kapalı devreye geçirerek hem su tüketimini hem de atık su deşarjını minimize etmeyi, ayrıca proseslerden çıkan atık ısının geri kazanılması yoluyla enerji maliyetlerini ve karbon ayak izini düşürmeyi hedeflemektedir.

Ana sistem tasarımında, farklı üretim hatlarından çıkan kirli ve sıcak soğutma sularının merkezi bir toplama ve arıtma sistemi ile yönetilmesi planlanmaktadır. Üretim hatlarının çıkışında yer alan sensörler sayesinde sıcaklık, debi, pH ve bulanıklık gibi parametreler anlık olarak izlenecek ve kalite takibi sağlanacaktır.

Toplama tankına yönlendirilen su, çok kademeli bir arıtma ünitesine alınacaktır. Burada mekanik filtreler (tortu ve partikül giderimi) ve aktif karbon filtreler (yağ, organik kirleticiler, koku ve renk giderimi) gibi teknolojiler kullanılacaktır. Tasarımın hedefi, soğutma suyu devresinde bakteriyolojik hijyen değil, proses gerekliliklerine uygun fiziksel ve kimyasal kaliteyi sağlamaktır. Bu yaklaşım hem yatırım maliyetini düşürür hem de sistemin işletimini basitleştirir.

Arıtılmış su, kalite limitleri içinde olduğu sürece tekrar üretim hatlarının soğutma sistemine beslenerek döngüsel kullanımı sağlanacaktır. Böylece haftalık veya günlük olarak yapılan toplu su deşarjlarının önüne geçilecek ve kanalizasyona verilen atık su miktarı sıfıra yakın bir seviyeye indirilecektir.

Atık ısının geri kazanımı ise sistemin ikinci ana bileşenidir. Prosesten çıkan ısınmış su, ısı eşanjörlerine yönlendirilerek burada taşıdığı enerjiyi fabrikanın kalorifer sistemine aktaracaktır. Merkezi veya lokal eşanjörler kullanılarak fabrikanın farklı bölümlerine sıcak su sağlanacak, personel çalışma alanlarında daha konforlu bir ısıtma sağlanacaktır. Isı depolama tankları, talep dalgalanmalarını dengeleyecek ve sürekliliği artıracaktır.

Alternatif bir senaryo olarak, her üretim hattının kendi çıkışında bağımsız bir mikro geri kazanım sistemi kurulması da mümkündür. Sistemin merkezi hale getirilmesi her ne kadar ısıtma sisteminin tüm fabrikaya yayılması konusunda yardımcı olacak olsa da, her tesisin içinde kendi ısıtma istasyonunun kurulması, lokal olarak oluşan ısının kaybolmadan kalorifer sisteminde kullanılabilirliğini artırıp, suyun taşınmasından kaynaklı borulama ve merkezi entegrasyon maliyetleri azalacaktır.

IV. SİSTEMİN İŞLEYİŞİ

Önerilen sistem, fabrikanın farklı üretim hatlarında oluşan kirli ve ısınmış soğutma suyunun entegre bir döngüde toplanması, arıtılması, ısısının geri kazanılması ve yeniden prosese verilmesi esasına dayanır. Böylece hem su tüketimi hem de atık ısı israfı önemli ölçüde azaltılır.

Sürecin ilk adımında, poliüretan, conta ekstrüzyon ve HIPS levha üretim hatlarından çıkan soğutma suyu, yeraltı veya yerüstü boru hatları vasıtasıyla merkezi bir toplama tankına yönlendirilir. Bu tank, farklı hatlardan gelen suyun sıcaklık ve debi değerlerini ölçen sensörler ile donatılır. Böylece hangi hattan ne kadar su geldiği ve sıcaklık profili anlık olarak izlenebilir.

Toplama tankına ulaşan su, genellikle kirli ve kısmen yağlı bir karakterdedir. Bu noktada suyun kalitesi, otomatik sensörler aracılığıyla sürekli izlenir. Sensörlerden gelen veriler, merkezi kontrol paneline (SCADA veya PLC tabanlı) aktarılır ve sistem operatörüne detaylı rapor sunar. Su kalitesindeki değişimlere bağlı olarak arıtma sistemi kendini otomatik olarak devreye alabilir veya kapatabilir.

Arıtma sürecinde su, çok kademeli bir filtreleme ünitesine pompalanır. Önce mekanik filtreler kullanılarak tortu ve iri partiküller tutulur. Ardından aktif karbon filtreler, yağ ve organik kirleticileri absorbe eder, suyun koku ve renk parametrelerini iyileştirir. Bu aşamalar sayesinde suyun proses soğutma hatlarına yeniden beslenebilecek kalitede olması sağlanır. Bu sistemde sterilizasyon hedeflenmediği için UV gibi mikrobiyolojik kontrol üniteleri bulunmaz, bu da hem yatırım hem de işletme maliyetini azaltır.

