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Textiles 4all - Textiles 4ever

CORTEP 2026

BOOK OF ABSTRACTS

20th ROMANIAN TEXTILES AND LEATHER CONFERENCE

05-07 November, 2026
Iasi, Romania

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Iași, Romania
05-07 November 2026

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Faculty of Industrial Design and Business Management

PROCEEDINGS PUBLISHED BY

Paradigm Publishing Services

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Asociația Absolvenților Facultății de Textile-Pielărie din Iași

The General Association of Engineers in Romania

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WELCOME MESSAGE

Dear colleagues and friends,

On behalf of the Faculty of Industrial Design and Business Management of the "Gheorghe Asachi" Technical University in Iași, Romania, it is a great honour for me to welcome you all to the 20th Romanian International Textile and Leather Conference, CORTEP 2026, which will be held under the logo "Textiles 4all, Textiles 4ever".

CORTEP 2026 is organised in Iasi, as the oldest textile faculty in Romania has been located here since 1952. Iași is the most important political, economic and cultural centre of the province of Moldova, as well as one of the oldest cities in Romania. Located in the North-East of the country, Iași was for many centuries the hub of the most important trade routes connecting Poland, Hungary, Russia and Constantinople.

The conference topics have been carefully selected to highlight the diversity of research problems in the field of textiles and leather and to provide you with many opportunities to exchange knowledge.

Our sincere thanks go to the Keynote Speakers, for their generosity in sharing their high level of expertise on research topics with us, increasing thus the visibility of this scientific event.

We thank the members of the International Scientific Committee for their willingness to support and promote the conference in the textile research community and the scientific reviewers for their contribution in ensuring high-quality research contributions.

CORTEP 2026 is the second edition of the conference in which the accepted papers will be published as Open Access Proceedings by Paradigm (De Gruyter Brill) and indexed in various databases, thanks to the work of our colleagues from the editorial team, to whom we are very grateful.

Our sincere thanks go to the members of the organising committee, for their unconditional commitment and dedication to this team effort.

We are honoured to have two international partners, whose network we belong to, the Association of Universities for Textile, AUTEX, and the Balkan Society of Textile Engineers, BASTE, whose presidents will delight us with their presence in Iași.

In this edition, CORTEP 2026 benefits from the presence and support of MDPI (Multidisciplinary Digital Publishing Institute). Selected papers presented at CORTEP 2026 will have the opportunity to be submitted to Textiles (WoS ESCI indexed, Q1, Impact Factor: 4.8) for publication in the Special Issue "Emerging Innovations in Textile Materials, Technologies and Sustainable Manufacturing".

CORTEP 2026 included 5 keynote lectures, 6 plenary speakers, 87 registered abstracts, 69 oral presentations and 11 posters from participants from 19 countries (Albania, Bulgaria, France, Germany, Greece, India, Iran, Kosovo, Lithuania, Morocco, Moldova, Portugal, Pakistan, Slovenia, Turkey, Ukraine, United Kingdom, Uzbekistan).

Therefore, we would like to express our sincere gratitude to all participants for their valuable contribution and willingness to spend part of their time in Iași or online during the conference days.

Prof. Habil. Ph.D. Eng. Mirela BLAGA
President of CORTEP 2026

TABLE OF CONTENTS

SECTION 1: ARTIFICIAL INTELLIGENCE APPLIED IN TEXTILES **13**

ARTIFICIAL INTELLIGENCE IN TEXTILE COLOR SCIENCE: FROM COLOR MEASUREMENT TO INTELLIGENT DECISION-MAKING 14
Razieh JAFARI

GENERATIVE AI IN FASHION MARKETING: NAVIGATING THE AUTHENTICITY PARADOX, ETHICAL DISCLOSURES, AND BRAND TRUST IN THE WAKE OF MANGO'S CAMPAIGN 15
Costel Cristian DĂNĂILĂ, Lidia ALEXA

MACHINE LEARNING APPROACH FOR PREDICTING VISUAL COLOR ACCEPTABILITY IN BLACK FABRIC MATCHING 16
Razieh JAFARI

SECTION 2: INNOVATIVE TEXTILE MATERIALS AND PROCESSING **17**

EVALUATION OF CHANGES IN THE ELECTRICAL RESISTIVITY OF COTTON FIBRE ASSEMBLIES THROUGH DIFFERENT STAGES OF THE SPINNING PREPARATION 18
Riana Hida, Ilda Kazani, Përllumb Berberi, Ayoub Nadi, Artan Sinoimeri

OPTIMIZATION OF THE DYEING PROCESS OF MECHANICAL STRETCH POLYESTER KNITTED FABRICS WITH RESPONSE SURFACE METHODOLOGY 19
Aliye AKARSU ÖZENÇ, Zeynep ATLAS, Semiha EREN

APPLICATION OF THE IMPULSE EXCITATION TECHNIQUE FOR DYNAMIC CHARACTERIZATION OF TEXTILE MATERIALS 20
Cristina GROSU, Mirela BLAGA, Neculai Eugen SEGHEDIN, Mihaela PERDEVARĂ

ADVANCED TEXTILE MATERIALS AND PRODUCTS FOR PROTECTION AGAINST MECHANICAL VIBRATIONS 21
Mirela BLAGA, Cristina GROSU, Mihaela PERDEVARĂ, Neculai-Eugen SEGHEDIN

COMPARATIVE ASSESSMENT OF THE MECHANICAL PERFORMANCE OF FIREFIGHTER PROTECTIVE FABRICS AFTER REPEATED LAUNDERING 22
Cristina GROSU, Doina TOMA, Alina POPESCU, Adrian SALISTEAN, Georgeta POPESCU, Catalin ENESCU, Marcel ISTRATE

DIGITAL RECONSTRUCTION OF TRADITIONAL ROMANIAN HAND-WOVEN TEXTILES 23
Cristina PASCAL, Irina-Niculina CRISTIAN

A WEB-BASED RESPONSE SURFACE MODELLING TOOL TESTED ON OIL-IN-WATER EMULSIONS INTENDED FOR TEXTILE FUNCTIONALIZATION 24
Radu-Gabriel DĂNILĂ, Romeo PRUNEANU, Angela DĂNILĂ, Vasilica POPESCU, Laura CHIRILĂ

EFFECT OF TEXTILE PRETREATMENTS ON FTIR-DERIVED STRUCTURAL INDICES OF PERIODATE OXIDISED COTTON FABRICS 25
Romeo PRUNEANU, Melinda PRUNEANU, Mihaela Dana SUFLET, Vasilica MAIER, Nicoleta TOFĂNESCU

TEXTILE SUBSTRATE FIXATION ON THE BUILD PLATE FOR STABLE FDM PRINTING 26
Radu FIRICEL, Constantin-Eugen AILENEI, Irina-Elena MARIN, Savin-Dorin IONESI, Maria-Carmen LOGHIN

CHEMICAL SAFETY IN TEXTILE PROCESSING: HAZARDOUS SUBSTANCES, SAFER ALTERNATIVES AND MATERIAL DEVELOPMENT – A REVIEW 27
Romeo PRUNEANU, Melinda PRUNEANU, Ingrid BUCIȘCANU, Nicoleta TOFĂNESCU

THE VISUAL GRAMMAR OF FOLK DRESS IN MOLDAVIA: MOTIFS, COLOUR AND ETHNOGRAPHIC CONTEXT 28
Ștefania-Felicia GĂLĂȚANU, Daniela NEGRU, Andreea-Mădălina TALPĂ

COMPARATIVE STRUCTURAL EFFICIENCY AND WARP YARN CONSUMPTION ANALYSIS OF HIGH-TENACITY POLYESTER SAFETY-BELT WEBBING 29
Daniela NEGRU, Adrian VÎLCU, Cătălin VÎLCU, Alexandru-Vasile MĂRIEI

PROPERTIES OF ANTISTATIC WOVEN FABRICS PRODUCED WITH RING-SPUN AND ROTOR-SPUN COTTON/STAINLESS STEEL WEFT YARNS 30
Mariana ICHIM, Doina CAȘCAVAL, Marius Răzvan ZVONARU
EXPERIMENTAL INVESTIGATION INTO THE TENSILE BEHAVIOR OF HIGH-STRENGTH POLYETHYLENE FISHING LINES 31
Marius Răzvan ZVONARU, Cristina RACU, Doina CAȘCAVAL, Andreea Ana Maria ASANDULUI
THE CURRENT STATE OF RESEARCH ON UV-PROTECTIVE TEXTILE STRUCTURES FOR WORKWEAR: A REVIEW 32
Laura NATU, Iuliana MOTRESCU, Mihai Alexandru CIOLAN
SECTION 3: SMART TEXTILES, MEDICAL TEXTILES, COMPOSITES **33**
SMART TEXTILES AND WEARABLE ELECTRONICS DEVICES: CHALLENGES AND INTEGRATION STRATEGIES 34
Roohollah BAGHERZADEH
DESIGN AND FABRICATION OF HIGH-STABILITY TEXTILE STRAIN SENSORS FOR SMART COMPRESSION GARMENTS 35
Shahood uz ZAMAN, Maham RAZA, Aqsa IMRAN
OPTIMIZATION OF CONDUCTIVE COATING PROCESSES FOR AGRICULTURAL WASTE-DERIVED TEXTILE STRUCTURES 36
Ayşenur MEMİŞ, Münire Sibel ÇETİN, Özgür ATALAY
LUFFA AEGYPTIACA FIBER-REINFORCED PLA BIOCOMPOSITES: FABRICATION AND MECHANICAL CHARACTERIZATION 37
Mehmet Niyazi DURUKAN, Dicle Ayça Ertek KİRAZ, Abdulkadir PARS, Fatma Zehra Engin SAGİRLİ, Ali BEYİT
EVALUATING CHROME-FREE LEATHER AS A SUSTAINABLE SUBSTRATE FOR SMART APPLICATIONS 38
Elona HIDRI, Majlinda HYLLI, Aulon SHABANI, Ilda KAZANI
MULTIFUNCTIONAL JANUS BILAYER COATED POLYESTER FABRIC FOR PERSONAL THERMAL MANAGEMENT 39
Nazife KORKMAZ MEMİŞ, Aziza ZHOLDOSHOVA
THE EFFECT OF JUTE FIBER SURFACE MODIFICATION ON THE MECHANICAL BEHAVIOR OF JUTE/POLYLACTIC ACID COMPOSITES 40
Saghar HEMATKHAHAN, Hooshang NOSRATY, Seyed Abolfazl MIRDEHGHAN
COMPARATIVE ANALYSIS OF EMBROIDERY TECHNIQUES FOR CONDUCTIVE TEXTILE CIRCUITS 41
Andreea TALPĂ, Luminița CIOBANU, Ion Răzvan RĂDULESCU, Nicolae MILITARU, Ștefania-Felicia GĂLĂȚANU, Sebastian PÎRCIU
INVESTIGATION OF WILLOW–POPLAR–HEMP FIBER HYBRID REINFORCEMENTS FOR COMPOSITE MATERIALS IN UPHOLSTERED FURNITURE APPLICATIONS 42
Mariana ICHIM, Florin CIOLACU, Emil Ioan MUREȘAN
FROM PREDICTION TO PRECISION: THE INTEGRATED PRECISION NEONATAL CARE FRAMEWORK (IPNCF) FOR PRETERM BIRTH MANAGEMENT 43
Victoria DANILA, Stela BALAN
ANALYSIS OF MULTILAYER TECHNICAL EMBROIDERY TECHNIQUES 44
Andreea TALPĂ, Carmen LOGHIN, Irina IONESCU, Ștefania-Felicia GĂLĂȚANU
STRUCTURAL OPTIMIZATION OF LOW-AREAL-DENSITY WOVEN FABRICS FOR MILITARY PROTECTIVE GEAR: BALANCING TENSILE AND TEAR RESISTANCE 45
Niki Vlad MANCAȘI, Irina Niculina CRISTIAN
BIOMATERIALS IN MEDICINE: CURRENT USES AND RECENT ADVANCES 46
Diana Andreea PLĂCINTĂ, Mirela BLAGA
SECTION 4: DIGITAL PRODUCT DEVELOPMENT FOR TCLF INDUSTRY **47**
DIGITALIZATION PRACTICES IN ROMANIAN FASHION MANUFACTURING COMPANIES: A FOUR-LEVEL FRAMEWORK FOR POSITIONING COMPANIES IN RELATION TO APPAREL 4.0 48
Emil-Constantin LOGHIN, Laura-Diana LUCA, Ionuț BOSTAN, Cristina-Mihaela CODREANU

FUNCTIONAL AND ERGONOMIC ASPECTS OF PERSONAL PROTECTIVE CLOTHING FOR URBAN FARMERS 49
Stela BALAN, Aurelia MIRCA, Manuela-Lacramioara AVADANEI, Elena-Andreea VASILE, Alexandru HANU
SUSTAINABLE DEVELOPMENT OF MODERN MENSWEAR: ZERO WASTE DESIGN 50
Svetlana CANGAS, Marcela IROVAN, Ecaterina BOGATAIA, Manuela-Lacramioara AVADANEI, Caius-Laurentiu BALAN, Irina IONESCU
COMPREHENSIVE EVALUATION OF 3D VIRTUAL PROTOTYPING OF CORPORATE APPAREL BASED ON AN INTEGRAL COMPLIANCE INDEX 51
Tetiana NADOPTA, Evridiki PAPACHRISTOU, Oksana MYKHAILOVSKA, Oleksandr KUNTSOV
INDUSTRY 4.0 TECHNOLOGY ADOPTION IN ROMANIAN FASHION INDUSTRY SMES: AN EXPLORATORY ANALYSIS 52
Laura-Diana LUCA, Emil-Constantin LOGHIN, Cristina-Mihaela CODREANU
SECTION 5: COMFORT, QUALITY OF TEXTILES AND SENSORY EVALUATION **53**
THERMO-PHYSIOLOGICAL COMFORT AND COOL TOUCH PERFORMANCE OF LIGHTWEIGHT POLYPROPYLENE WOVEN APPAREL FABRICS 54
Yasemin DULEK, Ipek YILDIRAN, Bugce SEVINC, Melis ERDEM OZTURK, Cem GUNESOGLU
COMPUTATIONAL STUDY OF THERMAL COMFORT IN COMPRESSION STOCKINGS: ASSESSING THE FPC MODEL'S SENSITIVITY TO ACTIVITY LEVEL AND SEX DIFFERENCES IN WARM CONDITIONS 55
Ingrid PERAZA, Olena KYZYMCHUK, Karl HESSE, Yordan KYOSEV
HYBRID EMBROIDERY-FDM STRUCTURES: INFLUENCE OF STITCH DENSITY ON ADHESION 56
Ștefania-Felicia GĂLĂȚANU, Radu FIRICEL, Daniela NEGRU, Ionuț DULGHERIU, Andreea-Mădălina TALPĂ
SECTION 6: INNOVATIONS IN TEXTILE DYEING AND FINISHING **57**
DEVELOPMENT OF ANTIFUNGAL WOOL FABRICS USING LIPOSOME-ENCAPSULATED NATURAL AND SYNTHETIC ACTIVE AGENTS 58
Kağan AYDIN, Gülşah Ekin KARTAL
WATER-BASED ZIF-8 SYNTHESIS AND ITS APPLICATION IN COTTON DYEING 59
Gezu Ketema JANKA, Huseyin Aksel EREN, Aminoddin HAJI
PRELIMINARY STUDIES ON THE CONTENT OF MICROPLASTICS FOUND IN WASTEWATER RESULTING FROM HOUSEHOLD LAUNDRY 60
Vasilica MAIER, Melinda PRUNEANU, Romeo PRUNEANU, Stelian Sergiu MAIER
CASE STUDY REGARDING BACTERIAL AND FUNGAL LOAD OF SEASONALLY WORN SHEEPSKIN CLOTHING 61
Vasilica MAIER, Melinda PRUNEANU, Romeo PRUNEANU, Stelian Sergiu MAIER
SECTION 7: RECYCLING, LIFE CYCLE ANALYSIS, SUSTAINABILITY AND CIRCULARI **62**
MECHANICAL RECYCLING OF WOOL 63
Holger CEBULLA, Megi BASHO
FROM FIBRE TO MARINE USE: DEVELOPING A SUSTAINABLE WOOL ROPE FROM RATHLIN BLACKFACE WOOL FOR THE KELP INDUSTRY 64
Alison GAULT, Kate DRURY
BEYOND KNITTING: AIRBORNE FIBRE CONCENTRATIONS ACROSS FLEECE PRODUCTION STAGES 65
Khadija FATIMA, Habib AWAIS, Laiba UBAID, Urwa MEHMOOD, Muzzamal HUSSAIN, Saqib SOHAIL
GREEN CHEMISTRY IN TEXTILES: DES APPLICATIONS FROM ECO-DYEING TO WASTE RECYCLING 66
Aminoddin HAJI
IMPLEMENTING EDUCATION FOR SUSTAINABLE DEVELOPMENT AS A GUIDING PRINCIPLE IN FASHION DESIGN PROGRAMMES – A COMPARATIVE STUDY ACROSS GERMANY AND IRAN 67
Hanieh CHOOPANI, Martina GLOMB, Anne-Marie GRUNDMEIER

CONSISTENCY AND CONTRADICTIONS IN EU SUSTAINABLE TEXTILE AND APPAREL POLICIES: A CRITICAL REVIEW 68
H.Ziya OZEK
VALORIZATION OF NATIVE ALBANIAN SHEEP WOOL THROUGH NATURAL DYEING USING PLANT EXTRACTS AND AGRO-INDUSTRIAL WASTE 69
Majlinda HYLLI, Sidorela VISHKULLI, Benarda KALLAKU, Ilda KAZANI
THE CONSTRUCTIVE-DECORATIVE EVOLUTION OF TRADITIONAL BAGS AND PURSES IN THE CONTEXT OF CONTEMPORARY DESIGN: VALORIZING THE CRAFTSMANSHIP HERITAGE THROUGH INNOVATION AND SUSTAINABILITY 70
Ana ISCHIMJI, Victoria DANILA, Liliana CONDRATICOVA
DESIGNING CIRCULARITY: A SUSTAINABLE UPCYCLING FRAMEWORK FOR POST-CONSUMER TEXTILE WASTE AND CRAFT-BASED INNOVATION. 71
Kanishka SINGH, Manoj Kumar PARAS
DIVERGING STANDARDS: METHODOLOGICAL FRAGMENTATION IN TEXTILE LIFE CYCLE ASSESSMENT 72
Luminița CIOBANU, Andreea NISTORAC
A CASE STUDY ON ROMANIAN CULTURAL HERITAGE FOR A SUSTAINABLE FASHION COLLECTION 73
Elena SECARĂ, Manuela – Lăcrămioara AVĂDANEI, Irina – Elena MARIN
ASSESSING ECO-MAINTENANCE MATURITY IN THE TEXTILE AND LEATHER INDUSTRY: A DATA-DRIVEN APPROACH 74
Denisa-Alexandra NICA, Ion VERZEA, Adrian VÎLCU, Stejărel BREZULEANU
CLOTHING DURABILITY AS A KEY FACTOR IN REDUCING ENVIRONMENTAL IMPACT: A REVIEW 75
Irina – Elena MARIN, Constantin – Eugen AILENEI, Radu FIRICEL
FROM HEMP CULTIVATION TO STEM VALORISATION: A STRUCTURED REVIEW OF HEMP HARVEST MATURITY, FIBRE QUALITY AND END-USE POTENTIAL 76
Constantin-Eugen AILENEI, Ioan PUIU, Radu FIRICEL, Irina-Elena MARIN, Lucian Constantin HARAGA
FROM SHOP-FLOOR KPIS TO PRODUCT PASSPORTS: A LEAN SIX SIGMA INDUSTRY 4.0 DATA GOVERNANCE ARCHITECTURE FOR TEXTILE SMES 77
Nicoleta-Mihaela CASANEANU (DASCALU), Marius PISLAU, Adrian VILCU
ENVIRONMENTAL ASSESSMENT OF TEXTILE WASTE-REINFORCED COMPOSITE MATERIALS FOR BUILDING APPLICATIONS 78
Eugen Constantin AILENEI, Sebastian George MAXINEASA, Irina Elena MARIN, Radu FIRICEL, Ramona BUDEANU, Ioana-Roxana VIZITIU-BACIU
FROM DIGITAL REPRESENTATION TO PREDICTIVE TRACEABILITY: THE INTEGRATED PREDICTIVE TRACEABILITY FRAMEWORK (IPTF) FOR SUSTAINABLE INDUSTRY 5.0 TEXTILE ECOSYSTEMS 79
Victoria DANILA, Stela BALAN, Ana ISCHIMJI
INTEGRATED MICROWAVE-ASSISTED EXTRACTION OF CURCUMINOIDS FROM TURMERIC POWDER AND SUSTAINABLE HEMP DYEING THROUGH DYE BATH REUSE 80
Andrei POPESCU, Alina Mihaela PALCU, Andreea TIMOFTE, Iuliana PETCU, Vasilica POPESCU, Angela DĂNILĂ, Melinda PRUNEANU, Madalina Maria POPESCU-BREZULEANU, Valentina-Gabi STĂNESCU
FROM LINEAR TO CIRCULAR MODELS: PERSPECTIVES IN THE CONTEXT OF INDUSTRY 5.0 81
Petrina-Delia VAGIUC, Marius PÎSLARU, Adrian VÎLCU, Larisa IVAȘCU, Ionuț-Viorel HERGHILIGIU
SUSTAINABLE TEXTILE MATERIALS AND THEIR IMPACT ON THE ENVIRONMENT 82
Adriana-Denisa STAN, Ionuț-Viorel HERGHILIGIU
CONTRIBUTIONS TO THE RESEARCH OF INNOVATIVE SUSTAINABLE PRODUCTION PROCESSES FOR FUNCTIONAL GARMENTS 83
Sebastian POPA, Casandra-Alina FOTACHI