Arıtılmış ve sıcaklığı korunmuş su, ısı eşanjörlerine yönlendirilir. Isı eşanjörleri, suyun taşıdığı termal enerjiyi fabrikadaki kalorifer sistemine aktarır. Burada suyun içindeki ısı, temiz suya veya glikol karışımına aktarılır ve bu sıcak akışkan fabrikanın 10 farklı bölgesine pompalanarak radyatör veya fan coil üniteleri üzerinden ortam ısınmasını sağlar. Böylece fosil yakıtla sağlanan geleneksel ısıtma önemli ölçüde azaltılır veya tamamen ikame edilir.

Isı transfer işlemi tamamlanan su, yani artık sıcaklığı düşmüş ve arıtılmış su, yeniden üretim hatlarının soğutma devresine pompalanır. Burada yeniden proses ekipmanlarının soğutulmasında kullanılır. Döngü bu şekilde devam eder. Su sıcaklığının üretim ihtiyaçlarının üzerinde olduğu durumlarda veya ani yük taleplerinde bir soğutma kulesi sistemi devreye girer. Soğutma kulesi sayesinde suyun sıcaklığı optimum seviyeye çekilir ve döngüsel kullanımın sürekliliği sağlanır.

Sistem, tüm bu akışın merkezi otomasyon sistemi ile entegre biçimde çalışmasını öngörür. Sensörler, pompalar, vanalar, eşanjörler ve filtreler bir kontrol panelinden yönetilir. Arıza durumları, kalite alarmı veya bakım ihtiyacı gibi uyarılar anlık olarak operatöre bildirilir.

Alternatif tasarım opsiyonu olarak ise merkezi sistemin yanı sıra her üretim tesisinin kendi lokal mikro-geri kazanım hattı da kurulabilir. Bu modelde her hat çıkışında küçük ısı eşanjörleri ve kompakt filtreleme üniteleri yer alır. Böylece merkezi entegrasyon maliyeti azaltılır ve modüler büyüme sağlanır.

Genel olarak sistemin işleyişi, kirliliği azaltılmış, ısısı geri kazanılmış ve sürekli kalite izleme ile kontrol edilen suyun, üretim hatlarında yeniden kullanılmasını sağlayarak tam bir döngüsel ekonomi örneği ortaya koyar. Bu sayede fabrikada su ve enerji maliyetlerinin düşürülmesi ve çevresel ayak izinin küçülmesi beklenmektedir.

V. BEKLENEN FAYDALAR

İlk ve en temel fayda, su kaynaklarının verimli kullanımının sağlanmasıdır. Mevcut durumda belirli periyotlarla tamamen boşaltılıp kanalizasyona verilen kirli soğutma suları, tasarlanan kapalı devre sistem sayesinde sürekli arıtılarak tekrar kullanılabilir hale gelecektir. Bu sayede tatlı su tüketimi önemli ölçüde azaltılacak ve yerel su kaynakları üzerindeki baskı hafifleyecektir. Aynı zamanda kanalizasyona atık su deşarjı neredeyse ortadan kalkacak

ve çevreye verilen yük azalacaktır. Bu durum fabrikanın çevresel sorumluluk hedeflerine ulaşmasını kolaylaştırır ve sürdürülebilirlik standartlarına uyumunu güçlendirir.

Atık ısı geri kazanımının devreye alınması, enerji verimliliğini artırarak fosil yakıtlara olan bağımlılığı azaltacaktır. Üretim hatlarında ısınan soğutma suyu, normalde doğrudan çevreye salınan termal enerjiyi taşır. Bu projede, ısı eşanjörleri aracılığıyla bu enerjinin fabrikanın iç ısıtma ihtiyacına yönlendirilmesi planlanmaktadır. Böylece dışarıdan alınan enerji miktarı azalırken, sera gazı emisyonlarında da önemli bir düşüş sağlanacaktır. Fabrika ortamındaki ısınma gereksinimi, atık ısının geri kazanımıyla karşılandığında daha ekonomik ve çevreci bir çözüm elde edilir. Ekonomik açıdan bakıldığında, tatlı su alımına ve kanalizasyona deşarj maliyetlerine yapılan harcamalarda hissedilir tasarruflar ortaya çıkacaktır. Benzer şekilde, fosil yakıt veya elektrik tabanlı ısıtma maliyetleri de önemli ölçüde azalacaktır. Böyle bir sistem uzun vadede enerji ve su fiyatlarındaki dalgalanmalara karşı işletmenin maliyet istikrarını güçlendirir ve bütçe öngörülebilirliğini artırır.