SECTION 8: FOOTWEAR DESIGN AND TECHNOLOGY **84**
DEVELOPMENT OF AN IMPROVED DESIGN OF CUSTOMIZED SUPPORTIVE AND PRESSURE-RELIEVING INSOLES FOR PREGNANT WOMEN USING 3D PRINTING TECHNOLOGY 85
Natalia KUZINA, Liliia CHERTENKO, Tymofii LYPSKYI, Andriy LIPSKYI, Viktoriia KERNESH
OVERVIEW OF 3D PRINTED APPLICATIONS FOR TEXTILES AND FABRICS IN THE FOOTWEAR SECTOR 86
Pedro DUARTE, Margarida MATA, Florbela SILVA
FUNCTIONALITY AND DESIGN OF HEALTHCARE FOOTWEAR: IMPACT ON THE MUSCULOSKELETAL HEALTH AND PROFESSIONAL PERFORMANCE 87
Mariana COSTEA, Ioana OJOG, Arina SEUL, Aura MIHAI, Adriana CHIRILĂ, Marta HARNAGEA
ARTIFICIAL INTELLIGENCE IN FOOTWEAR DESIGN: A COMPARATIVE CASE STUDY 88
Aura MIHAI, Iuliana CHIHAI, Arina SEUL, Mariana COSTEA, Raluca LUPU
SECTION 9: NEW BUSINESS MODELS AND EMERGENT ECOSYSTEMS **89**
DIGITALIZATION – VECTOR OF FINANCIAL SUSTAINABILITY IN FASHION 90
Mihaela Brîndușa TUDOSE, Mihaela ONOFREI, Nicoleta ȚÎCU, Gabriela COJOCARIU
MULTIPRODUCT BREAK-EVEN-ANALYSIS: SALES MIX RECONFIGURATION, MARGIN OF SAFETY AND OPERATING LEVERAGE 91
Mihaela DIACONU, Elena AVRAM
ASSESSING THE IMPACT OF SUSTAINABILITY PRACTICES ON THE PERFORMANCE OF COMPANIES IN THE TEXTILE SECTOR 92
Marinela NEȘTIAN, Mihaela Brîndușa TUDOSE
SECTION 10: ENTREPRENEURSHIP AND INNOVATION **93**
TRANSLATING BRAND HERITAGE INTO DESIGN DECISIONS: A 35TH-ANNIVERSARY PREMIUM DENIM PRODUCT GROUP 94
Özgür CEYLAN, Irmak TAŞ, Nesligül KILIÇ, Emel AYDIN, Neslihan AK, Ecem GÖKAY, Tuğçe YAVAŞ
THE SOCIO-ECONOMIC IMPACT OF RUDA SHEEP WOOL IN THE KUKËS REGION, ALBANIA: PAST, PRESENT AND FUTURE PERSPECTIVES 95
Blerina KOLGJINI, Julie KOLGJINI, Ermira SHEHI, Armida ALIKAJ, Elias MASLOUM
FORM, FINISH AND IDENTITY IN HEAVYWEIGHT DENIM: A DESIGN SYSTEM FOR PREMIUM DURABILITY AND TIMELESS STYLE 96
Özgür CEYLAN, Irmak TAŞ, Emel AYDIN, Nesligül KILIÇ, Neslihan AK, Özgen ÖZTURAN, Ecem KARAMANLARGİL
DIGITAL-ADAPTIVE EMPLOYEE-CENTRIC MANAGEMENT: A CONCEPTUAL MODEL FOR VIRTUAL FIRMS 97
Ioana-Adelina POPA, Ion VERZEA, Adrian VILCU
THE EVOLUTION OF MAINTENANCE MODELS IN INDUSTRIAL DIGITALIZATION 98
Nicoleta Loredana CIURARIU, Ion VERZEA
ORGANIZATIONAL CHANGE MANAGEMENT IN THE PUBLIC SECTOR: A RISK-BASED PERSPECTIVE 99
Mihai-Doru BULIGA, Stejărel BREZULEANU, Ion VERZEA
STRESSFUL WORK ENVIRONMENT AND WELLBEING: ARE THEY INTERCONNECTED? 100
Nicoleta-Andreea FILIP, Ion VERZEA, Dănuț-Constantin FILIP
SECTION 11: ENGINEERING EDUCATION **101**
MIXED-METHODS RESEARCH IN TEXTILE AND FASHION STUDIES: QUALITATIVE AND QUANTITATIVE INSIGHTS FROM THE TEXUNITE PROJECT 102
Maleika Anna SCHMIDBLEICHER, Anne-Marie GRUNDMEIER, Matejka BIZJAK, Mirela BLAGA, Manuela BRÄUNING, Mustafa ERTEKIN, Zlatinka KAZLACHEVA, Zlatin ZLATEV
BUILDING A PRACTICE-ORIENTED EDUCATIONAL ECOSYSTEM IN TEXTILE ENGINEERING THROUGH THE ADAPTATION OF EUROPEAN BEST PRACTICES: EXPERIENCE OF THE ERASMUS+ TEX4FUTURE PROJECT 103
Nikolaos BILALIS, Malokhat ILKHAMOVA

EVALUATION OF FASHION DESIGN AND TEXTILE AND FASHION DESIGN UNDERGRADUATE PROGRAMS IN TÜRKİYE IN TERMS OF DIGITAL FASHION EDUCATION 104
Selma DOLANBAY DOĞAN, Meral İŞLER
AN ANALYSIS OF THE STRUCTURE AND TYPES OF QUESTIONS USED IN THE CREATION OF TESTS USED IN TEXTILE HIGHER EDUCATION ASSESSMENT 105
Adrian BUHU, Liliana BUHU, Daniela NEGRU
BLENDED 3D CAD TRAINING FOR FOOTWEAR DESIGN: ENHANCING DIGITAL COMPETENCIES THROUGH AN INTERNATIONAL CAPACITY-BUILDING PROGRAMME 106
Mariana COSTEA, Aura MIHAI, Arina SEUL, Evridiki PAPACHRISTOU, Raluca LUPU
ARTIFICIAL INTELLIGENCE IN ADVERTISING DESIGN 107
Carmen TIȚĂ
ADDRESSING THE URGENT NEEDS OF THE TEXTILE SECTOR FOR SKILLS ON SUSTAINABILITY 108
Luminița CIOBANU, Irina MARIN, Elena AVRAM
LEADERSHIP AS A DRIVER OF EMPLOYEE PERFORMANCE IN CONTEMPORARY ORGANIZATIONS: AN EMPIRICAL STUDY RELEVANT TO ENGINEERING EDUCATION AND MANAGEMENT TRAINING 109
Adrian VÎLCU, Raluca-Petronela LĂZĂRESCU, Cătălin VÎLCU, Petrina-Delia VAGIUC, Cristian GORINCIOI
COGNITIVE AND SOCIAL USE OF GENERATIVE AI: EFFECTS ON ACADEMIC LEARNING, SATISFACTION AND INNOVATION AMONG ENGINEERING AND MANAGEMENT STUDENTS 110
Adrian VÎLCU, Teodor Ion VERZEA, Cătălin VÎLCU, Denisa-Alexandra NICA

SECTION 1:
ARTIFICIAL INTELLIGENCE APPLIED IN TEXTILES

ARTIFICIAL INTELLIGENCE IN TEXTILE COLOR SCIENCE: FROM COLOR MEASUREMENT TO INTELLIGENT DECISION-MAKING

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Abstract*. Color is a fundamental attribute of textile products, contributing not only to product development, quality control, and manufacturing consistency, but also to their commercial appearance and consumer perception. Color can strongly influence consumers' initial evaluation and purchase decisions, as the visual attractiveness of a product may be substantially shaped by its color. Conventional colorimetry, instrumental measurement, and spectral analysis provide the scientific foundation of textile color science. However, the increasing complexity of materials, manufacturing processes, market requirements, and human perception calls for approaches that extend beyond color measurement and description. This perspective aims to examine the emerging role of artificial intelligence (AI) in textile color science and to propose a research pathway for integrating AI with established color science, material and process knowledge, human perception, and market requirements. Drawing on selected recent research and applications, the main contribution of this perspective is the proposed framework,* ***Measure → Understand → Predict → Decide → Feedback****, which connects established color measurement and analysis with deeper understanding, prediction, intelligent decision-making, and continuous improvement. The analysis shows that AI can extend textile color science from measurement and interpretation toward predictive and decision-oriented systems by integrating color, spectral, material, process, and perceptual information. In particular, AI-enabled online and real-time quality control can support earlier detection of color deviations and process variations, potentially reducing defects, production costs, time, material and energy waste while improving consistency and overall product quality. Such capabilities can also support more targeted production by connecting manufacturing decisions with market requirements and desired product characteristics. The perspective further highlights that the value of AI in textile color science extends beyond predictive accuracy, with future intelligent color systems requiring scientific meaningfulness, perceptual relevance, physical consistency, interpretability, transferability, and adaptability. The proposed pathway therefore emphasizes that AI should complement rather than replace established color science, providing a basis for transforming color data into actionable knowledge and supporting more intelligent, efficient, adaptive, and sustainable textile production.*

Keywords: *artificial intelligence; textile color science; color measurement; machine learning; intelligent color systems; quality cont*

GENERATIVE AI IN FASHION MARKETING: NAVIGATING THE AUTHENTICITY PARADOX, ETHICAL DISCLOSURES, AND BRAND TRUST IN THE WAKE OF MANGO'S CAMPAIGN

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Abstract. *The transition from traditional fast fashion to a digitalized fashion ecosystem leverages Industry 4.0 technologies and Generative AI to address significant environmental waste and persistent operational inefficiencies. However, high-profile applications of synthetic content, such as Mango's first fully AI-generated campaign for its Teen collection, bring a critical strategic challenge to the forefront: the "authenticity paradox". This phenomenon arises from the inherent tension between hyper-realistic visual perfection and consumers' psychological need for genuine human connection. To explore how consumers evaluate AI-generated content and respond when the artificial origin of advertisements is concealed, this paper combines an analysis of Mango's campaign with an empirical quantitative study (n = 164 active Instagram users) examining the impact of synthetic models on perceived brand authenticity and consumer skepticism. The findings indicate that unlabeled AI-generated images trigger consumer resistance and feelings of deception, ultimately undermining brand trust, a vulnerability that is especially acute among digitally literate younger demographics (18-34 years old). By contrast, clear disclosure labels ("AI-generated") serve as an essential ethical safeguard by reducing perceptions of emotional manipulation and protecting brand equity. Finally, the study provides practical managerial recommendations for fashion industry decision-makers, advocating a hybrid strategy that effectively balances AI-driven operational efficiency with human authenticity and ethical digital communication.*

Keywords: *digitalized fashion, industry 4.0, authenticity paradox, artificial intelligence, consumer trust.*

MACHINE LEARNING APPROACH FOR PREDICTING VISUAL COLOR ACCEPTABILITY IN BLACK FABRIC MATCHING

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Abstract. *Black is among the most widely used and commercially important colors in textile products, making accurate and consistent color matching of black fabrics an important requirement in textile manufacturing and quality control. However, reliable assessment of visual color acceptability remains challenging because instrumental color-difference measurements do not always correspond closely with human visual perception, particularly for achromatic and low-lightness materials such as black fabrics. This study proposes a machine-learning-based approach for predicting visual color acceptability in black fabric color matching using instrumental color-difference parameters. Three logistic regression models incorporating ΔE*ab, ΔL*, and their combination (ΔE*ab–ΔL*) as predictive variables were developed to predict binary visual Pass/Fail responses. Model performance was evaluated through 100 repeated stratified random train–test splits of the 40 black fabric samples, with 35 samples used for training and five samples used for testing in each run. The combined ΔE*ab–ΔL* model achieved a mean accuracy of 81.2% and an F1-score of 0.713, compared with 80.0% accuracy and an F1-score of 0.614 for the ΔE*ab-only model. The combined model also yielded higher mean precision and recall than the individual-parameter models. Although the combined model showed higher mean accuracy and F1-score, the small test subset used in each validation run limits the precision with which differences in model performance can be established. The findings indicate that incorporating lightness information alongside overall color difference may provide useful information for predicting visual color acceptability in black fabric color matching. The proposed approach provides a data-driven framework for supporting industrial color-matching decisions, reducing reliance on time-consuming visual assessments, and improving the consistency and efficiency of color quality control for black textile products.*

Keywords: *machine learning, textile quality control, logistic regression, black fabrics, visual color acceptability.*

SECTION 2:
INNOVATIVE TEXTILE MATERIALS AND PROCESSING

EVALUATION OF CHANGES IN THE ELECTRICAL RESISTIVITY OF COTTON FIBRE ASSEMBLIES THROUGH DIFFERENT STAGES OF THE SPINNING PREPARATION

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Abstract*. Electrical resistivity is an important property of textile fibers, as it influences charge accumulation, fiber behavior, and electrostatic effects during spinning processes. Although cotton fibers undergo several mechanical processing stages before yarn formation, there is still limited information on how their electrical resistivity changes throughout the spinning preparation process under controlled atmospheric conditions. This work follows how the resistivity of cotton fiber assemblies changes over five consecutive steps of spinning preparation: raw cotton, opened fibers, carded sliver, first drawing and second drawing. All samples were taken from the same material batch to ensure consistency. Before testing, they were conditioned for 24 hours under standard atmospheric conditions (20°C and 65% relative humidity), making the resistivity values at different stages directly comparable. Electrical resistance was measured by compressing 10 g samples of fiber assemblies using a multiple-step resistivity method. The applied measurement method provided geometry-independent resistivity values, allowing reliable comparison of the electrical properties of cotton fiber assemblies throughout the spinning preparation process. For each sample, electrical resistance was recorded at 14 volume levels within the measuring cell. The electrical resistance–volume relationship was modeled using a power-law regression, from which electrical resistivity (Ω·m) was calculated. The fourteen electrical resistance measurements obtained for each sample resulted in high coefficient of determination $R^2 > 0.99$), indicating a very good fit of the regression model. The results showed a progressive increase in electrical resistivity from 6.48×10^4 Ω·m for raw cotton to 12.60×10^4 Ω·m after the second drawing stage. Fibers from each stage were also examined under an optical microscope to observe their morphological appearance along the processing line. The microscopic observations showed some local irregularities in the processed fibers. These changes may be related to the repeated mechanical actions during processing and may contribute to changes in electrical behaviour. The progressive removal of non-fibrous material may also contribute to the observed increase in electrical resistivity. These results provide a consistent, geometry independent basis for analyzing electrostatic behavior during cotton spinning preparation and may support future studies on process optimization and electrostatic control.*

Keywords: *cotton fibers; electrical resistivity; spinning preparation; compression method; power-law regression*

OPTIMIZATION OF THE DYEING PROCESS OF MECHANICAL STRETCH POLYESTER KNITTED FABRICS WITH RESPONSE SURFACE METHODOLOGY

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***Abstract**. This study aimed to investigate the effects of temperature and time parameters on the performance of 100% polyester mechanically stretchable knitted fabrics during the dyeing process and to determine the optimum process conditions. Experimental studies used 100% polyester mechanically stretchable knitted fabrics from the same batch obtained under industrial production conditions. Dyeing was performed using high-temperature disperse dyes; dyeing temperature was varied between 120–140 °C, and dyeing time between 30–60 minutes. A total of 13 experiments were conducted based on Face Centered Central Composite Design (FCCCD), and the effects of process parameters were modeled using Response Surface Methodology (RSM). Fabric touch, width shrinkage, and length shrinkage were evaluated as response variables. The obtained data were analyzed using second-order regression models and ANOVA with the Python programming language, and multiple response optimization was also performed. The R^2 values for the touch, shrinkage, and length shrinkage models were determined as 0.8062, 0.8027, and 0.8996, respectively. The findings showed that the second-order effect of dyeing temperature was significant in all three response variables, and that the interaction between temperature and time affected fabric performance. As a result of multiple optimization, the optimum process conditions were determined as approximately 129.44 °C dyeing temperature and 30 minutes dyeing time. Under these conditions, the estimated touch score was 3.7764, width shrinkage was 1.7194%, and length shrinkage was 1.1397%, with a total fit value of 0.7277. The obtained results show that the dyeing time can be reduced to 30 minutes compared to the current standard process conditions of 130 °C and 45 minutes, and that the fabric performance can be maintained at an acceptable level. It is believed that this study offers a viable optimization approach for improving both quality and production efficiency in the dyeing process of polyester knitted fabrics.*

***Keywords**: polyester knitted fabric, mechanical stretch, dyeing, response surface methodology, process optimization*

APPLICATION OF THE IMPULSE EXCITATION TECHNIQUE FOR DYNAMIC CHARACTERIZATION OF TEXTILE MATERIALS

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***Abstract**. The Impulse Excitation Technique (IET) is a well-established experimental method widely used in mechanical engineering for the resonance-based characterization of vibrating elastic bodies. Although extensively applied to conventional engineering materials, its application to textiles has received limited attention, despite the increasing demand for reliable methods for their dynamic characterization in vibration- protective applications. This paper investigates the applicability of IET to a representative set of spacer knitted fabrics through natural frequency analysis under free-vibration conditions. The experimental methodology is based on impulse excitation, response acquisition using an accelerometer and frequency-domain signal processing through the Fast Fourier Transform (FFT). The identified shifts in natural frequencies observed in representative case studies demonstrate the sensitivity of the method to subtle changes associated with wet-thermal finishing and fiber composition. These findings support the potential of the Impulse Excitation Technique as a sensitive method for the dynamic characterization of textile materials intended for vibration-protective applications.*

***Keywords:** Impulse Excitation Technique (IET), free-vibration response, natural frequencies, resonance, spacer knitted fabrics*

ADVANCED TEXTILE MATERIALS AND PRODUCTS FOR PROTECTION AGAINST MECHANICAL VIBRATIONS

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Abstract*. Occupational exposure to mechanical vibrations generated by industrial machinery, hand-held power tools, transportation systems, and mobile equipment represents a major challenge for workplace safety and health. Depending on the source and mode of transmission, mechanical vibrations may affect the hands and arms, the whole body, or localized body regions such as the feet and lower limbs, contributing to musculoskeletal disorders, vascular and neurological impairments, fatigue, discomfort, and reduced occupational performance. Consequently, the development of advanced textile materials and products capable of attenuating vibration transmission has become an important research area within protective textiles and personal protective equipment. This paper provides a comprehensive overview of recent advances in textile materials and products designed for protection against mechanical vibrations. Conventional vibration-damping materials, including elastomeric foams, rubber-based composites, and viscoelastic polymers, are reviewed together with innovative textile solutions such as three-dimensional knitted spacer fabrics. Particular attention is paid to the influence of yarn characteristics, fabric architecture, and structural parameters on vibration attenuation, energy dissipation, compression behaviour, and ergonomic comfort. The review further examines the application of advanced textile materials in protective products including anti-vibration gloves, footwear, insoles, seat cushions, vibration-isolation mats and other textile-based systems intended to reduce vibration transmission in occupational environments. Their performance is discussed in relation to relevant international standards governing the evaluation of vibration exposure and protective equipment. By integrating recent advances in textile engineering and material science, this review identifies current challenges and future opportunities for the development of high-performance textile products that provide effective protection against mechanical vibrations across a wide range of occupational applications.*

Keywords: *mechanical vibrations, personal protective equipment, damping, spacer knitted materials*

COMPARATIVE ASSESSMENT OF THE MECHANICAL PERFORMANCE OF FIREFIGHTER PROTECTIVE FABRICS AFTER REPEATED LAUNDERING

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***Abstract**. Structural firefighting protective clothing is one of the most important types of personal protective equipment (PPE) that keeps firefighters safe and enables them to perform their duties. It generally consists of a multilayer assembly comprising an outer shell, a moisture barrier and a thermal liner. The outer shell, as the first line of defence, is designed to resist various types of hazards, including extreme heat and flame, combustion gases, toxic chemicals and abrasion. The inherently flame-resistant high-performance fibers typically used in firefighters' protective clothing offer excellent protection when new. However, like all polymeric materials, these fibers undergo ageing. Different ageing factors to which firefighters' protective clothing is constantly exposed, including heat, ultraviolet (UV) radiation, moisture, abrasion and laundering, affect the performance of firefighter protective fabrics. This paper investigates the effect of repeated laundering on the mechanical performance of five woven fabrics made from different blends of para-aramid, meta-aramid and aramid copolymer fibers. Fabric specimens were subjected to up to 50 washing and drying cycles. Repeated laundering is necessary to remove fire-generated contaminants, including carcinogenic compounds, accumulated within the fabric layers of protective clothing. The selected laundering protocol corresponds approximately to one year of weekly laundering, assuming one laundering cycle per week. The mechanical properties, including tensile strength and tear strength, were tested according to the appropriate standards, while fabric thickness was also measured, and the changes induced by repeated laundering were subsequently evaluated. After 50 laundering cycles, fabric thickness increased by approximately 43-64%, tensile strength showed relatively limited, direction-dependent changes, while tear strength decreased in all fabrics, with reductions of up to 60%.*

***Keywords:** firefighters' protective clothing, service life, ageing, repeated laundering, tensile strength*

DIGITAL RECONSTRUCTION OF TRADITIONAL ROMANIAN HAND-WOVEN TEXTILES

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Abstract*. Traditional woven textiles represent a significant component of the national cultural heritage, preserving not only decorative motifs with symbolic value, but also technological knowledge developed and transmitted across generations. Although the aesthetic characteristics of these textiles have been extensively documented, the weaving techniques that enabled their production have received considerably less attention. Many traditional woven fabrics exhibit remarkable structural complexity despite being woven on manually operated looms equipped with a limited number of shafts and treadles. Through carefully designed sequences of heddle lifting, shuttle insertion, and repeated weaving cycles, skilled artisans were able to produce patterns that often appear far more complex than the mechanical capabilities of the loom would suggest. The progressive disappearance of traditional weaving practices has created an urgent need to preserve not only the visual appearance of historical textiles, but also the technological knowledge underlying their manufacture. Conventional documentation methods, focused primarily on photographic recording or motif cataloguing, fail to capture the structural logic of woven fabrics, including weave architecture, threading plans, treadling sequences, tie-up configurations, and the interaction between warp and weft during fabric formation. Essential information required for authentic reconstruction is frequently lost. This paper emphasizes the importance of process-oriented documentation and digital reconstruction of Romanian traditional woven textiles as an integrated strategy for safeguarding intangible cultural heritage. The proposed approach combines structural textile analysis with digital weaving technologies to reconstruct complete weaving workflows rather than only decorative surfaces. By reconstructing weave structures, identifying threading drafts and treadling sequences, and reproducing them within specialized textile design software, it becomes possible to generate accurate digital models of traditional fabrics while preserving the original manufacturing logic. The study further investigates how highly elaborate decorative effects were achieved using relatively simple loom configurations, demonstrating that weaving complexity originated primarily from the artisan's procedural knowledge rather than from sophisticated mechanical equipment. Understanding these relationships contributes not only to historical and ethnographic research, but also provides a scientific basis for textile conservation, educational applications, and the revitalization of endangered weaving techniques. The proposed methodology supports the creation of digital archives that preserve both the physical characteristics and the technological processes of traditional textiles, enabling reproducible reconstructions for museum conservation, academic research, and contemporary textile manufacturing. By shifting the focus from decorative preservation to process preservation, this work proposes a more comprehensive conservation framework in which traditional weaving techniques are recognized as an essential component of textile cultural heritage. Such an approach contributes to the long-term safeguarding of Romanian weaving traditions while facilitating their integration into modern digital manufacturing environments and future digital twin frameworks for cultural heritage preservation.*

Keywords: *traditional weaving techniques, textile conservation, digital archive, heritage preservation*

A WEB-BASED RESPONSE SURFACE MODELLING TOOL TESTED ON OIL-IN-WATER EMULSIONS INTENDED FOR TEXTILE FUNCTIONALIZATION

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Abstract. *The increased interest in dermo-active textiles has led to the development of systems capable of ensuring the controlled release of active compounds at the skin level. Among them, essential oils are intensively studied due to the beneficial properties they present, such as antioxidant, antimicrobial, and anti-inflammatory effects. Due to their high volatility and sensitivity to environmental factors, essential oils must be incorporated into appropriate encapsulation systems and subsequently applied to the textile support. In this study, rosemary essential oil was used as an active ingredient, being embedded in the form of biopolymer (pectin)-based emulsions, in order to obtain stable systems intended for the functionalization of textile materials with topical application. To design the experimental formulations and model their stability, the bifactorial central composite design (CCD) methodology was used, having as independent factors the concentration of rosemary essential oil and the concentration of the cosurfactant (glyceryl caprylate). In order to simplify and automate the statistical analysis process, a web application based on the Central Composite Design (CCD) method was developed. The application allows the introduction of the limits of the independent variables and the obtained results (dependent variables), the automatic generation of the experimental matrix, the calculation of the coefficients of the second-order regression model, the assessment of statistical significance by the Student's t-test and the Fisher–Snedecor test (ANOVA), as well as the graphical representation of the response surfaces and level curves. The results can also be exported in Excel and CSV format. The integration of the CCD method into a web platform reduces the time required for experimental data processing, facilitates the interpretation of the results, and provides researchers with a modern and accessible tool for the design and response surface modelling of bioactive formulations intended for dermo-active textiles.*

Keywords: *O/W emulsion, rosemary essential oil, response surface methodology, emulsion stability*

EFFECT OF TEXTILE PRETREATMENTS ON FTIR-DERIVED STRUCTURAL INDICES OF PERIODATE OXIDISED COTTON FABRICS

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Abstract. *The present study investigates the influence of textile pretreatments on the supramolecular structural changes induced by selective sodium periodate oxidation of cotton fabrics using ATR-FTIR-derived structural indices. Cotton fabrics subjected to alkali scouring (S), hydrogen peroxide bleaching (B), and combined scouring–bleaching (SB) were oxidised under controlled conditions using sodium periodate solutions of 0.04 and 0.08 mol L^{-1} at 30 and 40 °C for 4 h. The structural response of cellulose was evaluated through the Lateral Order Index (LOI), Total Crystallinity Index (TCI), and Hydrogen Bond Intensity (HBI), calculated from ATR-FTIR spectra. The results revealed that periodate oxidation produced distinct structural responses depending on the applied pretreatment. For the S and B series, LOI decreased by up to 13.8% and 12.7%, respectively, indicating a reduction in the lateral order of cellulose chains. In contrast, TCI exhibited only minor variations (−4.3% to +4.2%), suggesting limited changes in the overall crystalline structure. The most pronounced modifications were observed for HBI, which increased by up to 11.1% for the S series and 16.5% for the B series, reflecting significant reorganisation of the hydrogen-bonding network. The SB series exhibited a distinct structural response, characterised by moderate LOI variations, marked increases in TCI (up to 13%), and slight decreases in HBI, suggesting a different supramolecular rearrangement pathway. Overall, the findings demonstrate that ATR-FTIR structural indices provide valuable insight into cellulose reorganisation and highlight the critical role of textile pretreatments in determining the structural response of cotton fabrics to periodate oxidation.*