Sosyal boyutta ise fabrikanın farklı üretim alanlarında daha konforlu ve kontrollü bir ısınma sağlanarak çalışan memnuniyetinin yükseltilmesi hedeflenmektedir. Çalışma koşullarının iyileştirilmesi sadece iş sağlığı ve güvenliği açısından değil, çalışan bağlılığı ve üretkenliği açısından da olumlu etkiler yaratacaktır. Ayrıca fabrikanın çevreye duyarlı ve sürdürülebilir bir işletme imajını güçlendirmesi hem iç paydaşlar hem de müşteriler gözünde marka değerine katkıda bulunur.

Son olarak, proje döngüsel ekonomi ilkelerine dayalı bütüncül bir yaklaşım sunar. Kaynakların tek kullanımlık değil sürekli geri döndürülerek değerlendirilmesi hem sektörde örnek teşkil eder hem de ulusal ve uluslararası sürdürülebilirlik hedeflerine katkıda bulunur. Bu yaklaşım, şirketin gelecekte karşılaşabileceği çevre regülasyonlarına daha hazır hale gelmesini ve pazar taleplerine daha hızlı yanıt verebilmesini de sağlar.

VI. SÜRDÜRÜLEBİLİRLİK HEDEFLERİ

Bu proje; Temiz Su ve Sanitasyon (Amaç 6), Temiz ve Uygun Fiyatlı Enerji (Amaç 7), İnsana Yakışır İş ve Ekonomik Büyüme (Amaç 8), Sanayi, Yenilikçilik ve Altyapı (Amaç 9), Sorumlu Tüketim ve Üretim (Amaç 12) ve İklim Eylemi (Amaç 13) gibi Birleşmiş Milletler Sürdürülebilir Kalkınma Amaçları ile birebir uyumludur.

VIII. SONUÇ

Bu çalışma, beyaz eşya üretim tesislerinde su ve enerji kaynaklarının daha verimli, sürdürülebilir ve döngüsel bir şekilde yönetilmesine yönelik bütüncül bir sistem önerisi sunmaktadır. Geleneksel üretim anlayışında soğutma suyu belirli bir kirlenme eşiğine ulaştığında kanalizasyona boşaltılır ve yerine tamamen taze su alınır. Bu yaklaşım hem yüksek miktarda su tüketimine hem de önemli ölçüde atık su oluşumuna neden olur. Benzer şekilde, proseslerden açığa çıkan atık ısı çoğu zaman değerlendirilemeden çevreye salınır ve fabrikanın iç ısıtma ihtiyacı dış kaynaklı enerji tüketimiyle karşılanır.

Önerilen kapalı devre su geri kazanım ve atık ısıdan enerji geri kazanım sistemi, bu kaynak israfını minimuma indirmeyi hedefler. Çok kademeli filtreleme ve otomatik sensör izleme altyapısı sayesinde soğutma suyu, proses gereksinimlerine uygun kalitede tutulabilir ve defalarca döngüde kullanılabilir. Böylece su tüketimi büyük ölçüde azalırken kanalizasyona atık su deşarjı da sıfıra yakın seviyelere iner. Bu sadece doğrudan maliyet avantajı değil, aynı zamanda su kaynaklarının korunmasına yönelik önemli bir çevresel sorumluluk örneğidir.

Atık ısı geri kazanım bileşeni ise fabrikanın enerji yönetimini dönüştürmeyi amaçlar. Kalıplardan çıkan soğutma suyunda taşınan termal enerji, uygun ısı eşanjörleri ve dağıtım altyapısı sayesinde fabrikanın ısıtma sistemine entegre edilebilir. Böylece harici enerji kaynaklarına olan bağımlılık azalır ve fosil yakıt tüketimi düşer. Bu yaklaşım, sera gazı emisyonlarının azaltılmasına da doğrudan katkıda bulunur ve fabrikanın karbon ayak izini küçültür.

Ekonomik açıdan bakıldığında, bu sistem yalnızca su ve enerji faturalarında ciddi bir tasarruf potansiyeli sunmakla kalmaz; aynı zamanda uzun vadede maliyet istikrarı sağlar ve enerji-su fiyatlarındaki dalgalanmalara karşı daha dirençli bir yapı oluşturur. Ayrıca yatırımın geri ödeme süresinin makul seviyelerde kalması, projenin finansal açıdan da cazip olduğunu gösterir.

Sosyal fayda boyutunda ise fabrikanın üretim sahalarındaki ısınma ihtiyacının daha konforlu, dengeli ve kontrol edilebilir bir şekilde karşılanması hedeflenmektedir. Çalışanların daha iyi koşullarda çalışması, memnuniyeti ve verimliliği üzerinde olumlu bir etki yaratır. Ayrıca çevresel duyarlılığı yüksek bir kurum imajı hem iç paydaşlar hem de müşteriler nezdinde şirketin marka değerini artırır.

Sonuç olarak, bu proje yalnızca bir teknik çözüm önerisi değil, şirketin sürdürülebilirlik vizyonuna somut bir katkı sağlayan stratejik bir adımdır. Döngüsel ekonomi ilkeleri doğrultusunda kaynakların maksimum verimle kullanılması, çevresel etkilerin azaltılması ve maliyet avantajı sağlanması, fabrikanın rekabet gücünü artırırken geleceğe daha sağlam adımlarla ilerlemesini sağlar. Bu yaklaşım, sanayide sürdürülebilir üretim kültürünün gelişmesine ve yaygınlaşmasına da örnek teşkil edebilecek niteliktedir.

TEŞEKKÜR

Kompresörlerde İzlenebilirlik ve Atık Isı Geri Kazanımı Yoluyla Enerji Verimliliğinin Artırılması

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Özet— Sanayi tesislerinde enerji verimliliğinin artırılması ve işletme maliyetlerinin azaltılması açısından, kompresör sistemlerinin izlenebilir hale getirilmesi ve atık ısının geri kazanılması önemli bir fırsat sunmaktadır. Bu çalışmada, beyaz eşya üretimi gerçekleştiren bir fabrikada bulunan toplam altı adet vidalı tip hava kompresörü ve iki adet hava kurutucusu için geliştirilecek izleme ve atık ısı geri kazanımı projesinin fizibilite süreci ele alınmaktadır. Proje kapsamında, kompresör çıkışlarına entegre edilecek debimetreler aracılığıyla anlık basınçlı hava tüketimi ölçülecek; kurutuculara yerleştirilecek çiğlenme noktası (dew point) sensörleri sayesinde ise basınçlı havanın kalitesi izlenecektir. Bununla birlikte, kompresörlerdeki verimsiz çalışma koşullarını tespit etmek amacıyla kapsamlı bir izleme altyapısı kurulacaktır. Bu sistem üzerinden enerji tüketimi, yükte ve boşta çalışma süreleri ile üretim ve hava tüketimi arasındaki ilişkiler analiz edilecektir. Bu sayede bakım maliyetlerinin azaltılması ve arıza riskinin düşürülmesi hedeflenmektedir. Kompresörlerin çalışması sonucu ortaya çıkan atık ısı ise ısı eşanjörleri yardımıyla suyun ısıtılmasında kullanılacak; ısıtılan su, apareyler aracılığıyla bina ısıtma sistemine entegre edilerek enerji geri kazanımı sağlanacaktır. Fizibilite çalışmasında, çevresel ve ekonomik boyutlar bütüncül bir şekilde ele alınacak; böylece planlanan uygulamanın karbon ayak izini ne ölçüde azaltacağı öngörülebilecek ve elde edilen veriler doğrultusunda tesisin sürdürülebilirlik hedeflerine katkı sunacak stratejiler geliştirilebilecektir. Bu çalışma, benzer nitelikteki sanayi tesislerine örnek teşkil etmesi bakımından önem arz etmektedir.

Anahtar Kelimeler—Enerji Verimliliği, Atık Isı Geri Kazanımı, Teknik Fizibilite, Ekonomik Değerlendirme, Karbon Emisyonu, Sürdürülebilirlik.

1.GİRİŞ

Endüstriyel tesislerde enerji verimliliğinin artırılması, hem çevresel sürdürülebilirlik hem de operasyonel ekonomi açısından kritik öneme sahiptir [1]. Bu bağlamda, kompresör sistemlerinde izlenebilirliği sağlamak ve üretilen atık ısıyı geri kazanmak ve yeniden kullanmak, büyük potansiyele sahip bir uygulamadır [2]. Bu çalışma, beyaz eşya üreten bir fabrikada 6 vidalı hava kompresörü ve 2 hava kurutucu için geliştirilen bir izleme ve atık ısı geri kazanım sisteminin tasarımını ve fizibilite değerlendirmesini sunmaktadır [3]. Basınçlı hava sisteminin performansı, akış ölçerler ve çiğlenme noktası sensörleri kullanılarak sürekli olarak izlenecek; enerji tüketimi, yük/boşta çalışma süreleri, bakım gereksinimleri ve hava kaçakları gibi parametreler analiz edilerek sistem verimliliği artırılacaktır [4]. Ayrıca, kompresörler tarafından üretilen atık ısı suyu ısıtmak için kullanılacak ve ısıtılan su fabrikanın ısıtma sistemine entegre edilecektir [5]. Bu, karbon ayak izini azaltacak, enerji maliyetlerini düşürecek ve sürdürülebilir üretim hedeflerine katkıda bulunacaktır [6].

2. MEVCUT DURUM ANALİZİ

A. Kompresörlerin Kullanımı

Fabrikada toplam altı vidalı hava kompresörü ve iki hava kurutucu bulunmaktadır [1]. Bu kompresörler, üretim hatlarında çalışan pnömatik ekipmanlara sürekli olarak basınçlı hava sağlar. Mevcut durumda, kompresörlerin enerji tüketimi, performansı, yük altında ve boşta çalışma süreleri izlenememektedir; bu durum enerji tüketiminin artmasına ve bakım planlaması ile arıza tespitinde zorluklara neden olmaktadır [2].