Keywords: *cellulose; dialdehyde cellulose; supramolecular organisation; crystallinity; hydrogen bonding; textile pretreatment*

TEXTILE SUBSTRATE FIXATION ON THE BUILD PLATE FOR STABLE FDM PRINTING

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***Abstract**. Direct fused deposition modeling (FDM) on textile substrates offers considerable potential for the development of customized garments, wearable devices, protective components, decorative structures, and locally reinforced or functional textile products. Despite the growing number of studies concerning polymer–textile adhesion, printing parameters, and end-use applications, the method used to secure the textile to the build plate is rarely described in sufficient detail. Successful transfer from laboratory demonstrations to industrial applications requires more than adequate adhesion between the deposited polymer and the textile surface. The substrate must also remain flat, adequately supported and immobile throughout the printing process. This apparently minor omission limits experimental reproducibility and becomes particularly critical when printing tall or slender structures, where even small substrate movements may induce oscillation, dimensional deviations, interlayer misalignment, or complete print failure. This study compared mechanical clamping, direct double-sided adhesive fixation, and a hybrid adhesive system using a plain-woven cotton fabric and PLA. For each method, three cylindrical specimens with a diameter of 15 mm and a height of 50 mm were printed, while build instability, failure height, removal behavior, and visible adhesive transfer were assessed. Mechanical clamping produced visible instability at 20.3 ± 1.5 mm and complete failure at 24.3 ± 1.5 mm. Both adhesive-based methods enabled all specimens to reach 50 mm without visible instability. However, direct double-sided adhesive fixation caused visible adhesive transfer to the fabric reverse side, whereas the hybrid method allowed removal without visible transfer. The same hybrid fixation surface remained functional over 20 consecutive print–removal cycles. In a separate validation, three specimens were successfully printed to 250 mm without textile displacement, nozzle collision, or loss of deposition. Under the tested conditions, the hybrid method provided the best balance of build stability, textile cleanliness, localized application, and repeated-use capability.*

***Keywords:** 3D printing on textiles, fused deposition modeling, direct polymer deposition, flexible textile substrates, process stability, textile–polymer integration*

CHEMICAL SAFETY IN TEXTILE PROCESSING: HAZARDOUS SUBSTANCES, SAFER ALTERNATIVES AND MATERIAL DEVELOPMENT – A REVIEW

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Abstract. *Chemical safety in textile processing depends on the substances used during pretreatment, dyeing, printing and functional finishing, as well as on their potential to remain in the final material or to be released during use. This review examines major categories of hazardous substances associated with textile processing and evaluates current approaches for reducing or replacing them while preserving material performance. Particular attention is given to aromatic amines derived from certain azo dyes, formaldehyde, phthalates, per- and polyfluoroalkyl substances (PFAS), nonylphenol ethoxylates, and selected substances used in antimicrobial and flame-retardant treatments. The distinction between intrinsic hazard and exposure-dependent risk is considered together with the principal European regulatory instruments relevant to textile chemical safety. Safer alternatives and emerging processing strategies are discussed, including natural dyes and biomordants, formaldehyde-free crosslinking systems, PFAS-free water-repellent finishes, alternative antimicrobial and flame-retardant treatments, enzymatic processes and plasma technologies. The available evidence indicates that substitution should not be based solely on removing a hazardous substance or choosing a naturally derived compound. Safety, functional performance, treatment durability, resource demand and industrial applicability need to be assessed together to avoid regrettable substitution or transfer of impacts to other processing stages. Integrating these criteria within a Safe and Sustainable by Design approach can support the development of safer textile processes and functional materials with performance appropriate to their intended use.*

Keywords: *natural dyes; biomordants; functional finishing; green chemistry; Safe and Sustainable by Design (SSbD)*

THE VISUAL GRAMMAR OF FOLK DRESS IN MOLDAVIA: MOTIFS, COLOUR AND ETHNOGRAPHIC CONTEXT

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Abstract*. This paper examines ornamental motifs, colour and the organisation of decoration in folk dress from the historical region of Moldavia. It aims to describe a visual grammar and assess the limits of interpreting ornamentation in relation to information about the wearer. The study uses qualitative document analysis. The corpus comprises five museum records of women's shirts from Botoșani and Vrancea. Four garments are dated between the second half of the nineteenth century and 1928. The date of one garment is unspecified. The records are supplemented by regional ethnographic literature. The comparison examines motif shapes, documented colours and decoration placement. The findings highlight the combination of geometric and plant motifs and their distribution within distinct ornamental fields. Motifs are treated as elements of a visual vocabulary. Their repetition, alternation and placement are analysed as compositional regularities. These regularities do not constitute validated rules for the entire region. The available data do not support automatic identification of age, marital status or socioeconomic status from a motif or colour. Interpretation requires independent information about the garment and its context of use. The study proposes a descriptive framework for documenting ornamentation. Digitisation and applications in design and manufacturing are future directions that have not been implemented or validated in this research.*

Keywords: *Moldavia; folk dress; traditional motifs; colour; visual grammar; document analysis*

COMPARATIVE STRUCTURAL EFFICIENCY AND WARP YARN CONSUMPTION ANALYSIS OF HIGH-TENACITY POLYESTER SAFETY-BELT WEBBING

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Abstract. *Woven safety-belt webbings are narrow technical fabrics whose mechanical performance depends jointly on the properties of the constituent yarns and on the structural configuration of the fabric. This paper presents a comparative structural analysis of two high-tenacity (HT) polyester webbing constructions, denoted V1 and V2, based on experimental data concerning yarn linear density, breaking force and elongation, averaged over ten determinations for each yarn type. For each construction, a theoretical warp-yarn consumption indicator, the theoretical cumulative breaking force of the warp assembly and a structural efficiency coefficient were calculated to assess the extent to which the individual breaking capacity of the warp yarns is transferred to the finished webbing. Configuration V2, produced with fewer but individually stronger warp ends (270 ends, 1686.75 dtex and 136.63 N per yarn), achieved a webbing breaking strength of 2870 daN with a theoretical warp-yarn consumption of 45.54 g/m. Compared with V1, which reached 2850 daN with 400 warp ends of 1198.00 dtex and a theoretical consumption of 47.92 g/m, V2 reduced the theoretical material consumption by 4.96%. Its structural efficiency coefficient, $\eta s = 0.778$, was 18.6% higher than that of V1, $\eta s = 0.656$, indicating a more effective conversion of the theoretical warp breaking capacity into the actual breaking strength of the webbing. A discrete sensitivity analysis based on the V2 parameters evaluated seven configurations containing between 260 and 280 warp ends. The model estimated that 269 warp ends represent the theoretical minimum required to exceed the target breaking force of 28,500 N, while the experimentally tested configuration contained 270 ends. The results show that safety-belt webbing design should not rely solely on yarn linear density or on the number of warp ends, but should consider the relationship between the number of ends, their individual breaking force and the resulting structural efficiency, together with the relevant strength, elongation, thickness and width requirements. The proposed indicators and the discrete estimation model provide a transparent, low-cost preliminary tool for comparing and selecting webbing constructions prior to full experimental validation. Supplementary analysis of the individual yarn data gives warp breaking forces of 108.68 ± 3.48 N and 136.63 ± 7.43 N (mean ± SD), with an exploratory Holm-adjusted $p < 0.001$. Recalculated raw-data means update V1 warp linear density to 1198.60 dtex and the theoretical mass reduction to 5.01%. The 20 daN webbing difference remains descriptive, and the 269-end configuration is an untested constant-efficiency estimate rather than a demonstrated optimum.*

Keywords: *safety-belt webbing; high-tenacity polyester; warp yarn linear density; structural efficiency; breaking strength; warp material-use optimization*

PROPERTIES OF ANTISTATIC WOVEN FABRICS PRODUCED WITH RING-SPUN AND ROTOR-SPUN COTTON/STAINLESS STEEL WEFT YARNS

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Abstract*. Antistatic woven fabrics are widely used in protective clothing and technical textile applications to prevent the accumulation of electrostatic charges, which may compromise both user safety and the performance of sensitive electronic equipment. The effectiveness and durability of these fabrics are strongly influenced by the characteristics of the conductive yarns incorporated into their structure. This study investigates the influence of the spinning system of conductive weft yarns on the properties of antistatic woven fabrics. Two fabric variants with identical structural parameters were produced, differing only in the type of cotton/stainless steel (84%/16%) weft yarn: ring-spun and rotor-spun. The fabrics were evaluated in terms of tensile properties, air permeability, abrasion resistance, and surface resistivity before and after 3500 abrasion cycles. The results showed that the fabric containing ring-spun weft yarns exhibited higher breaking force in the weft direction and lower surface resistivity than the fabric produced with rotor-spun yarns, indicating superior electrical conductivity. In contrast, the fabric incorporating rotor-spun weft yarns showed higher breaking elongation, greater air permeability, and improved abrasion resistance. Abrasion increased the surface resistivity of both fabrics, particularly in the warp direction, owing to the disruption of electrical contacts between adjacent conductive weft yarns. However, the conductive network along the weft direction was largely preserved. The results demonstrate that the spinning system influences both the functional and mechanical performance of antistatic woven fabrics. Ring-spun yarns provide enhanced electrical conductivity, whereas rotor-spun yarns improve abrasion resistance and air permeability.*

Keywords*: antistatic woven fabrics, cotton/stainless steel yarns, ring-spun vs. rotor-spun yarn, surface resistivity, abrasion resistance, air permeability*

EXPERIMENTAL INVESTIGATION INTO THE TENSILE BEHAVIOR OF HIGH-STRENGTH POLYETHYLENE FISHING LINES

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Abstract. *Research on polyethylene fishing lines remains relatively limited, with most studies focusing on the mechanical characterization of polyethylene fibers, monofilaments, and fishing net yarns rather than on finished braided fishing lines. Existing studies have demonstrated the superior tensile performance of polyethylene-based materials; however, systematic investigations into the tensile properties and failure behaviour of polyethylene fishing lines are still scarce, highlighting the need for further experimental research. Therefore, this study investigates the physicomechanical behavior of three variants of polyethylene braided fishing lines with the same nominal rating, PE 1.0, according to the Japanese fishing line classification system. The investigated variants differ in the number and fineness of the multifilament yarns forming the braided structure, resulting in distinct geometric configurations, while maintaining comparable overall characteristics. The tensile analysis revealed that all three braided lines exhibit a similar deformation pattern, characterized by an initial linear region followed by a progressively increasing nonlinear deformation zone. Differences in the slope of the stress-strain response indicate variations in apparent stiffness, which can be attributed to differences in braid architecture, including filament distribution and alignment, as well as interfilament friction effects. The braided line composed of eight multifilament yarns exhibited higher tenacity, whereas the variant composed of four multifilament yarns demonstrated greater deformability under tensile loading. Further research is required to clarify the influence of braid architecture on the tensile behaviour of polyethylene fishing lines produced from different raw materials and structural configurations.*

Keywords: *braiding, polyethylene, yarns, tenacity, elongation*

THE CURRENT STATE OF RESEARCH ON UV-PROTECTIVE TEXTILE STRUCTURES FOR WORKWEAR: A REVIEW

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Abstract. *Ultraviolet (UV) radiation is a major occupational hazard for workers who spend prolonged periods outdoors, making UV-protective clothing an essential component of preventive strategies. This review examines the current state of research on textile structures designed for UV protection, with emphasis on fibre composition, fabric architecture, finishing technologies, and performance evaluation. The literature shows that the ultraviolet protection factor (UPF) is strongly influenced by structural parameters such as cover factor, porosity, thickness, mass per unit area, and yarn arrangement, as well as by fibre type and colour. Synthetic fibres, particularly polyester, generally provide higher intrinsic UV resistance than untreated natural fibres, while compact woven structures and dense knitted fabrics, such as interlock constructions, improve shielding performance. At the same time, real-world conditions such as stretching, moisture, repeated washing, and mechanical wear can significantly reduce protection levels, highlighting the need for more realistic testing protocols. Recent advances in UV absorbers, reflective coatings, and nanoparticle-based finishes, especially ZnO and TiO2 systems, offer promising routes to improving protection while preserving thermophysiological comfort. The review also underlines the importance of balancing UV shielding, breathability, durability, and wearability, particularly for workwear used in harsh outdoor environments. The contribution of this paper lies in synthesising the principal material, structural, and functional factors that govern UV protection in workwear textiles and in identifying future research directions towards more efficient and durable protective solutions.*

Keywords: *ultraviolet protection, workwear, UPF, functional textiles, textile structures, review*

SECTION 3:
SMART TEXTILES, MEDICAL TEXTILES, COMPOSI

SMART TEXTILES AND WEARABLE ELECTRONICS DEVICES: CHALLENGES AND INTEGRATION STRATEGIES

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Abstract. *The integration of wearable electronics into conventional textiles offers transformative potential but faces critical challenges, including mechanical mismatch, insufficient power supply, poor washability, and lack of standardized interconnection methods. This talk presents advanced strategies to overcome these bottlenecks, with a primary focus on textile-based piezoelectric and triboelectric nanogenerators (PENGs and TENGs) for sustainable biomechanical energy harvesting. We examine fabrication approaches across multiple textile architectures—from nanocomposite fibers and yarns to woven/knitted fabrics and electrospun nanofibrous webs—highlighting how each design influences electrical output and wearability. Special attention is given to incorporating advanced nanomaterials, such as carbon nanotubes and conductive polymer nanofibers, to enhance device performance while maintaining flexibility and breathability. Additionally, scalable manufacturing, encapsulation, and circuit-embedding protocols are discussed to ensure mechanical robustness. This work provides a comprehensive roadmap from material design to system integration, paving the way for durable, commercially viable e-textiles in healthcare monitoring, human-machine interaction, and beyond.*

Keywords: *smart textiles, wearable electronics, nanogenerators, piezoelectricity, triboelectricity, fibrous materials, integration challenge*

DESIGN AND FABRICATION OF HIGH-STABILITY TEXTILE STRAIN SENSORS FOR SMART COMPRESSION GARMENTS

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Abstract. *Compression garments are widely used in sports, rehabilitation, and medical applications where controlled pressure and reliable monitoring are important. Although flexible strain sensors have improved compatibility with soft textile substrates, maintaining continuous conductivity and functional stability during prolonged deformation, laundering, and wear remains challenging because conductive pathways can be disrupted by particle displacement, microcracking, adhesion failure, and nonuniform deposition on rough fabrics. This study developed textile-based flexible strain sensors with silver-based conductive ink and systematically examined the effects of sensor geometry, fabrication technique, and coating level. Two sensor designs were produced on an 85% polyester/15% Lycra warp-knitted substrate using knife coating (technique K) and direct ink writing (DIW; technique P), each at two coating levels. Following air drying and thermal curing, the sensors were characterized for electrical resistance, strain response at 10%, 20%, and 30% strain, bending at 90° and 180°, washing durability, and abrasion resistance up to 3500 cycles. The most stable configuration was subsequently integrated into compression leggings at the knee and assessed at bending angles from 30° to 90°. Overall, the second coating level improved conductivity and durability, while design B, a crisscross geometry with more connecting points and shorter distances between endpoints, consistently provided greater electrical and mechanical stability. The best overall performance was obtained with design B fabricated by knife coating at level 2. For this configuration, resistance was 0.96 Ω, the R'/R response increased from 0.9 at 10% strain to 1.5 at 30% strain, washing resistance increased from 0.9 Ω to 2.06 Ω after five cycles, and abrasion resistance increased from 0.9 Ω to 1.18 Ω after 3500 cycles. Knife coating outperformed DIW because the rough, stretchable knitted surface disturbed nozzle movement and caused uneven ink deposition during DIW printing. In the wear-on trial, the integrated sensor showed resistance changes from 1.34 to 2.36 Ω with increasing knee bending. These findings demonstrate that sensor geometry, coating thickness, and deposition uniformity are critical to stable textile strain sensing. Future work should investigate protective or functional finishes and additional coating techniques to further improve mechanical performance and washing stability.*

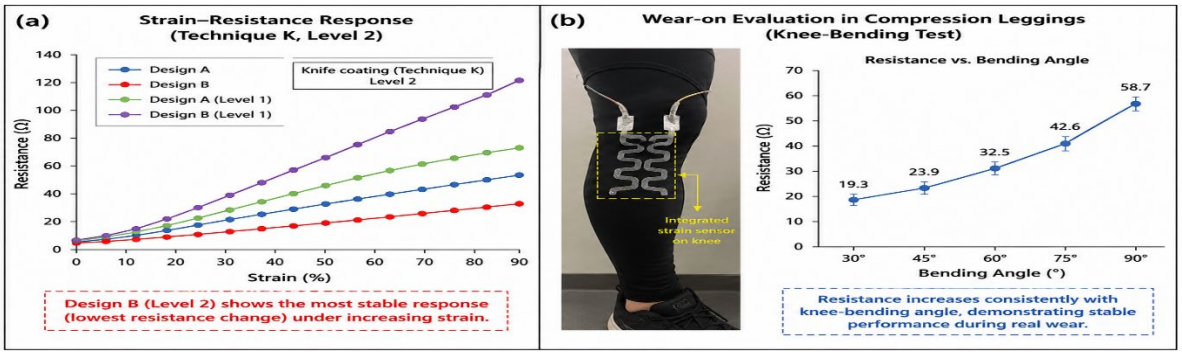


Figure 1. Performance of the developed textile sensor, a) strain-resistance response of Technique K at level 2, b) wear-on evaluation of sensor integrated into compression legging at different knee bend angles

Keywords:*textile-based sensors, strain sensors, knife coating, DIW printing, smart compression garments, conductive ink*

Acknowledgement: *We thank the lab staff for their help during sample development and testing.*

OPTIMIZATION OF CONDUCTIVE COATING PROCESSES FOR AGRICULTURAL WASTE-DERIVED TEXTILE STRUCTURES

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Abstract. *The increasing demand for wearable electronics and smart textiles has stimulated research on sustainable conductive textile materials. Agricultural waste-derived textile structures have attracted considerable attention due to their renewability, low environmental impact, and potential contribution to the circular bioeconomy. However, their inherently insulating nature limits their direct application in electronic textiles, highlighting the need for conductive coating technologies that provide stable electrical performance while preserving textile integrity.This study aims to optimize conductive coating processes for agricultural waste-derived textile structures intended for wearable electronic applications. Three approaches, namely graphene coating, hybrid graphene/copper coating, and electroless copper plating, were comparatively investigated in terms of coating quality, electrical conductivity, coating continuity, and applicability to textile substrates. Optimization studies were primarily conducted using poplar-based textile structures and subsequently validated on other agricultural waste-derived textiles. Although graphene-based coatings initially exhibited electrical conductivity, a significant conductivity loss occurred after drying due to the insulating polyurethane binder matrix. Therefore, electroless copper plating was selected as the most effective strategy. Its processing parameters, including substrate-specific pretreatment, sensitization, activation, plating bath composition, and plating duration, were systematically optimized. The optimized process produced continuous and homogeneous copper coatings with a minimum electrical resistance of approximately 0.30 Ω. SEM observations confirmed uniform copper deposition while preserving the original fibrous morphology. The conductive textiles maintained electrical functionality after repeated laundering, exhibiting resistance values below 10 Ω after five washing cycles, and retained conductive pathways during abrasion testing. The optimized electroless copper plating process was also successfully transferred to conventional woven and knitted fabrics without modification, demonstrating its scalability and industrial applicability. Furthermore, Capacitive pressure sensing experiments produced stable and repeatable capacitance responses of approximately 9.8–12.0 pF during 500 consecutive loading–unloading cycles, with an average force-normalized sensitivity of approximately 0.60 pF/N over the 0–3.8 N range and a response time of approximately 60 ms, between 0.1 and 3.8 N during 500 consecutive loading–unloading cycles. Overall, this study presents an effective and scalable approach for converting agricultural waste-derived textile structures into conductive materials for wearable electronics, flexible sensing platforms, and smart textile applications. Future work will focus on improving long-term environmental stability and integrating the developed conductive textiles into practical wearable electronic devices.*

Keywords: *wearable sensors, smart fabrics, electroless metallization, circular bioeconomy, flexible electronics*

LUFFA AEGYPTİACA FİBER-REİNFORCED PLA BİOCOMPOSİTES: FABRİCATİON AND MECHANİCAL CHARACTERİZATİON

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Abstract. *The growing interest in sustainable materials has encouraged the development of biodegradable composites reinforced with renewable natural fibers. Among the available lignocellulosic resources, Luffa aegyptiaca has emerged as a promising reinforcement due to its naturally interconnected three-dimensional fibrous network, low density, high porosity, biodegradability, renewability, and favorable specific mechanical properties. Unlike many conventional natural fibers, luffa's unique cellular architecture provides an efficient load-bearing framework while reducing the overall weight of composite structures. Furthermore, its abundant availability, low cost, and environmental friendliness make Luffa aegyptiaca an attractive candidate for lightweight green composites for automotive, packaging, construction, and other sustainable engineering applications. In this study, biodegradable green composites reinforced with Luffa aegyptiaca fiber mats were developed using polylactic acid (PLA) as the matrix material. To improve interfacial bonding and structural consolidation, bicomponent PLA fibers with a sheath–core structure were incorporated as a thermal bonding agent, eliminating the need for additional chemical adhesives. Composite laminates containing single-, double-, and triple-layer luffa reinforcements were fabricated by hot pressing under controlled processing conditions. The mechanical and acoustic performance of the developed composites was evaluated according to relevant ISO standards to investigate the influence of reinforcement layer content on their structural behavior. The results demonstrated that increasing the reinforcement content significantly enhanced the mechanical properties of the composites, with the triple-layer configuration achieving an ultimate tensile strength of 25 MPa. Furthermore, acoustic evaluations in the 500–4000 Hz frequency range revealed that the Sound Transmission Loss (STL) improved proportionally with the layer count, providing superior sound insulation particularly in the higher frequency bands (2000–4000 Hz). These findings confirm that Luffa aegyptiaca/PLA green composites represent a sustainable, lightweight, and high-performance alternative for future bio-based engineering applications requiring both structural integrity and acoustic attenuation.*

Keywords: *luffa aegyptiaca; polylactic acid (PLA); green composites; biodegradable composites; natural fiber reinforcement; mechanical properties; hot pressing*

EVALUATING CHROME-FREE LEATHER AS A SUSTAINABLE SUBSTRATE FOR SMART APPLICATIONS

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Abstract*. The increasing interest in sustainable materials has driven the development of conductive leather based on more environmentally responsible tanning processes. Chrome-free leather offers important advantages for products intended for children, individuals with sensitive skin or chromium allergies, as well as for sustainable smart leather products. The aim of this study was to evaluate the influence of the leather substrate on the electrical performance of conductive leather and to assess the feasibility of using chrome-free leather as an alternative substrate for smart applications. The chrome-free leather was treated using a single in-situ polymerization method with pyrrole and was compared with conventionally chrome-tanned leather processed using the same procedure. The polymerization process resulted in the formation of a polypyrrole (PPy) coating on the leather surface while maintaining the flexibility and characteristics of the leather. The electrical properties were evaluated by the sheet resistance using the Van der Pauw method. The obtained values, varying 80.2 - 216.08 Ω/□., were lower than 289-307 Ω/□. reported for chrome-tanned leather treated by the same polymerization process, which was reported in the cited previous study. The results show that chrome-free leather can be used for conductive leather production, providing electrical properties comparable to conductive conventional chrome-tanned leather, while offering advantages related to sustainability and skin contact applications. This approach provides new possibilities for smart leather applications that balance functional performance and material safety.*

Keywords: *chrome-free leather; conductive leather; polypyrrole; in-situ polymerization; electrical properties; sustainable leather*