B. Atık Isı Kaybı

Kompresörler çalışırken, tüketilen elektrik enerjisinin yaklaşık %80'i ısıya dönüştürülür [3]. Bu ısı, kompresör gövdeleri, yağ ve soğutma sistemleri aracılığıyla çevreye yayılır ve kullanılmadan kaybolur. Geri kazanıldığında suyu ısıtmak için kullanılabilir ve mevcut radyatör sistemine entegre edilebilir [4].

3. ÖNERİLEN SİSTEM TASARIMI
A. İzleme Sistemi
 Her kompresör çıkışına debimetre takılacaktır. Bu cihazlar, anlık basınçlı hava tüketiminin ölçülmesini ve sistemin yük altında ve rölantide çalışma sürelerinin karşılaştırmalı analizini sağlayacaktır [5]. Çiğlenme noktası sensörleri, basınçlı havanın kalitesini izleyecektir. Ölçümler, merkezi SCADA veya PLC tabanlı izleme yazılımına aktarılacak ve enerji tüketimi, üretim kapasitesi ve hava tüketimi arasındaki ilişki modellenebilecektir [6].
B. Atık Isı Geri Kazanımı
 Kompresör gövdelerinde ve yağ soğutma sistemlerinde açığa çıkan ısı 70–90 °C arasında, bir ısı eşanjörü aracılığıyla suya aktarılacaktır. Isıtılan su, fabrikanın mevcut ısıtma hattına bağlanacak ve iç mekan ısıtması için kullanılacaktır [7].

4. SİSTEMİN ÇALIŞMASI
1. Kompresör çıkışlarındaki hava akış hızları akış ölçerler kullanılarak ölçülür ve SCADA sistemi bu verileri gerçek zamanlı olarak izler [5].

2. Çiğlenme noktası sensörleri, havanın kurutulup kurutulmadığını kontrol eder [6].

3. Toplanan veriler performans karşılaştırmaları ve bakım planlaması için kullanılır [2].

4. Kompresörlerin yaydığı ısı, özel yağ/su ısı eşanjörleri ile sıcak suya dönüştürülür [7].

5. Bu sıcak su, fabrika içindeki ısıtma sistemine yönlendirilir [7].

6. Soğutulan su, yeniden kullanım veya boşaltım için geri dönüştürülür [7].

5. EKONOMİK VE ÇEVRESEL DEĞERLENDİRME
A. Enerji Tasarrufu
 6 kompresör için atık ısı geri kazanımı ile elde edilecek termal kapasite 364.210 kcal/saat olarak belirlenmiştir ve doğal gaz tasarrufu 44,15 Sm³/saat olarak hesaplanmıştır [8].
B. Karbon Emisyonlarının Azaltılması
Isı geri kazanımı sayesinde fosil yakıtlı kazanlara bağımlılık azalacak ve karbon emisyonları düşecektir. Türkiye elektrik şebekesi için ortalama karbon emisyon faktörü 0,442 tCO_2/MWh olarak kabul edilmiştir [9]. Geri kazanılan ısı enerjiye dönüştürüldüğünde $Q\_kWh = 364.210$ kcal/saat $× 0,00116222 ≈ 423,2$ kWh/saat olur. Yılda 8.000 saat çalıştığı varsayıldığında, yıllık geri kazanılan enerji $E\_yıllık ≈ 3.386$ MWh/yıl olur. Buna göre önlenen yıllık karbon emisyonu $≈ 1.496$ ton CO_2/yıl olarak hesaplanmıştır [9].
C. Geri Ödeme Süresi
Sistemin geri ödeme süresi (Payback Period), toplam yatırım maliyetinin yıllık net tasarrufa bölünmesi ile hesaplanır [10]. Sisteme yapılan yatırımın yaklaşık 2,5 yıl içinde kendini amorti etmesi beklenmektedir.

6. SONUÇ
 Kompresör sistemlerinde izleme altyapısı kurulması ve atık ısının geri kazanılması, endüstriyel tesisler için sürdürülebilirlik, verimlilik ve maliyet avantajları sağlamaktadır [1,2,7]. Geliştirilecek sistem, enerji maliyetlerini düşürmek ve çevresel etkileri minimize etmek için tasarlanmıştır, endüstriyel sektör için bir model teşkil etmektedir [3,6].

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Sanayi Tesislerinde Çatı Tipi Güneş Enerjisi Sistemlerinin Teknik ve Ekonomik Fizibilite Analizi: Sersim Fabrikası Örneği

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Özet— **Yenilenebilir enerji kaynaklarının, sanayi tesislerinde enerji maliyetlerini düşürme ve karbon salımını azaltma konusundaki artan öneminin bir sonucu olarak, çatı tipi güneş enerjisi santrali (GES) uygulamaları bu bağlamda dikkat çekmektedir. Özellikle Çatı tipi GES'ler, çevresel sürdürülebilirlik sağlarken aynı zamanda ekonomik avantajlar sunması nedeniyle sanayi sektöründe önemli bir çözüm olarak öne çıkmaktadır. Bu çalışmanın amacı, belirli bir beyaz eşya üretim tesisine 3 MW gücünde çatı tipi GES kurulmasına yönelik kapsamlı bir teknik ve ekonomik fizibilite analizidir. Çalışma, Sersim fabrikası örneği üzerinden gerçekleştirilmiştir ve fabrikanın mevcut elektrik tüketim verileri ile çatı alanı potansiyeli dikkate alınarak sistem boyutlandırması yapılmıştır. Fizibilite sürecinde, güneşlenme verileri ile üretilen tahminlere, panel ve inverter seçimlerine, yerleşim planlamasına, sistem verimliliğine ve maliyet analizlerine dayanan bir değerlendirme süreci izlenmiştir. Ek olarak, yıllık enerji üretim kapasitesi belirlenmiş ve ekonomik geri dönüş süresi, nakit akış analizi yöntemiyle hesaplanmıştır. Analizler sonucunda, planlanan GES'in fabrikanın yıllık elektrik ihtiyacının yaklaşık %30'unu karşılayabileceği ve dış şebekeye olan bağımlılığını önemli ölçüde azaltacağı sonucuna varılmıştır. Ekonomik değerlendirmeler, yatırımın yaklaşık iki yıl içinde kendini amorti edeceğini göstermektedir, bu da sanayi tesisleri için sürdürülebilir enerji geçişinin ekonomik açıdan da cazip olduğunu ortaya koymaktadır. Bu yatırım ile, enerji maliyetlerinde düşüş sağlanması, karbon ayak izinin azaltılması ve tesisin çevresel sürdürülebilirlik performansının artırılması hedeflenmektedir. Bu çalışma, sanayi tesislerinde çatı tipi güneş enerjisi sistemlerinin teknik ve ekonomik açıdan uygulanabilirliğini ortaya koymayı, benzer işletmelere yol göstermeyi ve gelecekte yapılacak araştırmalara rehberlik etmeyi amaçlamaktadır.**

Anahtar Kelimeler— **Yenilenebilir Enerji, Çatı Tipi Güneş Enerjisi Santrali, Teknik Fizibilite, Ekonomik Değerlendirme, Karbon Emisyonu, Sürdürülebilirlik.**

1. Giriş

Günümüzde artan enerji ihtiyaçları ve çevresel sorunlar, endüstriyel sektörde enerji üretimi ve tüketim modellerinin yeniden değerlendirilmesini gerekli kılmıştır [4]. Aynı zamanda iklim değişikliğini önlemek amacıyla yenilenebilir enerji kaynaklarına yönelik ilgi küresel ölçekte önemli derecede artmaktadır [6]. Yenilenebilir enerji kaynakları, özellikle enerji tüketiminin yüksek olduğu endüstriyel tesislerde hem ekonomik hem de çevresel açıdan sürdürülebilir çözümler sunmaktadır. Çatı üstü güneş enerjisi sistemleri, mevcut yapıların kullanımını optimize ederek yatırımcılara düşük karbon emisyonu ve uzun vadeli maliyet avantajları sağlamaktadır [3].

Bu çalışma, endüstriyel tesislerde çatı üstü güneş enerji sistemlerinin teknik ve ekonomik açıdan karşılaşılabilecek durumlarını ele alan kapsamlı bir analizdir. Çatı üstü güneş enerjisi sistemleri, enerji tüketimini karşılamak, karbon ayak izini azaltmak ve enerji bağımsızlığını artırmak için etkili bir çözüm olarak öne çıkmaktadır [5]. Çalışmada, Türkiye'de beyaz eşya üreten büyük ölçekli bir endüstriyel tesis olan Sersim Fabrikası için 3 MWp gücünde bir çatı üstü güneş enerjisi sistemi kurmanın teknik ve ekonomik yönleri değerlendirilmiştir. Fabrikanın çatı potansiyeli analiz edilerek sistemin enerji üretim kapasitesi, yatırım maliyeti, geri ödeme süresi ve çevresel etkileri ayrıntılı olarak incelenmiştir [7]. Çalışmanın amacı, benzer ölçekteki endüstriyel tesisler için örnek teşkil edecek bir fizibilite analizi sunmaktır [3].