MULTIFUNCTIONAL JANUS BILAYER COATED POLYESTER FABRIC FOR PERSONAL THERMAL MANAGEMENT

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Abstract. *Passive radiative heating (PRH) textiles hold great promise for ensuring personal thermal comfort by regulating radiant energy without an additional energy source. However, current PRH textiles have limitations in functionality and also adaptability to dynamic and complex climate changes with a single energy source. Recently, not only efficient and safe heating performance but also multifunctionality including moisture management, comfort, and fire safety has been highly demanded for heating textiles. Herein, a multifunctional textile with dual-mode synergistic heating capability, as well as moisture management and delayed flame spread was developed by spray coating a Janus bilayer on a commercial knitted polyester (PES) fabric. The Janus bilayer coating combined a hydrophilic layer with reduced graphene oxide (rGO) particles on the upper side and a porous thermoplastic polyurethane (TPU)-carbon nanotube (CNT) composite on the other side, achieving solar light absorption and higher infrared reflectivity that directs body heat towards the skin's surface. Indirectly solar and radiative heating performances were evaluated by measuring solar absorbance and infrared reflectivity using UV-VIS-NIR and FT-IR spectrometers, respectively. Also, solar-radiative dual-mode synergistic heating capability was characterized under simulated indoor condition using a self-designed hotplate system including sun simulator, as well as outdoor real-life conditions. The Janus bilayer coating achieved an average solar absorbance of 69.88% on the hydrophilic layer and a mid-infrared reflectance of 96.03% on the porous TPU-CNT composite layer. Furthermore, compared with uncoated PES, Janus bilayer coated ones demonstrated a PRH performance of 2.04°C and solar-radiative dual-mode synergistic heating capability of 14.65°C under simulated condition with 1000 W/m^2 solar intensity. Under real outdoor conditions, this fabric also can achieve a temperature increase of 28.1°C under both cloudy and clear sky condition. Concurrently, this Janus coated fabric exhibited asymmetric wettability, a delayed flame spread (burning time increased from 15.60 s to 21.47 s), and outstanding air and water vapour permeability, thereby combining efficient thermal management with enhanced burning behaviour. This design overcomes the energy limitations of conventional single-mode heating textiles, and offers a simple spray-coating route to multifunctional personal thermal management textiles.*

Keywords: *passive radiative heating, solar heating, janus coating, flammability, moisture management*

THE EFFECT OF JUTE FIBER SURFACE MODIFICATION ON THE MECHANICAL BEHAVIOR OF JUTE/POLYLACTIC ACID COMPOSITES

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***Abstract**. In recent years, green Jute/Polylactic Acid (PLA) composites have attracted attention for their low cost and biodegradability, although poor mechanical properties limit their structural use. Prior studies have explored various fiber surface treatments but no systematic comparison of NaOH, Silane, and Sodium Acetate (NaAc) under controlled conditions exists. This study investigates the effect of these three chemical agents on Jute yarn and resultant Jute/PLA composite properties. Yarn was treated at different concentrations and durations; mechanical changes were evaluated via tensile testing. Based on separate screening of treatment concentration and duration, the following candidate conditions were selected for composite fabrication: 4% NaOH for 6 h, 3% silane for 6 h, and 20% NaAc for 24 h. Four-layer [90/0/90/0] composites were then fabricated by hot-press molding, and their mechanical properties were evaluated. Surface modification significantly improved composite performance. NaAc treatment yielded the highest tensile strength (59 MPa) and modulus (1.5 GPa) as well as flexural strength (107.7 MPa). NaOH gave the greatest flexural modulus (5.68 GPa). Overall, NaAc provided a favorable combination of mechanical performance and environmental compatibility.*

***Keywords:** jute fibers, polylactic acid, green composites, chemical surface modification, mechanical properties*

COMPARATIVE ANALYSIS OF EMBROIDERY TECHNIQUES FOR CONDUCTIVE TEXTILE CIRCUITS

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Abstract*. The increasing demand for wearable electronics, smart garments, and multifunctional textile systems has accelerated the development of manufacturing technologies capable of integrating electrical functionality directly into textile substrates. Among the available fabrication methods, industrial embroidery has emerged as a promising approach due to its compatibility with conventional textile production, geometric flexibility, repeatability, and ability to produce complex conductive structures while preserving the flexibility of the textile substrate. Despite the progress achieved in recent years, the optimisation of embroidery techniques for conductive circuit fabrication remains challenging, as the functional behaviour of embroidered circuits is closely related to stitch architecture, conductive yarn characteristics, and manufacturing parameters. This study presents a comparative analysis of representative embroidery techniques for the fabrication of multifunctional textile circuits, with particular emphasis on conventional conductive-yarn embroidery, multilayer embroidered architectures, and controlled conductor placement techniques such as Tailored Wire Placement (TWP). Based on the relationships reported in the literature, particular attention is given to the potential influence of embroidery parameters—including stitch density, stitch length, thread tension, embroidery direction, number of conductive layers, and conductive material routing—on electrical resistance, dimensional stability, flexibility, durability, and manufacturing performance. The capabilities of an industrial dual-head ZSK embroidery system are considered in relation to the implementation of different conductive architectures. As a preliminary technological demonstration, a conductive structure with variable geometry is produced by depositing a stainless-steel-fibre-based conductive yarn as an additional material using the technical embroidery head. The study proposes a systematic framework for evaluating industrial embroidery techniques based on three interconnected groups of variables: conductive material characteristics, embroidery architecture, and manufacturing process parameters. These variables are discussed in relation to the electrical, mechanical, and technological requirements of multifunctional textile circuits. The proposed approach provides a basis for the systematic development of embroidered electronics and for future experimental optimisation of industrial embroidery processes for smart textile applications.*

Keywords: *e-textiles, conductive embroidery, textile circuits, Tailored Wire Placement, conductive thread*

INVESTIGATION OF WILLOW–POPLAR–HEMP FIBER HYBRID REINFORCEMENTS FOR COMPOSITE MATERIALS IN UPHOLSTERED FURNITURE APPLICATIONS

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Abstract*. The development of sustainable composite materials from renewable lignocellulosic fibers has attracted increasing attention as an environmentally friendly alternative to conventional wood-based panels used in the furniture industry. Although hemp has been extensively investigated as a reinforcement for polymer composites, the potential of fast-growing woody species such as willow and poplar, used individually or in hybrid fiber systems, remains insufficiently explored. This study evaluated the suitability of willow and poplar fibers, with and without hemp fibers, for the manufacture of environmentally friendly composite materials using the airlaying–thermobonding technology followed by hot pressing. Two thermobonded nonwoven formulations containing 60 wt.% reinforcing fibers and 40 wt.% polymer matrix were produced: a willow/poplar composite (30W/30P) and a willow/poplar/hemp hybrid composite (20W/20P/20H). The tensile strength, elongation at break, and flexural strength of the composites were determined and compared with those of oriented strand board (OSB). Both composite formulations exhibited higher tensile strength in both directions and higher flexural strength in the transverse direction than OSB. The results demonstrate that willow- and poplar-reinforced composites produced by hot pressing of thermobonded nonwovens represent a promising sustainable alternative to OSB for furniture applications. Since the incorporation of hemp fibers did not significantly improve the mechanical performance, future research should focus on optimizing fiber composition and processing parameters, as well as evaluating the durability and long-term performance of these bio-based composites.*

Keywords: *hybrid composites, thermobonded nonwoven, bio-based reinforcement, polypropylene matrix, mechanical properties*

FROM PREDICTION TO PRECISION: THE INTEGRATED PRECISION NEONATAL CARE FRAMEWORK (IPNCF) FOR PRETERM BIRTH MANAGEMENT

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Abstract*. Preterm birth remains a major global health challenge despite advances in prenatal risk prediction, maternal–fetal monitoring, neonatal artificial intelligence (AI) and developmental care. However, these capabilities are predominantly developed within separate technological and clinical domains, limiting functional continuity between predictive prenatal intelligence and individualized neonatal intervention. This study proposes the* ***Integrated Precision Neonatal Care Framework (IPNCF)****, a clinician-supervised, closed-loop architecture designed to connect antenatal risk stratification and continuous monitoring with prenatal-to-NICU information continuity, neonatal decision support, individualized developmental and positioning care, family participation and a functional textile interface. A structured conceptual synthesis of representative evidence was conducted across prenatal prediction, wearable monitoring, neonatal AI and informatics, developmental positioning, family-integrated care and functional textile solutions. Functional comparison of existing approaches identified substantial domain-specific progress but no approach within the reviewed corpus that explicitly integrated all components into a continuous information-to-action pathway. IPNCF addresses this gap through five interconnected stages: prenatal risk stratification; continuous maternal–fetal monitoring; clinical decision support and prenatal-to-NICU handover; individualized neonatal developmental care; and outcome assessment with adaptive feedback. A multidimensional validation framework is additionally proposed to evaluate predictive performance, monitoring reliability, information continuity, decision support, developmental care, family integration, safety and implementation. IPNCF shifts the analytical focus from isolated algorithm performance to* ***pathway performance****, providing a testable architecture for future prospective evaluation of integrated precision care for preterm infants.*

Keywords: *preterm birth, precision neonatal care, artificial intelligence, maternal–fetal monitoring, developmental care, functional textiles*

ANALYSIS OF MULTILAYER TECHNICAL EMBROIDERY TECHNIQUES

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Abstract*. The development of technical embroidery using industrial embroidery machines has expanded its role from decorative applications to the manufacturing of functional textile structures. Recent advances in multilayer embroidery and Tailored Fibre Placement (TFP) have demonstrated the potential of embroidery technologies for producing textile architectures with controlled fibre arrangements. Within this context, the number of deposited layers, their orientation, and the fixing stitches represent relevant aspects of structural design. This study analyses the influence of embroidery layer count and deposition strategy on the formation of multilayer textile structures. The analysis combines findings reported in recent literature with preliminary observations of configurations produced using an industrial embroidery machine from ZSK. Jute cord with a nominal diameter of 2 mm is deposited on a nonwoven substrate. Single-layer and multilayer configurations are considered, with different deposition directions and stacking sequences selected to illustrate variations in the resulting textile architecture. The digital embroidery layout and the manufactured sample provide complementary information on the prescribed paths and the visible organization of the assembly. The discussion focuses on the relationship between deposition strategy, cord overlap, and stitch-based fixation. The comparison addresses how changes in the directional arrangement modify the geometry of intersections, including configurations with the same layer count. Visible features at sector boundaries and in the central convergence region are also considered in relation to the programmed paths. These observations are discussed alongside findings from studies on technical embroidery and TFP preforms, including the reported influence of stitching parameters on local fibre arrangement. The research aims to identify design considerations for the fabrication of multilayer textile components using industrial embroidery technologies. The findings highlight the need to describe layer count together with deposition orientation, stacking order, and local path routing. The outcomes provide a basis for further research in technical textiles and composite reinforcements, where controlled fibre arrangements are required.*

Keywords: *technical embroidery, multilayer embroidery, cord placement, Tailored Fibre Placement*

STRUCTURAL OPTIMIZATION OF LOW-AREAL-DENSITY WOVEN FABRICS FOR MILITARY PROTECTIVE GEAR: BALANCING TENSILE AND TEAR RESISTANCE

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Abstract. *Lightweight outer shells for military tactical vests require an optimal balance of tensile strength and tear resistance to endure severe field conditions. Achieving high mechanical performance under strict mass constraints (~180 g/m²) presents a structural trade-off due to opposing yarn-mobility requirements: tight structural jamming optimizes tensile load bearing, whereas open yarn mobility promotes tear propagation resistance via yarn bundling. This study presents a comparative analysis of nine distinct woven fabric variants engineered for military protective vest outer shells, which carry the ballistick pack. Holding the warp system constant across all variants, structural design was systematically altered by varying weft linear density (83–333 dTex), weft density (18–60 yarns/cm), and float length (using 2/2, 3/3, 4/4, and 2/4 Basket weave structures), while maintaining areal mass between 179 and 188 g/m². Standardized testing according to ISO 13934-1 (strip tensile) and ISO 13937-3 (wing tear) evaluated performance against military benchmarks: ≥1300 N warp, ≥ 800N weft tensile strength, and ≥100N warp, ≥80 N weft tear resistance. Experimental results demonstrated significant performance variations across variants. Warp tensile strength ranged from 1500 to 1819 N (+21.3% relative variation), comfortably exceeding the 1300 N threshold in 100% of samples. Weft tensile strength spanned 750 to 1100 N (+46.7% variation), with 88.9% of samples clearing the 800 N mark. Crucially, weave float length and weft linear density governed tear performance: warp tear resistance varied between 76 and 182 N (+139.5% relative increase), while weft tear force exhibited dramatic variation from 36 to 206 N (+472.2% relative increase). Extended floats in Basket 4/4 and 2/4 weaves facilitated controlled yarn displacement and bundling under shear stress, overcoming the tear limitations of tighter Basket 2/2 interlacings. Among all variants, four configurations successfully met all four mechanical thresholds simultaneously, with one of them (Basket 2/4, 333 dTex weft) achieving peak forces of 182 N warp and 206 N weft (+82.0% and +157.5% above requirements). This study provides a quantitative framework for tailoring lightweight woven substrates for defense protective gear.*

Keywords: *tactical vest outer shells, tear resistance, tensile strength, yarn mobility, structural optimization, low-areal-density textiles*

BIOMATERIALS IN MEDICINE: CURRENT USES AND RECENT ADVANCES

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***Abstract**. Biomaterials are natural, synthetic, or hybrid materials designed to interact with biological systems for diagnostic, therapeutic, or regenerative purposes. Owing to their biocompatibility, controlled biodegradability, and mechanical performance, biomaterials have become essential components of modern medical practice, enabling the replacement, repair, or regeneration of damaged tissues and organs while improving patient outcomes. They are widely applied in orthopedics, cardiovascular medicine, dentistry, wound healing, and tissue engineering. This paper provides a comprehensive review of the current applications of biomaterials in medicine and highlights recent technological advances that are shaping the field. Natural biomaterials, including collagen, fibrin, chitosan, alginate, and hyaluronic acid, are discussed alongside synthetic materials such as biodegradable polymers (e.g., polylactic acid, polycaprolactone, and polyglycolic acid), bioactive ceramics, and metallic biomaterials including titanium and stainless steel. Recent developments in nanotechnology, targeted drug delivery systems, additive manufacturing (3D printing), tissue engineering, and neural regeneration are examined, emphasizing their potential to enhance treatment efficacy and promote personalized medicine. The review demonstrates that continuous advances in biomaterial design, manufacturing technologies, and interdisciplinary research are expanding the clinical potential of biomaterials and enabling the development of increasingly functional and patient-specific medical devices and regenerative therapies. Future progress is expected to focus on smart biomaterials, biofabrication technologies, and multifunctional systems capable of responding dynamically to biological environments.*

***Keywords:** biomaterials, biocompatibility, biodegradable materials, tissue engineering, nanotechnology, drug delivery*

SECTION 4:
DIGITAL PRODUCT DEVELOPMENT FOR TCLF INDUSTR

DIGITALIZATION PRACTICES IN ROMANIAN FASHION MANUFACTURING COMPANIES: A FOUR-LEVEL FRAMEWORK FOR POSITIONING COMPANIES IN RELATION TO APPAREL 4.0

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Abstract. *Digitalization is increasingly influencing the development of fashion manufacturing companies by supporting operational efficiency, production flexibility and information management. However, the implementation of digital technologies in individual manufacturing activities does not necessarily indicate an integrated digital production system. This distinction is particularly relevant in the context of the transition toward the Smart Fashion Factory/Apparel 4.0 concept, which requires interconnected processes and coordinated information flows across organizational functions. This paper proposes a four-level analytical framework for describing digitalization practices in fashion manufacturing companies and positioning them in relation to Apparel 4.0. The study adopts a conceptual and descriptive approach, drawing on existing literature concerning Industry 4.0 and digital transformation, together with previously documented qualitative observations of Romanian clothing companies. The proposed framework distinguishes between point-based operational digitalization, product development digitalization, production flow digitalization and integrated digital transformation. These levels describe different configurations of digital technology adoption and process integration rather than mandatory sequential stages or a quantitative maturity scale. The interpretation of documented practices suggests that digitalization in Romanian clothing companies is more evident in individual operations and product development activities, while integration across production flows and management functions remains more limited. The main challenges associated with the transition toward Apparel 4.0 concern interoperability, information exchange, digital competences and organizational coordination, alongside the technological particularities of clothing manufacturing. The proposed framework provides a qualitative basis for interpreting existing digitalization practices and identifying the requirements of more integrated manufacturing systems, without introducing new empirical measurements or claiming quantitative validation.*

Keywords: *industry 4.0; smart fashion factory; digital transformation; conceptual framework; digital integration levels; interoperability*

FUNCTIONAL AND ERGONOMIC ASPECTS OF PERSONAL PROTECTIVE CLOTHING FOR URBAN FARMERS

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Abstract*. Physical work requires specialized protective clothing. These garments must protect users from environmental factors while allowing them to perform tasks and move freely. The garment and the user form a complex system in which the user must be safe and comfortable, expend minimal energy to perform tasks (repetitive or not), and be protected from various possible injuries. Agriculture is a field where personal protective clothing is essential. Designing and producing such garments requires knowledge of textile engineering, ergonomics, sustainability principles, and clothing pattern development solutions. To achieve this goal, the authors examined the evolution of agricultural workwear, the characteristics of urban farming, ergonomic principles, environmental considerations, and trends in functional and sustainable apparel design. Functional requirements for personal protective clothing include repetitive movements, variable working postures, and exposure to multiple environmental conditions. The authors conducted ergonomic observations and surveyed user requirements. Based on their observations and conclusions, the authors proposed various garment types, developed ergonomic patterns, and recommended textile materials to ensure comfort, durability, breathability, and mobility. The authors created and evaluated a physical prototype to validate the design. The findings show that incorporating user-centered design, sustainable materials, and ergonomic principles enhances wearer comfort, functionality, and flexibility while promoting environmentally conscious product development.*

Keywords: *urban agriculture, personal protective clothing, ergonomic design, user-centered design, sustainable product development*

SUSTAINABLE DEVELOPMENT OF MODERN MENSWEAR: ZERO WASTE DESIGN

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***Abstract**. Sustainability has become a key driver of business success. Entrepreneurs must be creative and open-minded to identify and apply a circular business model if they want to enter new markets or attract new customers (and achieve competitiveness in a dynamic market, such as fashionable garments). This shift affects every stage of developing a new model, from inception to delivery. The model path is complex and requires deep knowledge of how to translate customer requirements or needs into technical information, select materials and the proper fabrication technology, and determine the fabrication costs required to produce it. One of the most important issues in the fashion industry is reducing material costs and extending the lifecycle of an item (either garments or other apparel items). In this paper, the authors study and apply a solution that reduces material costs by designing fashionable items with reduced textile waste (zero-waste design for male garments). To achieve this goal, the authors analyzed menswear fashion trends and design solutions (geometric pattern development, modular garment construction, puzzle-layout marker planning) and used these findings to develop a contemporary menswear collection using zero-waste design principles. Integrating zero-waste design principles into garment collection development will help transform the fashion industry into a sustainable one.*

***Keywords:** zero-waste design principle, sustainability, menswear garments, modular garment construction*

20th Romanian Textiles and Leather Conference
Iasi, 05-07 November 2026

COMPREHENSIVE EVALUATION OF 3D VIRTUAL PROTOTYPING OF CORPORATE APPAREL BASED ON AN INTEGRAL COMPLIANCE INDEX

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Abstract. *Modern processes for designing fashion industry products are driving the active adoption of three-dimensional modelling, virtual prototyping, and digital fitting technologies. At the same time, one of the current challenges is to determine the degree of correspondence between the results of 3D simulation and the characteristics of the physical product, since the accuracy of a digital prototype determines the possibility of making well-founded design and technological decisions prior to its manufacture. This is of particular importance in the design of corporate apparel, which is subject to simultaneous aesthetic, ergonomic, functional, structural, and technological requirements. The aim of the study is to develop a methodological approach to the comprehensive assessment of the adequacy of 3D virtual fitting of corporate apparel by determining the degree of correspondence between a digital 3D model and the physical product. The study was conducted within the framework of the international ERASMUS+ 3D4U project, "3D Concepts for Fashion Education in Ukraine", during the implementation of a pilot project for the development of corporate apparel commissioned by a company in the beauty industry. The digital design of a corporate tunic was carried out in the VStitcher (Browzwear) software environment. The research procedure included the development of a design concept, selection of an average female avatar, development of a set of 2D patterns, their positioning and digital assembly on the surface of the 3D avatar, simulation and virtual fitting, adjustment of structural parameters, export and 1:1 scale printing of the patterns, material cutting, and manufacture of a physical prototype of the corporate tunic. To objectify the comparative analysis of the digital and physical prototypes, a system of indicators was proposed, structured into five functional groups: geometric (G), structural (K), visual (V), fit (P), and technological (T) compliance. Geometric compliance was proposed to be determined based on the absolute and relative deviations of the principal linear parameters of the digital model and the physical product. Structural compliance was assessed according to the degree of preservation of the shape of garment components, the position of the shoulder line, armhole, waist and hip lines, fastening or wrap-over construction, and structural divisions. Visual assessment involves comparing the digital and physical prototypes in three views – front, side, and back – using indicators of silhouette, proportions, garment length, shape and position of sleeves, structural lines, and the characteristics of draping and wrinkle formation. For fit assessment, a zonal approach was proposed, distinguishing six control areas: the shoulder area, armhole and sleeve, bust area, waist, hips, and garment hem. In each zone, the nature of garment-to-body contact, the formation and direction of wrinkles, and displacement of structural lines are analysed. Technological compliance characterises the feasibility of transitioning from a digital prototype to the manufacture of a physical product and takes into account the correctness of pattern export, preservation of scale, suitability for cutting, manufacturability of the design, and the possibility of reproducing the design in production. For the quantitative aggregation of the results, an Integral 3D Model Compliance Index (IC3D) was proposed, formulated as a weighted additive function of five normalized partial coefficients: G, K, V, P, and T. In the absence of a justified differentiation of the relative importance of the components at the initial stage of methodology validation, equal weighting coefficients of 0.20 were proposed for each component. The scientific novelty of the study lies in the development of a comprehensive methodological approach to assessing the adequacy of 3D virtual fitting of corporate apparel, which combines quantitative geometric parameters, expert assessment of structural and visual characteristics, zonal fit analysis, and assessment of the technological reproducibility of the digital construction, followed by the integration of the obtained results into a single normalized indicator, IC3D.*

Keywords: *3D design, VStitcher, virtual fitting, digital garment prototype, Integral 3D Model Compliance Index.*

INDUSTRY 4.0 TECHNOLOGY ADOPTION IN ROMANIAN FASHION INDUSTRY SMES: AN EXPLORATORY ANALYSIS

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Abstract. *Digital transformation has become one of the main directions of development in the garment manufacturing industry, supported by the implementation of Industry 4.0 technologies such as ERP systems, CAD/CAM applications, the Internet of Things (IoT), artificial intelligence (AI), process automation and real-time monitoring solutions. The benefits of these technologies have been widely reported in the literature, including higher productivity, improved product quality and increased manufacturing flexibility. However, the level of implementation varies considerably from one company to another, particularly among small and medium-sized enterprises (SMEs). Most existing studies focus on presenting Industry 4.0 technologies or analysing the benefits and challenges associated with their implementation. Comparatively few studies provide an overview of the current level of digitalization in Romanian garment manufacturing companies or examine the extent to which different digital technologies are currently used in practice. This paper assesses Industry 4.0 technology adoption, process digitalization, and systems integration and data use in Romanian garment manufacturing SMEs. The research methodology combines a review of the relevant literature with an empirical study based on a questionnaire completed by representatives of 25 garment manufacturing SMEs, including 19 small and six medium-sized enterprises. The questionnaire collected information on the adoption of Industry 4.0 technologies, the digitalization of different business processes, and systems integration and data use. Based on the collected data, three normalized indices were calculated to assess technology adoption, process digitalization, and systems integration and data use, together with an Overall Digitalization Index. The results indicate an uneven level of digitalization among the participating companies. CAD applications recorded the highest technology adoption score (2.44 on a 0–3 scale), while RFID and Digital Twin technologies showed the lowest levels of adoption. Pattern making and technical preparation were the most digitalized processes. The mean Technology Adoption Index was 45.83, compared with 34.09 for the Process Digitalization Index and 30.83 for the Systems Integration and Data Use Index, highlighting the gap between the adoption of individual technologies and their integration into company processes. Medium-sized enterprises recorded a higher mean Overall Digitalization Index (48.10) than small enterprises (34.01), with a statistically significant difference between the two groups ($p = 0.003$). The findings provide an overview of digitalization practices in the investigated Romanian garment manufacturing SMEs and identify areas where further technological integration and development are needed. The calculated indices provide exploratory analytical measures for comparing digitalization levels among the participating companies, although the limited sample size prevents generalization to the Romanian garment manufacturing sector as a whole.*

Keywords: *digitalization, digital transformation, digital maturity, ERP systems, CAD/CAM, digital skills*

SECTION 5:
COMFORT, QUALITY OF TEXTILES AND SENSORY EVALUATION

THERMO-PHYSIOLOGICAL COMFORT AND COOL TOUCH PERFORMANCE OF LIGHTWEIGHT POLYPROPYLENE WOVEN APPAREL FABRICS

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***Abstract**. The increasing demand for lightweight apparel has intensified the search for fibre materials capable of improving thermo-physiological comfort without compromising mechanical performance. Although polypropylene (PP) fibres offer advantages such as low density, hydrophobicity and rapid heat transfer, their use in woven apparel fabrics remains limited compared with conventional polyester (PET). This study evaluates the thermo-physiological comfort, cool touch performance and mechanical properties of woven fabrics produced using polypropylene and polyester filament yarns with identical linear density under identical fabric construction and finishing conditions. Fabric performance was characterised by measuring thermal conductivity, thermal resistance, thermal absorptivity, wettability, tensile strength, tear strength, dimensional stability, pilling resistance and colour fastness according to standard textile test methods. The experimental results showed that polypropylene fabrics exhibited significantly lower liquid absorption, confirming their superior moisture management behaviour. In addition, polypropylene fabrics presented higher thermal conductivity and thermal heat flow values, indicating more efficient heat transfer and a noticeably cooler initial skin sensation than polyester fabrics, while maintaining satisfactory mechanical performance and dimensional stability for apparel applications. These findings demonstrate that polypropylene filament yarns can be considered a promising alternative to polyester for lightweight woven garments requiring enhanced thermo-physiological comfort and cool touch performance. The study contributes to the development of functional woven apparel fabrics by providing experimental evidence on the comfort advantages of polypropylene fibres and establishes a foundation for future research on improving the dyeability, handle properties and finishing technologies of polypropylene-based woven textiles.*

***Keywords**: polypropylene, polyester, thermal comfort, moisture behaviour*

COMPUTATIONAL STUDY OF THERMAL COMFORT IN COMPRESSION STOCKINGS: ASSESSING THE FPC MODEL'S SENSITIVITY TO ACTIVITY LEVEL AND SEX DIFFERENCES IN WARM CONDITIONS

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Abstract. *The perception of thermal comfort is complex, the human body does not average out all bodily sensations. Instead, it is always most influenced by the areas that feel most uncomfortable and thus amplifies these negative signals. This phenomenon is known as the "weakest link" principle in human thermoregulation. This principle is particularly important when designing, optimizing, or studying specialized garments such as compression stockings, which although are widely used in the medical field to treat venous disorders and in sports to enhance performance, their effects on thermal comfort are understudied, given that, ultimately, their benefits related to users' medical needs are of greater importance. However, since users of compression stockings, especially those with venous diseases, already deal with ailments inherent to their condition, it is important to reduce or study the effect these stockings have on their thermal comfort, particularly in high-temperature conditions such as summer. This computational study investigates how compression stockings influence local and overall thermal comfort under different activity levels, using the Fiala physiological comfort model (FPC, Ergonsim) to simulate the thermal responses of a male and a female person at rest (1 met) and during jogging (6.5 met). Eight scenarios, with and without compression stockings, were simulated in summer thermal conditions (30 °C, 50 % RH, air speed 0.1 m/s; 1.75 m/s relative air speed while jogging). All simulated persons wore standardized clothing (briefs, long-sleeve shirt, shorts and shoes) using default software values. The locally measured thermal (Rcl) and evaporative (Re,cl) resistances of the stocking were assigned to the upper and lower legs, so that its effects could be isolated from other variables. Their effects were evaluated through skin temperature, skin wettedness and the Local Percentage of Dissatisfaction (PDL) of each body sector, identifying comfort-limiting zones according to the weakest link principle. Four comparisons were made: A) with and without stockings at rest, B) with and without stockings during jogging, C) the effect of activity level while using stockings, and D) differences between the male and the female person. At rest, the stocking increased the skin wettedness of the legs by 23–30 % and their skin temperature by 0.13–0.15 °C. During jogging, wettedness increased by 71–81 % and skin temperature of the lower legs by 0.8–1.0 °C, while the weakest link was not systematically changed. The differences between the persons reflect their reference anthropometry and cannot be attributed to sex alone. This work evaluated the sensitivity of the FPC model to stocking properties and activity-dependent changes, contributing to the application of computational thermal models to garment design, particularly for medical populations in warm environments.*

Keywords*: thermal comfort, compression stockings, FPC model, physiological thermal modeling, sex differences, and local percentage of dissatisfaction*

HYBRID EMBROIDERY-FDM STRUCTURES: INFLUENCE OF STITCH DENSITY ON ADHESION

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Abstract*. The combination of embroidery and fused deposition modelling (FDM) creates new possibilities for producing customised decorative elements on textile substrates. While embroidery can modify the appearance, texture and local structure of a fabric, FDM printing allows three-dimensional features to be added directly to its surface. However, the interaction between the embroidered area and the deposited polymer is not yet fully understood. This study examines how stitch density influences the adhesion of FDM-printed elements to an embroidered textile substrate. Several embroidery configurations with different stitch densities were produced and compared with a non-embroidered textile reference. All specimens were manufactured under controlled conditions, and the printing height was adjusted to account for the differences in thickness introduced by the embroidered structures. Adhesion was evaluated through mechanical pull-off testing, and the recorded detachment forces were used to compare the investigated configurations. The results showed that changes in stitch density affect the adhesion behaviour of the printed elements, confirming that the embroidered structure plays an important role in the formation of the textile–polymer interface. The findings provide a better understanding of how embroidery parameters can be used to control the adhesion of FDM-printed elements. This hybrid approach may support the development of customised decorative applications and value-added textile products that combine traditional textile techniques with additive manufacturing.*

Keywords: *embroidery, fused deposition modelling, textile substrates, stitch density, adhesion, hybrid manufacturing*

SECTION 6:
INNOVATIONS IN TEXTILE DYEING AND FINISHING

DEVELOPMENT OF ANTIFUNGAL WOOL FABRICS USING LIPOSOME-ENCAPSULATED NATURAL AND SYNTHETIC ACTIVE AGENTS

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Abstract*. The development of durable antifungal textile materials has become increasingly important due to the growing demand for hygienic products in healthcare, technical textiles, and protective clothing. Although numerous antifungal agents have been investigated for textile finishing, the high volatility of natural essential oils and the limited durability of conventional surface treatments remain major challenges. Encapsulation technologies, particularly liposomes, have emerged as promising carrier systems that can protect active compounds and improve their retention on textile substrates. The present study comparatively evaluates the application of a natural antifungal agent, thyme (Origanum vulgare) essential oil, and a synthetic antifungal agent, clotrimazole, encapsulated within phosphatidylcholine-based liposomes and applied to wool fabrics. Liposomes were prepared using the thin-film hydration (Bangham) method with different active ingredient-to-phospholipid ratios to determine the optimum formulation. The resulting liposomal systems were characterized by optical microscopy and particle-size analysis before being applied to 100% wool woven fabrics via a conventional textile finishing process. The treated fabrics were subsequently evaluated for antifungal activity according to AATCC 30, water vapor permeability, and retention of thyme essential oil components after laundering, using gas chromatography–mass spectrometry (GC–MS). The results indicated the formation of well-defined vesicular structures suitable for textile applications. The selected formulations exhibited effective antifungal performance while maintaining the breathability of the wool fabrics. Furthermore, the encapsulation system enhanced the retention of the active compounds on the textile surface after washing, indicating the potential of liposomes as efficient delivery systems for functional textile finishing. The comparative evaluation also revealed the potential of thyme essential oil as an environmentally friendly alternative to conventional synthetic antifungal agents. These findings highlight the potential of liposome-assisted delivery systems for developing durable antifungal textile materials.*

Keywords: *liposome technology; wool fabric; thyme essential oil; clotrimazole; antifungal finishing; functional textiles*

WATER-BASED ZIF-8 SYNTHESIS AND ITS APPLICATION IN COTTON DYEING

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Abstract. *Recently, metal-organic frameworks (MOFs) have gained attention in textile applications because of their high surface area, tunable structures, and potential to enhance the functional properties of textile materials. In this study, zeolite imidazole framework (ZIF-8) was synthesized using deionized water as a solvent at a mild temperature (40 °C) for 120 minutes under magnetic stirring and investigated for its application on cotton. The effects of zinc nitrate hexahydrate and 2-methylimidazole molar ratios on the yield percentage were evaluated using a three-level (3^2) full-factorial design analysed by response surface methodology. The aqueous synthesis produced ZIF-8 with yields ranging from 31.8% to 98.1%, with the highest yield of 98.1% obtained at an imidazole-to-zinc nitrate hexahydrate molar ratio of 24:1. The synthesized ZIF-8 powders were applied to cotton fabrics via padding process, and ZIF-8 functionalized samples were subsequently dyed with Rubia cardifolia (madder) to evaluate their dyeing performance. The results showed that the colour strength of all ZIF-8 functionalized cotton fabrics was enhanced compared to untreated fabric. The ZIF-8-treated fabrics showed average K/S values between 3.11 and 5.33, while untreated cotton showed an average of 2.90. A─2-methylimidazole-to-zinc ratio of 24:1 produced the highest colour strength (K/S = 5.33), however, this condition showed poor repeatability and colouration consistency relative standard deviation of 10.88%. The 8:1 ratio yielded a comparable K/S value of 5.21, however the 4:1 ratio provided a better compromise between repeatability (RSD = 3.3%) and colour strength (K/S = 4.42). The necessity for better fixing of ex-situ deposited ZIF-8 particles onto the cotton surface is highlighted by the fact that while aqueous-synthesized ZIF-8 increased the apparent colour strength of cotton, washing fastness remained poor. Overall, the results demonstrate the feasibility of water-based ZIF-8 synthesis for textile applications and highlight its potential to enhance the colouration performance of cotton fabrics while reducing reliance on organic solvents during MOF synthesis.*

Keywords*: metal-organic frameworks, madder, colour strength, sustainable synthesis, textile functionalization.*

PRELIMINARY STUDIES ON THE CONTENT OF MICROPLASTICS FOUND IN WASTEWATER RESULTING FROM HOUSEHOLD LAUNDRY

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Abstract. *Inherently, there is a wide variability in the blends of textiles subjected to home washing and in the conditions under which washing is carried out (type of commercial washing machines, water characteristics and volume of water used, nature and quantity of detergents and chemical auxiliaries used, etc.). In this context, domestic washing results are markedly different from standardized ones, making comparisons difficult. When it comes to the question of the amount of microplastic released as a result of household washing, the variability of the results is doubled by the failure to meet standardized criteria (e.g. according ISO 4484-3:2023, and especially according ISO 4484-1:2023) regarding the formation of the batch of textiles subjected to washing (e.g. a single fiber type) and the repetition of washings for the same batch in order to measure process variability. For the case of systematic domestic laundry studies, the literature cites microplastic values ranging from hundreds to thousands of milligrams per kg of clothing, depending on the nature of the component fibers, but also on the detergents used and even the type of washing machine (types A, B or C, according ISO 6330:2021). This paper aimed to conduct a preliminary statistical pilot study on the amount of microplastics released into the sewer together with household wastewater. An unplanned pre-study was first conducted on nine washes to establish the sample size needed, considering the amount of discharged microplastic (expressed in mg / L per washing). Random and unsystematic determinations were carried out in three different locations, over a period of half a year. To ensure complete randomness, the laundry subjected to washing was not intentionally selected (except perhaps only vaguely) according to the criterion of fibrous composition or batch weight, and neither chemical washing auxiliaries nor the type and washing program of the washing machine were imposed. To comparatively quantify the amount of microplastic generated by household laundry, the experimental results were subjected to clustering analysis and modeled according to statistical algorithms suitable for an unplanned experimental design. As expected, synthetic textiles are the main source of microplastics. Compared to a predominantly natural textile base of 178.3 mg/L (adjusted R^2 0.9861), synthetic compositions significantly increased the mass of microplastic produced by 72.74 mg/L ($p < 0.001$), while artificial fibers increased emissions by only 38.54 mg/L ($p < 0.001$).*

Keywords: *domestic laundry washing, microplastics amount, quantitation, statistical pilot study*

CASE STUDY REGARDING BACTERIAL AND FUNGAL LOAD OF SEASONALLY WORN SHEEPSKIN CLOTHING

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Abstract. *It is a common recommendation of sheepskin clothing manufacturers to thoroughly clean the heavily worn fur garments before storing them in closed closets for the next season. A large consortium of bacteria and molds accumulates and survives on the surface and in the section of both suede side and woolly side. Cleaning this type of clothing involves delicate brushing of both sides, followed by a physical-chemical treatment adapted to each of the two sides, possibly completed by spraying them with a protective composition mainly based on essential oils with antimicrobial effect. The chemicals involved should be minimal and must be correlated with the microbial load of the clothes. This paper describes an illustrative spot investigation to determine the microbial load of sheepskin garments worn intensively during the cold season, in periods with alternating severely cold and wet weather. Microbial sampling was carried out in areas with significance for the habit of wearing clothes, using the prescriptions of EN ISO 18593:2018, on square surfaces of 10x10 cm for both the suede and the woolly side, using sterile swabs soaked first in Ringer's solution. Three passes of the swab are applied to the same area, in different directions, the second pass perpendicular to the first, and the third, oblique to the first two. After sampling, the probes were introduced into 1 mL of peptone water and vortexed for three minutes. Subsequently, the determination of the microbial load was performed by successive decimal dilutions (according to EN ISO 6887-1:2017), plating and incubation (according a technique derived from EN ISO 7218:2024) on three types of culture media: (i) TSA (Tryptic Soy Agar), a general-purpose one for bacteria and moulds, (ii) SDA (Sabouraud Dextrose Agar with Chloramphenicol and Gentamicin), selective for yeasts and moulds, and (iii) BAg (Blood Agar), for the detection of fastidious bacteria and induced hemolysis. Content of viable microbes was expressed as CFUs (colony-forming units) for bacteria and fungi. The determined CFUs were evaluated in comparison with the limit bioburden considered as the upper threshold for the microbial cleanliness by EN 13795-1:2025 in the case of surgical gowns and high-risk sterile fields, which is 300 CFU/dm^2 (3 CFU / cm^2) so that the surgical garment can still be sterilized. The results of our case study indicate that the average microbial load of the most contaminated area on suede side was of 970 CFUs/dm^2 for consortia of bacteria and fungi, and of 510 CFUs/dm^2 for fungi only. Few hemolytic bacteria were identified. Therefore, it is advisable to clean and treat sheepskin garments worn daily with an antimicrobial agent before storing them in the closet for the summer. Further statistical studies should be dedicated to establishing the UFC threshold that would require antimicrobial treatment of fur and sheepskin garments before being stored seasonally in the closet.*

Keywords: *sheepskin / fur garments, microbial cleanliness, investigation procedure, potential thresholds*

SECTION 7:
RECYCLING, LIFE CYCLE ANALYSIS, SUSTAINABILITY AND CIRCULARITY

MECHANICAL RECYCLING OF WOOL

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Abstract. *The mechanical recycling of pre-consumer textile waste represents an important approach to implementing a circular economy for textiles. Wool and wool blends, in particular, offer great potential for the production of recycled yarns due to their high material cost and long fibre length. A key challenge in this context is maintaining fibre length during the recycling process. This study therefore focuses on the systematic analysis of various factors influencing fibre length retention and, based on this, develops approaches for a targeted recycling strategy. The first step in the recycling process is the sorting of the raw material. Three sorting parameters are particularly relevant for the targeted processing of woollen textiles. Firstly, sorting by colour takes place to create as homogeneous a starting point as possible for the subsequent yarn colour. Furthermore, sorting into coarse and fine textiles is necessary, as the fineness of the textile has a significant influence on the behaviour of the material during mechanical disintegration. The material mix must also be taken into account as a further parameter. Unless a single material is present, materials with different fibre compositions should be collected separately. Wool sorting thus forms the basis for the subsequent stages of the recycling process. These studies examined only knitted structures. The knit structure has a very significant influence on the retention of fibre length. Various structures were examined, such as 1x1 rib, single jersey, double jersey and interlock. The respective knit structure determines the path of the yarn within the knitted fabric and thus the length of the fibres released during cutting and unravelling. Denser and more interlaced structures, such as double jersey, exhibit different recycling behaviour to open and loose structures such as single jersey. Building on the influence of the knit structure, stitch length was investigated as a further structural parameter. To this end, different stitch lengths were examined. The results show that the stitch geometry influences the yarn length within the knitted fabric and thus the required cutting dimension. Shorter stitch lengths may require a greater cutting length, whilst longer stitch lengths allow for the preservation of fibre length even with shorter cutting dimensions. The influence of the cutting parameters was then investigated. These include, in particular, the size of the cut units and the cutting angle. Shorter cutting dimensions lead to a reduction in the length of the resulting fibres due to greater fragmentation of the yarn, whilst larger cutting dimensions better preserve fibre integrity. Optimal cutting ranges were identified for the knitted structures investigated. The cutting angle was considered as a further influencing factor. The orientation of the cut relative to the row or column direction of the knit influences the yarn length and thus the fibre length. Deviations from an optimal cutting direction result in shorter fibres. Large cutting angles, in particular, lead to short fibres. Overall, the investigations show that the preservation of fibre length during the mechanical recycling of woollen knitted fabrics is determined by the interaction of several parameters. The stitch structure, cut size and cutting angle are the key influencing factors in this regard. Through a favourable combination of these parameters, the loss of fibre length during the recycling process can be significantly reduced, and the conditions for high-quality reprocessing into recycled yarns can be improved. The study thus provides a basis for the development of efficient and material-specific process strategies for closed-loop textile value chains.*

Keywords: *wool recycling, fiber length retention, circular economy, cutting-angle optimization, knitted fabrics*

FROM FIBRE TO MARINE USE: DEVELOPING A SUSTAINABLE WOOL ROPE FROM RATHLIN BLACKFACE WOOL FOR THE KELP INDUSTRY

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Abstract. *Wool across the UK and Ireland is increasingly undervalued to the point that it is often no longer economically viable to transport fibre off the farm. This challenge is amplified on Rathlin Island, where additional ferry logistics further reduce the financial viability of wool, resulting in the fibre being treated as a low-value by-product rather than a functional bio-based material. Concurrently, there is limited research examining the adaptation of anchorage and rope systems in seaweed aquaculture using natural fibres. Current kelp cultivation relies pre-dominantly on synthetic polymer ropes, which contribute to microplastic pollution and present end-of-life disposal challenges. This research addresses both issues by investigating the technical feasibility of wool rope as a biodegradable alternative within kelp farming systems. The research adopts a mixed-methods, design-led and materials-testing approach combining textile science, circular design, and applied marine research. Using Rathlin Blackface wool as a primary case study, alongside comparative analysis of selected UK wools, the project evaluates fibre and yarn performance in relation to tensile strength, abrasion resistance, twist structure, moisture behaviour, biodegradation, and marine durability. These properties are assessed against the functional requirements of kelp longline and anchorage systems. The study is underpinned by circular economy principles and carbon counting, recognising carbon sequestration in wool fibres, carbon capture through kelp cultivation, and end-of-life scenarios in which post-harvest wool ropes are composted alongside residual seaweed biomass for fertiliser production. This integrated land-sea system aligns with the EU Green Deal, the EU Circular Economy Action Plan, and the EU Blue Economy Strategy, offering a low-impact, regenerative mate-rial solution that reduces reliance on petrochemical inputs. The paper presents a replicable and scalable model for coastal and island communities, demonstrating how locally sourced wool can be valorised through cross-sector in-novation between textiles and marine agriculture, supporting green transition, rural resilience, and nature-based solutions.*

Keywords*: regenerative textiles, biodegradable, green transition, circular*

BEYOND KNITTING: AIRBORNE FIBRE CONCENTRATIONS ACROSS FLEECE PRODUCTION STAGES

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Abstract. *Airborne fibre release during textile manufacturing remains less quantified than shedding during laundering, although workers operate close to machinery where fibres are generated. This study compared airborne particulate and microfibre release from three 75/25 cotton-polyester CVC fleece-knitted fabrics (320 g/m² Cross Terry, 285 g/m² Plain Terry and 270 g/m² Mini-Loop), during knitting, pre-stentering, raising and post-stentering. Air was sampled for 180 min at 12 L/min with a purpose-built three-stage filtration device positioned at worker breathing height. Total suspended particulate (TSP) concentration was determined gravimetrically and collected fibres were examined by optical microscopy. Mean TSP rose from 0.721 mg/m³ during knitting to 5.369 mg/m³ after raising and final stentering. Raising and post-stentering together represented 83.24% of the summed stage means, while Cross Terry consistently produced the highest concentrations. The results identify fleece-surface formation and subsequent heat-setting as priority stages for emission control and occupational exposure management.*

Keywords: *airborne microfibres; fleece-knitted fabrics; total suspended particulates; raising; textile manufacturing*

GREEN CHEMISTRY IN TEXTILES: DES APPLICATIONS FROM ECO-DYEING TO WASTE RECYCLING

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Abstract. *The global textile industry currently has a massive environmental footprint caused by its overreliance on water, heavy metals and hazardous chemicals during dyeing and finishing processes. The industry requires immediate transformative and sustainable solutions in order to reduce the ecological impact created through these processes. Deep Eutectic Solvents (DESs) and Natural Deep Eutectic Solvents (NaDESs) have emerged as promising eco-friendly alternatives for replacing conventional aqueous media. This presentation will review the innovative applications of DESs throughout the entire textile processing, highlighting how they can significantly reduce water use, eliminate the use of harsh chemicals and enhance overall manufacturing efficiency. Recent studies have shown that DESs can serve as an effective dyeing medium for many types of fabric. For example, glycerin-based eutectic solvents can be used to dye polyester fabrics with comparable or superior color strength and fastness to traditional dyeing methods using a fraction of the water. Additionally, salt-free reactive dyeing of cotton is possible using hydrophobic DES systems made from naturally occurring menthol, thus allowing excellent recycling of the solvent. Furthermore, pretreatment of wool with DESs promote the use of natural dyes, allowing for greater dye uptake compared to traditional metal-based mordants. In addition, DESs have shown their ability as excellent and safe anti-felting agents for natural wool by effectively removing the surface scales of the wool fiber while not compromising the mechanical integrity of the fiber or causing yellowing over time. In addition to their use as a sustainable dyeing agent, the DESs have begun to serve as an innovative solution to textile recycling and circularity through their use as efficient agents to recycle waste polyester/cotton (PET/CO) blended fabrics. These environmentally friendly solvents enable the selective decomposition and separation of the polyester fibers from the cotton fibers, allowing for a truly circular economy. To further improve the separation efficiency of these blended fabrics, new hybrid systems that utilize both DESs and NaOH have been developed, providing a sustainable pathway for converting textile waste into economically viable materials without relying on conventional harsh chemicals. Overall, the reusability and innate biodegradability of these novel solvent formulations align perfectly with the principles of a circular economy, providing the textile industry with a proven solution to creating a truly sustainable and zero-waste future through textiles.*

Keywords: *deep eutectic solvent, eco-friendly dyeing, sustainability, waterless dyeing, recycling*

IMPLEMENTING EDUCATION FOR SUSTAINABLE DEVELOPMENT AS A GUIDING PRINCIPLE IN FASHION DESIGN PROGRAMMES – A COMPARATIVE STUDY ACROSS GERMANY AND IRAN