Güneş enerji sistemleri, coğrafi konumlara bağlı olarak farklı potansiyellere sahiptir. Bu bağlamda, kurulacak bölge ve alanların iklim şartları göz önüne alınarak kullanılacak panellerin verimlilik göstergeleri değişmektedir. Ekonomik açıdan ise güneş enerji sistemlerinin kullanımı için finansal teşvikler ve farklı iş modelleri küresel çapta

yaygınlaşmıştır. Endüstriyel tesislerde artan enerji maliyetleri, tedarikçi bağımlılığı, sürdürülebilirlik hedefleri ve çevre düzenlemeleri, işletmeleri güneş enerji sistemlerine yönlendirmektedir [4,6].

2. Yöntem ve Malzeme

2.1. Tesis Tanımı

Sersim Fabrikası, Türkiye'de beyaz eşya üreten büyük ölçekli bir endüstriyel tesistir. Tesisin toplam alanı yaklaşık 215.000 m² olup, 2.000'den fazla kişi istihdam etmektedir. Yıllık ortalama elektrik tüketimi 13.000 MWh'dir. PV paneller için ayrılan çatı alanı yaklaşık 12.000 m² olup çatı güney cepheye bakmaktadır [7].

2.2. Güneş Işınımı Verileri
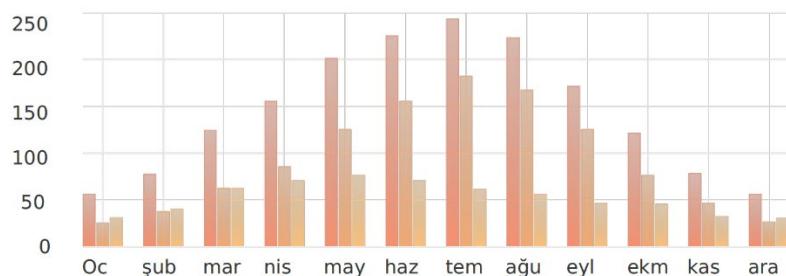
Tablo, Kayseri iline ait güneş enerjisi panellerinin aylık bazda elektrik üretim miktarlarını göstermektedir ve simülasyon sonuçlarına dayanmaktadır.Gerçekleştirilen fizibilite çalışmasında Kayseri iline ait uzun vadeli meteorolojik veriler kullanılmıştır. Türkiye Güneş Enerjisi Potansiyel Atlası verilerine göre bölgenin yatay düzlemdeki ortalama yıllık küresel güneş ışınımı 1.620–1.700 kWh/m² arasında olup, bu çalışmada 1.675 kWh/m²/yıl referans değer olarak alınmıştır [3].

PV sistemlerinin teknik ve ekonomik fizibilitesini değerlendirmek için PVsyst yazılımı kullanılmıştır. Bu yazılım, sistemin elektrik üretim kapasitelerini, gölgelenme etkilerini, panel eğimi, sıcaklık profili, yatırım geri dönüş süresi ve yatırım karlılığı gibi parametreleri dikkate alan profesyonel bir simülasyon aracıdır [5]. Kayseri'nin karasal iklimi, yaz aylarındaki yüksek güneş ışınımı süresi ve kış aylarındaki düşük sıcaklıklar, panel verimliliğine olumlu katkı sağlamaktadır [5].

2.3. Sistem Bileşenleri

- Fotovoltaik Panel: 595 Wp değerinde monokristal panel seçilmiştir. Yüksek güç çıkışı nedeniyle daha az panel kullanımı gerektirir. Monokristal panellerin yüksek verimliliği, az yer kaplaması ve uzun ömürlü olmaları, çatı uygulamaları için uygunluğunu artırmaktadır [2].
- İnvertör: 125 kW kapasiteli 20 adet dizi invertör, %98 verimlilik ile seçilmiştir. 100 kW'lık modellere kıyasla daha yüksek kapasiteye sahip olmaları, aynı kurulu güç için daha az sayıda invertör kullanımına imkân tanır; bu da kurulum, bakım ve kablolama maliyetlerini azaltır [1].
- Montaj Sistemi: Eğimli çatılar için uygun alüminyum destek yapısı kullanılmıştır. Hafif, dayanıklı ve korozyona karşı dirençli olması, çatıya ek yük bindirmeden uzun ömürlü bir taşıyıcı sistem sağlar. Montaj kolaylığı ve bakım gerektirmemesi de toplam maliyetleri düşürmektedir [9].
- Toplam Güç Kapasitesi: 3 MWp kapasite, mevcut çatı alanının verimli kullanımı ve enerji ihtiyacının önemli bir kısmının karşılanması amacıyla seçilmiştir. Toplamda yaklaşık 5.040 panel kullanılacaktır. Bu güç seviyesi, yatırımın ekonomik geri dönüşünü hızlandırmakta ve karbon emisyonlarının azaltılmasına katkı sağlamaktadır [3].