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Abstract. *UNESCO's Education for Sustainable Development (ESD) 2030 programme, which is operationalised through Sustainable Development Goal Target 4.7, calls on higher education institutions to integrate sustainability principles into all disciplines (UNESCO, 2020). This is especially important in fashion and apparel design because the global fashion industry is one of the most resource-intensive and environmentally harmful sectors. It causes significant pollution, textile waste, and labour inequities (Amed et al., 2025). However, there is limited empirical guidance on how to embed ESD as a guiding principle in fashion design curricula, and existing initiatives often rely on fragmented, stand-alone interventions. This gap is particularly pronounced in under-researched contexts such as Iran (Choopani et al., 2023; Grundmeier & Höfer, 2023; Ermer & Schwarzkopf, 2021). Therefore, the doctoral research addresses this issue by investigating how ESD can be implemented as a guiding principle in higher education fashion design programmes in Germany and Iran. The study follows a six-phase Design-Based Research (DBR) approach (Reinmann, 2023), combining a systematic literature review, a comparative curriculum analysis, and expert interviews with twenty faculty members from both countries. The study also includes participant observations and the iterative development, piloting, and cross-cultural implementation of a Sustainable Fashion Design Strategies course (Choopani et al., 2025b). Centred on the USE-LESS Product Lifecycle as its core didactic tool (USE-LESS Centre for Sustainable Design Strategies, n.d.), the course was piloted, refined, and implemented across four iterations at the Hochschule Hannover University of Applied Sciences and Arts, the Anna Siemsen Vocational School in Hannover, and Alzahra (Farah Pahlavi) University in Tehran, Iran (total n = 73 students). Data from all phases were analysed using Mayring's deductive-inductive structuring content analysis, supported by MAXQDA (VERBI Software, 2026; Mayring, 2022). The initial phases revealed that the integration of ESD is influenced more by deeper structural conditions than by gaps in curricular content. These conditions are fragmented and instructor-dependent in Germany's decentralised system and constrained by the centralised education system in Iran (Choopani et al., 2025a, 2025c). They informed the design of the course itself. Throughout all four iterations, students demonstrated progressive learning trajectories towards differentiated conceptual understanding, practical competence, and sustained ethical engagement, particularly through experiential, material-based learning (Choopani et al., 2026a, 2026b). Building on this, the cross-cultural implementation confirmed that such integration is achieved through principled adaptation rather than direct replication. Initially, Iranian students relied more on instructor guidance, reflecting cultural and systemic structural differences. However, scaffolded peer critique progressively fostered collaborative orientations comparable to those of the German cohorts. For a subset of Iranian students, the course functioned less as the transmission of new knowledge than as the professional legitimisation of resource-efficient practices already embedded in their cultural context. Across both countries, students consistently described material and aesthetic constraints as generative rather than restrictive (Choopani, in press). These findings inform an evidence-based recommendation framework for curricular integration, pedagogical strategy, and contextual adaptation. A competency-mapping analysis across all four cohorts identifies which of UNESCO's eight sustainability competencies are consistently demonstrated and which remain absent or partially developed. These findings offer educators and institutions an empirically grounded basis for moving sustainability integration beyond individual instructor initiative towards curricular change.*

Keywords: *Education for Sustainable Development (ESD), Design-Based Research (DBR), fashion design higher education, curriculum integration, cross-cultural implementation*

CONSISTENCY AND CONTRADICTIONS IN EU SUSTAINABLE TEXTILE AND APPAREL POLICIES: A CRITICAL REVIEW

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Abstract: *The European Union (EU) has introduced an extensive set of legislative initiatives to accelerate the transition towards a sustainable and circular textile and apparel industry. Key policy instruments, including the EU Strategy for Sustainable and Circular Textiles, the Ecodesign for Sustainable Products Regulation (ESPR), the Digital Product Passport (DPP), the Corporate Sustainability Reporting Directive (CSRD), the Corporate Sustainability Due Diligence Directive (CSDDD), Extended Producer Responsibility (EPR), REACH, and the Green Claims Directive, collectively aim to improve environmental performance, resource efficiency, product transparency, and supply chain accountability. Although these initiatives share common sustainability objectives, their combined implementation has generated important questions regarding policy coherence, industrial feasibility, and regulatory consistency. This study aims to examine the interactions among major EU textile sustainability policies by evaluating their environmental, economic, technological, and operational implications. A structured policy analysis framework is employed to compare legislative objectives, implementation mechanisms, expected benefits, and potential contradictions affecting manufacturers, brands, retailers, and global supply chains. The review identifies several areas of strong policy consistency, including the promotion of circular economy principles, safer chemical management, enhanced product traceability, and increased corporate transparency. However, significant challenges are also identified. These include overlapping regulatory requirements, increasing compliance costs for small and medium-sized enterprises (SMEs), limited technological readiness for Digital Product Passport implementation, inconsistencies between ambitious sustainability targets and global sourcing practices, and insufficient alignment between circular economy objectives and current textile recycling capabilities. The study further discusses how regulatory complexity may unintentionally reduce competitiveness while simultaneously promoting environmental responsibility. The findings suggest that the EU has established one of the world's most comprehensive sustainability frameworks for the textile and apparel sector; however, greater harmonisation, simplification, and stakeholder-oriented implementation strategies are required to maximise environmental benefits while maintaining industrial competitiveness.*

Keywords*: sustainable textiles, European Union, circular economy, eco-design, Digital Product Passport, extended producer responsibility, policy consistency*

VALORIZATION OF NATIVE ALBANIAN SHEEP WOOL THROUGH NATURAL DYEING USING PLANT EXTRACTS AND AGRO-INDUSTRIAL WASTE

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Abstract. *The preservation and valorization of native Albanian sheep breeds represent an important opportunity to promote sustainable rural development and protect the country's textile heritage. Wool obtained from Albanian sheep breeds has traditionally been used to produce handcrafted textile products, including rugs, blankets, garments, and decorative items. These artisanal products are gaining attention due to their authenticity, biodegradability, and eco-friendliness. One promising approach is to replace synthetic dyes with natural dyes obtained from locally available plant materials and agro-industrial waste. The utilization of plant resources and agro-industrial waste for textile dyeing offers a sustainable alternative to synthetic dyes, contributing to waste valorization, circular resource use, and reduced environmental impact. This study investigates the dyeing performance of aqueous extracts obtained from quince tree bark, avocado peels and seeds, beetroot, and other locally available natural sources on wool fibers collected from different native Albanian sheep breeds. Wool samples were dyed using different mordants applied by the pre-mordanting technique to evaluate their effects on dye uptake, color development, shade variation, and dye fixation. Absorbance measurements of the aqueous extracts were performed using a UV–VIS spectrophotometer to identify characteristic absorption wavelengths and evaluate dyeing efficiency. The dyed wool samples were further evaluated for color fastness to washing in order to determine their suitability for textile and handicraft applications. The results show that combining these natural dyes, appropriate mordants, and optimized mordanting methods produces a wide range of attractive colors with increased dye fixation and improved color fastness. The findings indicate that the use of renewable plant resources and agricultural waste contributes to the principles of the circular economy by transforming agro-industrial waste into value-added textile dyes, reducing dependence on petroleum-based synthetic chemicals, and minimizing wastewater pollution. By turning local plants and native Albanian sheep's wool into eco-friendly textiles, this initiative directly supports the United Nations Sustainable Development Goals (SDGs) 12, 13, and 15 by reducing waste, cuttting processing pollution, and protecting biodiversity while creating rural jobs and keeping traditional craftsmanship alive.*

Keywords*: wool fibres, natural dyes, plant-based extracts, pre mordanting, UV-VIS spectroscopy, color fastness properties*

THE CONSTRUCTIVE-DECORATIVE EVOLUTION OF TRADITIONAL BAGS AND PURSES IN THE CONTEXT OF CONTEMPORARY DESIGN: VALORIZING THE CRAFTSMANSHIP HERITAGE THROUGH INNOVATION AND SUSTAINABILITY

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***Abstract**. In the context of the accelerated development of the fashion industry and the current orientation towards authentic, sustainable and culturally valuable products, the craft heritage represents an important source of inspiration for the design of contemporary accessories. Bags and purses made by folk craftsmen illustrate the evolution of the relationship between functionality, aesthetics and cultural identity, reflecting the social, economic and technological transformations specific to different historical periods. These products have surpassed their initial utilitarian role, becoming representative elements of the material heritage and of local artistic expression, preserving in their structure and decoration valuable information about the traditional leather processing techniques and about the aesthetic particularities of the communities from which they come. The aim of the paper is to highlight the constructive and decorative evolution of bags and purses made by folk craftsmen and to identify the ways in which traditional values can be reinterpreted and integrated into the current process of designing leather goods. The research aims to demonstrate that the craft heritage can constitute a relevant support for the development of innovative, competitive and sustainable products, capable of meeting both the aesthetic and functional requirements of the contemporary consumer, as well as the need to preserve cultural identity. The objectives of the research aimed at analyzing the historical, constructive and functional evolution of bags and purses, identifying the main morphological and decorative characteristics specific to the different stages of development, evaluating the influence of traditional techniques on current design and establishing directions for capitalizing on cultural heritage in the development of modern products. At the same time, the existing relationships between the execution technology, the materials used, the constructive solutions and the ornamental elements that give individuality to these accessories were analyzed. The research methodology was based on an interdisciplinary approach, using documentary analysis of specialized literature, comparative study of traditional and contemporary pieces, morphological and structural analysis of leather goods, as well as examination of manufacturing and decoration techniques used by folk craftsmen and local designers. The interpretation of the results was achieved by correlating historical information with current trends in the field of product design, circular economy and sustainable development. The research results highlight the fact that the evolution of leather processing technologies and the diversification of constructive solutions have allowed the continuous adaptation of bags and purses to the requirements of users, without diminishing their cultural value. The study demonstrates that elements such as constructive proportions, closure systems, functional compartmentalization, decorative stitching, perforations, ornamental motifs and traditional finishing techniques can be reinterpreted through modern technologies and integrated into contemporary products with a high level of functionality, aesthetic quality and sustainability. At the same time, the research confirms that the responsible use of natural resources and the promotion of sustainable materials contribute to increasing the competitiveness of products inspired by traditional heritage. The novelty and originality of the work consist in achieving an integrated approach to the constructive and decorative evolution of bags and purses, by correlating the craft heritage with the current principles of sustainable design, innovation and circular economy. The study proposes a conceptual model for capitalizing on traditional identity elements in the design of modern leather goods, providing premises for the development of authentic collections, with cultural value and potential for application in the creative industry. The results obtained contribute to expanding knowledge on the conservation of material heritage and demonstrate that the dialogue between tradition and innovation can generate relevant solutions for the contemporary design of leather accessories.*

***Keywords**: bags, purses, cultural heritage, traditional crafts, contemporary design, leather goods, sustainability, innovation*

DESIGNING CIRCULARITY: A SUSTAINABLE UPCYCLING FRAMEWORK FOR POST-CONSUMER TEXTILE WASTE AND CRAFT-BASED INNOVATION.

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Abstract. *With rising consumption and the fast-fashion trend, India produces significant textile and fashion waste. The country produces about 7.2 million tonnes of textile waste each year: 3.3 million tonnes of pre-consumer waste (fibre scraps, offcuts, and defective fabrics) and 3.9 million tonnes of post-consumer waste (discarded clothing). Although this waste is valued for its material content and reuse potential, poor collection systems, sorting practices, and limited design implementation keep it largely undervalued. This study introduces an innovative framework for textile waste upcycling that combines systematic collection, high-tech sorting, repair, and craft-based redesign processes all within the context of circular sustainability. A structured literature review was carried out with scientific and grey literature such as websites, newsletters, blogs, and newspaper articles. The upcycling framework model proposes a sustainable value chain that comprises advanced textile technologies: NIR scans the textile by using near-infrared light; then the NIR data are analyzed using deep learning algorithms-CNNs- which analyze, identify patterns, and classify the textile samples. The study also incorporates the Sustainable Textile Repair through Indigenous Embroidery (STRIE) approach that promotes the repair, restoration, and continued use of discarded textiles through culturally rooted embroidery practices. The process of redesign includes the incorporation of endangered Indian surface embellishment techniques, thus connecting the valorization of textile waste with the preservation of cultural heritage. The proposed framework is based on the principles of resource efficiency, landfill reduction, social inclusion, and sustainable entrepreneurship through scalable circular value chains.*

Keywords*: textile waste, upcycling, circular economy, sustainable fashion, reverse supply chain*

DIVERGING STANDARDS: METHODOLOGICAL FRAGMENTATION IN TEXTILE LIFE CYCLE ASSESSMENT

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Abstract. *Life Cycle Assessment (LCA) is widely regarded as the reference method for evaluating the environmental performance of products across their entire life cycle, and its relevance for the textile and footwear sector has grown substantially within European regulatory frameworks concerned with sustainability and product transparency. Despite the existence of a common methodological basis in ISO 14040 and ISO 14044, the specialized literature on textile LCA has expanded rapidly in recent years without achieving a corresponding degree of methodological convergence, raising concerns about the reliability and comparability of published results. This paper reports a review of the specialized literature on LCA studies applied to textile and footwear products, examining how methodological choices are made and reported across this body of research. The review focuses on several recurring dimensions of methodological divergence, including the definition of functional units, the delimitation of system boundaries, the impact assessment methods applied, and the software and background databases used. The findings indicate that these choices vary considerably from one study to another, that certain simplifications, such as excluding the use phase, can lead to a systematic underestimation of environmental impact, and that differences in impact assessment methods and database versions further limit the extent to which results can be meaningfully compared. Distinct functional unit types are in concurrent use, with few studies adopting the per-wear approach recommended by the Product Environmental Footprint Category Rules (PEFCR) for apparel and footwear; that some cradle-to-gate studies omit the use phase, which can account for a large proportion of a garment's total emissions; and that comparisons between studies using ReCiPe 2016, CML 2001/2002, or standalone IPCC/GWP indicators remain methodologically unreliable. Dependence on a number of software platforms and on successive, non-harmonized Ecoinvent database versions further compounds this variance. These results demonstrate that current textile LCA literature does not constitute a directly comparable evidence base, with implications for benchmarking, policy-making, and environmental claims made by industry. Taken together, these observations suggest that the current body of textile LCA literature does not yet constitute a fully comparable evidence base, which has implications for benchmarking, policy-making, and environmental claims made by industry. The paper contributes a structured overview of the main sources of incomparability in textile LCA and outlines directions for greater methodological harmonization, including more consistent functional units, standardized system boundaries, and clearer reporting practices. Future work should explore how these harmonization efforts could be supported by emerging regulatory tools and by wider use of primary data from the textile supply chain.*

Keywords: *textile industry, textile sustainability, methodological comparability, functional unit, system boundary, environmental footprint.*

A CASE STUDY ON ROMANIAN CULTURAL HERITAGE FOR A SUSTAINABLE FASHION COLLECTION

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Abstract*. The contemporary fashion industry is increasingly challenged by accelerated consumption, visual uniformity and the environmental impact of the fast-fashion phenomenon. This paper explores the Romanian cultural heritage as a strategic resource for sustainable fashion design through the development of the "Noapte de Sânziene" mini-collection. The research is based on the reinterpretation of Romanian mythological and traditional references, including the symbolism of Sânzienele, traditional costume structures, ornamental motifs, and the aesthetics of natural materials in modern garment models. Rather than reproducing folklore in a mimetic manner, the collection proposes a contemporary design language that integrates cultural identity, emotional durability and ecological responsibility. The methodology combines theoretical and visual documentation, creative concept development, material selection, textile surface experimentation, constructive and technological garment design, and 3D virtual prototyping. Sustainable strategies are implemented through the use of natural and organic materials, versatile silhouettes, detachable and interchangeable components, handmade decorative surfaces, natural dyeing processes, and felting techniques, in order to create textured applications inspired by traditional Romanian ornamentation. The study demonstrates that integrating cultural heritage and sustainable principles with digital technologies can support the development of contemporary fashion collections that are both environmentally responsible and culturally meaningful. Nevertheless, the conservation of the cultural heritage was an important element that defined the identity of the collection.*

Keywords*: sustainable fashion, etnodesign, Romanian cultural heritage, emotional durability, 3D virtual prototyping*

ASSESSING ECO-MAINTENANCE MATURITY IN THE TEXTILE AND LEATHER INDUSTRY: A DATA-DRIVEN APPROACH

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Abstract*. The need for applying eco-maintenance practices in the TCLF industry is growing due to the demands of CSRD and the European Green Deal. Eco-maintenance has been studied for many sectors such as manufacturing, energy, construction, IT and automotive; however, the maturity level of eco-maintenance in the TCLF industry has not been analyzed yet. In this paper, the authors use nine-dimensional eco-maintenance maturity index on the chosen sample of TCLF companies. The main weight for calculating EMMI is the same weight for all nine dimensions, and PCA-weighted model is applied as sensitivity analysis. There are three main actions to apply the methodology in this study: choosing of representative TCLF companies depending on the presence of sustainability reports; extracting and coding of relevant indicators according to sustainability and CSRD/ESRS reports for the period 2024-2025; calculating each company score in each dimension to calculate the composite maturity index. In this paper, there is an example of applying the tool which was not designed for this industry.*

Keywords*: eco-maintenance, maturity assessment, TCLF industry, sustainability reporting, Principal Component Analysis (PCA)*

CLOTHING DURABILITY AS A KEY FACTOR IN REDUCING ENVIRONMENTAL IMPACT: A REVIEW

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Abstract*. Clothing durability is increasingly recognised as a fundamental factor in reducing the environmental impact of textile products. While sustainability strategies in the fashion and textile sector often focus on fibre selection, recycled content, cleaner production, waste reduction and end-of-life solutions, the length of time for which a garment remains usable plays an equally important role. A product with lower production impacts may still generate a high environmental burden if it is discarded after only a few wears, while a durable garment can distribute its environmental impact over a longer period of use. In this context, durability becomes an essential link between product design, consumer behaviour and life cycle performance. The current state of research shows that the environmental impact of clothing is strongly influenced by the relationship between production, use and disposal. Life cycle assessment studies frequently demonstrate that the number of wears, laundering frequency, repair practices and consumer expectations regarding appearance can significantly affect the impact per use of a garment. Durability is therefore not limited to physical resistance, but includes several interconnected dimensions: physical durability, aesthetic durability, functional durability and emotional durability. Physical durability refers to the ability of a garment to resist mechanical stress, washing, abrasion and seam failure. Aesthetic durability concerns the preservation of appearance, including resistance to pilling, colour fading, deformation and surface degradation. Functional durability refers to the garment's capacity to maintain comfort and performance, while emotional durability reflects the consumer's willingness to keep, repair and reuse the product over time. This paper aims to review how clothing durability influences environmental impact and how it can be integrated into sustainability assessment. The methodology consists of analysing relevant literature on textile durability, garment lifespan, consumer use tendencies and life cycle assessment. Particular attention is given to the way durability modifies the functional unit of environmental evaluations, especially when impacts are expressed per wear rather than per product unit. The review highlights that extending garment lifespan can reduce the need for replacement, lower production demand and decrease waste generation. However, the environmental benefits of durability depend on actual consumer behaviour, including washing habits, care practices and willingness to continue using the product. Therefore, improving durability requires an integrated approach involving material selection, product design, quality testing, care instructions, repairability and consumer education. The contribution of this paper consists in framing clothing durability as a key sustainability indicator rather than only a technical quality parameter.*

Keywords*: clothing durability, garment lifespan, environmental impact, life cycle assessment, sustainable consumption, textile quality*

FROM HEMP CULTIVATION TO STEM VALORISATION: A STRUCTURED REVIEW OF HEMP HARVEST MATURITY, FIBRE QUALITY AND END-USE POTENTIAL

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Abstract. *Industrial hemp (Cannabis sativa L.) has attracted renewed interest as a renewable resource for textile materials, bio-based composites and other value-added products. Its relevance to sustainable production is associated not only with the use of natural fibres, but also with the possibility of valorising several fractions of the same crop. Hemp seeds can be directed towards food, oil and feed applications, while stems provide bast fibres and woody core material for textiles, composites, paper, insulation and construction products. Leaves and inflorescences may also be used in specialised value chains, depending on the cultivated variety, production objective and regulatory context. Consequently, the economic viability and resource efficiency of hemp cultivation may depend on the coordinated use of multiple plant fractions rather than on a single primary product. However, hemp stems obtained from different cultivation systems are often discussed as if they represented a relatively uniform fibre source. In practice, fibre crops, dual-purpose crops, and seed- or floral-oriented crops differ in cultivar selection, planting density, plant architecture, harvest stage and post-harvest management. These differences may influence the amount, structure and technological properties of the fibres recovered from the stems. This paper presents a structured comparative review of the relationship between cultivation purpose, harvest timing and bast fibre valorisation. Peer-reviewed studies are examined according to the production system, phenological stage at harvest, stem morphology, fibre yield, fibre dimensions, chemical composition and reported physical or mechanical properties. The study aims to organise the available evidence into a comparative framework linking hemp production systems with fibre characteristics and possible textile or composite applications. It also identifies areas where direct and standardised comparisons remain limited, particularly for stems obtained as secondary biomass from seed and floral production. The resulting framework is intended to support more efficient use of hemp biomass and to guide future experimental studies on fibre recovery, quality and end-use suitability.*

Keywords: *cannabis sativa L. crop specialisation, phenological stage, secondary biomass, whole-crop valorisation, circular bioeconomy*

FROM SHOP-FLOOR KPIS TO PRODUCT PASSPORTS: A LEAN SIX SIGMA INDUSTRY 4.0 DATA GOVERNANCE ARCHITECTURE FOR TEXTILE SMES

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Abstract. *European textile and clothing SMEs face growing sustainability-information requirements arising from Corporate Sustainability Reporting Directive (CSRD) value chains and from the Ecodesign for Sustainable Products Regulation (ESPR) and its forthcoming Digital Product Passport (DPP) requirements for textiles. Although several frameworks combine Lean Six Sigma, Industry 4.0, and sustainability indicators, such as the GreenLean 4.0 framework, governance frameworks linking the KPIs tracked within these SMEs to the DPP and the CSRD remain underdeveloped. Such frameworks emphasize process improvement and capture data on process-linked KPIs, but the DPP and the CSRD require product-level information. To address this gap, this paper proposes a governance framework for SMEs, structured around the DMAIC cycle, that is designed to help them collect product- and process-level sustainability data relevant to DPP requirements, VSME reporting, and sustainability-information requests within CSRD value chains. The framework draws on existing literature reviews, examines EU sustainability regulation in the textile industry, and builds on the GreenLean 4.0 architecture to develop a structural proposal for SMEs, illustrated through a scenario of a hypothetical SME in Romania. The framework is developed according to five principles: alignment with the DMAIC cycle, the use of a single dictionary of key performance indicators, traceability of those indicators to each product manufactured by the SME, the use of technology appropriate to an SME, and auditability of the reported data. The framework yields three core artifacts: a minimal set of KPIs, fewer than ten, linking operational metrics to each product sold by the SME; a five-layer data flow diagram tracing the data from textile production through to KPI reporting, centered on the timestamps, workstation identifiers, and batch identifiers of those textiles; and a role model allocating five data-collection responsibilities across existing positions within the SME. Together, these components are intended to support textile SMEs in responding to these requirements while improving their processes, and the paper states the propositions and the pilot protocol through which that intention can be tested. As the KPI values defined within the framework are illustrative of the magnitudes that may arise in textile SMEs, the framework is intended to be tested in future doctoral work.*

Keywords: *CSRD compliance, DMAIC, product-level traceability, sustainability reporting, circular economy*