2.4. Yerleşim Planı

Çatıda bacalar, aydınlatma noktaları ve diğer yapısal engeller dikkate alınarak gölgeleme kayıpları en aza indirilmiştir. Panel yönü ve aralıkları, simülasyonlar yoluyla optimize edilmiştir [5].

3. Teknik Fizibilite Analizi

3.1. Yıllık Enerji Üretimi

Kayseri'de yer alan Sersim Fabrikası için 3 MWp gücünde çatı güneş enerji sisteminin yıllık üretimi, spesifik verim (SY) yöntemi kullanılarak hesaplanmıştır. Spesifik verim (kWh/kWp/yıl) kurulu güce çarpılarak yıllık üretim elde edilir. Bu çalışmada 3.000 kWp × 1.500 kWh/kWp/yıl = 4.500.000 kWh/yıl olarak hesaplanmıştır. Spesifik verim 1.500 kWh/kWp/yıl olup, Kayseri için seçilen yatay yıllık güneş ışınımı (1.675 kWh/m²/yıl, GEPA) göz önüne alındığında bu değer yaklaşık %89–90 performans oranına (PR) karşılık gelmektedir. PR değeri; invertör verimliliği, sıcaklık kayıpları, gölgelenme, kirlenme, kablolama ve eşleşme kayıpları gibi parametrelerin birleşik etkisini temsil eder.

3.2. Sistem Verimliliği ve Kayıpları

Sistem Verimliliği (%80): Panellerin verimliliği, invertör ve kablo kayıpları dikkate alınarak hesaplanmıştır. İnvertör verimi %98, kablo kayıpları %2–3 aralığında alınmıştır [1].

Gölgeleme Kaybı (%2,5): Çatı üzerindeki bacalar, çevresel engeller ve binalar gölgelenme oluşturabilir. PVsyst simülasyonlarıyla bu kayıp %2,5 olarak belirlenmiştir [5].

Isı Kayıpları (%3,8): Panel verimi sıcaklık arttıkça azalır. Kayseri'nin yüksek yaz sıcaklıkları ve panel sıcaklık katsayısı (-0,35 %/°C) dikkate alınarak yıllık üretimden %3,8 kayıp hesaplanmıştır [2].

4. Ekonomik Değerlendirme

Yatırım geri dönüş süresi (Payback Period), sistemin toplam yatırım maliyetinin yıllık net tasarrufa bölünmesi ile hesaplanmıştır. Toplam yatırım maliyeti paneller, invertörler, montaj ve altyapı giderlerini kapsarken; yıllık net tasarruf, üretilen elektrik miktarının birim fiyat ile çarpılması ve sistem kayıplarının düşülmesiyle belirlenmiştir. Bu hesaplamaya göre, 3 MWp gücündeki sistemin yatırımının Sersim fabrikası için yaklaşık 3 yıl içinde geri dönüş sağlayacağı öngörülmüştür [3].

5. Çevresel Etkiler ve Karbon Ayak İzi

Kurulacak 3 MWp gücündeki fotovoltaik (PV) sistemin devreye alınmasıyla, yıllık yaklaşık 4.500.000 kWh elektrik enerjisi üretimi beklenmektedir. Bu üretim, Türkiye elektrik şebekesinden sağlanacak enerjiye kıyasla önemli bir karbon emisyonu azaltımı sağlayacaktır.

Emisyon Faktörü ve Hesaplama Yöntemi: 3 MWp gücündeki PV sistemin yıllık üretimi 4.500.000 kWh olarak öngörülmektedir. Türkiye elektrik şebekesi için kullanılan ortalama emisyon faktörü 0,442 tCO_2/MWh kabul edilmiştir [8,9]. Bu değer, elektrik üretiminde kullanılan enerji kaynaklarının karışımını yansıtan bir ortalama değerdir.Güneş paneli sisteminin ürettiği 4.500.000 kWh elektrik enerjisi, 4.500 MWh'ye eşittir.Bu değer emisyon faktörü ile çarpılarak CO_2 emisyonu hesaplanmıştır.Bu durumda, önlenen CO_2 emisyonu 1989 ton CO_2-eşdeğer olarak hesaplanmıştır. Bu değer, sistemin çevresel sürdürülebilirlik açısından önemini ve Türkiye'nin karbon azaltma hedeflerine katkısını göstermektedir. [8,9].

6. Sonuç ve Öneriler

Fizibilite çalışması, endüstriyel tesislerde çatı üstü güneş enerjisi sistemlerinin uygulanabilirliğini göstermektedir. Sistem, enerji bağımsızlığını artırmakta, karbon emisyonlarını azaltmakta ve sürdürülebilirlik performansını iyileştirmektedir. Artan enerji maliyetleri ve sürdürülebilirlik hedefleri ışığında, endüstriyel kuruluşların benzer fizibilite analizleri ile güneş enerjisi yatırımlarını değerlendirmeleri kritik önem taşımaktadır [6,4].

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