ENVIRONMENTAL ASSESSMENT OF TEXTILE WASTE-REINFORCED COMPOSITE MATERIALS FOR BUILDING APPLICATIONS

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***Abstract**. Achieving sustainable development requires practical routes for transforming low-value waste streams into products with measurable environmental performance. This study evaluates prototype thermoplastic composite panels produced using textile-waste reinforcement and polypropylene-waste matrices for construction-related applications. The investigated material contains 60% textile waste reinforcement and 40% polypropylene matrix obtained from nonwoven polypropylene and biaxially oriented polypropylene film. A life cycle assessment (LCA) was performed using GaBi software and the International Reference Life Cycle Data System (ILCD) impact-assessment recommendations. The comparison used composite and oriented strand board panels of identical geometry. The model of production, delivery and the specified end-of-life treatments included waste preparation, shredding, manual layering, thermocompression, cooling, transport, use-phase assumptions, and end-of-life scenarios. Results show that the composite material cannot be considered a universally lower-impact substitute for oriented strand board. Within the modelled system boundaries, oriented strand board shows lower values in several categories, mainly due to its lower density and the biogenic carbon contribution associated with wood. However, the composite panel recorded lower values for selected indicators, including human toxicity with carcinogenic effects, aquatic freshwater eutrophication, aquatic marine eutrophication, terrestrial eutrophication, and photochemical ozone formation. The material should therefore be interpreted as a potential textile-waste valorisation route that requires further process optimisation, especially regarding the energy demand of thermocompression and realistic end-of-life implementation.*

***Keywords**: life cycle assessment, polypropylene matrix, circular economy, thermocompression, impact categories*

FROM DIGITAL REPRESENTATION TO PREDICTIVE TRACEABILITY: THE INTEGRATED PREDICTIVE TRACEABILITY FRAMEWORK (IPTF) FOR SUSTAINABLE INDUSTRY 5.0 TEXTILE ECOSYSTEMS

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Abstract. *Textile traceability systems increasingly combine Internet of Things (IoT), Digital Twin (DT), Blockchain and Digital Product Passport (DPP) technologies; however, their functions remain largely fragmented between retrospective provenance verification, real-time monitoring and predictive process optimisation. This study proposes an* ***Integrated Predictive Traceability Framework (IPTF)*** *for sustainable textile Industry 5.0 ecosystems. A structured scoping analysis of representative scientific literature published between 2021 and September 2026 was combined with functional technology mapping and conceptual modelling. Twelve representative studies were examined across nine functional dimensions, while relevant standards and institutional sources were analysed separately. The study operationally defines* ***predictive traceability*** *as the capability to combine historical, real-time and simulated data not only to reconstruct and verify material and process events, but also to anticipate potential non-conformities, resource inefficiencies and traceability disruptions before they materialise. IPTF integrates IoT-enabled physical–digital identification, Digital Twin synchronisation and simulation, predictive intelligence, Blockchain-based event integrity, smart-contract-supported verification, mass-balance control, DPP-compatible information exchange and human-centred decision feedback. The framework distinguishes an operational–predictive flow from a traceability–verification flow and links them through identifiable physical entities and transformation histories. A compact validation framework is proposed using indicators for traceability integrity, physical–digital consistency, predictive performance, material-flow consistency, decision support and operational impact. The contribution is conceptual and methodological; future work will require pilot implementation and empirical comparison with retrospective and real-time traceability configurations.*

Keywords: *predictive traceability, Digital Twin, mass balance, human-centred decision support, textile manufacturing, circular supply chains*

INTEGRATED MICROWAVE-ASSISTED EXTRACTION OF CURCUMINOIDS FROM TURMERIC POWDER AND SUSTAINABLE HEMP DYEING THROUGH DYE BATH REUSE

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Abstract. *The development of sustainable textile coloration requires environmentally friendly extraction methods and efficient utilization of natural dyes. This study investigated an integrated approach combining microwave-assisted extraction of curcuminoids from turmeric powder with the dyeing of hemp fabrics. Five extraction systems differing in solvent composition were evaluated and compared with conventional extraction. The extracts were characterized by UV–Vis spectroscopy, optical density and CIELab color measurements, whereas the dyed fabrics were evaluated in terms of colorimetric properties, color strength expressed as the Kubelka–Munk coefficient (K/S), and wash and rubbing fastness. Dye bath reuse was also investigated as a strategy to reduce water, energy and dye consumption. Microwave-assisted extraction significantly improved curcuminoid recovery, whereas the extraction system containing ethanol and kojic acid reached* A_{max} *= 0.3336. Nevertheless, the extraction system containing kojic acid only yielded K/S = 1.69, demonstrating that extraction efficiency alone does not necessarily determine dyeing performance. Reused dye baths enabled a second dyeing cycle while maintaining satisfactory color characteristics and good fastness. Furthermore, the detailed evaluation of the CIE L*, a*, b*, C*, and h colorimetric coordinates confirmed excellent shade consistency and minimal data dispersion across successive processing cycles. The proposed integrated approach combines microwave-assisted extraction, renewable raw materials and dye bath reuse, providing a promising strategy for sustainable textile coloration based on natural dyes.*

Keywords*: curcuminoids, microwave-assisted extraction, hemp fabrics, sustainable dyeing, dye bath reuse, green chemistry*

FROM LINEAR TO CIRCULAR MODELS: PERSPECTIVES IN THE CONTEXT OF INDUSTRY 5.0

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Abstract*. The traditional models, based on the "produce-consume-dispose" approach, are increasingly challenged due to their environmental impact, inefficient use of resources and lack of long-term sustainability. In contrast, the circular economy model promotes a system focused on reducing waste, reusing materials, and extending the life of the product. The present study is based on a qualitative literature review and analysis of the transition from linear models to circular ones, in the context of the new industrial paradigm, Industry 5.0. While Industry 4.0 focuses on automation and digitalisation, Industry 5.0 introduces a human-centric, resilient and sustainable perspective, providing new opportunities for circular transformation. Within this framework, circular economy principles become essential for designing more adaptive and responsible industrial systems. This paper also highlights how advanced technologies and smart systems can enable the implementation of this model by improving resource optimization and supporting the process of making a decision. It also discusses the main opportunities and challenges associated with this transition, underlining the need for an interdisciplinary approach. To conclude, the shift from linear to circular models goes beyond a technological change; it also represents a conceptual shift to a more sustainable and responsible industrial development. Future work should focus on empirical validation of circular strategies in real industrial environments and the development of measurable performance indicators for circular transformation.*

Keywords*: circular economy, Industry 5.0, resource efficiency, industrial models, sustainability, innovation*

SUSTAINABLE TEXTILE MATERIALS AND THEIR IMPACT ON THE ENVIRONMENT

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Abstract. *The textile industry significantly contributes to environmental degradation through intensive resource consumption, high water and energy demands, and the generation of textile waste and greenhouse gas emissions. In this context, sustainable textile materials and environmentally responsible manufacturing practices are essential for reducing the environmental impact of the sector. This study examines key sustainable textile fibres, including organic cotton, recycled polyester, lyocell, hemp and flax, focusing on their environmental characteristics and potential to improve resource efficiency. The research is based on a review of scientific literature addressing textile production, resource utilisation and sustainable materials management. Furthermore, the study explores the 4R principle—Reduce, Reuse, Recycle and Recover -as a framework for waste minimisation and resource conservation. Particular attention is given to innovative manufacturing technologies, circular economy strategies and consumer behaviour. The analysis highlights the importance of responsible material selection, efficient production processes and effective textile waste management. It also emphasises that the environmental performance of textile materials depends on their production methods, life-cycle resource consumption and end-of-life management. In conclusion, improving sustainability in the textile industry requires coordinated efforts to promote circular production and consumption, reduce waste and enhance resource efficiency, thereby minimising environmental impacts.*

Keywords: *sustainable textile materials, sustainable fibres, environmental impact, textile waste, circular economy, 4R principle*

Acknowledgement*: This work was supported by a KING CAROL I-st research fellowship granted by the National Research Autority, contract number 2/2024*

CONTRIBUTIONS TO THE RESEARCH OF INNOVATIVE SUSTAINABLE PRODUCTION PROCESSES FOR FUNCTIONAL GARMENTS

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Abstract. *The textile and apparel industry faces increasing pressure to improve resource efficiency and reduce waste generation while maintaining the high-performance requirements of functional garments. Cutting operations represent one of the main sources of pre-consumer textile waste, generating significant quantities of valuable materials that are commonly disposed of or used in low-value applications despite their potential for recovery and reintegration into production systems. Recent studies highlight the importance of implementing circular economy strategies based on efficient collection, sorting, recycling and reuse of textile waste in order to reduce environmental impacts and improve the sustainability of manufacturing processes. This research addresses the following question: How can a functional garment manufacturing process be transformed from a wasteful and reactive linear system into a circular, efficient and productive model capable of converting textile into a thermo-insulating fibrous material able to replace natural or synthetic down without compromising thermal performance, breathability and perceived product quality? The proposed solution consists of an innovative technological workflow integrated directly into a functional garment factory. The model begins with the systematic collection and rigorous sorting of textile waste generated in the cutting department according to fibre composition, colour and material category. Dedicated sorting stations are integrated into the cutting area to prevent contamination and maximize the recovery potential of textile residues. Subsequently, the sorted waste is processed using a mechanical fibre-opening machine installed directly within the cutting department, allowing the conversion of cutting scraps into reusable fibrous material. The recovered fibres are then blended, conditioned and transformed into thermos-insulating structures intended for jackets, vests and other functional apparel products. The novelty of the proposed research consists in integrating the fibre-opening system directly within the cutting department and transforming pre-consumer textile waste generated during garment production into a recycled thermos-insulating filling material. The developed material is intended to partially or completely replace natural or synthetic down used in functional garments while maintaining thermal insulation, breathability and perceived product quality. The proposed circular workflow contributes simultaneously to waste reduction, material recovery and resource efficiency while reducing dependence on virgin insulating materials. Scientific literature demonstrates that mechanically recycled textile fibres can be successfully converted into insulation materials and reintegrated into circular manufacturing systems, supporting waste diversion and sustainable resource management. Furthermore, efficient collection, sorting and reintegration processes are recognised as key enablers for textile circularity and sustainable production. The expected outcomes include reduced waste disposal costs, improved material utilization rates, lower environmental impact, decreased consumption of virgin resources and the development of a scalable industrial model that can be adopted by textile manufacturers seeking to transition towards circular production systems.*

Keywords: *circular economy, textile waste recycling, functional garments, thermos-insulating materials, sustainable manufacturing, fibre recovery*

SECTION 8:
FOOTWEAR DESIGN AND TECHNOLOGY

DEVELOPMENT OF AN IMPROVED DESIGN OF CUSTOMIZED SUPPORTIVE AND PRESSURE-RELIEVING INSOLES FOR PREGNANT WOMEN USING 3D PRINTING TECHNOLOGY

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Abstract. *This study proposes an improved, scientifically substantiated approach to the design and fabrication of customized orthopedic insoles for pregnant women with regions of variable stiffness based on three-dimensional (3D) foot scanning, baropodometric analysis, NURBS surface modeling, mathematical description of insole geometry, and fused deposition modeling (FDM) using flexible thermoplastic materials. Initial data were obtained through 3D foot scanning and plantar pressure distribution analysis performed on a pressure measurement platform. A method for designing the insole geometry was developed in which the product shape is determined by the morphology of the plantar foot surface, the internal footwear contour, and functional requirements, whereas local physical and mechanical properties are assigned according to the plantar pressure distribution map. The three-dimensional insole geometry is represented by three NURBS surfaces, including a mathematical model of the anatomically optimized upper surface incorporating longitudinal and transverse arch support elements and a heel cup. A 3D-printing technique with differentiated internal infill was developed to create regions of variable stiffness and reduce excessive plantar pressure. A variable-density Gyroid lattice structure was employed, with its parameters defined during the slicing stage according to plantar pressure data. The TPU insoles provided comfortable wear and reduced pain in high-load plantar regions.*

Keywords: *customized orthopedic insoles; pregnant women; 3D foot scanning; plantar pressure analysis; FDM 3D printing; gyroid lattice structure*

OVERVIEW OF 3D PRINTED APPLICATIONS FOR TEXTILES AND FABRICS IN THE FOOTWEAR SECTOR

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Abstract. *Additive Manufacturing (AM) has emerged as a disruptive technology with significant potential for the fashion industry, particularly in the footwear, leather goods, and textile sectors. Beyond its established role in product development, AM enables the production of highly customized and personalized products while offering geometric freedom for the creation of complex structures, textures, and functional features without the need for conventional tooling. These capabilities have fostered growing interest in integrating 3D printing with textile substrates and in developing novel textile-inspired structures. This work provides a comprehensive overview of the current state of the art on the application of 3D printing to textiles and fabrics, with a particular focus on fashion-related applications. The paper distinguishes three main strategies adopted for integrating additive manufacturing with textiles: on-fabric, where materials are directly deposited onto textile or leather substrates; for-fabric, where 3D printed components are manufactured separately and subsequently assembled or integrated with textile products; and fabric-like, where additively manufactured structures are specifically designed to mimic the flexibility, and mechanical behavior of conventional textile materials. The advantages, limitations, and typical applications of each approach are discussed. The paper also reviews the main additive manufacturing technologies employed for these applications, including Material Extrusion, Vat Photopolymerization, Powder Bed Fusion, and Material Jetting, highlighting its processing methods and design features capabilities. Additionally, the most used materials are presented with respect to their adhesion to textile substrates, flexibility, and applicability in fashion products. Finally, this work presents representative examples reported in the literature alongside research and development activities carried out at the Portuguese Footwear Technological Centre (CTCP). By combining a critical literature review with practical industrial case studies, the paper provides a perspective on the current developments, challenges, and future opportunities of additive manufacturing for textile and fashion applications, supporting the wider adoption of 3D printing technologies in the design and production of next-generation footwear, leather goods, and textile products.*

Keywords: *additive manufacturing, textiles, fashion applications, product personalization*

FUNCTIONALITY AND DESIGN OF HEALTHCARE FOOTWEAR: IMPACT ON THE MUSCULOSKELETAL HEALTH AND PROFESSIONAL PERFORMANCE

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***Abstract**. Healthcare workers especially nurses employed in neonatal intensive care units are subject to prolonged periods of standing, walking and strenuous shiftwork which predisposes them to musculoskeletal disorders affecting their lower limbs. The purpose of this research is to find out how occupational footwear functionality and design affect the musculoskeletal condition, comfort, fatigue levels and professionalism of medical workers. A questionnaire-based research has been conducted among 50 nurses employed in Neonatal Intensive Care (NIC) and Premature Newborn (PN) units at a Romanian hospital. The questionnaire consists of seven parts that collect information related to the respondent's demographics and profession, type and usage of occupational footwear, musculoskeletal pain measured on a five-point scale, physical and mental fatigue, comfort from the wearers' point of view, impact on professional activity and aesthetic aspect of the design of occupational footwear. Results show that most respondents are women aged 30-50 years old, who work 12-hour shifts including 6-8 hours of standing. Sport/orthopaedic shoes and medical clogs are the most common footwear types used. Nearly half report moderate to severe foot pain, while lumbar and cervical discomfort are also common, correlating with increased fatigue toward the end of the shift. Key footwear attributes-comfort, arch support, shock absorption and anti-slip performance-were positively associated with perceived safety, efficiency and reduced accident risk. Although functionality outweighed aesthetics during long shifts, combining ergonomic features with an appealing design improved acceptance and compliance. The findings support the development of ergonomic occupational footwear as a preventive measure against work-related lower-limb disorders.*

***Keywords:** healthcare footwear, occupational ergonomics, musculoskeletal disorders, footwear design*

ARTIFICIAL INTELLIGENCE IN FOOTWEAR DESIGN: A COMPARATIVE CASE STUDY

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Abstract. *Artificial Intelligence (AI) is rapidly transforming product development by enabling the automatic generation of design concepts from textual prompts, sketches, or reference images. In the footwear industry, these technologies support designers throughout the creative process by accelerating concept generation, facilitating iterative refinement, and enabling rapid exploration of multiple design alternatives. Rather than serving solely as a support tool, generative AI increasingly functions as a collaborative design partner capable of producing and iteratively refining visually developed design concepts. This paper presents an exploratory comparative case study of two generative AI platforms—Google Gemini (Nano Banana 2) and ChatGPT Images (OpenAI)—applied to the iterative design of footwear products. The proposed workflow begins with generating a baseline footwear concept, which serves as the foundation for subsequent design iterations and the development of a coherent footwear collection. To ensure an objective comparison, both platforms were evaluated using an identical set of standardised prompts, with no modification to the input parameters. The generated concepts were assessed according to criteria relevant to footwear design, compliance with the technical prompt, concept development, consistency across iterations, iterative design, development of a product range, response to feedback (targeted edits), control over design and pattern, creative exploration, visual realism, commercial rendering, editing of existing images, manufacturing potential. The study examines each platform's interpretation capabilities and its ability to generate technically feasible, visually coherent footwear concepts with potential relevance to industrial footwear-design workflows. The proposed evaluation framework provides practical insights into integrating generative AI into digital footwear design workflows and highlights the potential of these technologies to support rapid concept validation and product personalisation.*

Keywords: *generative design, iterative design, prompt engineering, human–AI co-design, concept development, product visualisation*

SECTION 9:
NEW BUSINESS MODELS AND EMERGENT ECOSYSTEMS

DIGITALIZATION – VECTOR OF FINANCIAL SUSTAINABILITY IN FASHION

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Abstract*. This study starts from the paradox of the textile industry: the need for speed (specific to the fast fashion trend) and the pressure of sustainability (specific to the low-fashion trend). The integration into the area of debates on digitalization is supported by the fact that the study aims to assess the role of artificial intelligence in demand forecasting and omnichannel strategy in reducing excess inventory, respectively, in increasing profitability. Drawing on secondary data from annual (non)financial reports and sustainability reports, the research is based on quantitative and comparative analyses. According to the first case study, the use of artificial intelligence in demand forecasting provides support both for sales growth (according to the fast fashion trend) and minimizing residual inventory (responding to waste minimization concerns). The second case study reveals that omnichannel strategy (based on digitalization) has the potential to favorably influence product profitability in conditions of reducing inventory volume. The results indicate that digitalization is not just a cost center, but a facilitator of sustainability. Optimizing production according to market trends is an important premise for reducing production and logistics costs, which positively influences the profitability and sustainability of businesses in the fashion industry. The study has practical implications because it provides a conceptual model of good practices for fashion companies that operate internationally in both production and sales.*

Keywords*: digitalization, demand forecasting, omnichannel, sustainability, financial indicators, fashion*

MULTIPRODUCT BREAK-EVEN-ANALYSIS: SALES MIX RECONFIGURATION, MARGIN OF SAFETY AND OPERATING LEVERAGE

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Abstract. *Cost-volume-profit (CVP) analysis becomes more complex in multiproduct settings because profitability and break-even sales depend on the composition of the sales mix. This paper examines how changes in the sales-mix structure affect break-even sales, contribution margin, margin of safety, and degree of operating leverage. The study integrates established CVP relationships into a comparative scenario-analysis framework in which total turnover, selling prices, variable costs, and fixed costs are held constant while the sales mix is reconfigured. A three-product numerical case study demonstrates that shifting the sales mix toward products with higher contribution-margin ratios improves operating profitability and margin of safety while reducing the calculated degree of operating leverage. The findings highlight the importance of sales-mix composition in assessing the operating-risk profile of multiproduct firms and demonstrate its usefulness as a managerial sensitivity-analysis tool. However, the deterministic framework does not explicitly incorporate demand uncertainty, price elasticity, capacity constraints, or product interdependence. Consequently, the results should not be interpreted as direct evidence of greater resilience to macroeconomic shocks. Future research could extend the analysis through stochastic multiproduct CVP models that incorporate uncertainty and more complex market conditions.*

Keywords: *multiproduct CVP analysis; break-even point; sales mix; margin of safety; degree of operating leverage; operating risk; scenario analysis*

ASSESSING THE IMPACT OF SUSTAINABILITY PRACTICES ON THE PERFORMANCE OF COMPANIES IN THE TEXTILE SECTOR

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Abstract. *Debates on the impact of sustainability practices on the performance of companies in the textile sector are on the priority list of researchers and practitioners. This is because the textile industry is considered one of the most polluting industries globally, being responsible for high CO_2 emissions, intensive water consumption and waste generation. Therefore, this article addresses a field marked by a significant impact on the environment. To carry out the research, based on carefully selected keywords, studies were identified following predefined inclusion and exclusion criteria. Thus, the methodology involved a systematic review focused on recent studies indexed in the Web of Science database, using bibliometric analyses to identify the main research directions. The results demonstrate that the integration of environmental, social and governance (ESG) pillars in the business strategy directly improves the financial performance, profitability and long-term growth of companies in the analyzed field. Digital transformation and visionary leadership are identified as key factors for optimizing resources, stimulating green investments and ecological innovation. The success of sustainability in the textile industry depends on its deep integration into corporate strategy and all daily activities, by assuming economic, social and environmental responsibilities at all organizational levels. The study concludes that the transition to the circular economy and the assumption of sustainability must be based on strategic tools, indispensable for the global competitiveness of the textile industry. Responsible resource management and social responsibility contribute directly to the long-term profitability and resilience of companies in the researched field..*

Keywords: *textile industry, sustainability practices, EGS (environmental, social and governance), corporate performance, literature review*

Acknowledgement: *This work was supported by a KING CAROL I-st research fellowship granted by the National Research Autority, contract number 11 RCI / 11.12.2025.*

SECTION 10:
ENTREPRENEURSHIP AND INNOVATION

TRANSLATING BRAND HERITAGE INTO DESIGN DECISIONS: A 35TH-ANNIVERSARY PREMIUM DENIM PRODUCT GROUP

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Abstract. *Fashion products that promise timeless design and long use life are gaining ground against fast-fashion consumption, and premium denim positioning is being reshaped around perceived value, durability, identity, sustainability and quality. For a denim brand, such positioning depends on the fit between its accumulated experience and current fashion. If brand heritage is a dynamic construct reproduced through storytelling, the design question is how a brand translates it into the concrete decisions of a new product group. The brand-heritage literature treats heritage as inherited experience, values and symbolic codes that a brand preserves, interprets and manages strategically rather than archives. Heritage collections reinterpret these codes for contemporary consumers to strengthen identity, authenticity and emotional attachment, by different routes: French fashion houses recompose inherited values through future-oriented creative work; Asian brands blend traditional prototypes, fabrics and craftsmanship with contemporary design. This study asks how a denim brand operationalizes heritage in the fabric, form, wash and detail decisions of one product group. The case is the premium denim product group that Mavi's Design Center is developing for the brand's 35th founding anniversary under the "Studio" approach: trousers, shirts and jackets designed as coordinated sets. We conduct a qualitative single-case study from within the design team, drawing on the Design Center's project documentation and records, and read the decisions on four axes (fabric development; silhouette and form; wash and surface effects; detail design) against the heritage narrative. The Studio approach defines denim in its purest, timeless form: restrained, refined, long-lasting style, high workmanship and selected materials, positioned as an investment piece in a capsule-wardrobe logic for users across age and gender. The fabric axis specifies seven qualities new to the brand, spanning approximately 254-483 g/m² (7.5-14.25 oz/yd²), mostly 100 % cotton plus one 82/18 cotton-Tencel and one 99/1 cotton-elastane quality, woven mainly as 3/1 Z twill. The form axis combines wide-leg and baggy/barrel-leg trousers with a twisted-seam detail, relaxed and fitted shirts including a balloon-hem cut, and relaxed and fitted jackets with concealed snaps, wide cuffs and semi-concealed button placement. The wash axis builds a two-theme wash story of dark, homogeneous rinse washes and softly shaded "Sophisticated Retro" washes; recipes are calibrated per fabric quality, with lot-to-lot repeatability as the acceptance criterion. The detail axis carries the anniversary through micro-components (logo plates including the "M Logo Plate", pocket-top plates, selvedge placements, buttons and belt loops), whose final forms follow sample review. Together, the axes show heritage operationalized as design decisions, namely material longevity, timeless forms, restrained surfaces and hardware as heritage cues, rather than as brand communication alone. The study contributes a decision-level account of heritage-to-design translation in premium denim and a four-axis frame applicable to other anniversary or heritage product groups.*

Keywords: *storytelling, capsule wardrobe, investment piece, wash development, product innovation*

THE SOCIO-ECONOMIC IMPACT OF RUDA SHEEP WOOL IN THE KUKËS REGION, ALBANIA: PAST, PRESENT AND FUTURE PERSPECTIVES

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Abstract*. The aim of this article is to assess the potential of Ruda sheep wool, historically known as 'white gold', in the Kukës region of northern Albania. The study uses a qualitative-dominant mixed-methods design: fieldwork carried out by Social Development Investment (SDI) in 2022, with semi-structured interviews and focus groups involving 35 key informants across the value chain (shepherds, artisans and institutional actors), combined with an earlier impact study of 120 participants and secondary data. About 85% of raw wool is discarded each year, while hand-woven carpets (qilim) reach €150–350 per m², and women in cooperative weaving networks report household income increases of 30–50%. The study concludes that a revitalized Ruda wool economy, aligned with global trends for sustainable and ethical products, could contribute to rural development, cultural preservation, women's empowerment, and reduced pressure for out-migration. The Kukës case offers lessons for integrating intangible cultural heritage with sustainable economic development in post-socialist mountain regions.*

Keywords: *ruda sheep, wool value chain, socio-economic impact, cultural heritage, rural development, kukës, albania, artisan crafts, gender econom*

FORM, FINISH AND IDENTITY IN HEAVYWEIGHT DENIM: A DESIGN SYSTEM FOR PREMIUM DURABILITY AND TIMELESS STYLE

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Abstract. *Premium denim positioned on durability and timeless style has to hold up physically and look right over time, and heavyweight rigid fabrics make fabric weight, finish and mechanics interdependent. This paper documents how a design center decided fabric, form, finish and branding elements together for one heavyweight product group. The case is the HEAVY DENIM theme group of Mavi's Design Center, an internal product-development group of women's and men's jeans, studied as a practice-based insider case from its project form, completion questionnaire and sample-card record. The group separates fabric weight, a heavyweight band of 458-500 g/m² (13.5-14.75 oz/yd²) plus one complementary 381 g/m² (11.25 oz/yd²) quality, from silhouette volume, baggy and barrel forms built as a three-dimensional pattern across five women's and one men's fit code. Seven qualities from Cone Denim, Orta Anadolu and DNM were sampled for the first time, six of them heavyweight (five in 100 % cotton, one in 99/1 cotton-elastane; one certified by the Better Cotton Initiative). The Classic Denim back patch, metal button and plate rivet were renewed as one set and the five-pocket layout was re-dimensioned to the rivet; washes referencing the 2000s were placed by fabric behavior in the baggy and barrel forms. The records document interdependencies among the four dimensions rather than a fixed decision order. The contribution is a documented heavyweight baggy-and-barrel design system and a four-dimension frame with a fabric-form-finish matching record that premium denim teams can reuse.*

Keywords: *baggy/barrel silhouettes, pattern geometry, garment washing, brand hardware, product longevity*

DIGITAL-ADAPTIVE EMPLOYEE-CENTRIC MANAGEMENT: A CONCEPTUAL MODEL FOR VIRTUAL FIRMS

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Abstract. *Digitalization of management processes and the expansion of remote and hybrid work have generated an unstable business environment, in which organizations need leadership models capable of continuously self-adjusting based on data generated by employees themselves. Digital-Adaptive Employee-Centric Management (DAECM) is proposed as a new theoretical construct, situated at the intersection of three research lines that have so far developed separately: adaptive management (rooted in ecology and systems science), digital management (from digitization, to digitalization and digital transformation) and employee experience management (Employee Experience). This paper aims to conceptualize and theoretically ground the DAECM model, applicable to virtual firms and organizations with a high degree of digitalization of managerial processes, through the integration of three components: artificial intelligence and data analytics, structural adaptability and employee experience management. Research methodology is exploratory, based on a critical analysis and a conceptual synthesis of recent specialized literature, to be further complemented by a preliminary qualitative and/or quantitative test, with the possibility of focusing on digital, virtual or hybrid firms. Findings show that, although the three domains increasingly converge in recent literature, they have not yet been unified into a coherent model, with defined dimensions and a proper name. Original contribution consists in defining DAECM as a distinct management category and in proposing a paradigm shift, whereby employee experience is no longer treated only as an outcome of managerial practices, but as an active feedback mechanism, through an "employee experience adaptive digital feedback loop", in which data generated by employees is collected through AI and people analytics, turned into managerial information, used to adapt decisions, and decisions generate new employee experiences, with the cycle repeating continuously. Practitioners in human resource management and leaders of virtual or hybrid organizations, as well as researchers interested in the convergence of digitalization, organizational adaptability and employee well-being, may find these results useful.*

Keywords: *digital-adaptive management, employee experience, virtual firms, Digital HRM, artificial intelligence in human resources*

THE EVOLUTION OF MAINTENANCE MODELS IN INDUSTRIAL DIGITALIZATION

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Abstract *This paper analyses how maintenance models have evolved in the context of industrial digitalization and clarifies the differences between traditional and advanced approaches. The study compares reactive, preventive, predictive, prescriptive and intelligent maintenance, highlighting their characteristics, technological requirements and managerial implications. The analysis shows that traditional models remain useful for simple or low-digital environments, but they are insufficient in modern industrial systems where decisions must be proactive and data driven. As organisations advance in technological maturity, maintenance strategies become increasingly integrated, data-centric and autonomous. The study contributes by offering a structured conceptual comparison of maintenance models and by refining the interpretation of technological maturity. Instead of assuming a linear progression, the paper emphasises that maintenance strategies often coexist within organisations, depending on asset criticality, data availability and managerial readiness. This perspective provides a more realistic understanding of how maintenance evolves in practice and clarifies the organisational conditions required for adopting advanced digital approaches. The findings support practitioners in assessing digital readiness, selecting appropriate maintenance strategies and planning gradual transitions toward intelligent maintenance systems. For researchers, the paper offers an accessible conceptual foundation that can guide future empirical studies on maintenance transformation in digitalized industrial environments.*

Keywords: *predictive maintenance, intelligent maintenance, digital transformation, technological maturity*

ORGANIZATIONAL CHANGE MANAGEMENT IN THE PUBLIC SECTOR: A RISK-BASED PERSPECTIVE

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Abstract. *Public sector organizations are increasingly confronted with the need to redesign structures, processes and services in response to digitalization, regulatory reform and shifting citizen expectations. Although risk management has been widely adopted in for-profit organizations for decades, its systematic application to organizational change processes within public institutions remains limited, leaving change initiatives exposed to avoidable failure. This paper explores organizational change as a source of institutional risk and proposes a risk-oriented perspective for managing public sector transformation. To define the study we used as research methods: the system approach, analysis, and synthesis, by examining the specialized literature on change management, risk governance, and public administration reform. As the main results of this literature-based framework, we highlighted the main risk factors that tend to undermine organizational change in the public sector - insufficient leadership commitment during the transition, poor internal communication between decision-makers and staff, resistance to change generated by unclear role redefinition, and the absence of a formal risk-assessment stage prior to implementing reforms. In line with the existing body of knowledge on organizational risk management, we consider that public institutions could benefit from a structured risk-identification and mitigation plan integrated into their change strategy, adapted to the real needs of each department. Based on these findings, the paper proposes a preliminary risk-management framework tailored to organizational change in public institutions, structured around three stages: risk identification prior to change, risk monitoring during implementation, and risk evaluation post-implementation. This framework is intended as a starting point for future empirical validation and could support public managers in anticipating and mitigating the risks associated with organizational transformation.*

Keywords: *organizational change, public sector, risk administration*

STRESSFUL WORK ENVIRONMENT AND WELLBEING: ARE THEY INTERCONNECTED?

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Abstract. *Workplace stress and employee wellbeing are two of the most extensively debated constructs in contemporary organizational research, particularly with regard to the direction and nature of their relationship. The objective of this article is to examine whether stressful work environments and employee wellbeing are interconnected, and if so, whether this relationship is unidirectional or reciprocal. Employees exposed to high job demands, limited autonomy, insufficient organizational support or unfavourable physical conditions tend to report lower levels of psychological and physical wellbeing, which can further intensify workplace stress, suggesting a circular rather than a strictly linear pattern. To pursue this objective, the paper adopts a conceptual, literature-based research method, critically analysing established occupational stress frameworks, namely the Job Demand-Control model, the Effort-Reward Imbalance model and the Conservation of Resources theory, in order to identify the theoretical arguments supporting each possible direction of causality between the work environment and wellbeing. The analysis indicates that both directions are plausible, depending on the specific stressor, individual coping resources and organizational context, which challenges the assumption of a simple one-way relationship. Reduced wellbeing is also associated with lower engagement, higher absenteeism and increased turnover, generating measurable organizational costs. These insights are intended to support the design of an original empirical study, in which specific employee groups will be examined in order to test the extent and direction of this interconnection within a real organizational context. Future research should therefore prioritize longitudinal and mixed-method designs able to capture this reciprocal dynamic, contributing both theoretical clarification and practical guidance for reducing workplace stress and enhancing sustainable employee wellbeing.*

Keywords: *workplace stress, employee wellbeing, occupational stress models, organizational justice, reciprocal relationship, work environment*

SECTION 11:
ENGINEERING EDUCATION

MIXED-METHODS RESEARCH IN TEXTILE AND FASHION STUDIES: QUALITATIVE AND QUANTITATIVE INSIGHTS FROM THE TEXUNITE PROJECT

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***Abstract**. To further develop and improve textiles, it is essential to generate new knowledge about user practices, sustainability perceptions, and material performance. In textile research, these insights are predominantly pursued through quantitative empirical methods, which involve collecting and analysing large amounts of numerical data, often via standardised questionnaires. However, empirical research can also be conducted qualitatively. Qualitative empirical research prioritises a deeper, holistic understanding of individuals and their experiences. Thus, it holds the potential to reveal consumers' values, attitudes, and preferences comprehensively. Such deep insights are important to improve textiles and tailor them to the target group. Special potential lies in combining qualitative and quantitative empirical research approaches within a single study, known as the mixed-methods approach. Due to its methodological advantages, including strong validity, rich explanations, improved transferability, and generalisability, this approach is widespread across academic disciplines. An example employing the mixed-methods research approach is the Erasmus+ project "TexUnite – Service Learning on Sustainability in Textile and Fashion Education" (project duration: September 2024 - August 2027). TexUnite integrates Service Learning (SL) and Virtual Exchange (VE) to promote sustainability competencies in fashion and textile higher education. To this end, it brings together universities with fashion and textile departments in Germany, Slovenia, Romania, Bulgaria, and Türkiye. Within TexUnite, a stocktaking report (Grundmeier & Schmidbleicher, 2026), based on expert interviews with representatives of the textile industry from each partner country, was written. All SL seminars are accompanied by student pre- and post-tests, as well as post-seminar surveys with lecturers and stakeholders. The questionnaires contain qualitative and quantitative items. Responses are evaluated using descriptive statistics, Principal Component Analysis, and qualitative content analysis (Kuckartz & Rädiker, 2023; Mayring, 2022) with MAXQDA software (VERBI Software, 2025). In addition, lecturers who will not conduct further SL projects within TexUnite will be interviewed regarding their perceptions of integrating and combining SL and VE. The interviews are analysed using deductive–inductive qualitative content analysis. Drawing on quantitative and qualitative data from the TexUnite project, this presentation demonstrates opportunities for integrating a mixed-methods approach into empirical textile research, with a focus on qualitative data analysis.*

***Keywords:** mixed-methods research, empirical textile research, textile and fashion studies, service learning, virtual exchange, fashion and textile education*

BUILDING A PRACTICE-ORIENTED EDUCATIONAL ECOSYSTEM IN TEXTILE ENGINEERING THROUGH THE ADAPTATION OF EUROPEAN BEST PRACTICES: EXPERIENCE OF THE ERASMUS+ TEX4FUTURE PROJECT

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***Abstract**. The rapid digital transformation of the textile industry requires higher education institutions to modernize engineering education through innovative teaching approaches, digital technologies and stronger cooperation with industry. The Erasmus+ CBHE TEX4FUTURE project provides an effective framework for transferring European experience to partner universities in Central Asia and for developing practice-oriented educational models. This paper proposes a conceptual framework for building an integrated educational ecosystem in textile engineering based on the adaptation of European best practices implemented through the TEX4FUTURE project. The study applies comparative analysis, benchmarking, case-study methodology and systems analysis to evaluate project implementation. The proposed ecosystem integrates curriculum modernization, digital technologies, university–industry cooperation, international academic collaboration, research and innovation, lifelong learning and Textile Innovation Centres into a unified model. Unlike conventional modernization focused mainly on equipment acquisition, the proposed framework considers educational, technological and industrial components as an integrated system supporting sustainable capacity building. The model contributes to strengthening practice-oriented engineering education, improving digital competencies, enhancing graduate employability and reinforcing university–industry collaboration. The results demonstrate that adaptation of European educational practices provides an effective mechanism for sustainable modernization of textile engineering education.*

***Keywords:** practice-oriented education; textile engineering; Erasmus+; TEX4FUTURE; educational ecosystem; university–industry cooperation; digital transformation; capacity building*

EVALUATION OF FASHION DESIGN AND TEXTILE AND FASHION DESIGN UNDERGRADUATE PROGRAMS IN TÜRKİYE IN TERMS OF DIGITAL FASHION EDUCATION

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Abstract. *The rapid digital transformation of the fashion industry has increased the need to integrate digital competencies into fashion design education. This study examines undergraduate programs in Fashion Design and Textile and Fashion Design in Türkiye from the perspective of digital fashion education. Document analysis was used to evaluate current curricula and course information packages published by universities. Of the 36 programs identified in the 2026 YKS Guide, 31 with accessible curriculum data were included in the analysis. A total of 250 digital courses were identified and classified into six main domains: Digital Design and Visualization, Digital Textile and Surface Design, CAD Patternmaking and Production, 3D Garment Design and Virtual Prototyping, Digital Communication and Marketing, and Emerging Digital Technologies. Of these courses, 62.0% were classified as core digital courses and 38.0% as supporting digital courses, while 52.0% were compulsory and 48.0% elective. The mean digital course load was 34.7 ECTS, corresponding to 14.46% of the total 240 ECTS undergraduate curriculum. Digital Design and Visualization was represented in all programs (100.0%), followed by Digital Textile and Surface Design (80.6%) and CAD Patternmaking and Production (67.7%). In contrast, 3D Garment Design and Virtual Prototyping was represented in 25.8% of programs, Digital Communication and Marketing in 32.3%, and Emerging Digital Technologies in 38.7%. The findings indicate considerable variation in the scope, curricular position, and integration of digital competencies across programs and show that digital fashion education should be evaluated not only by course presence but also by compulsory/elective and core/supporting status.*

Keywords: *digital competencies, computer-aided design, computer-aided pattern making, three-dimensional garment design, digital design and visualization, curriculum analysis*

AN ANALYSIS OF THE STRUCTURE AND TYPES OF QUESTIONS USED IN THE CREATION OF TESTS USED IN TEXTILE HIGHER EDUCATION ASSESSMENT

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Abstract. *The purpose of education is to instill in students, and not only, skills and knowledge that can lead to changes in perception and behavior. The acquisition of these skills and knowledge can be assessed using several tools that have the role of improving such processes. The most widely used tools used to measure student performance are tests of various types. They can improve class attendance and engagement in studying course materials (tests serve as a motivating tool - students can attend classes regularly and allow them to interact more deeply with the course content). If in the pre-COVID 19 period, assessment was carried out through oral exams, formative and summative tests carried out on paper, the sudden shift to online learning has transformed traditional education delivery systems by moving to more flexible teaching and assessment models. Online assessments using technology can be unsupervised or supervised. Test results can be analyzed with the quiz analyzer integrated into the Moodle platform, which can provide indications about easy questions (all students answer) or difficult questions (students do not answer or answer incorrectly for various reasons - they did not read the question correctly, they do not have the relevant knowledge, they did not have access to sufficient materials, etc.). The article attempts to rank the types of questions that students answer most often. The quizzes conducted included three types of questions (multiple choice, matching, and essay questions). It can be noted that, in general, multiple-choice questions are preferred over a question to which the answer is an essay.*

Keywords: *assessment, quiz, multiple-choice, essay*

BLENDED 3D CAD TRAINING FOR FOOTWEAR DESIGN: ENHANCING DIGITAL COMPETENCIES THROUGH AN INTERNATIONAL CAPACITY-BUILDING PROGRAMME

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***Abstract**. Three-dimensional computer-aided design (3D CAD), 3D scanning and additive manufacturing have become key enabling technologies in the European footwear industry, supporting virtual prototyping, digital last development, anthropometry-based customisation and photorealistic visualisation while reducing product development time and material waste. Although these technologies are well established in major European footwear-producing countries, including Spain, Italy, Portugal, France and Romania, higher education institutions in Ukraine continue to face a shortage of specialists proficient in advanced digital footwear design. Within an international capacity-building initiative, the Gheorghe Asachi Technical University of Iași (TUIASI) developed and delivered two of the programme's six training modules: 3D CAD for Basic Footwear Design and 3D CAD for Advanced Footwear Design. Structured into six learning units, the modules covered digital last processing, upper modelling for women's, men's and children's footwear, bottom-component design, photorealistic rendering, and footwear design for special-needs users using the Icad3D+ software platform. The training programme was completed by 37 Ukrainian professors and PhD students, together with 4 TUIASI academic staff members participating across the two sessions. Delivered in both onsite and online formats, the programme combined theoretical instruction, supervised practical activities and independent study over 25 hours. Learning outcomes were assessed through portfolios comprising 3D footwear models and digital patterns. The results demonstrate that the blended delivery model effectively supported the transfer of advanced 3D CAD competencies, with high participant engagement and positive feedback across both training formats. The study highlights the role of targeted capacity-building initiatives in strengthening digital design education and reducing the skills gap in footwear engineering, while contributing to the wider adoption of Industry 4.0 technologies in European higher education and the footwear sector.*

***Keywords:** 3D CAD footwear design, 3D scanning, 3D printing, capacity building, Icad3D+, virtual prototyping, Erasmus+*

ARTIFICIAL INTELLIGENCE IN ADVERTISING DESIGN

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Abstract. *Artificial Intelligence is frequently used in various fields, which this research is propuse to analyze how we can generate and subsequently edit various promotional materials design from the fashion industry (posters, flyers, labels, etc.). The objective of the research is to apply the same prompt on different LLM applications and to comparatively analyze how we can edit the results and to identify differences or similarities between promotional materials design specific to the fashion industry obtained through AI applications. These results help us to establish a series of relevant aspects for the creator of promotional materials and to identify a series of inconsistencies regarding the conditions under which AI-generated advertising is perceived.*

Keywords: *artificial intelligence, promotional materials, design, AI-generated*

ADDRESSING THE URGENT NEEDS OF THE TEXTILE SECTOR FOR SKILLS ON SUSTAINABILITY

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Abstract. *The environmental crisis, the increased pollution and waste issues face the textile sector with the need for transition from linear models to sustainable ones, as well as increasing its potential for circularity. Addressing these needs involves a multilevel response, adapting technologies, changing design practices, promoting recycling technologies, textile waste management, and reviewing the value chains. Such transformations for the sustainability of the textile sector require specialists with precise, well-tailored skills and this means that their education has to ensure such skills. It is an effort that must be undertaken by academia in partnership with the industry, especially clusters and organisations representing the EU textile companies. The ERASMUS project Upskilling and reskilling the textile industry sector to face the challenges in recycling, traceability and certification of recycled products, Skills4Circularity addresses the need for new skills on sustainability for the textile sector. It brings together a representative consortium of 21 partners from 12 EU countries. The main objective of the project is to enhance the competitiveness, resilience, and sustainability of the European textile industry by fostering a skilled workforce capable of driving the digital and green transitions. The activities to be implemented in the 4 years of the project are designed as a roadmap to a skilled and sustainable textile future. This paper presents the activities already carried out for the first specific objective – addressing the urgent needs of the sector (the reactive response). After determining the current market demands and sustainability requirements, three intensely practical online modules were designed to be delivered to specialists from the industry through 3-hour webinars. The modules discuss the topics of textile recycling, eco-design for the circular economy, and sustainable manufacture. The description of these modules is available on the project's site (https://www.skills4circularity.eu/wp-content/uploads/WP-1-%E2%80%93-Internal-Workshop.pdf.). Each module contains 4 lessons, corresponding to a specific learning outcome. The paper exemplifies the implementation of the first lesson in module, EU legal requirements for textile recycling. Understanding the legislation on textile waste and recycling is extremely important, as a lot of companies are adapting to the new EU regulations, such as the Waste Framework Directive and the Extended Producer Responsibility. The content of the lesson is presented, and the process of developing this content, the theoretical and practical parts is discussed. In the end, the experience gained during the webinar and the interaction with the participants is emphasised.*

Keywords: *textile industry, textile sustainability, methodological comparability, functional unit, system boundary, environmental footprint*

LEADERSHIP AS A DRIVER OF EMPLOYEE PERFORMANCE IN CONTEMPORARY ORGANIZATIONS: AN EMPIRICAL STUDY RELEVANT TO ENGINEERING EDUCATION AND MANAGEMENT TRAINING

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Abstract. *This paper extends and synthesizes the empirical findings of a dissertation study investigating the influence of leadership on employee performance. The research is positioned within the field of engineering education, considering that graduates of engineering and management programmes are increasingly required to lead multidisciplinary teams, coordinate technical and human resources, communicate effectively, motivate employees, and contribute to organizational performance. A quantitative research design was employed, based on a survey conducted among 101 respondents from various professional sectors. The proposed conceptual framework considered leadership as the independent variable and employee performance as the dependent variable, while work motivation and work engagement were examined as explanatory and mediating mechanisms. Data were collected using a five-point Likert-scale questionnaire and analysed through descriptive statistics, Cronbach's alpha reliability analysis, Pearson correlation analysis, and simple linear regression. The results revealed strong, positive, and statistically significant relationships between leadership, work motivation, work engagement, and employee performance. Leadership accounted for 58.9% of the variance in employee performance, 68.4% of the variance in work motivation, and 57.3% of the variance in work engagement. Furthermore, work engagement explained 68.5% of the variance in employee performance, emerging as the strongest immediate predictor of performance. These findings suggest that leadership influences performance not only directly, but also by creating motivational and behavioural conditions that encourage employees to invest greater effort, energy, and involvement in their work. From an educational perspective, the results support the integration of leadership development into engineering and management curricula as a practical and measurable professional competence. Evidence-based exercises, organizational case studies, and quantitative diagnostic methods could help students develop the ability to evaluate and improve leadership practices in technical and industrial organizations.*

Keywords: *leadership; employee performance; work motivation; work engagement; engineering education; management training*

COGNITIVE AND SOCIAL USE OF GENERATIVE AI: EFFECTS ON ACADEMIC LEARNING, SATISFACTION AND INNOVATION AMONG ENGINEERING AND MANAGEMENT STUDENTS

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Abstract. *This paper investigates how the dual use of generative artificial intelligence (GenAI) - cognitive/functional and social - influences academic learning, academic satisfaction and academic innovation among engineering and management students. Building on a socio-cognitive perspective on GenAI, the study proposes and tests a sequential model in which the cognitive/functional and social use of GenAI predict academic learning and knowledge transfer, learning predicts academic satisfaction, and satisfaction predicts GenAI-supported academic innovation. Data were collected through an online questionnaire, measured on a five-point Likert scale, administered to students enrolled in the Business Engineering programme, Faculty of Industrial Design and Business Management, Gheorghe Asachi Technical University of Iași. After applying a filter question and removing incomplete responses, the final valid sample consisted of 125 students. Construct reliability, assessed with Cronbach's alpha, ranged from acceptable to very good for all five constructs. Simple linear regression confirmed that cognitive/functional use of GenAI explains 40.7% of the variance in academic learning (H1), while social use explains 19.1% (H2). Academic learning explains 32.5% of the variance in academic satisfaction (H3), and satisfaction explains 35.9% of the variance in GenAI-supported academic innovation (H4). A sequential regression analysis of the cognitive/functional path shows that its total effect on innovation (Beta = 0.585) decreases but remains significant (Beta = 0.265) once learning and satisfaction are entered simultaneously, indicating partial mediation (H5); the full model explains 51.0% of the variance in academic innovation. The results suggest that GenAI functions as a socio-cognitive resource whose contribution to academic innovation depends on how it is translated into learning and a satisfying academic experience, rather than on direct use alone. Practical implications are discussed for integrating GenAI literacy into engineering and management curricula.*

Keywords: *generative artificial intelligence; academic learning; academic satisfaction; academic innovation; mediation analysis; engineering and management education*

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